Bivariate Modelling of the Influence of Trade on Aggregate and Disaggregate Energy Use in Ghana

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Abstract

The current research has explored the trade-energy nexus for Ghana using annual data within 1970-2011, using the Autoregressive distributed lag model (ARDL) and the Granger predictive causality test in bivariate modelling. The research findings provide evidence of a cointegration association between trade liberalisation (proxied by trade openness) and energy resources (proxied by aggregate energy use, electricity energy use, and fossil fuel energy use). However, there is an insignificant positive long-run effect of trade on energy use for all the energy resources under investigation. In the short-term, there is a positive significant effect of trade on electricity energy use and fossil fuel energy use, but an insignificant positive effect of trade on aggregate energy use. Concerning aggregate energy use, the research findings show that for aggregate energy use, there is causality from trade to aggregate energy use without feedback. However, in the case of electricity use and fossil fuel energy use, trade predicts energy use with feedback. For policy, energy conservation (fossil fuel energy use, and electricity energy use) may not have a deleterious effect on trade in Ghana. Future research may focus on how structural breaks and panel analysis improves the current study, controlling for the effect of other variables that influence energy use.

Keywords: Trade liberalization; Energy resources, Long-term, Energy conservation.

1. Introduction

Energy demand modelling research continues to attract attention in the literature because of energy's vital role in any economy. Concerning environmental pollution, international relations, legal, technical, economical, energy plays a significant role as an input in the various production functions as the cost factor (Zeren and Akkus, 2020). It impacts significantly on macroeconomic variables. In all economies, there is massive investment in the energy sector to ensure sustainable growth. Various factor such as urbanisation, industrialisation, technology, population growth continues to increase energy use.

There have been much research works on the factors that influence energy use in the literature with less research work on the role of trade in energy use empirically (Zeren and Akkus, 2020), especially in the developing and very open economy, such as Ghana. According to Nasreen and Anwar (2014) trade openness takes an important part in the openness-led economic growth proposition in the energy literature. The proposition shows that when trade openness increases growth and energy use are engendered and as such trade openness is a key explaining variable in energy demand modelling. Also, previous studies on energy consumption modelling either focus on aggregate energy consumption and trade or disaggregate energy consumption and trade (either fossil fuel or electricity). The current research focuses on trade openness and aggregate energy use, trade openness and fossil fuel energy use, trade openness and electricity energy use in bivariate modelling.

The purpose of the study is to model the influence of trade openness on energy use from the period 1970 to 2011. The purpose is attained by specifically assessing the cointegration association between energy use and trade openness; determining the long-term parameter coefficients, and the short-term dynamic coefficients, and the predictive causality direction between energy consumption and trade openness. The research question for the research paper is what is the nature of the relationship between trade openness and energy consumption (aggregate energy use, fossil fuel energy use, and electricity energy use) for the period under review and what is the nature of causality between energy use (aggregate energy use, fossil fuel energy use, and electricity energy use) and trade. The assumption underlying the research is the trade openness has a positive influence on energy use variables; trade openness predicts aggregate energy use without feedback; trade openness predicts electricity energy use and fossil fuel energy use with feedback.

The estimation is based on the ARDL model and the findings may be affected by the challenges of the model which is that, in the existence of a stochastic (random) trend in the time series data, the dynamics in an ARDL model will be approximating the trend instead of modelling the 'real' dynamics in the data (MVA Consultancy, 2008). Also, in bivariate modelling, the effect of a third variable is not accounted for, unlike multivariate modelling.

The next part of the study is organised into literature review (section 2), research methodology (section 3), empirical results (section 4), discussions (section 5), and conclusions (section 6).

2. Literature Review

Previous empirical works on trade and energy consumption variable have either focused on aggregate or disaggregate energy or both aggregate and disaggregate energy consumption. Some looks at renewable energy, alone, or non-renewable energy alone. Other studies also deal with both renewable and non-renewable energy. The findings are reported in the works of various previous research works (See (Dedeoğlu and Kaya, 2013; Erkan *et al.*, 2010; Farhani *et al.*, 2014; Halicioglu, 2011; Hossain, 2012; Katircioglu, 2013; Lean and Smyth, 2010; Narayan and Smyth, 2009; Sadorsky, 2011;2012; Sami, 2011; Sebri and Ben-Salha, 2014; Shahbaz *et al.*, 2013b; Shahbaz *et al.*, 2013a). This section provides a review of these works as reported in the literature in brief.

In different income level countries studies, Shahbaz *et al.* (2014) investigated the trade-energy use association for the period 1980 to 2010. The findings of their research show evidence of cointegration, with feedback causality link between trade and energy use. They reported that the income level of a country plays a significant role in determining trade effect on energy use, which must be taken into consideration in providing policy to ensure sustainable growth. The estimation was based on panel cointegration test and Homogenous causality and non-causality tests as well as heterogeneous causality test. Nasreen and Anwar (2014), studied the effect of trade on energy consumption in a panel study for Asian countries. The study period was from 1980 to 2011. The findings of their study supported the cointegration proposition with a positive effect of trade on energy use. The feedback proposition was valid in their study. Their analysis was based on Pedroni (1999), Pedroni (2004) and Larsson *et al.* (2001) panel cointegration method Sebri and Ben-Salha (2014) for the BRICS countries analysed the association among trade, growth, carbon emissions, and energy use for the period 1992 to 2010. Their results provided evidence for cointegration in the model estimated and reported feedback causality between energy consumption and trade for the period under discussion in India and Brazil. Their estimation was based on the VECM and the ARDL methods. Yazdi and Mastorakis (2014), appraised the association among trade, carbon emissions, energy consumption (renewable energy), growth, and population density using ARDL and the VECM causality tests. There was evidence of cointegration and causality without feedback from trade to energy consumption in Iran.

Al-Mulali and Ozturk (2015), evaluated the association among energy consumption (renewable energy), urbanisation, growth, financial development, trade and carbon emissions, for 23 European countries for the period 1990 to 2013. The results provide evidence for cointegration among the variables, with trade causing causality without feedback. Jebli *et al.* (2015), studied the part energy use and trade play in the environmental Kuznets proposition for the OECD countries from 1980 to 2009 and reported that no significant causality between energy consumption and trade. Their study estimation was based on the panel cointegration method by Pedroni. Najarzadeh *et al.* (2015), studied the trade association with energy consumption for OPEC countries from 1985 to 2009. The findings of the study show energy consumption is a function of trade. The causality direction test results show trade (proxied by export) predicts energy consumption, whereas trade (proxied by import) predicts energy consumption with feedback. Their results analysis was based on Pedroni (1999), Pedroni (2004) cointegration test. Mehdi and Slim (2015), explored the link among trade, non-renewable energy consumption, renewable, and growth for 69 countries for the period 1980 to 2010, and reported that cointegration exists among the variables with both short-term and long-term stable relation with feedback causality between trade and non-renewable energy (short-term) and unidirectional causality from renewable energy to trade (short-term). In the long-term feedback, causality exists between trade and renewable energy consumption. The analysis is based on our long-run ordinary least squares (OLS), fully modified OLS (FMOLS) and dynamic OLS (DOLS). Tiba *et al.* (2015), explored the link among growth, trade, carbon emissions, energy (renewable energy) consumption, for middle- and high-income countries from 1990 to 2011. The research findings indicate feedback causality between trade and renewable energy consumption in the study for the UK, Sweden, and China. The GMM estimation method was employed in the study.

Akar (2016), probed the factors that influence renewable energy consumption for 12 Balkan countries using the GMM estimation model. The trade variable in the model influenced renewable energy consumption for the period under investigation. Dogan and Seker (2016), examined carbon emissions determinants for the European Union from 1980 to 2012. The variables in the model were renewable and non-renewable energy consumption, real income, carbon emissions and financial development. The research findings supported the cointegration proposition but could not provide support for the causality proposition. The analysis was based on the Pedroni panel and Kao and LM bootstrap cointegration and the Dumitrescu-Hurlin panel Granger causality test. Shahbaz *et al.* (2017) explored the environmental Kuznets proposition for the United States accounting for structural breaks from 1960 to 2016 base on the ARDL and the VECM causality test. Evidence of cointegration was among the variable was established with the granger causality emanating from trade to biomass energy consumption without feedback.

Iheanacho (2018), in a Nigerian study examined the effect of trade on energy use from 1971 to 2013. The analysis was based on ARDL and the VECM Granger causality test. The study findings indicate a positive effect of trade on energy consumption. The Granger causality test results indicate causality runs from trade to energy consumption. The use of the ARDL model is appropriate for their study since the sample size is not very large enough.

