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Could the Expanding Economic Growth and Trade Openness of the United Kingdom Pose a Threat to its Existing Energy Predicaments?

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ABSTRACT: This study examined whether the expanding economic growth prospects of the UK could pose a threat to its existing energy predicaments. To ensure this, time series data from 1970-2013 was used while the Zivot-Andrew structural break unit root test, the Bayer-Hank combined cointegration test, the ARDL bounds test and the VECM Granger causality test were applied, and this was validated using the innovation accounting test. The findings of the study confirmed the existence of cointegration among the variables. Following to this development, the study discovered that economic growth is negatively linked with energy demand in the UK, while trade openness adds to energy consumption; in addition to that, the position of the capital-labour ratio in UK was discovered to have a composite effect and with significant pressure on the country's energy consumption. To support the direction of these findings, the study discovered that while a 1% increase in economic growth in UK declines energy consumption by 0.5422% surprisingly however, a 1% increase in Trade openness and capital-labour ratio were found to lead to an escalation of energy demand by 0.9817% and 3.3906% respectively. These statistics may be a threat to the UK energy predicaments only if electricity generation should fall below the expected and potential requirements. In view of this development, the study proposes the need to pursue mix energy policies and strategies that will ensure the use of advanced technology at the industrial level; an exclusive use of renewable energy at the household level and ensure adequate investment priorities within the renewable energy sector among others.

Keywords: Electricity demand; Economic Growth; Innovation accounting test; Zivot-Andrew test
JEL Classifications: C61; D24; Q42

1. Introduction

In 2007, a White paper was made available in the United Kingdom intended to "Meet the Energy Challenge" for the entire of the UK. Subsequent to this development, the White Paper details the manner in which the international and domestic energy strategy should be implemented to address the long-term energy predicaments faced by the country, and to also offer four key policy objectives: (1) To position the UK on a course of reducing carbon dioxide emission by 60% by the year 2050, with actual improvement by 2020; (2) To sustain reliable reserves of energy supplies; (3) To advance competitive markets within the UK and beyond with the hope of raising the extent of sustainable economic growth in the UK that will as best as possible lead to the improvement of productivity; and (4) To ascertain that every household is sufficiently and economically heated. To carry out this strategic mission, the scope of the energy policy as contained in the white paper was detailed to encompass the generation and distribution of electricity, transport fuel usage, and method of heating (this refers to the efficient provision of, Natural Gas). This policy aims at making energy as the most essential aspect of daily life and for the general success of the UK economic system. To ensure this, the UK government observe the need for tackling two key long-term challenges and these are: (a) controlling the challenges of carbon dioxide emission both within the UK and abroad; and (b) Ensuring secure, clean and affordable energy taking into consideration the huge sum engulfed by fuel importation and its fluctuating costs. Apart from these challenges the UK also estimated the need for about 30-35GW of newly established electricity generation possibilities for the next two decades in order to attain objective 3 and 4 that requires the UK to meet its energy challenge Notwithstanding these laudable developmental goals, surprisingly, in June 2013, the major energy regulator in UK warned that there could be every possibilities for electricity power production capacity to fall by 2% in 2015, thereby, increasing the risk of blackouts"(BBC, 2013).

In another development DECC (2013) established that the total electricity generated in the UK was 364,346 GWh in 2011, 360,439 GWh in 2012 and 356,253 GWh in 2013. These figures exclude the total existing electricity in storage. To sum up with the existing pumped electricity figures in storage, the total electricity supplied in the UK in 2011 was put at 373,473 GWh while in 2012 it was 375,277 GWh and 373,581 GWh in 2013. Notwithstanding this laudable development, in 2013, indigenous electricity production declined to the tune of 1.2% (DECC 2013). The DECC (2013) statistics continued to show that importation of electricity from France and the Netherland rose significantly from 22% in 2012, to 28% in 2013. This trend indicate that electricity generation in the UK is declining amidst a corresponding excess in demand which is put at 0.5% in 2012, while in 2013 primary energy production also fell by 6.3% creating an excess demand to the tune of 0.7% (DECC, 2013). In contrast to the earlier development, the renewable energy sector in the UK was found to be doing remarkably well. In 2013 electricity generation from renewable energy rose to 30% accounting for 14.9% of total electricity generated in the UK as against 11.3% in 2012 (DECC, 2013).

