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Modelling Electric Power Consumption, Energy Consumption and Economic Growth in Zimbabwe: Cointegration and Causality Analysis

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Abstract This paper examines the causal relationship between electric power consumption, energy consumption and economic growth in Zimbabwe during the period 1970-2014. The Chow test showed that there is a structural break in the year 2008. Compared to previous studies, our model include both electric power consumption and energy consumption in influencing economic growth and for this purpose, Johansen cointegration test and Vector Error Correction Model (VECM) were used to analyse the short-run and long-run dynamics of the variables in the full sample (1970-2014). In the short-run model, the study results failed to establish any causal relationship between energy consumption, electric power consumption and economic growth in the short run. However, in the long run, there was a unidirectional causality running from electric power consumption and energy consumption to economic growth. The long-run model showed that electric power consumption has impact on economic growth while energy consumption was found to have no impact on economic growth. In the sub-sample (1970-2008), Autoregressive Distributed Lag (ARDL) model was used and a long-run relationship was found to exist between the variables but however, no short-run relationship was found. We conclude that in the Zimbabwean context, the growth hypothesis is supported in the long-run. Therefore, the study recommends relevant authorities to ensure supply of electricity by increasing investment in energy and electricity generation capacity since its availability in the long run is critical for economic growth.

Keywords Economic Growth, Electric Power Consumption, Energy Consumption, Vector Error Correction Model

1. Introduction

The causal relationship between energy consumption and economic growth has become an area of contention in literature since the seminal work of Kraft and Kraft [1] and some studies concluded that there is a strong relationship between these variables (Yasar [2], Khobai [3], Eggoh *et al*. [4]). In Zimbabwe, recent efforts to revive the economy have seen an increase in electricity demand across all sector of the economy. According to Makonese [5], 40% of the households in Zimbabwe have access to electricity and in the near future, electricity demand is expected to increase as the country takes steps to revive all sectors of the economy. On the other hand, since the late 1990's, Zimbabwe Electricity Supply Authority (ZESA) holdings has been failing to produce enough electricity to meet rising demand leading to unprecedented energy crisis which is being attributed to reduced water levels in Kariba dam, ageing power plants, transmission and distribution network which has suffered years of neglect and minimal maintenance among other factors. In addition to severe load-shedding in the country, there is unstable macroeconomic environment and economic growth has not been favourable, with predicted economic growth for 2019 of -6.5% (Reserve Bank of Zimbabwe [6]). It therefore becomes an issue of research curiosity and a matter of policy concern as to why? Answers to this question can be derived from the investigation of the causal relationship between electric power consumption[1] as an alternative source of energy, energy consumption and economic growth.

However, the causal relationship between electric power consumption, energy consumption[2] and economic growth in ambiguous both empirically and at the level of theory. In empirical for example, while Shahateet [7] found no causal

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1 This is a form of energy consumption that uses electric energy and it is the actual energy demand that is made against the existing electricity supply.

2 In this study, energy consumption is the total amount energy or power used, which is the use of primary energy before transformation to other end-use fuels within the economy.

relationship between energy consumption and economic growth, Khobai [3] found a unidirectional causality from economic growth to electric power consumption in the long run. Yasar [2] found that the causal relationship between energy consumption and economic growth differs depending on the income group the country belongs to. The bidirectional causality was found to hold for upper middle income countries in the long-run and high income countries while unidirectional causality from economic growth to energy consumption was found to hold in upper-middle income countries in the short-run and lower middle-income countries in the long-run. However, no causality was found for low and lower-middle income countries in the short-run. Shahbaz *et al*. [8] found that electric power as an input has less importance at lower levels of economic growth and energy demand decreases with increases in the level of economic growth. The existing empirical evidence does not provide enough attestation on the causal relationship between electric power consumption, energy consumption and economic growth in Zimbabwe.

At the level of theory, various explanations also exists on the relationship between energy consumption [3] and economic growth and the outcome has been ambiguous. Four hypotheses regarding the link between economic growth and energy consumption exist in literature and these are growth hypothesis, conservative hypothesis, neutrality hypothesis and feedback hypothesis. Growth hypothesis assumes that there are countries in which energy consumption is an important element of economic growth, hence there is unidirectional causality running from energy consumption to economic growth. Furthermore, in addition to capital and labour from the Solow [9] growth model, energy consumption is indispensable for economic development and is an important intermediate input for economic growth (Shahbaz *et al*. [8]).The conservative hypothesis is based on the assumption that changes in energy consumption is based on changes in economic activities, hence there is unidirectional causality running from economic growth to energy consumption. The neutrality hypothesis states that there are some countries where energy consumption does not influence economic growth and economic growth does not influence energy consumption. The feedback hypothesis states that there are some countries in which there is bi-directional causality between energy consumption and economic growth. Whether economic growth is attributed to capital and labour or together with electricity consumption and energy consumption as an intermediate input is subject to empirical investigation since various contradicting hypotheses exist in empirical literature. The research issue is that economic growth relies heavily on energy consumption in production but the role of energy consumption on economic growth is not clear in literature, hence a matter of policy concern given severe load-shedding being experienced in Zimbabwe. Therefore, the objective of this study is to examine the causal relationship between energy consumption, electric power consumption and economic growth in Zimbabwe. The specific objectives are:

- To examine the relationship between energy consumption and economic growth.
- To examine the relationship between electric power consumption and economic growth.