Alkhateeb and Mahmood (2019), investigated trade-energy use link for Egypt from 1971 to 2014. The findings of the research revealed an association between energy use and trade. The findings indicate further that there is a significant positive effect on the long-term and short-term when a trade is increase and decrease. However, there is

an insignificant effect on the long-term when a trade is decreasing. The ARDL cointegration method was used in the estimation of the study, which performs well in not a large sample study.

Zeren and Akkus (2020), assessed the association between energy use (both non-renewable and renewable) for Bloomberg emerging countries from 1980 to 2015. The findings of their study indicate an increase in trade is a function of the use of non-renewable energy use, whereas a decrease in trade is a function of the use of renewable energy use. Concerning the direction of causality, their study supported the neutrality proposition between trade and renewable energy use, whereas the energy-led growth proposition was supported between trade and non-renewable energy use. Their study is of interest for considering the effect of structural breaks in assessing the long-term effect. Their study estimation method was Westerlund (2006) panel cointegration test, (Pesaran, 2006) CCE-MG cointegration estimator, and Dumitrescu and Huriin (2012) panel causality test

The above review indicates mixed findings concerning the trade-energy association and that calls for further empirical works such as the current study in which energy resources are and trade liberalisation are modelled in bivariate analysis.

3. Methodology
3.1. Data
The research is based on annual data for the period 1970-2011 for Ghana. Table 1 shows the variables used in the estimated model with their full names and sources.

<div align="center">Table-1. Data Description, Proxy, and Sources</div>

Variables and full names	Proxy	Source
Trade liberalisation (TO)	Trade openness	World Development Indicators (WDI)
Aggregate energy consumption (AEC)	Total energy consumption	
Disaggregate energy consumption (EC)	Electricity consumption	
Disaggregate energy consumption (FF)	Fossil fuel consumption	

3.2. Unit Root Analysis
The unit root test is conducted to determine the stationarity features of the series in the models estimated for the order of integration. This is necessary since the study is a time series research based on cointegration, which demands that the variables should not be integrated of order 2 or other higher-order values. In the case where the variables are not stationary in levels, they are made stationary by differencing. The two main tests performed in the current research are the Dickey and Fuller (1981) and the Kwiatkowski *et al.* (1992). Following the work of Nanthakumar and Subramaniam (2010), the ADF is specified in equations (1). The ADF test distribution proposes that the distribution is not normally distributed. Where γ = time trend, Y= time series variable in the model, ε_t = error term or stochastic error term. The ADF can further be specified as in equations (2), (3), and (4).

$$\Delta Y_t = \alpha_t + \beta_t \gamma_t + \rho Y_{t-1} + \sum_{i=1}^{q} \partial \Delta Y_{t-1} + \varepsilon_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

$$\Delta Y_t = \sum_{i=1}^{p} \gamma_i \Delta Y_{t-1} + \varepsilon_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. \quad (2)$$

$$\Delta Y_t = \mu + \beta Y_{t-1} + \sum_{i=1}^{p} \gamma_i \Delta Y_{t-i} + \varepsilon_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \quad (3)$$

$$\Delta Y_t = \mu + \partial T + \beta Y_{t-1} + \sum_{i=1}^{p} \gamma_i \Delta Y_{t-i} + \varepsilon_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. \quad (4)$$

Where Y_t = level of the series variable, μ= drift term, T = time trend, P = number of lags, Δ= shows the series are in their first difference. The ε_t is the white noise which has the properties of normal distribution. Its variance is constant and has an expected mean value of zero. The errors are independent of each other. In equation (2), there is no constant term and time trend whereas in equation (3) there is a constant term. In equation (4), there are both constant term, and time trend.

The ADF null proposition (H_0) is that the series are non-stationary in levels. The alternative proposition (H_1) is that the series is stationary. The critical values are compared with the calculated values at 10%, 5%, and 1% levels of significant. The decision rule for the use of the ADF test is that when the calculated ADF value is less in absolute term than the ADF critical value in absolute term, the series in the model are not stationary or has unit-roots. In the analysis, when the series is not stationary, the series must be difference until they become stationary.

In the current research, the KPSS test is normally used as a confirmatory test for the ADF test analysis. The KPSS test null proposition is that the series of variables under investigation are stationary against the alternative proposition that they are non-stationary (Kwiatkowski *et al.*, 1992). Equation (5) specifies the KPSS models, with equation (6), specifying the random walk model. The Kwiatkowski *et al.* (1992), test is adopted because it is more powerful in small samples in which the null proposition is a stationary process against the alternative of the unit root process.

Given that X_t is the series variable under investigation, Kwiatkowski *et al.* (1992), specify an equation as shown in equation (3.5) to decompose the series into the sum of a deterministic trend (t), a random walk (r_t) and a stationary error (ε_t).

$$X_t = \xi t + r_t + \varepsilon_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \tag{5}$$

Where deterministic trend = t; $X_{t=}$ series variables; random walk = r_t; stationary error = ε_t.

$$r_t = r_{t-1} + \mu_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \tag{6}$$

In equation (6), μ_t is considered to be IID $(0, \sigma^2_\mu)$, that is it obeys the ordinary least square regression proposition. The initial value of r_t, is = r_0, and it is considered as the fixed value it plays the role of an intercept in the model. The stationarity proposition is given as σ^2_μ and it is =0. The series variable under assessment (X_t) is trend stationery since the error term is stationary. In model (5), Kwiatkowski *et al.* (1992), set the coefficient as $\xi = 0$, where the null proposition that the series variable (X_t) is stationary around a level (r_0) and not around a deterministic trend. The authors considered this as a special case of the model. The Lagrange multiplier (LM) statistic is the test statistic, and the proposition is that $\sigma^2_\mu = 0$, given the assumption that μ_t is normally distributed and that the error term (ε_t) is IID $N(0, \sigma^2_\varepsilon)$. Kwiatkowski *et al.* (1992), specified a partial sum process of the residuals as in equation (7).

$$S_t = \sum_{i=1}^{t} e_i, \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. \tag{7}$$

Where t= 1, 2, 3, …, T.

Kwiatkowski *et al.* (1992), specified equation (8) based on equation (7) as the LM statistic.

$$LM = \sum_{t=1}^{T} S_t{}^2 / \hat{\sigma}^2_\varepsilon, \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \tag{8}$$

In testing for stationarity in the levels of the series, Kwiatkowski *et al.* (1992) without considering the trend, the error term (e_t) is considered as the residual from the regression of the series (X) on an intercept only. Equation (9) indicates that.

$$e_t = X_t - \bar{X}, \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \tag{9}$$

3.3. The Cointegration Estimation Method

The present research estimation is based on the ARDL model developed by Pesaran *et al.* (2001) for cointegration which has become very popular for its various merits in assessing the long-term and short-term association in time series research. The ARDL model allows for the examination of statistically significant long-term and short-term relationship among series variables whether in their levels or their differenced forms. The ARDL bound test approach has many advantages (Banerjee *et al.*, 1993; Haug, 2002; Laurenceson and Chai, 2003; Pesaran and Shin, 1999). The test makes it possible to examine the long-term association without prior knowledge of the order of integration of the series provided they are not of order two. It also performs well in small sample study and also able to distinguish between dependent and independent variables. The dynamic error correction model is also available in the estimation. The estimation process is also based on a specific-to-general method and adopts enough number of lags. No information is also lost in the process of estimating the parameters in incorporating the short-term into the long-term.

In line with previous studies (Belke and Polleit, 2006; Shahbaz *et al.*, 2010), the ARDL model is specified as in equations. In the estimation of the ARDL model all, the values in the model are used as a dependent variable and the analysis is repeated. In the model in which a cointegration relationship is identified, the model is estimated for the long-run parameters or coefficients.

$$\Delta y_t = C_{0y} + C_{1y}t + b_1 y_{t-1} + b_2 x_{1,t-1} + b_3 x_{3,t-1} + \ldots + b_k x_{k,t-1} +$$

$$\sum_{i=1}^{m-1} \gamma_i \Delta y_{1,t-1} + \sum_{i=0}^{n_1-1} \alpha_{ik} \Delta x_{k,t-i} + e_{ty} \ldots\ldots\ldots\ldots. \tag{10}$$

Equation (10) is an unrestricted error-correction model (ECM). Variable y is regressed on variable x. Where variable x is a vector. In the model 'b's measure the long-term effects (long-term Parameters). The γ and 'α' is the short-term parameters and measure the short-term effects. The M and N are the order of lags, t is the time trend. The variable 'k' is the number of "forcing variables in the model under investigation.

$$\Delta y_t = \sum_{i=1}^{p} \alpha_i \Delta y_{t-1} + \sum_{i=1}^{s} \beta_i \Delta x_{t-1} + \sum_{k=1}^{q} \beta_k \Delta z_{t-k} + \gamma ECM_{t-1} + e_t \ldots. \tag{11}$$

The null proposition (H_0) is that there is no cointegration among the variables in the model against the alternative proposition (H_1) that the variables are cointegrated. That is, H_0: $b_1 = b_2 - b_3 = \ldots = b_k = 0$; against the alternative proposition H_1: Not H_0. The rejection /acceptance of the H_0 is based on the Wald /F tests. If there is a significant long-term relationship in the model, the Wald/F test shows which variable needs to be normalized. According to Belke and Polleit (2006), the Wald/F-statistics are non-standard in the case of the null proposition of no cointegration. Hence, the critical value provided by Pesaran *et al.* (2001) for the bound testing approach is used.