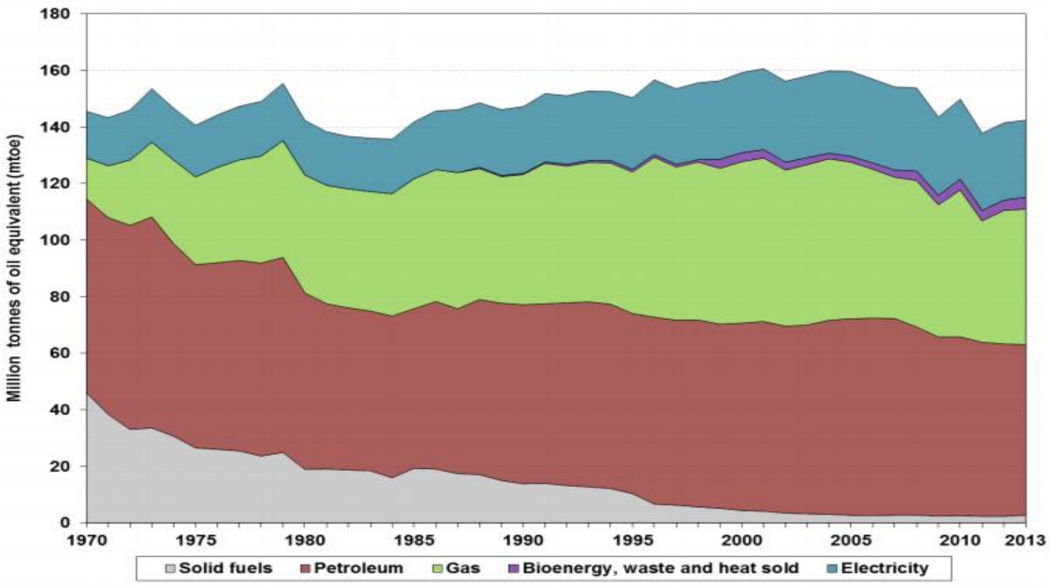
Theoretically four views were identified by scholars that established the direction leading to the causal relationship between energy consumption and economic growth. The first being, "*the growth hypothesis*" which established the existence of significant correlation between energy consumption and economic growth irrespective of whether the country is developed or developing, this theory further suggests that economic growth absolutely relies on energy consumption; consequent to this, any procrastination on energy will undoubtedly lead to a commensurate reduction on economic growth. In addition to this, the theory continued to establish that energy may have the tendency to restrict economic growth if concrete efforts were not put to ensure its sustainability and diversification. The second view, commonly known as "*the conservative hypothesis*", asserts that there is unidirectional causality between economic growth and energy consumption, meaning that energy conservation policies may have minimal impact on economic growth whenever conservation policies are applied in such a situation. The thrust of the theory continue to establish that if an increase in real GDP leads to an increase in energy consumption then this supports the conservative hypothesis. The third view, "*neutrality hypothesis*", suggests that there is no causality between energy consumption and economic growth. The fourth view, "*feedback hypothesis*", claims that there is bi-directional causal relationship between energy consumption and economic growth reflecting how they are interdependent and complementary to each other (Payne 2010, and Ozturk 2010)

Having regard to the foregoing, and considering the mixed result yielded by other past studies this study aims to investigate empirically the position of the long-run and short-run relationship of whether the expanding economic growth and Trade Openness of the United Kingdom could pose a threat to its existing energy predicaments. This is in consideration of the rising demand for energy amidst rising production shortfalls and other electricity generation constraints. In addition to that what are the positions of capital-labour ratio relation and the UK's Trade openness in energy demand? To ensure this, the paper is organised as follows: Section 2 provides an overview of the recent empirical literature on energy consumption, linking energy consumption to trade openness and economic growth; Section 3 the methodology section which introduce the data, the model specification, and the model estimation procedure; Section 4 contains the results and discussion. Finally, section 5 presents the conclusion and policy implication. In the figures and tables below, Table 1 indicates the position of Energy in UK and Figure 1 shows final energy consumption in the UK from 1970-2013. While figure 2 shows UK electricity demand by sector in 2012.