2. Overview of the Study

The Zimbabwe's electricity supply is dominated by state owned enterprise, ZESA holdings and has the mandate to generate, transmit and distribute electricity to all sectors of the economy. Less than 1 per cent of Zimbabwe's electricity is produced by private companies such as Nyangani Renewable Energy (Pvt) Ltd (Makonese [5]). ZESA holdings delegate its tasks to its subsidiaries, Zimbabwe Power Company (ZPC) and Zimbabwe Electricity Transmission and Distribution Company (ZETDC). The power supply in Zimbabwe is sourced from local generation as well as imports and the domestic generation comes from Kariba hydropower, Hwange coal-power fire station and three small thermal power stations. The most reliable plant has been Kariba power station but from 2015, the capacity to generate electricity was constrained due to reduced water levels and supply from Hwange thermal power station is erratic due to age of the plant and lack of regular maintenance. In addition, high debt of the Government of Zimbabwe on electricity from ZESA holdings and foreign suppliers such as Eskom from South Africa has worsened power cuts. The table below shows the installed generation capacity and actual generation capacity as at 9 August 2019.

Table 1. Power Generation Statistics as at 09 August 2019

Power station	Installed capacity	Actual Energy (MW)-2016	Actual Energy (MW)-2019
Hwange	920	268	521
Kariba	750	440	160-342
Harare	80	30	15
Munyati	80	30	18
Bulawayo	90	15	0
Imports			0-400
Total	1920	783	1092

Source: Zimbabwe Electricity Supply Authority website

ZESA's actual generation capacity in 2016 totalled 783 MegaWatts and it increased to 1092 MegaWatts in 2019 as this includes imports. In addition to having a low capacity utilisation, the actual energy generation fell in most of the power stations between 2016 and 2019 and there is a severe load-shedding schedule affecting industries.

Electricity in Zimbabwe is generated mainly from

3 While electricity is a form of energy that is used, which is actual energy demand against existing supply and electric power consumption is narrow relative to energy consumption.

hydropower (57 per cent) and coal (43 per cent). Kariba hydropower stations as a capacity of 666 MW against a theoretical hydropower capacity of 750MW and because electricity generation rely on availability of water, the supply of electricity from Kariba has fell severely due to lower levels of water, which is below 30 per cent. Concerning thermal power, Hwange Colliery Company, a state owned enterprise has failed to boost output due to limited financial resources, limited maintenance of plant and ageing plant. This has resulted in some industries relying on diesel powered generators during pick and load-shedding hours to meet their energy needs.

Due to energy problems in Zimbabwe and decline in supply of both electricity and energy, there has been a general decline in the electric power consumption (kWh/ capita) and total energy consumption (kg of oil equivalent per capita) over the period 1970 to 2015. This decline in consumption of energy could be attributed to decline in supply of both electricity and energy and is shown in Figure 1 below.

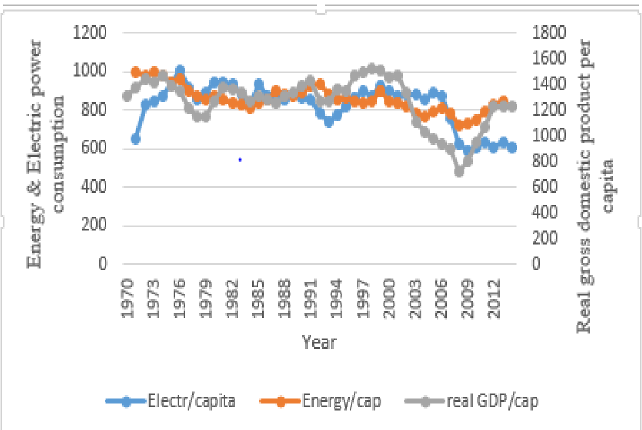

Figure 1. Real GDP, Electric power consumption and Total energy consumption, *Source: World Bank website and Author's Illustration*

From 1970 to 1984, total energy consumption had been falling while electric power consumption was increasing from 1971 to 1976 and then fell in 1979. According to the data from Word Bank [10], total energy consumption fell from 876.4 kg of oil equivalent per capita in 1980 to 808.2 kg of oil equivalent per capita in 1984, which translate to 7.78 per cent decline while electricity power consumption (kWh/capita) also declined by 12.06 per cent during the same period from 944 kWh/capita to 830 kWh/capita. From 1984 to 1985, electricity power consumption went up by 12.72 per cent, from 830 kWh/capita to 936 kWh/capita. In addition to increase in electric power consumption, there was an increase in total energy consumption by 11.05 per cent, from 808.2 kg of oil equivalent per capita to 897.47 kg of oil equivalent per capita between 1984 and 1987. From 1987 to 1997, total energy consumption fell down by 7.23 per cent from 897.47 kg of oil equivalent per capita to 832.58 kg of oil equivalent per capita while electric power consumption fell by 3.68 per cent during the period 1985 to 1997, from 936 kWh/capita to 901 kWh/capita.