There are two critical sets of variables for the upper limit and lower limit, for series integrated of order one, I (1) and those integrated of order zero I (0). The calculated (Fob/Wald critical) values are compared with the upper and lower limit values for the bound test at various levels of significance such as 10%, 5%, and 1%. If the computed F-

statistics (Fob) lies between the upper limit and lower limits the results are considered inconclusive. This means no decision can be made. In the case where the Fob value is higher than the upper limit values, the H_0 is rejected which means significant cointegration association and statistically significant long-term association. If the Fob value is lower than the lower limit values given as the bound critical values, the Ho is not rejected which indicate there are a statistically significant cointegration association and possible long-term association in the model.

The Akaike (AIC), and Schwarz information criteria (SIC) were used for the lag selection. The number of regressions determined in the ARDL model according to Pesaran *et al.* (2001) is provided by $(n+1)^k$. In this case, 'n' is the maximum number of lags used in the model and K is the number of series variables in the estimated model.

Various diagnostic tests such as J-B Normality test, Breusch-Godfred LM test, ARCH LM test, White Heteroskedasticity test, Ramsey RESET were used to explore the model goodness of fit. The cumulative sum of recursive residuals (CUSUM) and the cumulative sum of squares of recursive residuals (CUSUMSQ) was used to explore the stability of the estimated model parameters. With the plots (CUSUM and CUSUMSQ), when the statistics stay within the critical bonds of a 5% level of significance, the null proposition of all coefficients in the given model are stable and are accepted.

3.4. The Conceptual Framework of the Empirical Model

The conceptual model is bivariate. There are two variables in the model estimated and the model is as specified in equation (12). The dependent variables are the energy sources (Total energy use electricity energy use and fossil fuel energy use). The independent variable is the Trade Openness (TO).

$$N_{tj} = \sum_{i=1}^{6} \beta M_{1i} + \varepsilon_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots. \tag{12}$$

Where N, and M represent the dependent variables (Total energy use, Electricity energy use and Fossil Fuel energy use) and independent variable (TO) respectively. Where j=1 for Total energy use; 2 for Electricity energy use and 3 for Fossil fuel energy use for the dependent variables (M). For the independent variables (N), i=1, 2, 3, 4, 5, 6 for 1=TO.

4. Empirical Results
4.1. Descriptive Statistics
4.1.1. Central Tendencies and Dispersion Results

The summary statistics results of the variables are reported in Table 2. The central tendency of the series variables was explored using the mean, and the values indicate a good fit. The volatility of the data set was explored using the coefficient of variation. The coefficient of skewness was used to explore the distribution of the data. The series distributions are either normal or asymmetric. The results of the summary statistics of the variables as shown in Table 2 show that electricity energy use falls as low as 92.359GWh and rise as high as 421.233GWh. Total energy use falls as low as 304.95GWh and rises as high as 433.12GWh whereas fossil fuel energy use falls as low as 11.529GWh and 31.205GWh. Of the types of energy series, the most volatile is electricity energy use (0.229) followed by fossil fuel use (0.195) and total energy demand (0.079). Among the series variables, the least volatile series variable is total energy (0.079) followed by fossil fuel demand (0.195). The nature of the distribution of the series as measured by the coefficient of skewness indicate the series is normal and asymmetric. The types of skewness are positive and negative. In a positive distribution, the asymmetric tail moves towards the right. In a negative skewness, the asymmetric tail moves in the left direction. Hildebrand (1986) stated that an absolute value of the coefficient of skewness greater than 0.2 indicates greater skewness. The range of the coefficient of skewness is between a positive one (1) and a negative one (-1). The results as shown in Table 2 show total energy and electricity consumption variables are negatively skewed whereas fossil fuel energy and trade openness variables are positively skewed. None of the series variables is an outlier.

Table-2. Summary Statistics, using the Observations 1970-2011

Vars.	Mean	Min	Max	SD	CV	SK
AEC	376.720	304.950	433.120	30.022	0.079	-0.140
EC	311.580	92.359	213.630	71.435	15.308	-0.897
FF	21.797	11.529	31.205	4.257	0.195	0.097
TO	53.603	6.320	116.050	29.326	0.547	0.364

Source: Author's computation, 2015. SK=Skewness;
CV=Coefficient of Variation; Min. Minimum; Max. =Maximum; SD=Standard
Deviation

4.1.2. Correlation Results

The presence of multicollinearity in the series variables was explored using the correlation matrix. The results are shown in Table 3. The results show that electricity energy use shows an insignificant negative (-0.019; -0.149) association with fossil fuel use and trade openness and a positive association with total energy use (0.141). Fossil fuel demand (FF) shows a significantly positive association with TO (0.575) and total energy use (0.818). Total energy use (AEC) exhibits a significant positive association with TO (0.746). Overall, the magnitudes of the correlation coefficients indicate that multicollinearity is not a potential problem in the regression models estimated.