Table 1. Indicating the position of Energy in the United Kingdom

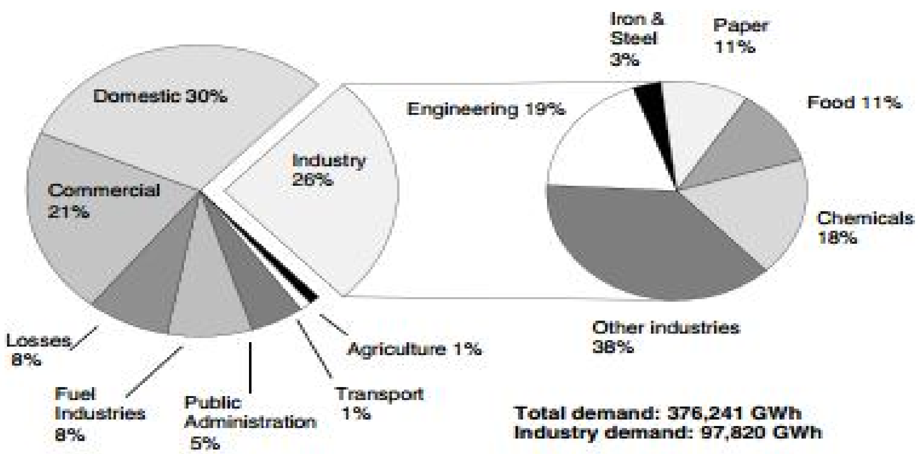
	Capita	Prim. Energy	Production	Import	Electricity	CO_2-emission
	Million	TWh	TWh	TWh	TWh	Mt
2004	59.8	2,718	2,619	135	371	537
2007	60.8	2,458	2,050	522	373	523
2008	61.4	2,424	1,939	672	372	511
2009	61.8	2,288	1,848	641	352	466
2010	62.2	2,355	1,730	705	357	484
2012	62.7	2,187	1,507	843	346	443
Change 2004-10	3.9%	-13.3 %	-33.9 %	420%	-3.9 %	-10.0 %
Mtoe = 11.63 TWh>, Prim. energy includes energy losses that are 2/3 for nuclear power Sources: IEA (2013)						

Figure 1. shows final energy consumption in the UK from 1970-2013



Sources: : DECC, Table 1.06

<u>Figure 2. Shows UK electricity demand by sector in 2012</u>



Sources: Department of Energy and Climate Change DECC.

2. Empirical Review

The pioneering work of Kraft and Kraft (1978) on the nexus between economic growth and energy is still regarded as the leading authority in the field of energy economics. The authors were the first to discover a unidirectional causal relationship between GNP growth and energy usage in the United States in the period from 1947-1974. Following this noble finding, several distinguished researchers like Akarca and Long (1980) made a follow-up investigation with respect to the finding of Kraft and Kraft (1978), while using different data set and different study periods the authors refuted the finding of a unidirectional link between energy and economic growth. This reaction led to the stimulation of early writers to continue the research investigation in the field of energy economics through using a different research background. For instance, Erol and Yu (1988) strategically conducted their study from 1952-1982 by dichotomising their case study areas into six world leading industrial nations commonly known to have strong energy consumption. The findings of their study revealed significant bidirectional causality for Japan. However, a contrasting result was obtained in the case of their findings of Canada which exhibited some tendencies of unidirectional causality from energy to economic growth, similarly, non-uniform research findings were also discovered with respect to Germany and Italy which in that period showed that it is economic growth that stimulates energy consumption and surprisingly none for France and England.

In another startling empirical research similar to that of Erol and Yu (1988), Masih and Masih (1996) discovered how energy use piques economic growth in India, and converse was found to be the case with regard to the author's findings in the case of Pakistan and Indonesia. In addition to that, the research discovered that it is economic growth that piques energy consumption in Pakistan and Indonesia, and no causal relationship exists with respect to the findings on Malaysia, Singapore and the Philippines. These degrees of mixed results stimulated Soytas and Sari (2003) to commission their research investigation and to adopt different research methodology. In their finding, the authors reported that economic growth Granger causes energy consumption in Italy and South Korea, but the case was different with respect to their findings on Germany, Japan, Turkey and France where the study discovered a simple unidirectional causality from energy use to economic growth. Similar to this finding, Huang *et al.* (2008) discovered the absence of any causal link between energy consumption and economic growth in low-income countries, rather, it was discovered that there is a unidirectional link from economic growth to energy use in the case of middle and high income countries. This startling finding stimulated Shahbaz and Lean (2012) and Shahbaz and Feridun (2012) to re-study the position of energy consumption and economic growth for Pakistan; while Lee (2006) studied the same situation for the case of France, Italy and Japan, and Lee and Chien (2010) for France and Japan again, while Narayan and Smyth (2008) and Bowden and Payne (2009) studied Canada, UK, Germany, Sweden, Switzerland and the G-7 countries. The latter group, on the other hand, re-studied the US. The findings of these authors was summarised to report a mixed result and all contend with the fact that there exist no stable and uniform direction of causality among countries, with most research findings showing a reverse causality, particularly in the study of Lee (2006). The lack of uniformity in the findings of these authors was reported to be attributable to the divergence in econometric methodologies, continental heterogeneity particularly in climatic conditions, time period and accumulated level of economic growth which spells out the direction, utilisation and consumption pattern of energy at both industrial and domestic level.

