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Electricity Consumption and Economic Growth Nexus: A Time Series Analysis for Libya

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Abstract:
The study investigates the causal relationship between electricity consumption and economic growth in Libya using annual data covering the period from 1990 to 2020. We used Granger causality test framework of vector autoregressive (VAR) model to test the causal relationship between the variables. the results of testing Granger's causality that runs GDPPC to CPCKW for Libya country does not have causality, from CPCKW to GDPPC also does not have causality, from GDPPC to P does not have Granger causality, and from P to CPCKW no causality. It is also clear from the results that there is a causal relationship from P to GDPPC, and CPCKW to P.

Keywords: Electricity Consumption, Economic Growth, Granger Causality Test, Libya.

الملخص
تبحث هذه الدراسة العلاقة السببية بين استهلاك الكهرباء والنمو الاقتصادي في ليبيا باستخدام بيانات سنوية تغطي الفترة من 1990حتى2020. استخدمنا اختبار العلاقة السببية جرانجر لنموذج المُتجه ذاتي الانحدار لاختبار العلاقة السببية بين المتغيرات. من النتائج اتضح أنه لا توجد علاقة مسببة بين نصيب الفرد من الناتج المحلي الإجمالي ونصيب الفرد من استهلاك الكهرباء في ليبيا ومن نصيب الفرد من استهلاك الكهرباء إلى نصيب الفرد من الناتج المحلي ولا توجد علاقة سببية أيضًا، ومن نصيب الفرد من الناتج المحلي الإجمالي إلى أسعار الكهرباء للكيلو وات أيضًا حسب النتائج، ولا توجد علاقة سببية وكذلك من الأسعار إلى نصيب الفرد من استهلاك الكهرباء لا توجد سببية، ومن الواضح أيضًا من النتائج أنه توجد علاقة سببية من الأسعار إلى نصيب الفرد من الناتج المحلي الإجمالي ونصيب الفرد من استهلاك الكهرباء إلى الأسعار.

الكلمات المفتاحية: استهلاك الكهرباء، النمو الاقتصادي، اختبار السببية لجرانجر، ليبيا.

Introduction

Libya has been facing an electricity crisis for several years, which has resulted in frequent power outages and disruptions to daily life. The root causes of the crisis are complex and include a lack of investment in infrastructure, poor maintenance of existing facilities, and damage to power plants and transmission lines during the country's civil war. To address the electricity crisis, the Libyan government have implemented several policies and initiatives, including increasing investment in power generation and transmission infrastructure, promoting renewable energy sources, and improving the efficiency of existing plants. However, the electricity crisis in Libya has also been politicized, with different political factions using it as a tool to gain support and undermine their opponents. Some political groups have blamed the crisis on corruption and mismanagement within the government, while others have accused foreign powers of intentionally sabotaging Libya's electricity infrastructure. This politicization of the electricity crisis has made it more difficult to find a comprehensive and sustainable solution to the problem. It has also hindered efforts to attract foreign investment in the energy sector, which is crucial for the country's economic development.

The world's energy demand and consumption have continued to increase steadily over the last few decades(Suganthi & Samuel, 2012). Economic development is accelerating in emerging markets and developing nations. The world's rising energy consumption is mostly being driven by urbanization and rapid population expansion (Aydin, 2019).For instance,(Ferguson, Wilkinson, & Hill, 2000) in more than 100 nations, examined the relationships between the use of electricity and economic development . They discovered a significant link between the consumption of energy and wealth development for the entire global economy. According to the annual reports of auditors, the cost of energy in Libya's agricultural and industrial sectors has depleted the government's public budget during the past thirty years(GPCFAAL, 2007). The goal of Libya's development goals is to connect all regions to the national electrical grid, therefore the average amount of energy used by each person is seen as one of the key indicators of how well modern societies are doing in the growth level(Ibrahim, 2006) .

Currently, the cost of producing power is high, especially for agricultural uses, due to the extensive region that the network must cover and the magnitude of the infrastructure investment(Mohamed, Al-Habaibeh, & Abdo, 2013). According to the annual reports of auditors, the cost of energy in Libya's agricultural and industrial sectors has depleted the government's public budget during the past thirty years(Ibrahim, 2006) . In the areas of electrical power production, transportation, and distribution, the value of projects that were contracted or in the final stages of construction was 17,144 million Libyan dinars (1 US dollar = 1.420 Libyan dinar) (Ministry, 2009) .