Table-3. Correlation Matrix for Test's Variables

Var	AEC	EC	FF	TO
AEC	1.000			
EC	0.141	1.000		
FF	0.818	-0.019	1.000	
TO	0.746	-0.149	0.575	1.000

**Source:** Author's computation, 2015
**NOTE:** 5% critical value (two-tail) = 0.3044

4.2. Unit Root Tests
4.2.1. Time Series Plot of the Variables in Levels

The Time Series plot results shown in figures (figure 1, 2, 3, figure 4) indicate the series is not stationary in levels and might achieve stationarity by differencing (figure 5, 6, 7, figure 8). This calls for further scientific investigation of the nature of unit root using the KPSS model of a unit root.
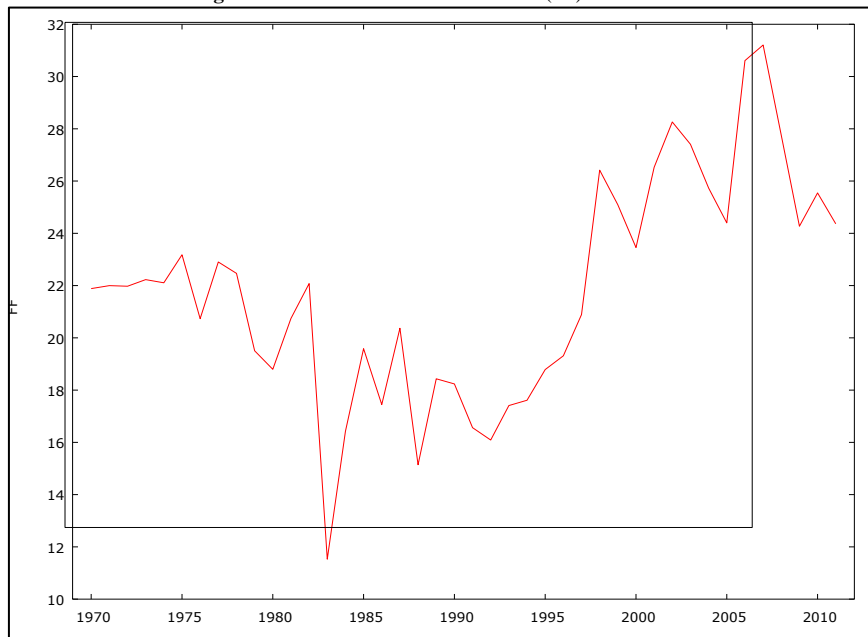
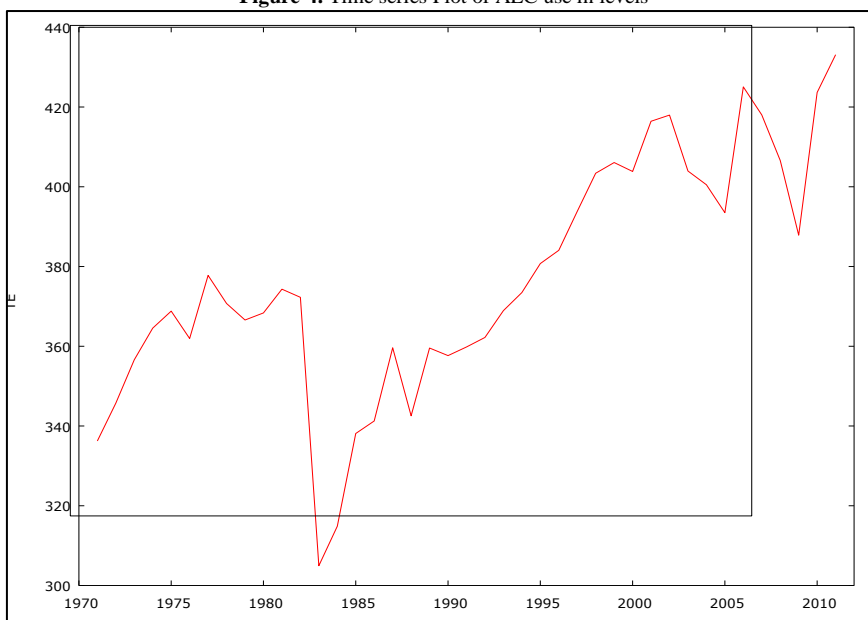**Figure-1.** Time series Plot of Electricity consumption (EC) in levels
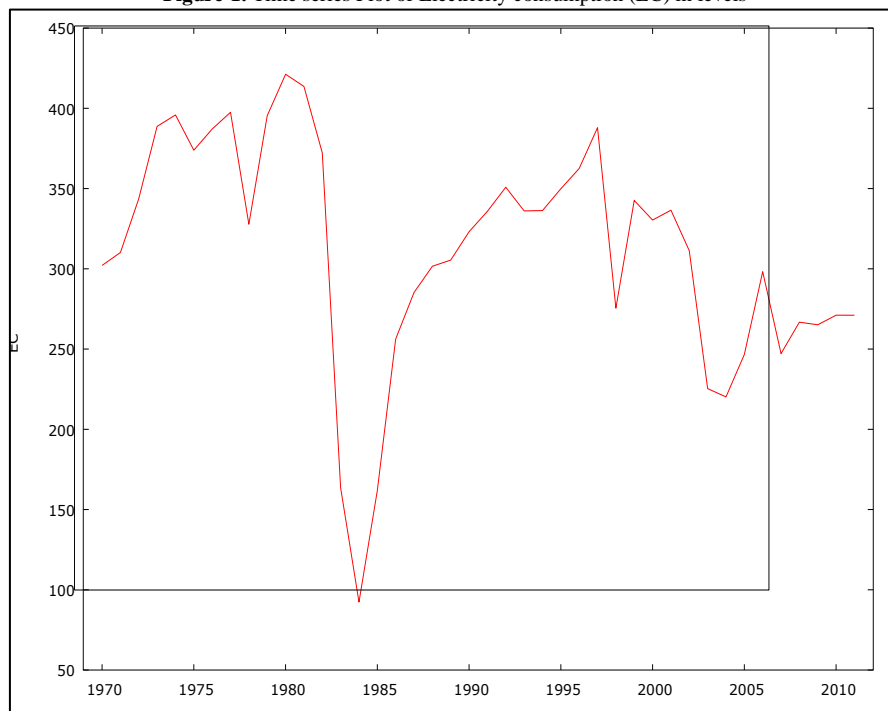
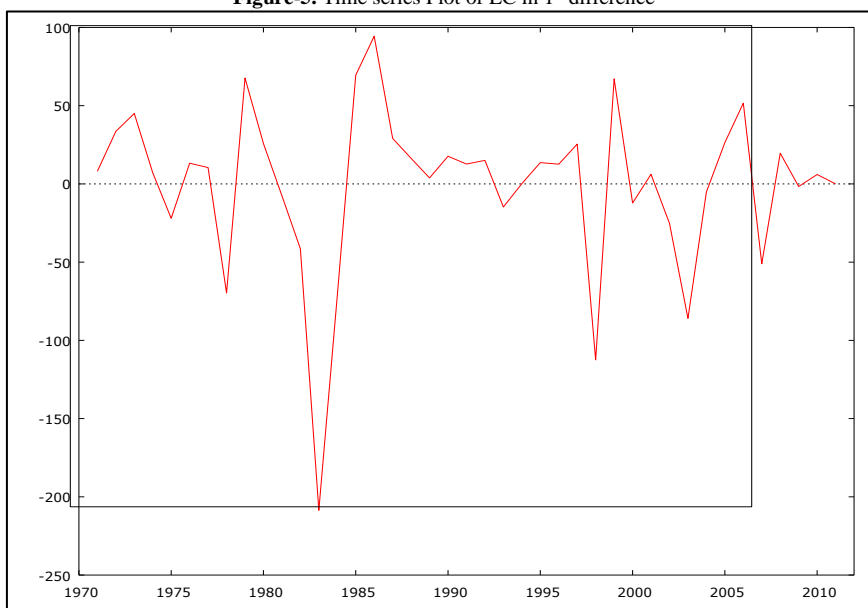**Figure-2.** Time series Plot of TO in levels
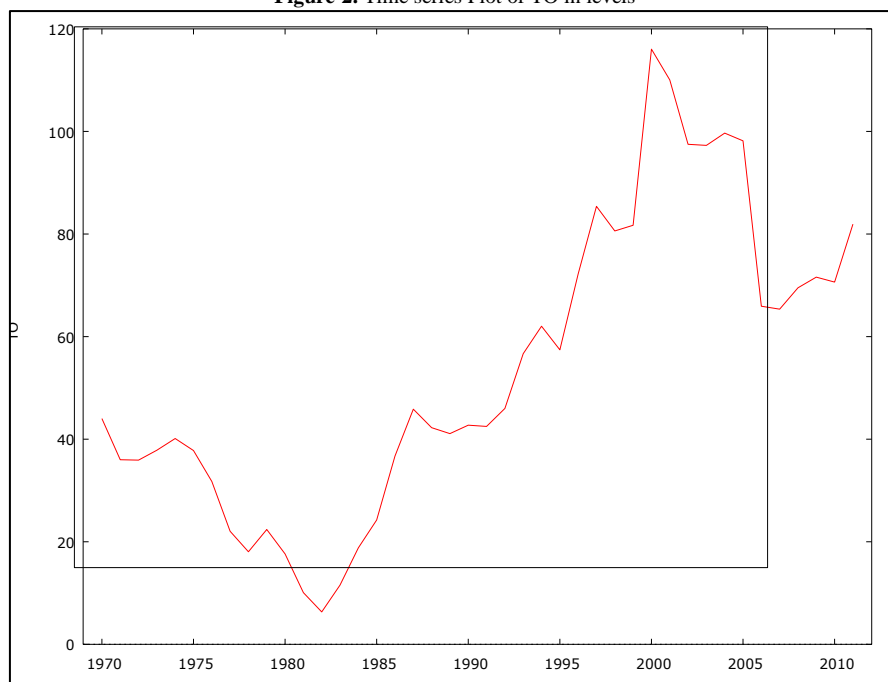
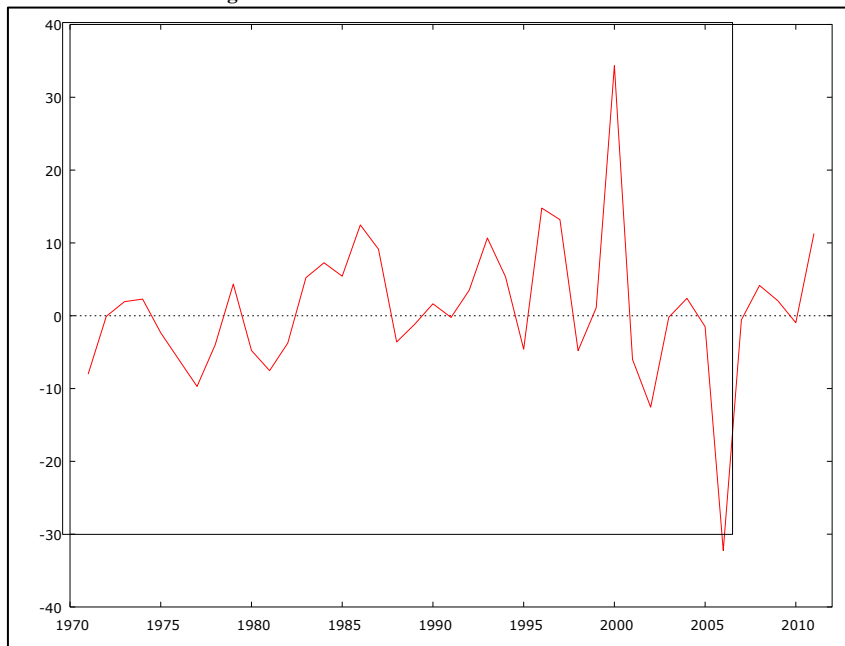**Figure-3.** Time series Plot of Fossil fuel (FF) use in levels