Notwithstanding the direction of causality between energy consumption and economic growth however, the study of Shahbaz and Lean (2012) established that the relationship between energy and export is very vital and that export cannot be efficient without sufficient energy. In this respect, whenever, energy use is found to Granger-cause exports or that the existence of a feedback relationship is detected between energy use and exports, the authors argued that, the adoption or application of energy conservation policies will undoubtedly affect exports and this could in turn influence the direction of economic growth. However, if causality is found moving from exports to energy or that the existence of no Granger causality was found in either direction then energy conservation policies can be implemented without major recourse to exports. From the foregoing development, and from the theoretical inferences, a rise in efficient and effective entrepreneurial activities will lead to a possible increase in export thereby, necessitating the need for more machineries and export led equipment for usage in haulage and transportation to either the harbours or airports where these exports are then loaded to overseas. The chain of activities in this transaction requires energy to operate. Consequent to this, an expansion in entrepreneurial productivities, exportations and other value added economic activities will lead to an increase in energy consumption and the converse will be the case. Additionally, the export-led energy hypothesis argues that a reduction in exports influence energy consumption. While the energy-led export hypothesis on its part established that any significant decline in energy consumption influences the direction of exports. Further to this, researchers maintain that the existence of a feedback relationship between energy and exports is quite substantial, considering the fact that energy is a significant factor in determining the movements in exports while exports are important factors in accounting for energy consumption.

The relationship between energy use and imports was also found to have similar dynamic trend comparable with export; in the two respective cases, energy consumption cannot be avoided. Theoretically any decline in imports will affect energy consumption through a significant impediment in channeling the imported goods to the right destination and respective networks thus halting transportation, and impinging on the distribution network systems. In general, apart from the collapse in the welfare system, it is obvious that a significant production derailment will be imminent. The link between international trade and energy use was investigated by Narayan and Smyth (2009) among others. The authors looked into the effect of energy consumption, export and economic growth using Middle Eastern countries as their case study. The result made no discoveries on the Granger cause between export and energy use. This finding warranted Erkan *et al*. (2010) to apply an entirely different methodology and to re-examine the relationship between energy and export in Turkey. Surprisingly, the outcome of their empirical exercise showed co-integration between export and energy consumption. They further established that energy consumption Granger causes export. Converse results were however discovered in the case of Malaysia in the study of Lean and Smyth (2010a, b). In the case of Japan, however, Sami (2011) assessed the impact of export on energy use. The empirical exercise of the author confirmed unidirectional causality moving from export to economic growth to energy use. In another development, Rafindadi (2015) discovered that, economic growth adds to energy demand in Germany, and that a 1% increase in economic growth leads to an increase in energy consumption by 2.1053% and this is found to be statistically significant at 1% level. The author in his research development further discovered that financial development does not have any significant influence on the German energy consumption, however, the relationship between trade openness and capital use in the case of Germany was found to be bidirectional, while Trade openness was found to Granger-cause energy demand and economic growth in Germany.

Using a panel data approach, Sadorsky (2011) examined the short-run and long-run Granger causality between export and energy use in the Middle Eastern countries between 1980 and 2007. The findings of the study showed a dynamic relationship between exports to energy use. The author further argued that a bidirectional feedback effect exists in the short-term and positive long-term effects were also observed on the variables. The study of Squalli (2007) determined the long-term relationship between energy consumption and economic growth among the OPEC countries. The study underscored the relevance of energy use in enhancing the economic prospects of these continents and further established that relying on the exportation of energy products by these continents is not a sufficient criterion for attaining economic growth. However, there should be a significant need for electricity consumption in countries like Nigeria, Indonesia, Iran, Venezuela and Qatar if an enhanced and sustainable economic growth is to be achieved.