Based on the data from World Bank [10], during the period 1997 to 1999, there was a steady increase in both electric power consumption and total energy consumption by 2.83 per cent and 7.56 per cent respectively. This could be attributed to quasi-fiscal operations which might have been used to finance electricity supply. Between 1999 and 2009, total energy consumption fell by 18.55 per cent from 895.54 kg of oil equivalent per capita to 729.38 kg of oil equivalent per capita while electric power consumption fell by 36.84 per cent from 927 kWh/ capita to 585 kWh/ capita during the same period. This can be based on the argument that the period was associated with inflation which might have negatively affected supply of electricity and energy. While electric power consumption increased by 8.68 per cent from 2009 to 2011, maybe due to dollarization in 2008 and Government of National Unity (GNU), it later fell by 4.26 per cent between 2011 and 2014 from 636 kWh/capita to 609 kWh/ capita. Although electric power consumption fell, total energy consumption increased by 16 per cent from 729 kg of oil equivalent per capita to 845 kg of oil equivalent per capita during the period 2009 to 2013.

Real GDP per capita had been increasing from 1970 to 1974 and then fell dramatically from 1974 to 1979 before it raised to US$1378 in 1981. Based on the data from Word Bank [10], during the first five years of post-independence, real gross domestic product (GDP) per capita increased by 2.71 per cent from US$1269.245 in 1980 to US$1303.651 in 1985. Initially, it increased by 8.6 per cent between 1980 and 1981, and then fell by 8.32 per cent from US$1378.548 in 1981 to US$1263.88 in 1984 before it increased from US$1263.88 in 1984 to US$1303.651 in 1985, by 3.15 per cent. Real GDP per capita then fell by 3.77 per cent during the period 1985 to 1987, from US$1303.651 to US$1254.518 before it slightly increased to US$1429.506 in 1991 by 13.95 per cent. From 1991 to 1993, real GDP per capita increased by 11.47 per cent from US$1429.506 to US$1265.515 and then increased to US$1361.646 in 1994 by 7.6 per cent. During the period 1994 to 1995, real GDP per capita declined slightly by 1.15 per cent and then increased from US$1345.993 in 1995 to US$1524.34 in 1998 by 13.25 per cent. From 1998 to 2000, there was a fall in real GDP per capita by 4.94 per cent from US$1524.34 to US$1449.043, followed by a slight increase in real GDP per capita to US$1464.672 in 2001 by 1.08 per cent. Between 2001 and 2008, there was a sharp decline in real GDP per capita by 50.46 per cent, from US$1464.672 in 2001 to US$725.576 in 2008 and this sharp decline was followed by a sharp increase in real GDP per capita from US$725.576 in 2008 to US$1223.203 by 68.58 per cent. From 2012 to 2014, real GDP per capita increased slightly by 0.79 per cent from US$1223.203 to US$1232.865 and then fell to US$1224.31 in 2016 by 0.69 per cent below it increased to US$1322.344 in 2018 by 8 per cent.

During the period 1980 to 2018, energy consumption, electric power consumption and GDP were moving almost together in the same direction. This implies that the variables might be causing each other over time or there might be other factors driving such a trend. In addition, economic growth was not stable since 1980 and the perspectives on which one causes the other between electric consumption and economic growth are always contradicting, both in theory and in empirical literature. Given the importance of electricity in promoting production as an intermediate input, massive load shedding in Zimbabwe and ambiguity in empirical literature on electric power consumption-growth nexus, it is important to seek answers on country specific empirical point of view. It is upon this background that a study needs to be done to examine the causal relationship between electric power consumption, energy consumption and economic growth in Zimbabwe.

Energy consumption is a critical factor for achievement of economic development and its scarcity imposes a constraint on the growth of an economy given the efforts being made to revive all sectors of the economy. Knowledge on the causality between energy consumption, electric power consumption and economic growth enables policy makers to formulate and implement appropriate policy responses that support either the growth hypothesis, conservative hypothesis, neutrality hypothesis or feedback hypothesis. If this study is not done, the negative outcomes of severe load-shedding and power cuts on economic growth will receive less immediate attention. Although several studies have been done in the area of energy consumption, electric power consumption and economic growth (Khobai [3], Shahbaz *et al*. [8], Sylvester and Okorie [11], Yasar [2], Shahateet [7]), few studies, if they exist have been done on electric power consumption, energy consumption and economic growth nexus especially in Zimbabwe, hence this study will contribute to the existing literature and body of knowledge on the causality between electric power consumption, energy consumption and economic growth.

The remainder of this paper is organised as follows: Section 3 provides the theoretical and empirical literature, Section 4 provides the data, econometric methodology used in the analysis and the empirical results. Conclusions are made in Section 5.