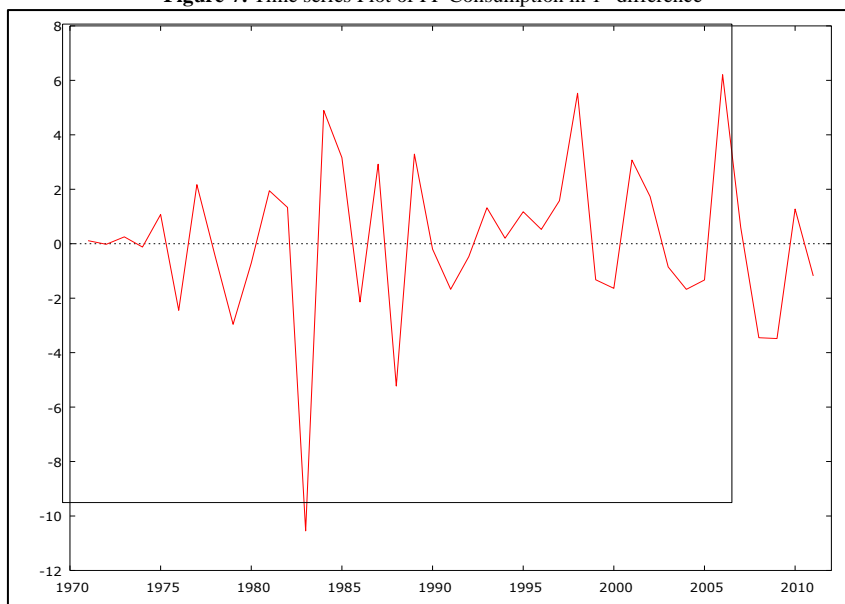**Figure-4.** Time series Plot of AEC use in levels

Figure-5. Time series Plot of EC in 1st difference
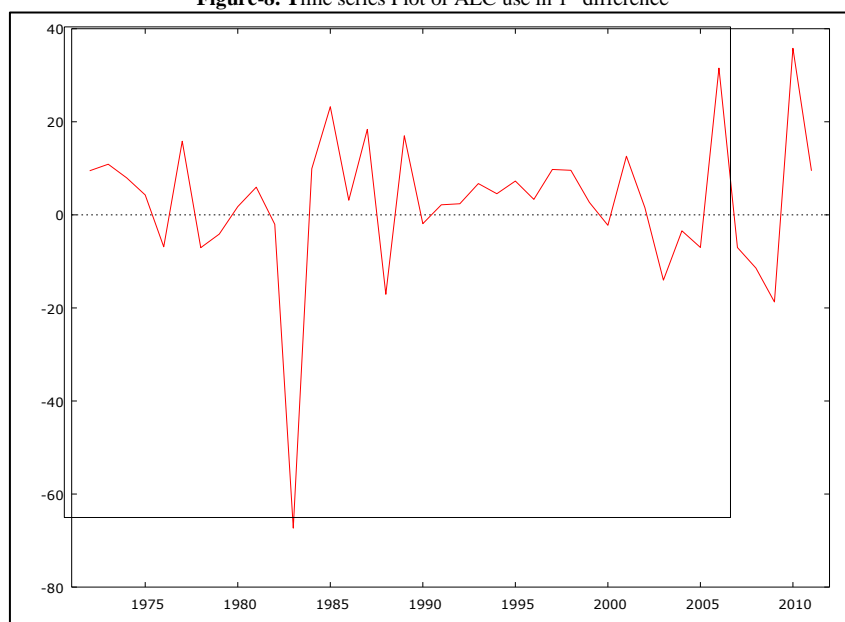
Figure-6. Time series Plot of OPEN in 1st difference

Figure-7. Time series Plot of FF Consumption in 1st difference

Figure-8. Time series Plot of AEC use in 1st difference

4.2.2. The Adf Test

The unit root test results based on the ADF test are shown in Table 4. The results in levels show that the series are non-stationary in the intercept. The null proposition of unit root was accepted for all the series.

Table-4. ADF stationarity test results with a constant and trend

Variables	t-statistics	ADF/P-Value	Results	Lag length
TO	-2.0358	0.5649	Not stationary	1
TO-1st dif.	-5.4388	0.0004***	Stationary	1
EC	-3.4705	0.0426**	Stationary	1
EC-1st dif.	-5.2808	0.0005***	Stationary	1
FF	-2.7613	0.2191	Not stationary	1
FF-1st dif.	-6.9492	0.0000***	Stationary	1
AEC	-2.6421	0.2650	Not stationary	1
AEC-1st dif.	-6.7773	0.0000***	Stationary	1

Source: Author's computation, 2015: Note: *** and ** denote significance at 1% and 5% levels of significance

The series when first differenced were not stationary. Taking the logarithm of the first difference of the series, and testing these with intercept, and trend made the series stationary. That is, the null proposition of unit root is not accepted. The results are shown in Table 5. These results show that the series depicts unit root processes in levels.

Table-5. ADF stationarity test results with a constant and a time trend

Variables (1st dif.)	t-statistics	ADF/P-Value	Results	Lag length
ΔlnTO	-4.6744	0.0007***	Stationary	1
ΔlnEC	-5.4304	0.0000***	Stationary	1
ΔlnFF	-7.2478	0.0000***	Stationary	1
ΔlnAEC	-6.7841	0.0000***	Stationary	1

Source: Author's computation, 2015: Note: *** denotes significance at 1% level

4.2.3. The Kpss Test

The null proposition (Ho) of the KPSS test is that the series variables under investigation are stationary (series are not unit root) with an alternative proposition (H1) that the series is not stationary (series are unit root). The KPSS is considered as an opposite test for stationarity. In the present research, it is used for confirmation of the stationarity properties of the series. The results are reported in Table 6, and Table 7. The series were examined in their levels in linear form, and the first difference (Table 6) in their logarithm form (Table 7). The series were stationary in the levels except for fossil fuel consumption; however, they are all stationary on the first difference of the linear form. This means fossil fuel consumption is order one integrated, whereas the rest of the series orders zero integrated. The levels of significance are 1%; 5% and 10%. The logarithm form results show the series is stationary on the first difference.

Table-6. KPSS stationarity test results with a constant and a time trend

Variables	t-statistics	P-Value	Results	Lag length
TO	0.1348	0.076	Stationary	3
TO-1st dif.	0.1211	n.a	Stationary	3
EC	0.0650	n.a	Stationary	3
EC-1st dif.	0.0477	n.a	Stationary	3
FF	0.2307	n.a	Not stationary	3
FF-1st dif.	0.0993	n.a	Stationary	3
AEC	0.1576	0.044	Stationary	3
AEC-1st dif.	0.0660	n.a	Stationary	3

(Author's computation, 2015): Critical values at 10%, 5% and 1% significant levels are 0.122 0.149 0.212 respectively

Table-7. KPSS stationarity test results with a constant and a time trend

Variable	KPSS P-value	Results	Lag Length
ΔlnTO	0.1038	Stationary	3
ΔlnEC	0.0451	Stationary	3
ΔFF	0.0872	Stationary	3
ΔlnAEC	0.0646	Stationary	3

(Author's computation, 2015): Note: Critical values at 10%, 5% and 1% significant levels are 0.122; 0.149; 0.212 respectively.

4.3. Results of the Cointegration Test
4.3.1. The Autoregressive Distributed Lag (Ardl) Model/Bound Approach to Cointegration

The cointegration test results are reported in Table 8. For each energy consumption model, two models (model 1 and model 2) were estimated, with model 1 having energy consumption variable (AEC, EC, FF) as the dependent variable and the trade openness variable as the independent variable (TO) The results shown in Table 8 indicate

significant cointegration between all energy consumption variables (AEC, EC, FF) and trade openness (TO) since the calculated F-statistics of all the first cointegration models (model 1) are not less than the critical values of the upper bounds at the 90%, 95% and 99% levels of significance. However, in all the second cointegration models estimated (model 2) with the trade openness variable as the dependent variable, there is no significant cointegration in the model since the calculated F-statistics values are not greater than the critical values of the upper bounds at the 90%, 95% and 99% levels of significance. Hence, the null proposition of no cointegration is rejected in model 1, but not in model 2 for all the energy consumption models estimated. The results indicate that trade openness is a long-term equilibrium variable that explains total energy use, electricity energy use and fossil fuel energy use in the period under review.