The paper investigates the impact of electricity consumption on economic growth in Nigeria from 1986 to 2021 using the Autoregressive Distributed Lag (ARDL) model. The study finds that energy consumption, inflation, and industrial product have a statistically significant and positive effect on Nigeria's short and long-run economic growth. Unemployment, on the other hand, has a negative and statistically significant impact on economic growth in both the short and long run.

The paper recommends that the government should take measures to address the shortage of electricity consumption in the country to promote economic growth. Additionally, appropriate policies should be adopted to reduce unemployment, which negatively affects economic growth(Mohammed, 2023). The impact of electricity consumption on Vietnam's economic growth between 1986 and 2020 is evaluated in this article. The ARDL model's projected results demonstrate that electricity consumption affects economic growth over the long and short terms.(Lan & Cong, 2023).

The main objective of the study is to employ Granger Causality analysis, co-integration tests, and ordinary least square techniques to analyze the factors influencing Libya's electricity demand between 1980 and 2010. It also uses a questionnaire and case study approach to look at the factors that influence power projects in Libya. The findings of the regression indicate that 99% of the variance in power demand can be explained by factors such as the average real price of electricity, the real value of imported electrical appliances, GDP, population, temperature differential, and lagged electricity consumption.

According to the analysis, there is a need for elasticity in the Libyan economy because both the price and income elasticity of demand are inelastic. The population and the average price of elasticity are identified by the suggested model as important factors influencing the demand for electricity. The report also emphasizes how crucial it is to build additional infrastructure to expand Libya's electrical projects. The validation procedure verifies that the suggested framework for handling Libya's rising electricity demand is workable (Ochieng, 2014).

Using time-series methods, the study examines the connection between electricity consumption use and economic growth in seven South American nations. The results show that the causal nexus between electricity consumption and economic growth varies across countries, with unidirectional, short-run causality from electricity consumption to real GDP in Argentina, Brazil, Chile, Columbia, and Ecuador, bidirectional causality in Venezuela, and no causal relationships in Peru(Yoo & Kwak, 2010).The paper investigates the causal relationship between electricity consumption and economic growth in Lebanon using monthly data from January 1995 to December 2005. The study confirms the absence of a long-term equilibrium relationship between electricity consumption and economic growth in Lebanon but the existence of unidirectional causality running from electricity consumption to economic growth(Abosedra, Dah, & Ghosh, 2009).This paper examines the relationship between electricity consumption and economic growth for OPEC members. The study finds evidence of a long-run relationship between electricity consumption and economic growth for all OPEC members, and causality results suggest that economic growth is dependent on electricity consumption in some countries, less dependent in others, and independent in some(Squalli, 2007).The paper aims to forecast the long-term electricity demand in Libya from 2011-2022 using a quantitative forecasting model based on a time series stochastic method. The results indicate a continuous growth in demand for oil and electricity due to rapid population growth in Libya(Saleh, 2014).

Economic growth and electricity use are tightly related, and Libya is no exception. Increased electricity use can boost economic expansion by facilitating the growth of enterprises, infrastructure, and industries. In a similar vein, since more people rely on electricity for everyday requirements, a larger economy may also result in higher electricity consumption. In Libya, the relationship between electricity consumption and economic growth has been complex. Historically, the country has been heavily reliant on its oil and gas resources, and the electricity sector has not received sufficient investment to keep up with the country's growing demand for energy. This has resulted in frequent power outages, which have negatively impacted the economy.