3. Theoretical and Empirical Literature

Various theories exist to explain the causality between electricity consumption and economic growth such as the neoclassical and endogenous growth theories. The neoclassical and endogenous growth theories analyse the effects of primary factors of production such as labour and capital on economic growth. Energy and the type of energy used in the production process are often ignored as important element of economic growth, but is considered as an intermediate input. For example, while Solow growth model put more emphasis on technological progress to facilitate economic growth, the AK model of endogenous growth put more emphasis on technology as endogenous and high savings rate to promote economic growth. The Schumpeterian growth models highlight on the importance of capital accumulation and innovation to promote economic growth. The neoclassical growth model of economic growth by Solow [9] does not include resources and the theory argue that the only cause of continuing economic growth is technological progress, which is assumed to be exogenous. The endogenous growth model attempts to explain technological progress in the growth model as an outcome of decisions taken by firms and individuals (Yucel *et al*. [12]). Although the Solow growth model, AK model and Schumpeterian growth models does not explicitly state electric power and energy consumption as a driver of economics growth, the factors which these models posit as critical to economic growth, that is technological progress, capital accumulation and innovation highly depend on electric power and energy consumption. Thus, in these models, electric power consumption and energy consumption serves as an intermediate input in facilitating economic growth.

In addition to these theoretical models, four hypotheses regarding the link between electricity consumption and economic growth exist in literature and these include the growth hypothesis, conservative hypothesis, feedback hypothesis and neutrality hypothesis. The growth hypothesis argue that energy consumption contribute directly to economic growth and development and work as a complement to labour and capital in the production process (Shahbaz *et al*. [8]). Thus, the growth hypothesis postulates that an increase in energy consumption lead to an increase in economic growth. The conservation hypothesis suggest that a country is less dependent on energy inputs and that energy conservation-oriented policies may not impede economic growth. This hypothesis implies that an increase in economic growth lead to an increase in energy demand (Dogan [13], Shahbaz *et al*. [8]). The feedback hypothesis stipulates that energy consumption and economic growth are interdependent and serve as complements to one another (Shahbaz *et al*. [8]). Thus, an increase (decrease) in energy consumption lead to an increase (decrease) in economic growth and likewise, an increase (decrease) in economic growth lead to an increase (decrease) in energy consumption (Shahbaz *et al*. [8]). The neutrality hypothesis postulates that energy inputs plays minor role on economic development of a country and does not significantly contribute to economic growth. As a result, energy conservation policies do not adversely affect economic growth. It is based on the argument that energy consumption represent a much smaller portion than labour and capital in production process and that this portion is so small to have a significance influence on economic growth. Thus, energy consumption and economic growth are independent and energy consumption play a minimal to non-existent role in production process (Sylvester and Okorie [11]). These hypotheses are inconsistent on the causality between energy consumption and economic growth. In the context of Zimbabwe, there has been high electricity consumption, low electric power supply leading to severe load-shedding and poor economic growth. It is worth to explore how the electric power consumption and energy consumption has an influence on economic growth.

Despite the inconsistence in theory on impact of electric power consumption on economic growth, empirical evidence also show that the causality between energy consumption and economic growth is inconsistent depending on country of study, methodology among other factors. Some of the methodologies used include the Pedroni, Kao and Johansen cointegration tests, Auto-Regressive Distributed lag (ARDL) model, Structural Vector Autoregressive framework, Dynamic Ordinary Least Square and Granger causality test to analyse the long run relationship between variables and inconsistent results were found. Pedroni, Kao cointegration tests and Autoregressive Distributed lag boundary approach were used by panel data based studies.

Some of the studies that used panel data include Bayar and Ozel [14] who analysed the relationship between electricity consumption and economic growth in emerging economies for the period 1991-2011. The study examined the long run relationship between the variables using Pedroni, Kao and Johansen Fisher cointegration tests and analysed the existence and direction of causality using the Vector Autoregressive Granger causality test. The study found that there is bidirectional causality between economic growth and electricity consumption. In investigating the causal links between economic growth, renewable energy, financial development and foreign trade in Gulf Cooperation Council Countries during the period 1980-2012, Hassine and Harrathi [15] used Pedron and Kao cointegration tests and the Engle and Granger [16] test to determine the direction of causality in the short run and long run. The variables used were gross domestic product, renewable energy consumption, private sector credit, exports, financial development, labour and capital. The study found that there is bidirectional causality in short run and long run between output and exports while no evidence of causality was found in the short run between output and renewable energy consumption, contrary to Bayar and Ozel [14] findings. The long run results showed that renewable energy consumption, private sector credit and exports had impact on output.

In addition to mixed findings in different countries, the relationship has also been found to be inconsistent in different income country groups. A typical example is the study of Yasar [2] who examined the relationship between energy consumption and economic growth using panel Autoregressive Distributed Lag Boundary approach, Vector Error Correction Model (VECM) and Granger causality analysis techniques to determine the long run dynamics of the variables. The study found that there is a causal relationship between energy use and economic growth depending on which income group the county belongs to. Bidirectional causality was found to hold in upper-middle income groups in the long run and high income group while the unidirectional causality from economic growth to energy consumption (conservation hypothesis) was found to hold for upper-middle income group in the short run and lower-middle income group in the long run. No direction of causality was found in low and lower-middle income groups in the short run. Whether these results imply that Zimbabwe as an upper-middle income country has sufficient economic growth to influence energy consumption despite high loading-shedding and unstable macroeconomic environment is subject to investigation.