From a continental African perspective, studies on energy consumption and economic growth were relatively found to be yielding mixed results. For instance, using Nigerian data Akinlo (2009) investigated the causality between energy consumption and economic growth for the periods of 1980-2006. The findings of his study indicated that real gross domestic product and electricity consumption are cointegrated, and there is unidirectional Granger causality running from electricity consumption to real gross domestic product. In another similar development, Kouakou (2011) investigated the causal relationship between the electric power industry's supply of the country and the economic growth of Cote d'Ivoire from 1971-2008. The findings reveal bidirectional causality between per capita electricity consumption and per capita gross domestic product in the short-term, but a unidirectional causality from electricity to gross domestic product was discovered in the long-term.

Odhiambo (2009) studied the link between energy consumption and economic growth in Tanzania for the period 1971-2006. The study utilises the Granger causality tests and the ARDL methodology. The finding of the study established the existence of stable, long-term relationship between the variables. The results of the causality test, on the other hand, revealed the existence of unidirectional causal relationship between energy consumption to economic growth. In another development, Jumbe (2004) examined the relationship between electricity consumption and overall gross domestic product of Malawi. The author in his research wisdom divided the time series data into agricultural gross domestic product and non-agricultural gross domestic product from 1970-1999. In a bid to obtain robust result, the residual-based cointegration approach was applied. The outcome of this empirical exercise suggests that electricity consumption is co-integrated with the gross domestic product of the non-agriculturally based gross domestic product, and cointegration relationship was not found with respect to agricultural gross domestic product of Malawi. The Granger causality tests proved bidirectional causality between electricity consumption and gross domestic product, but a unidirectional causality running from non-agricultural gross domestic product to electricity consumption. With these findings, the author proceeds to examine the elasticity of the variables and the finding indicates that the impact of electricity consumption is only significant in the long-term.

Panel data studies on energy and economic growth that relate to Africa can be traced to the noble work of Wolde-Rufael (2006). The author used data of 17 African countries for the period 1971-2001 and investigated the long-term causal relationship between electricity consumption per capita and real gross domestic product per capita. He applied the ARDL bounds test to cointegration; in addition to the causality test proposed by Toda and Yamamoto. The findings reveal unidirectional causality moving from electricity consumption per capita to real gross domestic product per capita for Benin Congo, DR, and Tunisia. On the other hand, the results suggest unidirectional causality moving from real gross domestic product per capita to electricity consumption per capita for the case of Cameroon, Ghana, Nigeria, Senegal, Zambia, and Zimbabwe. The study further reported bi-directional causal relationship with respect to Egypt, Gabon, and Morocco, while no causality was found for Algeria, Congo Rep., Kenya, Sudan and South Africa. Squalli (2007) on his part reported a contradictory finding with respect to the research efforts of Wolde-Rufael (2006). In his finding, the author established a unidirectional causal relationship moving from economic growth to electricity consumption for the case of Algeria and a bidirectional relationship between economic growths to electricity consumption for Nigeria.

From the above review, the contributions of this study are:

In contrast to other research, and considering the mixed result yielded by other past studies this study aims to investigate empirically the position of the long-run and short-run relationship of whether the expanding economic growth and Trade Openness of the United Kingdom could pose a threat to its existing energy predicaments. This is in consideration of the rising demand for energy amidst production shortfalls. In addition to that what are the position of capital-labour ratio and the UK's Trade openness to energy demand? From these empirical findings, the study will seek to offer some policy guides with respect to the empirical discoveries made in this study.

The majority of previous studies have mainly used ADF, PP, DF-GLS, KPSS and Ng-Perron tests. However, these unit root tests are less parsimonious and susceptible to a loss of vital information. In addition to this, these tests cannot provide the mechanism of dealing with structural breaks in the series. Following this, after checking the stationarity properties of the data using ADF and the PP test, the study then proceed to apply the Zivot-Andrews (1992) unit root test to identify possible structural breaks in the series. In addition to that the Bayer and Hanck (2013) co-integration technique was also applied in this study.