The development of Libya's electricity sector

The electric power industry in Libya has undergone significant development since the country's independence in 1951. Before independence, electricity was mainly generated by small diesel generators in urban areas and by traditional methods such as windmills and water wheels in rural areas. In the 1960s, the Libyan government began to invest in the development of the electric power industry. The first power station was built in Tripoli in 1962, with a capacity of 30 MW. Over the following decades, additional power stations were built in various parts of the country, including Benghazi, Misrata, and Zawiya. During the 1970s and 1980s, the Libyan government continued to invest heavily in the electric power industry, with the goal of providing electricity to all parts of the country. In 1989, the General Electricity Company of Libya (GECOL) was established to manage the country's electricity generation, transmission, and distribution. In the 1990s, Libya's electric power industry faced several challenges, including a lack of investment in infrastructure and the impact of economic sanctions imposed by the international community. Despite these challenges, the government continued to invest in the industry, and in 1999, the Sirte Combined Cycle Power Plant was inaugurated, with a capacity of 1,300 MW. In the 2000s, Libya's electric power industry continued to expand, with the construction of new power plants and the upgrading of existing infrastructure. In 2008, the Al-Khums power plant was inaugurated, with a capacity of 640 MW. In 2010, the Zawiya Power Plant was upgraded to increase its capacity to 1,000 MW. However, the political and economic instability that followed the 2011 revolution had a significant impact on the electric power industry in Libya. The ongoing conflict and lack of investment in infrastructure have resulted in frequent power outages and a shortage of electricity in many parts of the country. In summary, the electric power industry in Libya has undergone significant development since the country's independence, with the establishment of a national electricity company and the construction of numerous power plants. However, the ongoing political and economic instability has had a negative impact on the industry in recent years.

In addition to the challenges posed by the political and economic instability in Libya, the electric power industry has also faced other challenges in recent years. These include a lack of investment in infrastructure and equipment, as well as a shortage of skilled personnel. One of the main challenges facing the industry is the aging infrastructure. Many power facilities and transmission lines in the nation are antiquated and require upgrading and maintenance. This has contributed to frequent power outages and blackouts, particularly during the hot summer months when electricity demand is highest. Another challenge is the shortage of skilled personnel. Many experienced engineers and technicians have left the country due to the conflict and unstable political situation, leaving a gap in expertise and knowledge. This has made it difficult for the national electricity company, GECOL, to maintain and operate the existing infrastructure and to plan and implement new projects. Despite these challenges, the Libyan government has continued to invest in the electric power industry. In 2019, the government declared its intention to renovate the current infrastructure and construct multiple new power plants. These initiatives are meant to boost the nation's capacity for producing electricity as well as the power grid's dependability and stability. Furthermore, the government has made an effort to draw in outside capital for the sector. In 2017, the Libyan Investment Authority signed an agreement with a Turkish company to build a new power plant in Misrata, with a capacity of 1,000 MW. The project is expected to be completed in 2024. Overall, while the electric power industry in Libya has faced significant challenges in recent years, the government's continued investment in the industry and efforts to attract foreign investment are aimed at improving the situation and ensuring a reliable and stable supply of electricity for the country's population.

The historical development of the electric power industry in Libya can be traced back to the early 20th century. Here is a brief overview of its key milestones:

1. Early Development (early 1900s-1960s): The first electricity generation in Libya began in the early 1900s, mainly in urban areas such as Tripoli and Benghazi. These early power plants were small and primarily served local communities. The Italian colonization of Libya during the early 20th century also led to the establishment of some power plants.
2. Nationalization (1970s): Following the Libyan Revolution in 1969, the country's electricity sector underwent a significant transformation. The government nationalized the electric power industry, consolidating various private and foreign-owned power companies into a single state-owned entity called the General Electricity Company of Libya (GECOL). This move aimed to centralize the industry and ensure equal access to electricity across the country.
3. Expansion and Modernization (1970s-1990s): During this period, Libya witnessed a rapid expansion of its electricity infrastructure. The government invested heavily in building new power plants, transmission lines, and distribution networks to meet the growing electricity demand. The country also started importing electricity from neighbouring countries like Tunisia and Egypt to supplement its domestic production.
4. International Cooperation (2000s): In the early 2000s, Libya began to explore partnerships with international companies to develop its electricity sector further. It signed agreements with several foreign firms to upgrade existing power plants, improve transmission networks, and introduce renewable energy projects. These collaborations aimed to enhance the efficiency and reliability of the electric power industry in the country.

5. Post-Civil War Challenges (2011-present): The Libyan Civil War, which began in 2011, had a significant impact on the electric power industry. Infrastructure damage, disruptions in fuel supply, and security issues hampered electricity generation and distribution. The country faced frequent power outages and struggled to meet the rising demand for electricity. However, efforts are underway to rehabilitate and modernize the sector in the post-war period.

Data and the Framework for Methodology

Using annual data from 1990–2020 to explore the interaction between the electricity growth nexus for the case of Libya with data obtained from the Libyan government and the world Bank.

This study will use two main variables to build the model. The three main variables are GDP per capita as the dependent variable, Electricity per capita and Electricity and price as the independent variables.