Contrary to the findings of Yasar [2], Eggoh *et al*. [4] examined the relationship between energy consumption and economic growth in 21 African countries over the period 1970-2006 and found that there is a long run equilibrium between energy consumption, real gross domestic product, labour, capital for each group of countries as well as the whole set of countries. The study used Dynamic Ordinary Least Square and found a bidirectional causality between energy consumption and economic growth.

Khobai [3] investigated the causal relationship between electricity consumption and economic growth on BRICS countries using panel data for the period 1990-2014. The study used the Kao panel cointegration and Johansen Fisher cointegration techniques to analyse the long run relationship between the variables, economic growth, electricity consumption, carbon dioxide emissions and urbanisation as used by Bayar and Ozel [14] and Hassine and Harrathi [15]. The variables used include electricity consumption, real gross domestic product, carbon dioxide emissions and urbanisation. Vector Error Correction Model Granger causality test was used to estimate the causal relationship between the variables and the study found that there is a long run relationship between the variables. In addition, the study found that there is unidirectional causality flowing from economic growth to electricity consumption in the long run in BRICS countries.

Using Panel Vector Error Correction Model and Granger causality test as used by Khobai [3], Yucel *et al*. [12] analysed the relationship between renewable energy and non-renewable energy consumption and economic growth for a panel of fifteen European Union countries over the period 1990-2011. Heterogeneous panel cointegration test showed a long run equilibrium relation between real GDP, renewable energy and non-renewable energy consumption, greenhouse gases emissions and research and development. The study found a unidirectional causality running from non-renewable energy consumption to economic growth and a positive relationship between greenhouse gas emissions and real GDP.

Dogan [13] investigated the causal relationship between energy consumption and economic growth in four low-income countries in Sub-Saharan Africa using time series data for the period 1971-2011. The variables used were real GDP per capita and energy consumption. Using Johansen cointegration test and Granger-causality test, no long run relationship between real GDP and energy consumption was found for Kenya and Zimbabwe, contrary to the findings of Yucel *et al*. [12] and Khobai [3].

Consistent with the findings of Bayar and Ozel [14], the study found a unidirectional causality running from energy consumption to economic growth in Kenya and no causality between these variables was found in Zimbabwe, which is inconsistent with results of Eggoh *et al*. [4] and Khobai [3].

Shahbaz *et al*. [8] used a different approach from other panel studies, which is the quantile-on-quantile (QQ) approach to explore some nuanced features of the energy-growth nexus. The study examine the interlinkages between energy consumption and economic growth in top ten energy consuming countries, that is China, United States of America, Russia, India, Japan, Canada, Germany, Brazil, France and South Korea and found a positive association between economic growth and energy consumption with considerable variations across economic states in each country. In some countries, energy consumption was found to have less importance at low levels of economic growth and in some countries, energy consumption was found to decrease with increase in economic growth.

The results of panel data studies were mixed and inconsistent and the same applies to time series studies that were done especially in developing countries. For example, Sylvester and Okorie [11] evaluated the causal relationship between electricity consumption and economic growth in Nigeria over the period 1980-2014 using Johansen cointegration and VAR based techniques. The study found a long run relationship between electricity consumption and economic growth. A unidirectional causality between electricity consumption and economic growth was also found. Contrary to the findings of Sylvester and Okorie [11], Kasperowicz [17] investigated the relationship between electricity consumption and economic growth in Poland and found a bidirectional causality between electricity consumption and economic growth and a bidirectional causality between capital and economic growth. The study used Granger causality test and electricity was found to be a pro-growth variable in Nigeria. The variables used include real GDP, electricity consumption, gross fixed capital in real prices and total employment.

Jakovac [18] examined an empirical analysis on the relationship between economic growth and energy consumption in Croatia for the period 1952-2010 using Granger causality test. Chow break-point test showed a structural break in the year 1989, hence two subsamples were used. Johansen cointegration test showed a long run equilibrium relationship between economic growth and energy consumption. Consistent with the results of Kasperowicz [17], the study found a bidirectional causality between energy consumption and economic growth in the first subsample (1952-1989). After the structural break, the study found a unidirectional causality running from economic growth to energy consumption.

Zeshan and Ahmed [19] investigated the impact of energy consumption on real GDP, capital stock and labour force using annual data for the period 1971-2012. The study employed the Structural Vector Autoregressive (SVAR) framework and found that economic growth increase demand for labour force. The same was found to hold for energy and capital stock and the variables used were energy consumption, real GDP, capital stock and labour force. In Zimbabwe, Tsaurai [20] examined an empirical analysis of the nexus between energy consumption and economic growth using time series data. The study used the Johansen cointegration test procedure and bi-variate causality test framework to examine the relationship. The variables used were real GDP, energy consumption and contrary to the finding of Dogan [13], Kasperowicz [17], Sylvester and Okorie [11] among other studies, the study failed to establish any direct causality relationship between energy consumption and economic growth. The study found an indirect bidirectional causality relationship between energy consumption and economic growth.