Table-8. Test for cointegration relationship

Critical bounds of the *F* -statistic: intercept and trend						
	90% level		95% level		99% level	
	I(0) *I*(1) 2.915 3.695		*I*(0) *I*(1) 3.538 4.428		*I*(0) *I*(1) 5.155 6.265	
	Computed *F* -Stats		**Decision**			
Total Energy Consumption						
1. F_{TE}(AEC/TO)	27.0839***		Cointegrated			
2. F_{TO}(TO/AEC)	2.7035		Not Cointegrated			
Electricity Consumption						
1. F_{EC}(EC/TO)	38.8617***		Cointegrated			
2. F_{TO}(TO/EC)	2.9116		Not Cointegrated			
Fossil Fuel Energy Consumption						
1. F_{FF}(FF/TO)	5.6292**		Cointegrated			
2. F_{TO}(TO/FF)	2.9529		Not Cointegrated			

Source: Author's computation, 2015: Note: critical values are obtained from Pesaran *et al.* (2001) and Narayan (2004)

4.3.2. Long-Run Elasticities for Total Energy Consumption, Electricity Consumption, and Fossil Fuel Consumption

The long-term determinant of energy use was determined using the model in which energy use variables are the dependent variables (model 1). The results are shown in Table 9. The results show that trade openness (TO) statistically significantly does not determine energy use in the long-term since the coefficient values in all the models estimated are not significant. The coefficient of trade openness has expected a priori theoretical sign of positive in all the models estimated. The results show that an increase in trade openness leads to an increase in energy use (total energy, electricity energy use, and fossil fuel energy use).

Table-9. Estimated long-run coefficients. The dependent variable is LNAEC/ Dependent variable is *lnEC* / Dependent variable is LNFF/

Total Energy Model	Coefficient	Std. Error	T-ratio	P-value
Constant	5.6204	0 .1368	41.0745	0.000***
Trend	0.0023	0.0029	0.7973	0.431
lnTO	0.0709	0.0483	1.4680	0.151
Electricity consumption model	**Coefficient**	**Std. Error**	**T-ratio**	**P-value**
Constant	5.1355	0.4745	10.8227	0.000***
Trend	-0.0178	0.0097	-1.8389	0.075*
lnTO	0.2558	0.1636	1.5638	0.127
Fossil Fuel Consumption	**Coefficient**	**Std. Error**	**T-ratio**	**P-value**
Constant	1.8289	0.8322	2.1976	0.035**
Trend	-0.0023	0.0134	-0.1734	0.863
lnTO	0.3422	0.2789	1.2272	0.228

Author's computation, 2015: ARDL (1) selected based on the Akaike Information Criterion. NB: *** denotes significance at 1% level

4.3.3. Short-Term Elasticities for Total Energy Consumption, Electricity Consumption, and Fossil Fuel Consumption

The results of short-term dynamic equilibrium association coefficients determined with the trend, intercept and error correction term (ECM) are shown in Table 10. The result on the nature of the short-term for total energy consumption is similar to that of the long-run coefficients since the coefficient value is not significant. However, trade is a significant short-run determinant of electricity consumption and fossil fuel consumption at a 10% level of significance, with a positive effect on energy consumption.

The error correction mechanism was explored. The error correction term is statistically significant with the expected theoretical sign of negative in all the model estimated. For the total energy consumption model, the coefficient of -0.3526 shows that, after a 1 per cent deviation or shock to the system, the long-run equilibrium link of total energy consumption is quickly re-established at the rate of about 35.26% per cent per annum. The value indicates a stronger adjustment rate. In the case of electricity energy use, the coefficient of -0.4581 indicates that, after a 1 per cent deviation or shock to the system, the long-run equilibrium link of electricity energy use is quickly

re-established at the rate of 45.8% per cent per annum. The value does not indicate a stronger adjustment rate. In the fossil fuel energy use model, the coefficient of -0.2511 indicates that, after a 1 per cent deviation or shock to the system, the long-run equilibrium relationship of fossil fuel energy use is quickly re-established at the rate of about 25.1% per cent per annum. The value does not indicate a stronger adjustment rate.

Table-10. Short-term ARDL model results. ARDL (2) selected based on the Akaike Information Criterion. Dependent variable: ΔlnAEC/ Dependent variable: $\Delta lnEC$ / ΔlnFF

Total Energy Consumption Model	Coefficient	Standard Error	T-Ratio	Prob. Values
Constant	1.9818	0.7219	2.7449	0.010***
Trend	0.8062E-3	0.0011	0.7203	0.476
ΔlnTO	0.0249	0.0152	1.6442	0.109
ecm (-1)	-0.3526	0.1244	-2.8345	0.008***
Electricity Consumption Model	**Coefficient**	**Standard Error**	**T-Ratio**	**Prob. Values**
Constant	2.3528	0.7177	3.2781	0.002***
Trend	-0.0081	0.0043	-1.9017	0.066*
ΔlnEC-1	0.3933	0.1498	2.6262	0.013**
ΔlnTO	0.1172	0.0687	1.7063	0.097*
ecm (-1)	-0.4581	0.1178	-3.8899	0.000***
Fossil Fuel Consumption Model	**Coefficient**	**Standard Error**	**T-Ratio**	**Prob. Values**
Constant	0.4593	0.4351	1.056	0.299
Trend	-0.5857E-3	0.0032	-0.1805	0.858
ΔlnFF-1	-0.3684	0.1726	-2.1341	0.040**
ΔlnFF-2	-0.3570	0.1603	-2.2274	0.033**
ΔlnTO	0.0859	0.0500	1.7184	0.095*
ecm (-1)	-0.2511	0.1425	-1.7618	0.087*
ecm = LNTE -5.6204C -0.0022864T-0.070884LNTO……….				
ecm = LNEC-5.1355C + 0.017820T -0.25581LNTO………				
ecm = LNFF -10.8289C + 0.0023322T -0.34223LNTO ……..				

Source: Author's computation, 2015. Note: *** denotes statistical significance at the 1% level

4.3.4. Diagnostic Test Results for Energy Consumption Models
4.3.4.1. Results of Diagnostic Tests for Total Energy Consumption Model

Table 11 indicates the diagnostic tests of the short-run estimation of the reliability results of the error correction model for total energy consumption. The null proposition of no serial correlation was accepted using the Lagrange multiplier test and the F-statistics. The RESET test indicates proof of incorrect functional specification of the model through non-acceptance of the null proposition. The estimated model failed the normality test. The model did not fail the Heteroscadasticity test showing the variances do not change over time. The R^2 (0.7472) and the adjusted R^2 (0.7249) in Table 11 are an indication of a very well behaved model. The coefficient indicates approximately 76.63% of the variations in aggregate energy use are attributed to the independent variable.

4.3.4.2. Results of Diagnostic Tests for Electricity Consumption

Table 11 indicates the diagnostic tests of the short-run estimation of the reliability results of the error correction model for electricity energy use. The null proposition of no serial correlation was accepted using the Lagrange multiplier test and the F-statistics. The RESET test showed evidence of incorrect functional specification of the model through a rejection of the null hypothesis. The estimated model failed the normality test. The model did not fail the Heteroscedasticity test showing the variances do not change over time. The R^2 (0.6261) and the adjusted R^2 (0.5821) are an indication of a fairly behave model. The coefficient indicates approximately 62.61% of the variations in electricity energy use are attributed to the independent variable.

4.3.4.3. Results of Diagnostic Tests for Fossil Fuel Consumption

Table 11 shows the diagnostic tests of the short-run estimation used to examine the reliability of the results of the error correction model for fossil fuel consumption. The null proposition of no serial correlation was accepted using the Lagrange multiplier test and the F-statistics. The RESET test showed evidence of incorrect functional specification of the model through a rejection of the null proposition. The estimated model failed the normality test. The model did not fail the Heteroscedasticity test showing the variances do not change over time. The R^2 (0.6261) and the adjusted R^2 (0.5821) are an indication of a fairly behave model. The coefficient indicates approximately 62.61% of the variations in electricity energy use are attributed to the independent variable.