Two or more non-stationary series combined linearly (with the same integration order), as per (Engle & Granger, 1987), might be stationary. If there is a stable linear combination like this, the series are considered cointegrated and long-term equilibrium relationships exist. These cointegrated features might be used to construct the cointegration model, which would then be used to test for Granger causality of the series in at least one direction. The Granger Causality Test is specifically used in this study to investigate the Granger causality between price (P), electricity consumption per capita (CPCKW), and GDP per capita (GDPPS) in Libya.

Stationarity, cointegration, and Granger Causality Test

The application of the ECM requires cointegration with the same order, the series must first be verified for stationarity and cointegration. the series is deemed nonstationary (or stationary) if its mean, variance, and autocovariance all fluctuate over time at various delays. If a nonstationary series needs to be differentiated d times before it becomes stationary, it is said to be integrated of order d., i.e. I(d).

The augmented Dickey–Fuller (ADF) (Dickey & Fuller, 1979), and a new, high-power unit-root test is developed by (Elliott, Rothenberg, & Stock, 1992) . These authors study the asymptotic power envelope for a number of unit-root tests and propose the DF-GLS test, a simple ADF test modification that nearly reaches the power envelope. The null hypothesis, $\mathbf{H_0}$, which states that $\mathbf{Y_t}$ is nonstationary, is being tested against $\mathbf{H_1}$, which states that$\mathbf{Y_t}$ is stationary, in both tests.

Once both series have been integrated in the same sequence, we may check to see if cointegration exists. The Johansen maximum likelihood approach (Søren Johansen, 1988); (Soren Johansen & Juselius, 1990) are used to achieve this. If a long-run cointegrating relationship between the series is found, an extra error-correction term will be added to the ECM. Using vector autoregressive (VAR) data, the Johansen technique tests the bounds imposed by cointegration in the unrestricted VAR. The null hypothesis under investigation is $\mathbf{H_0}$, which states that there are fewer cointegration relationships than $\mathbf{H_1}$, which states that every series in the VAR is stable.

The integration features of GDP per capita (GDPPC), electricity consumption per capita (CPCKW), and electricity price (P) are reported by Table (1) based on the outcomes of the ADF and DFGLS tests. The two series are determined to be nonstationary at level based on the test results. Nonetheless, stationarity results from these series' initial differences. These suggest that Libya's integration of GDP per capita (GDPPC), consumption of electricity per capita (CPCKW), and price of electricity (P) is of order one, or I(1).

Table 1 Results of ADF and DFGLS tests

Variables	ADF		DFGLS	
	Levels	1st Difference	Levels	1st Difference
GDPPC	-2.57	-6.942**	-3.224	-6.967**
CPCKW	-1.49	-4.90**	-2.240	-4.989**
P	-2.26	-4.81 **	-1.497	-4.982**

Asterisks:(**) indicate statistically significant t 5 present level

Co-integration Analysis

Cointegration analysis is recommended by econometric methodologies to determine the long-term relationship between the variables in the model. The appropriate choice for co-integration is the Johansen and Juselius (1990) approach because all the variables are stationary at first difference. This method has been used to determine the long-term relationship between the expansion of the economy and the use of electricity.

The study selects the proper lag duration using the Hannan-Quinn Criterion (HQ), the Schwartz Bayesian Criterion (SBC), the Akaike information criterion (AIC), and the final prediction error (FPE). The outcomes are displayed in Table 2. As can be seen, HQ, SBC, AIC, and FPE suggest lag lengths of 4 and 1, respectively. The study follows Johansen and Juselius (1992) in selecting a lag length of one as the suitable lag length.

Table 2 Lag Length Selection Criteria for Order of VAR Model.

Lag	LL	LR	FPE	AIC	HQ	SBC
0	-852.678	NA	6.8e+23	63.3835	63.4264	63.5275
1	-788.592	128.17	1.1e+22	59.3031	59.4744	59.8791
2	-772.764	31.656	7.1e+21	58.7974	59.097	60.0479
3	-761.208	23.112*	6.4e+21*	58.608*	59.0362*	59.8052*
4	-753.297	15.822	8.0e+21	58.6887	59.2453	60.5605

The Trace Statistic and Maximum Eigenvalue tests are used to determine the number of co-integrating vectors. Using the Pantula principle, the model with "unrestricted intercept and no trend" has been determined to be the most suitable of the five co-integration models. These models take into account various intercept and trend term specifications. According to (ASTERIOU & Hall, 2007), the "unrestricted intercept and no trend" model postulates that the intercept in the co-integrating equation is cancelled out by the intercept in the Vector Autoregressive (VAR) model. As a result, the calculated model does not report the constant term (or intercept).