Using panel data based on 17 Arab countries, Shahateet [7] examined the relationship between energy consumption and real economic growth. Using the Autoregressive Distributed Lag (ARDL) model and Granger causality test, the study found no causality relationship between economic growth and energy consumption in Arab countries except the case of Kuwait which showed to confirm a bidirectional causality between economic growth and energy consumption.

Evidence from literature shows that electric power consumption and energy consumption, among other factors are important factors of economic growth but the relationship between these factors and economic growth is ambiguous and inconsistent, hence seeks further investigation.

4. Data, Methodology and Results

The study used secondary time series data which covered the period, 1970-2014 and was collected from the World Bank website. The data included: data on electricity consumption defined as electric power consumption (kWh per capita), data on energy consumption defined as energy use (kg of oil equivalent per capita) and real gross domestic product as a proxy for economic growth. The relationship between these variables, expressed in the Vector Autoregressive Granger-causality frame work is stated as follows:

$$\Delta GDP_t = \alpha_3 + \sum_{i=1}^{q} \beta_{31i} \Delta GDP_{t-i} + \sum_{i=1}^{q} \beta_{32i} \Delta ELEC_{t-i} + \sum_{i=1}^{q} \beta_{33i} \Delta EC_{t-i} + \varepsilon_{3t} \quad (1)$$

$$\Delta EC_t = \alpha_1 + \sum_{i=1}^{q} \beta_{11i} \Delta EC_{t-i} + \sum_{i=1}^{q} \beta_{12i} \Delta ELEC_{t-i} + \sum_{i=1}^{q} \beta_{13i} \Delta GDP_{t-i} + \varepsilon_{1t} \quad (2)$$

$$\Delta ELEC_t = \alpha_2 + \sum_{i=1}^{q} \beta_{21i} \Delta ELEC_{t-i} + \sum_{i=1}^{q} \beta_{22i} \Delta EC_{t-i} + \sum_{i=1}^{q} \beta_{23i} \Delta GDP_{t-i} + \varepsilon_{2t} \quad (3)$$

In order to test whether these variables are stationary to avoid spurious regression, the Augmented Dickey-Fuller (ADF) test proposed by Dicky and Fuller [21] was used. Dickey and Fuller [21] presented the ADF unit root test as follows:

$$\Delta X_t = \beta_1 + \delta X_{t-1} + \sum_{i=1}^{n} \alpha_i \Delta X_{t-i} + \varepsilon_t \quad (4)$$

$$\Delta X_t = \beta_1 + \beta_2 t + \delta X_{t-1} + \sum_{i=1}^{n} \alpha_i \Delta X_{t-i} + \varepsilon_t \quad (5)$$

Where ε_t is a normally distributed white noise error term, t is a deterministic time trend, X_{t-1} is the lagged value of the variable X_t, ΔX_{t-i} is the lagged values of the first difference of the variable X_t, β_1, β_2, δ and α_i are the estimated coefficients. Several integration techniques have been used by previous studies to test for co-integration exist such as Pedron cointegration test, Kao cointegration test and Johansen cointegration test (Bayar and Ozel [14], Khobai [3], Sylvester and Okorie [11], Dogan [13]). This study used the Johansen cointegration procedure to analyse the long run relationship between electric power consumption, energy consumption and gross domestic product as widely used in literature. The Vector Error Correction Model was used to determine the speed of adjustment towards the long run equilibrium while the ARDL model was used to examine the existence of short-run causality and long-run relationship between economic growth, electric power consumption and energy consumption.

4.1. Econometric Results and Discussion

4.1.1. Stationarity

After taking the natural logarithms of all the series, stationarity test as in Yasar [2] were done to find out whether the series are stationary or co-integrated. The Augmented Dickey-Fuller and Phillips-Perron (PP) unit root test were used to test for stationarity in order to avoid spurious relations among the variables. The results of the unit root test are shown in table 2 below.

Table 2. Stationarity Tests on Series using the Augmented Dickey-Fuller and Phillips-Perron Unit Root tests

	Unit Root test using ADF unit roots test			**Unit Root test using Phillips-Perron test**		
Variable	ADF statistic	Critical Value at 5%	Probability	PP statistic	Critical Value at 5%	Probability
		Unit root test for series in levels				
LogGDP	-1.5673	-2.9297**	0.4906	-1.7342	-2.9297**	0.4075
LogELEC	-1.3831	-2.9314**	0.5817	-1.7113	-2.9314**	0.4185
LogEN	-2.1529	-2.9332**	0.226	-2.1408	-2.9332**	0.2304
		Unit root test for series in first differences				
LogGDP	-5.0439	-2.9314**	0.0002	-5.0352	-2.9314**	0.0002
LogELEC	-6.0686	-2.9332**	0.0000	-7.0458	-2.9332**	0.0000
LogEN	-5.2661	-2.935**	0.0001	-5.1501	-2.935**	0.0001

ADF and PP indicate respectively, Augmented Dickey-Fuller and Phillips-Perron. (**) Critical values at the 5% significance level. LogGDP: logarithm of gross domestic product, LogELEC: logarithm of electric power consumption per capita, LogEN: logarithm of energy consumption.