Table-11. Short-Run Diagnostic Tests of ARDL Model

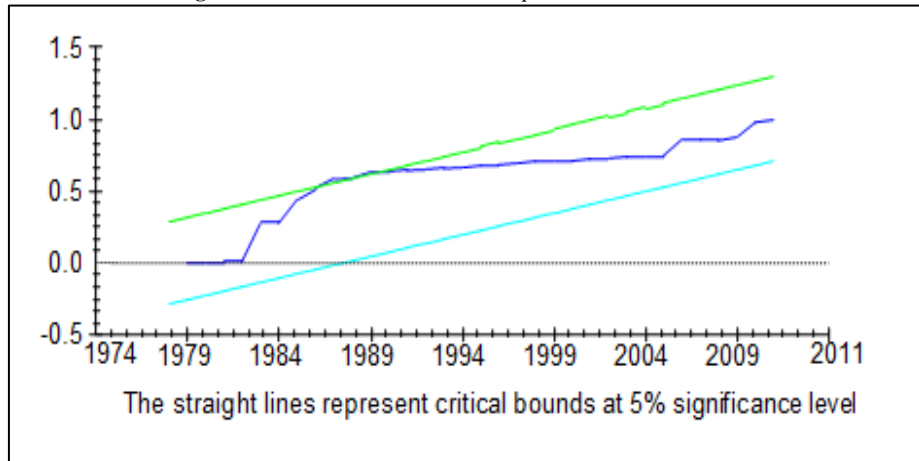| Total Energy Consumption Model		
Test Statistics	**LM Version**	**F Version**
A: Serial Correlation	CHSQ (1) = 0.6744[0.412]	F (1, 33) = 0.5962[0.446]
B: Functional Form	CHSQ (1) = .6285E-3[.980]	F (1, 33) = 0.5458E-3[0.982]
C: Normality	CHSQ (2) = 75.9622[0.000]	Not applicable
D: Heteroscedasticity	CHSQ (1) = 0.4324[0.511]	F (1, 36) = 0.4143[0.524]
R-Squared = 0.7472 R-Bar-Squared = 0.7248		
Akaike Info. Criterion = 64.6617 Schwarz Bayesian Criterion = 61.3865		
DW-statistic = 2.1622 Durbin's h-statistic = -0.77899[.436]		
Electricity Consumption Model		
Test Statistics	**LM Version**	**F Version**
A: Serial Correlation	CHSQ (1) = 0.1702[0.680]	F (1, 33) = 0.14463[0.706]
B: Functional Form	CHSQ (1) = 0.0491[0.825]	F (1, 33) = 0.0416[0.840]
C: Normality	CHSQ (2) = 18.4047[0.000]	Not applicable
D: Heteroscedasticity	CHSQ (1) = 4.8224[0.028]	F (1, 37) = 5.2207[0.028]
R-Squared = 0.6262 R-Bar-Squared = 0.58214		
Akaike Info. Criterion = 6.4449 Schwarz Bayesian Criterion = 2.2860		
DW-statistic = 2.0571		
Fossil Fuel Consumption		
Test Statistics	**LM Version**	**F Version**
A: Serial Correlation	CHSQ (1) = 5.5566[0.018]	F (1, 32) = 5.3168[0.028]
B: Functional Form	CHSQ (1) = 0.3217[0.571]	F (1, 32) = 0.2661[0.609]
C: Normality	CHSQ (2) = 29.5384[0.000]	Not applicable
D: Heteroscedasticity	CHSQ (1) = 0.8906[0.345]	F (1, 37) = 0.8647[0.358]
R-Squared = 0.62184 R-Bar-Squared = 0.5645		
Akaike Info. Criterion = 18.8569 Schwarz Bayesian Criterion = 13.8662		
DW-statistic = 2.2794		

Source: Author's computation, 2015

4.3.5. Cumulative Sum (Cusum) and Cumulative Sum of Squares (Cusumsq) Test Results For Energy Consumption

The long-term estimates stability was explored by using the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) methods. The residuals of the error-correction model estimated were used. The CUSUM test establishes the methodological arrangements of the estimates and its null proposition states the coefficients are stable. The null proposition is not accepted if the CUSUM exceeds the given critical boundaries which indicate the unstable nature of the estimates. The CUSMSQ establishes the stability of the variance. Both are shown in Figure 9 and Figure 10 for total energy use; Figure 11 and Figure 12 for electricity energy use; and Figure 13, and Figure 14 for fossil fuel energy use respectively. In both tests, as shown in Figures revealed that the estimates and the variance were stable as the residuals and the squared residuals fall within the various 5% critical boundaries. The null propositions are not accepted in both tests.
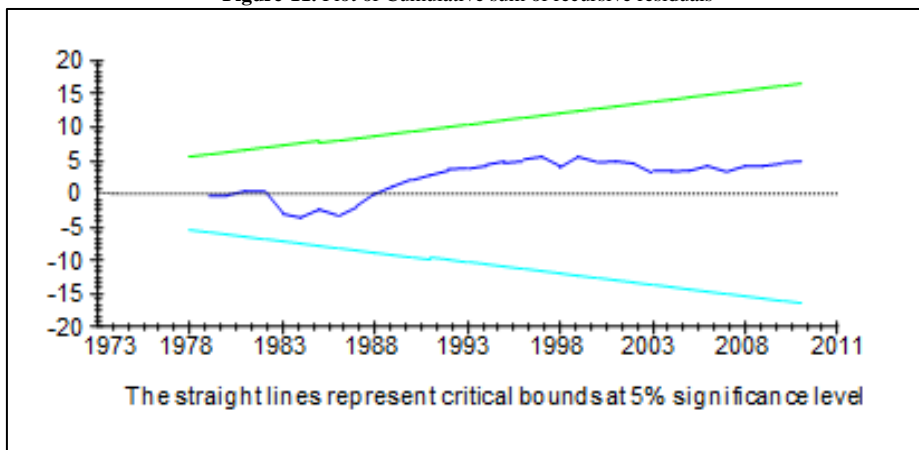
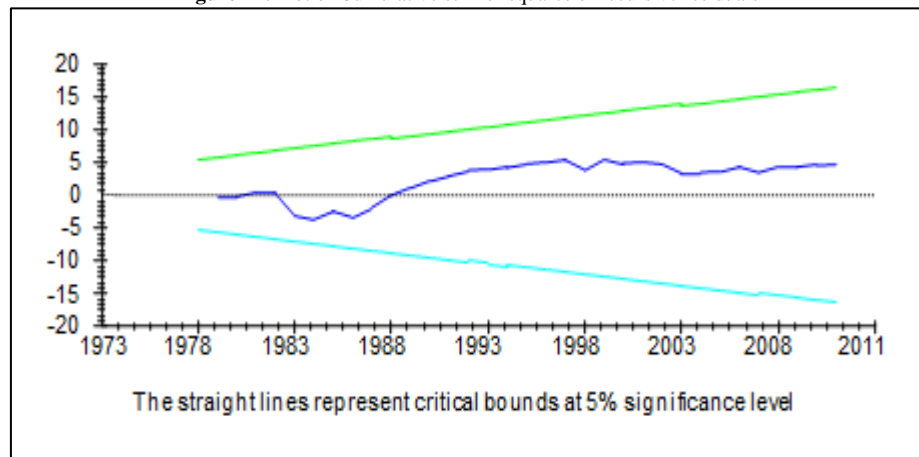**Figure-9.** Plot of Cumulative sum of recursive residuals

The straight lines represent critical bounds at 5% significance level
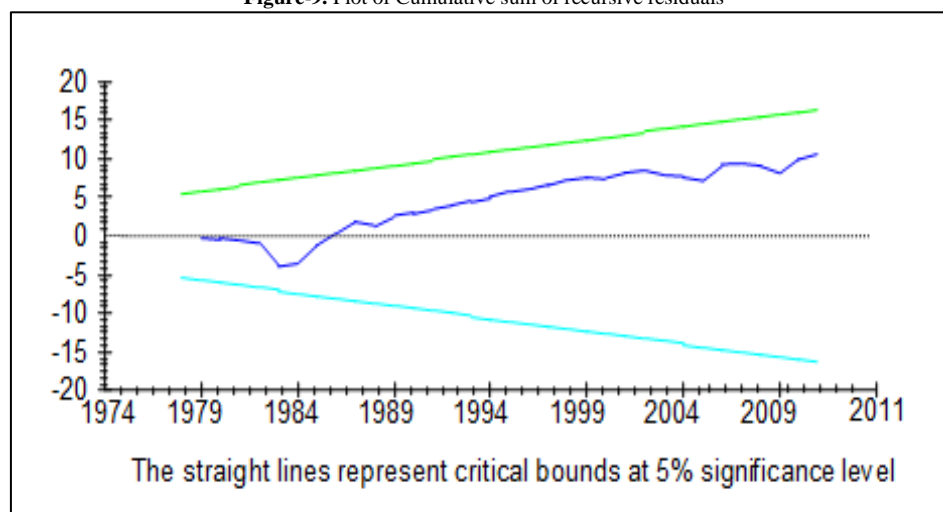
Figure-10. Plot of Cumulative sum of squares of recursive residuals