Tables 3 and 4 show the findings of the Maximum Eigenvalue test and the Trace Statistic test, respectively. There is just one co-integrating vector and Maximum reported by the Trace Statistic.

Table 3 Unrestricted Cointegration Rank Test (Trace).

Hypothesized No. of CE(s)	**Eigenvalue**	**Trace Statistic**	**0.05 Critical Value**	**Prob.****
None *	0.757781	74.38540	47.85613	0.0000
At most 1 *	0.434484	30.43016	29.79707	0.0422
At most 2	0.270565	12.75966	12.75966	0.1239
At most 3	0.091642	2.979608	2.979608	0.0843

Trace test indicates 2 cointegrating eqn(s) at the 0.05 level

Table 4 Unrestricted Cointegration Rank Test (Maximum Eigenvalue).

Hypothesized No. of CE(s)	**Eigenvalue**	**Max-Eigen Statistic**	**0.05 Critical Value**	**Prob.****
None *	0.757781	43.95524	27.58434	0.0002
At most 1 *	0.434484	17.67050	21.13162	0.1427
At most 2	0.270565	9.780048	14.26460	0.2268
At most 3	0.091642	2.979608	3.841466	0.0843

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level

The statement you provided suggests that in the context of a conflict between the Trace value test and the Maximum Eigenvalue test in cointegration analysis, the Trace statistic is preferred. According to Johansen and (Soren Johansen & Juselius, 1990) and (ASTERIOU & Hall, 2007), the Trace statistic is more powerful because it takes into account all of the smallest eigenvalues. This means that it has the ability to detect a larger number of cointegrating relationships between variables in a model.

Based on this understanding, the study you mentioned considered only one cointegrating relationship in the variables of the model. This implies that the researcher assumed that there is a single long-term relationship among the variables being analyzed.
It's worth noting that cointegration analysis is commonly used to examine the long-term relationships between variables and whether they move together in the long run. The choice between the Trace statistic and the Maximum Eigenvalue statistic depends on the specific research question, the characteristics of the data, and the underlying assumptions of the model. Researchers should carefully consider the suitability of each statistic for their particular analysis.

Granger Causality Test

Schwarz Information Criterion (SIC) is used to find the best solution for the direction of causality test, which is predicated on the idea that there are between one and seven delays. The findings of the Granger's causality test, which runs GDPPC to CPCKW for the country of Libya, show that there is no causation from CPCKW to GDPPC, no causality from GDPPC to P, and no causality from P to CPCKW. Table 5 makes it abundantly evident that there is a causal link between P and GDPPC as well as between CPCKW and P.

Where,

GDPPC, CPCKW and P: GDP Per Capita, Electricity consumption Per Capita kilowatt and price respectively.

Table 5 Granger Causality Test Results.

Null Hypothesis:	Obs	F-Statistic	Probability	Decision
GDPPC does not Granger cause CPCKW CPCKW does not Granger cause GDPPC	**28** **28**	**1.2101** **0.8587**	**0.3346** **0.4803**	**No causality** **No causality**
P does Granger cause GDPPC GDPPC does not Granger cause P	**28** **28**	**11.162** **1.0836**	**0.0002** **0.3812**	**P→ GDPPC** **No causality**
CPCKW does Granger cause P P does not Granger cause GPCKW	**28** **28**	6.1254 0.9537	0.0047 0.4357	**CPCKW→ P** **No causality**

Conclusion

- The study comes to the conclusion that there is a relationship between Libya's economic growth and its use of electricity.
- The authors propose that a suitably integrated methodological framework should be employed to investigate the correlation between economic growth and electricity consumption from a broader angle.
- In examining the connection between electricity consumption and economic growth, the study emphasizes the significance of model construction and variable selection.
- The authors note that due to differences in research duration, variable selection, and model building, the causal association between electricity consumption and economic growth may differ in different nations.
- All things considered, the study offers a thorough summary of the research on the connection between Libya's economic growth and electricity consumption, setting the groundwork for future studies in this field.

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