According to the results shown in Table 2, the null hypothesis that the series has a unit root cannot be rejected for all the series in levels since the ADF statistic and PP statistic is greater than the corresponding critical values, while the same null hypothesis can be rejected for all the series at 5% significance level after taking the first difference. Thus, all the variables were found to be non-stationary in levels and stationary after taking the first difference that is they are all integrated of order one.

4.1.2. Johansen Cointegration Procedure

Since all the variables were found to be non-stationary and integrated of the same order [**I(1)**], there is likely to be a long run relationship between these variables, making it worthwhile to test if co-integration exist. Before applying the Johansen co-integration test, optimal lag length of one was determined using the Akaike Information Criterion. The Johansen co-integration test was done using the following Vector Autogressive (VAR) model:

$$\Delta InY_t = \beta + \sum_{i=1}^{k} \Gamma_i \Delta InY_{t-i} + \Pi InY_{t-1} + \varepsilon_t \quad (6)$$

Where Y_t represents a n*1 vector of variables which are integrated of the same order. The parameters Γ and $\prod$ represent an $n*n$ matrice of coefficients of the lagged variables and ε_t is an $n*1$ vector of innovations. If the rank (r) is zero, then there is no co-integrating relationship, if the rank (r) is one, there is one co-integrating relation and if the rank (r) is two, there are two co-integrating relation and so on. The results for co-integration using the Trace method and Maximum Eigen value method are shown in the table 3 below.

Table 3. Cointegration test results

Unrestricted Cointegration Rank Test (Trace)				
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	Critical Value at 5%	Prob.**
None *	0.361536	32.52457	29.79707	0.0237
At most 1	0.249109	14.12831	15.49471	0.0795
Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	Critical Value at 5%	Prob.**
None	0.361536	18.39627	21.13162	0.1157
At most 1	0.249109	11.74627	14.2646	0.1205
At most 2	0.056443	2.382042	3.841466	0.1227

** denotes the rejection of the hypothesis at the 5% level. Trace test indicates 1 cointegrating eqn(s) at the 5% level. Max-eigenvalue test indicates no cointegration at the 5% level.*

Based on the Trace method shown in table above, the null hypothesis of no cointegration was rejected while the unrestricted cointegration rank test using the Maximum Eigen value test failed to reject the null hypothesis that there are no cointegrating equations. Thus, the Trace statistic showed that there is one cointegrating equation while the Maximum Eigen value showed that there are no cointegrating equations, yielding contradicting results. The results of Trace statistic and Maximum Eigen value statistic normally produce little contradiction. However, more importance was given to the results of Trace statistic because Trace statistc considers all of the smallest Eigen values and it hold more power than Maximum Eigen value statistic (Kasa, 1992; Serletis and King, 1997 as cited in Karacaer-Ulusoy and Özçelik [22]). In addition, Johansen and Juselius [23] recommend the use of the Trace statistic when there two statistics provides conflicting results. Therefore, the Johansen co-integration test showed the existence of long run relationship between the variables, which was contrary to the findings of Dogan [13] in Kenya and Zimbabwe.

4.1.3. Vector Error Correction Model

Since there is evidence of cointegration relationship among the series based on the Trace method, the Vector Error Correction Model was used to examine the long run dynamics of the variables. Before applying the VECM, Chow test was used to test if there is any structural break in the series. The null hypothesis that there is a structural break was tested using the F-test and the lag length was determined based on the Akaike Information Criterion. The F-statistic was found to be significant at 5% level and we cannot reject the null hypothesis that there is a structural break in the series. Therefore, the full sample (1970-2014) and subsample (1970-2008) was used. The subsample results showed that the variables are integrated of different orders, requiring the application of ARDL model. The results[4] of the Wald test on the ARDL model show that there is a long run relationship between economic growth, electric power consumption and economic growth but however, the error correction term was insignificant and no short-run causality was found between the variables. The long run model for the full sample shows that there is a long run equilibrium relationship between economic growth, electric power consumption and energy consumption as shown in table 4.

Table 4. Vector Error Correction Model

Dependent Variables	**Sources of Causality**			
	Short-run			**Long run**
	Δ LogGDP	**Δ LogELEC**	**Δ LogEN**	**ECT**
Δ LogGDP (7a)	0.1112 (0.8014)	0.2745 (0.7695)	-0.0435 (-0.0606)	-0.2261*** (-4.2692)
Δ LogELEC (7b)	0.0864 (1.4803)	0.2421 (1.6180)	-0.4125 (-1.3687)	-0.0060 (-0.2714)
Δ LogEN (7c)	0.0052 (0.1539)	0.0848 (0.9709)	0.1675 (0.9524)	-0.0195 (-1.5012)
	Long run Model			
LogGDP (7d)	**LogELEC**	**LogEN**	**C**	
	3.2967** (3.4506)	2.1567 (1.3891)	-25.7672	

*Lag length: 1. Log means logarithm. T-statistic are shown in parenthesis and ECT indicates Error Correction Term. *** indicates statistical significance at 1% level, ** indicates statistical significance at 5% level and * indicates statistical significance at 10% level.*