The straight lines represent critical bounds at 5% significance level

Figure-11. Plot of Cumulative sum of recursive residuals

The straight lines represent critical bounds at 5% significance level

Figure-12. Plot of Cumulative sum of squares of recursive residuals

The straight lines represent critical bounds at 5% significance level

Figure-13. Plot of Cumulative sum of recursive residuals

The straight lines represent critical bounds at 5% significance level
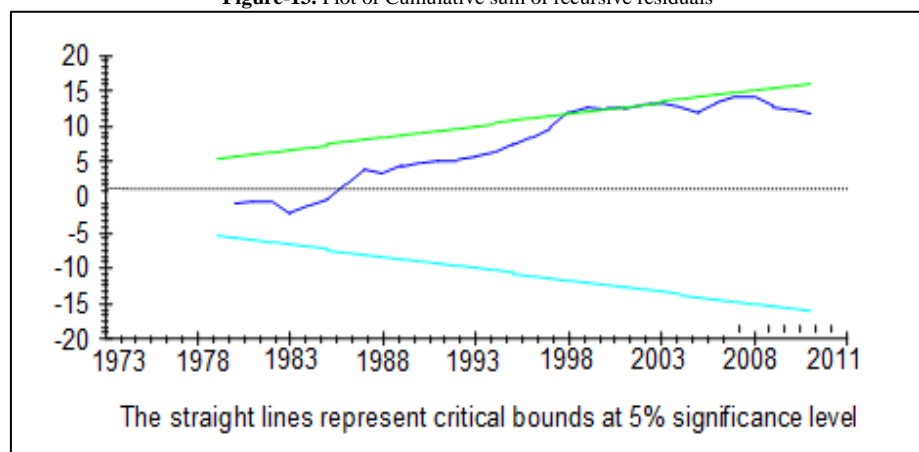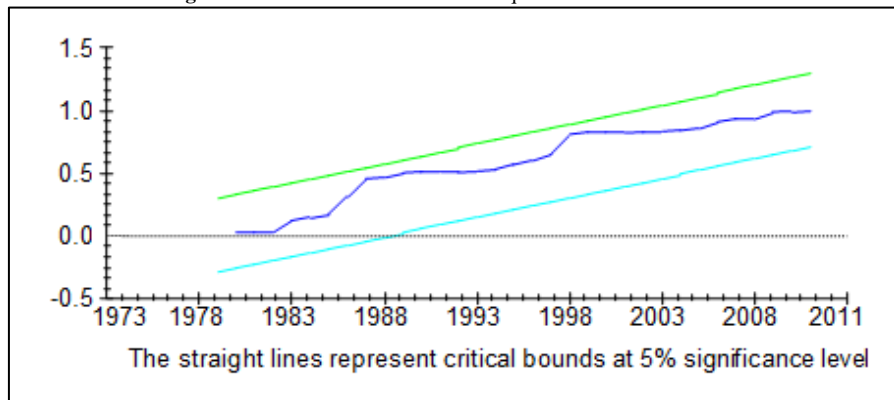
Figure-14. Plot of Cumulative sum of squares of recursive residuals

4.4. Results of Granger-Predictability Tests of Energy Consumption and Trade Openness

The null proposition of the test is that trade liberalisation does not Granger predict energy consumption, and energy consumption does not Granger cause the trade openness against the alternative proposition that trade openness Granger cause energy consumption, and energy consumption Granger cause trade openness.

The results of the granger-predictability test between total energy use, and trade liberalisation; trade liberalisation, and electricity consumption, and trade liberalisation, and fossil fuel consumption demand are shown in Table 12. The results indicate that trade liberalisation predicts total energy consumption without feedback (unidirectional causality); trade liberalisation predicts electricity consumption with feedback (bidirectional causality), and trade liberalisation predicts fossil fuel consumption with feedback (bidirectional causality).

Table-12. Granger Causality Test between the Trade Openness and Energy Consumption

Variables	Chi-square value	P-values	Decision	Conclusion
TOTAL ENERGY				
TO does not Granger cause **AEC** **AEC** does not Granger cause T**O**	19.277 4.454	0.000*** 0.216	Reject H$_O$ Accept H$_O$	Trade liberalisation predicts total energy consumption without feedback
ELECTRICITY CONSUMPTION				
TO does not Granger cause **EC** **EC** does not Granger cause T**O**	11.829 9.8125	0.008*** 0.020**	Reject H$_O$ Reject H$_O$	Trade liberalisation predicts electricity consumption with feedback
FOSSIL FUEL CONSUMPTION				
TO does not Granger cause **FF** **FF** does not Granger cause T**O**	19.277 4.454	0.002*** 0.026**	Reject H$_O$ Reject H$_O$	Trade liberalisation predicts fossil fuel consumption with feedback

Author's computation, 2015: Note: *** and ** denote significance at 1% and 5% levels

5. Discussions

The research sought to analyse the effect of trade liberalisation (proxied by trade openness) on energy consumption (aggregate energy use, electricity energy use, and fossil fuel energy use), as well as the nature of predictive causality between trade and energy use. The estimation method used is the ARDL cointegration method and the Granger predictive causality test.

The findings of the research indicate that there is a significant cointegration association between trade and energy consumption, but an insignificant long-term link between energy consumption and trade. However, a short-term stable link exists between trade and electricity and fossil fuel energy use, but an insignificant short-term link in the case of aggregate energy use. In both the short-term and long-term, there is a positive effect of trade on all the energy resources in the models estimated. This means when trade increase energy use variables also increase. The existence of cointegration and a positive link between trade and energy resources is in support with previous studies such as Al-Mulali and Ozturk (2015) for 23 European countries; Najarzadeh *et al.* (2015) for OPEC countries; Akar (2016), for 12 Balkan countries; Dogan and Seker (2016), for the European Union; Iheanacho (2018) for Nigerian; Alkhateeb and Mahmood (2019), for Egypt; and Zeren and Akkus (2020) for Bloomberg emerging countries.

The findings of the research further provide evidence of predictive causality between trade and energy resources. For aggregate energy use, causality runs from trade to energy use. For electricity energy use and fossil fuel use, causality runs from trade to energy use. The empirical finding of feedback causality between electricity energy use and trade is in support of previous studies such as Sebri and Ben-Salha (2014), for the BRICS countries; Tiba *et al.* (2015), for the UK, Sweden, and China. But the findings contradict that of Yazdi and Mastorakis (2014), for Iran (unidirectional causality); Shahbaz *et al.* (2017), for United States (unidirectional causality); Zeren and Akkus (2020), for Bloomberg (neutrality causality); Zeren and Akkus (2020), for Bloomberg emerging countries (neutrality). The research finding of feedback causality between trade and fossil fuel energy use is in line with that of

Mehdi and Slim (2015), for 69 countries, but contradicts that of Zeren and Akkus (2020), for Bloomberg (unidirectional causality from energy to trade).

The research findings imply that trade does not significantly explain changes in energy use both in the short-term and long-term. The feedback causality between trade and electricity energy use and fossil fuel consumption indicates that reducing energy use may not harm trade.

6. Conclusions

The research has examined trade-energy nexus for Ghana using annual data from 1970-2011. The analysis is based on the ARDL and the Granger predictive causality test in bivariate modelling. The findings of the study provide evidence of a cointegration association between trade and energy resources. However, there is an insignificant positive long-run effect of trade on energy use for all the energy sources under investigation. This means in the long-run trade do not influence energy use. In the short run, there is a positive significant effect of trade on electricity energy use and fossil fuel energy use, but an insignificant positive effect of trade on aggregate energy use. This means trade explains chances in fossil fuel and electricity energy use in the short-term.

Concerning aggregate energy use, the research findings show that for aggregate energy use, there is causality from trade to aggregate energy use without feedback. The policy implication is that reducing energy use does not hamper trade. However, in the case of electricity energy use and fossil fuel energy use, trade predicts energy use with feedback. For policy, the reduction in energy use may not have a deleterious effect on trade and Ghana's international competitiveness in the international commercial markets. Future research may focus on how structural breaks and panel analysis improves the current study, controlling for the effect of other variables that influence energy use.

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