As far as short-run dynamics is concerned, equation (7a) shows that electric power consumption and energy consumption each had no short run impact on economic growth. However, the coefficient of the ECT was statistically significant, implying long run causality running from electric power consumption and energy consumption to economic growth as found by Jakovac [18] in the first subsample and Sylvester and Okorie [11]. It shows that the previous period deviation from the long run equilibrium is corrected in the current period at a speed of 22.6%. Thus, 22.6% of the previous period disequilibrium from the long run equilibrium is corrected gradually in the current period through a series of partial short-run adjustment. Therefore, although electric power consumption and energy consumption might not affect economic growth in the short

4 The results are shown in table 5. No serial correlation was found and the model was found to be stable using the Recursive Estimation CUSUM test.

run, maybe because it constitutes an insignificant share in promoting economic growth relative to inadequate capital sufficient to ensure growth, in the long run, these factors are critical for economic growth. With respect to equation (7d), the long run model shows that electric power consumption has a statistically significant impact on economic growth, where a 1% increase in electric power consumption result in a 3.3% increase in economic growth. From equation 7(b) when electric power consumption was used as the dependent variable, short run analysis shows that there was no short run and long run causality flowing from economic growth and energy consumption to electric power consumption, supporting the neutrality hypothesis in the short run as found by Shahateet [7]. Similarly, equation 7(c) shows that there is no short run and long run causality flowing from economic growth and electric power consumption to energy consumption, contrary to the findings of Tsaurai [21] in Zimbabwe, Bayar and Ozel [14], Kasperowics [17] and Hassine and Harrathi [15]. The results of the study supports the neutrality hypothesis in the short run as corroborated by Yasar [2] and the growth hypothesis in the long run, which is contrary to the findings of Khobai [3], Eggoh *et al*. [4] and Yasar [2].

From the pre-estimation and post-estimation tests, it was found that there is no presence of multicollinearity as the absolute value of the correlation statistic in the pairwise correlation matrix is less than 0.8. In addition, there was no evidence of autocorrelation and the residuals were found to be normally distributed. The variance of the error term was also found to be homoscedastic and these results are shown in table 6.

Table 5. Estimation Results using Least Squares Method

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.008707	0.012544	0.694136	0.496
D(LOG_GDP(-1))	0.309128	0.221655	1.394638	0.1792
D(LOG_GDP(-2))	-0.056112	0.240826	-0.232999	0.8183
D(LOG_GDP(-3))	0.132799	0.242766	0.547024	0.5907
D(LOG_GDP(-4))	-0.272088	0.213542	-1.274167	0.218
D(LOG_EN(-1))	-0.046194	0.857828	-0.05385	0.9576
D(LOG_EN(-2))	0.330322	0.975921	0.338472	0.7387
D(LOG_EN(-3))	0.069477	0.896957	0.077459	0.9391
D(LOG_EN(-4))	0.211356	0.928257	0.227692	0.8223
D(LOG_ELEC(-1))	0.312552	0.543927	0.574622	0.5723
D(LOG_ELEC(-2))	-0.415434	0.543283	-0.764674	0.4539
D(LOG_ELEC(-3))	-0.587863	0.547339	-1.074039	0.2963
D(LOG_ELEC(-4))	-0.255717	0.469001	-0.545237	0.5919
ECT(-1)	-0.166571	0.126243	-1.319454	0.2027

Note: ETC is the error correction term and numbers in parentheses are the lag lengths chosen based on the Akaike Information Criterion (AIC) and Schwarz Information Criterion (SIC).

Table 6. Pre-estimation and Post-estimation Tests

VEC Residual Serial Correlation LM Tests			VEC Residual Heteroskedasticity Tests			
Lags	LM-Stat	Prob	Chi-sq	df	Prob	
1	3.5926	0.9361	97.6421	84	0.1466	
VEC Residual Normality Tests			Correlation Matrix			
Orthogonalisation: Cholesky (Lutkepohl)				LOG_GDP	LOG_ELEC	LOG_EN
Jarque-Bera	df	Prob	LOG_GDP	1		
7.943	6	0.2423	LOG_ELEC	-0.3492	1	
			LOG_EN	-0.4779	0.3855	1

5. Conclusions

This paper investigates empirically the causal relationship between economic growth, electric power consumption and energy consumption in Zimbabwe using time series data for the period 1970-2014. The relationship between these variables can be explained using the growth hypothesis, neutrality hypothesis, feedback hypothesis and conservation hypothesis. The growth hypothesis argues that energy and electric power consumption promote economic growth while the conservation hypothesis insist that economic growth fosters energy consumption. While feedback hypothesis highlight that both energy consumption and economic growth causes each other, neutrality hypothesis argue that there is no causality between the variables in both short run and long run. Using the Johansen cointegration and Vector Error Correction Model, the study failed to establish any causal relationship between energy consumption, electric power consumption and economic growth in the short run. However, in the long run, there was a unidirectional causality running from electric power consumption and energy consumption to economic growth. The study therefore recommends the Zimbabwean government, Zimbabwe Electricity Supply Authority and relevant authorities to ensure supply of electricity by increasing investment in energy and electricity generation capacity since its availability in the long run is critical for economic growth. Furthermore, there is need to improve investment in infrastructure and industrial production by improving ease of doing business and rule of law.

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