In order to determine the long-run and short-run relationship among the variables, the study applied the ARDL bounds testing approach to cointegration in the presence of structural break. This methodology was applied due its serial advantages which include: (i) flexibility and is robustly applicable within the range of I (0) and I (1) cointegrating properties of the data set. In addition to that, simulation results have widely shown that this methodology is parsimonious and effective in providing consistent results particularly for small sample data set. (Pesaran and Shin, 1999). (ii) allowing for the possibilities of ECM and OLS for short-run and long-run effects (iii) the VECM Granger causality technique for causal association.

3. The Model, Methodology and Data

The study explored the linkages between economic growth, trade openness and energy consumption for United Kingdom. Trade openness affects energy consumption via income effect, composite effect and technique effect. This leads us to construct functional form of energy demand function as following:

$$EC_t = f(Y_t, TO_t, CE_t, CA_t) \quad (1)$$

The variables are transformed into logarithm. The log-linear specification is superior to simple linear specification for reliable and efficient empirical results. The empirical equation of the model is constructed as follows:

$$\ln EC_t = \beta_1 + \beta_2 \ln Y_t + \beta_3 \ln TO_t + \beta_4 \ln CE_t + \beta_4 \ln CA_t + \mu_t \quad (2)$$

where, $\ln EC_t$ is natural log of energy consumption per capita, $\ln Y_t$ is natural log real GDP per capita (proxy for economic growth), $\ln TO_t$ is natural log of real trade (real exports + real imports) per capita, $\ln CE_t$ is natural log of composite effect proxies capital-labour ratio, $\ln CA_t$ is natural log of comparative advantages i.e. interaction term between composite effect and trade openness and μ_t is residual term with assumption of normal distribution.

Numerous econometric methodologies that aim at providing an insight into the likely possibility of whether key economic variables have attained the required level of cointegration have been in existence for quite a long time. Notable among them are the Engle-Granger (1987) residual-based cointegration test, the Johansen (1995) system based cointegration test and, the Boswijik (1994) and Banerjee *et al.* (1998) cointegration test which has the lagged error correction based approaches to cointegration. In modern times, all these cointegration tests were found with key econometric weakness. For instance Pesavento (2004) established that the potency of these tools to provide robust outcome is limited due to their insensitivity to filter the infiltrating level of nuisance inherent in most time series data basically due to recurring cases of financial crises, currency collapse and other macroeconomic ups and downs which the other cointegrating test could not observe. In addition to that, the author further established that the possibility of obtaining uniform outcome among the mentioned cointegration tools is virtually difficult. According to him, while one cointegration test rejects the null hypothesis another may be bound to accept it, and this is not supposed to be in real economic sense. It is following to this shortcoming that Bayer and Hanck (2013) developed a more parsimonious method that helps in eliminating the likely bias of the old existing estimators with respect to determining the cointegrating properties of time series data. The methodology of the Bayer and Hanck (2013) cointegration test as applied in this study aim at providing efficient estimates by eliminating the undue multiple testing procedures that is the common problem with other cointegration methodologies. To ensure its robustness, the Bayer and Hanck, (2013) when formulating their cointegrating model followed Fisher, (1932) formula, and this is given below:

$$EG - JOH = -2[\ln(P_{EG}) + \ln(P_{JOH})] \quad (3)$$

$$EG - JOH - BO - BDM = -2[\ln(P_{EG}) + \ln(P_{JOH}) + \ln(P_{BO}) + \ln(P_{BDM})] \quad (4)$$

In determining the possibility of the existence of cointegration among respective variables, Engle-Granger (1987); Johansen (1995); Boswijik (1994) and, Banerjee, Dolado and Mestre (1998) used the following notations as a key econometric guide: P_{EG}, P_{JOH}, P_{BO} and P_{BDM} respectively. However, in the case of the Bayer and Hanck (2013) their cointegration test mechanism was guided by the Fisher statistic. In this respect, to establish whether cointegration exists between the variables the null hypothesis of no cointegration must be rejected, and this can be ascertained when the critical values generated by Bayer and Hanck analysis are found to be less than the estimated Fisher statistics and vice versa. To determine the causal relationship between the variables on the other hand, the study applied the VECM (vector error correction method) and this is given by the following equation:

$$\begin{bmatrix} \Delta \ln EC_t \\ \Delta \ln Y_t \\ \Delta \ln TO_t \\ \Delta \ln CE_t \\ \Delta \ln CA_t \end{bmatrix} = \begin{bmatrix} b_1 \\ b_2 \\ b_3 \\ b_4 \\ b_5 \end{bmatrix} + \begin{bmatrix} B_{11,1} & B_{12,1} & B_{13,1} & B_{14,1} & B_{15,1} \\ B_{21,1} & B_{22,1} & B_{23,1} & B_{24,1} & B_{25,1} \\ B_{31,1} & B_{32,1} & B_{33,1} & B_{34,1} & B_{35,1} \\ B_{41,1} & B_{42,1} & B_{43,1} & B_{44,1} & B_{45,1} \\ B_{51,1} & B_{52,1} & B_{53,1} & B_{54,1} & B_{55,1} \end{bmatrix} \times \begin{bmatrix} \Delta \ln EC_{t-1} \\ \Delta \ln Y_{t-1} \\ \Delta \ln TO_{t-1} \\ \Delta \ln CE_{t-1} \\ \Delta \ln CA_{t-1} \end{bmatrix} + \ldots + \begin{bmatrix} B_{11,m} & B_{12,m} & B_{13,m} & B_{14,m} & B_{15,m} \\ B_{21,m} & B_{22,m} & B_{23,m} & B_{24,m} & B_{25,m} \\ B_{31,m} & B_{32,m} & B_{33,m} & B_{34,m} & B_{35,m} \\ B_{41,m} & B_{42,m} & B_{43,m} & B_{44,m} & B_{45,m} \\ B_{51,m} & B_{52,m} & B_{53,m} & B_{54,m} & B_{55,m} \end{bmatrix}$$
$$\times \begin{bmatrix} \Delta \ln EC_{t-1} \\ \Delta \ln Y_{t-1} \\ \Delta \ln TO_{t-1} \\ \Delta \ln CE_{t-1} \\ \Delta \ln CA_{t-1} \end{bmatrix} + \begin{bmatrix} \zeta_1 \\ \zeta_3 \\ \zeta_3 \\ \zeta_4 \\ \zeta_5 \end{bmatrix} \times (ECM_{t-1}) + \begin{bmatrix} \mu_{1t} \\ \mu_{2t} \\ \mu_{3t} \\ \mu_{4t} \\ \mu_{5t} \end{bmatrix} \quad (5)$$

Where Δ stands for the notation of the difference operator, while the ECM_{t-1} is obtained from the estimation of the long-run relationship of the ARDL model estimation result. In this case, the long-run causal relationship is ascertained by determining the significant position of the coefficient for the ECM_{t-1} following the T-test statistics. Apart from that, the F-test statistics for the first-differenced lagged independent variables is used for testing the direction of short-run causal relationship between the selected variables. The time series data of the United Kingdom from 1970-2013 as used in this study was obtained from the World Bank, development indicators (2013). Following to this, the data for the UK's real GDP, energy consumption (kg of oil equivalent) per capita, real exports, real imports, real capital, and labour force was obtained.

4. Results and Discussions

The study applied the ADF and PP unit root tests in order to investigate the unit root properties of the variables. Table 2 reveals that unit root problem exists at level with constant and trend. The variables such as energy demand, economic growth, trade openness, capital-labour ratio, interaction term of capital-labour ratio and trade openness are found to be stationary at first difference at 1% and 5% levels of significance respectively.

Table 2. Unit Root Test Analysis

	ADF Test		PP Test	
Variables	T-statistic	P.value	T-statistic	P.value
$\ln EC_t$	-1.1889(1)	0.9000	-1.1924(3)	0.8995
$\ln Y_t$	-1.7605(2)	0.7058	-1.0974(3)	0.9177
$\ln TO_t$	-2.9645(3)	0.1529	-3.1083(3)	0.1067
$\ln CE_t$	-2.1356(3)	0.5654	-1.4233(3)	0.8397
$\ln CA_t$	-2.0652(1)	0.5495	-1.3163(3)	0.8704
$\Delta \ln EC_t$	-7.1983(2)*	0.0000	-7.1995(3)*	0.0000
$\Delta \ln Y_t$	-4.2470(1) *	0.0078	-4.2267(3)*	0.0092
$\Delta \ln TO_t$	-5.1580(2) *	0.0008	-6.6581(3)*	0.0000
$\Delta \ln CE_t$	-3.9947(3)**	0.0167	-4.1336(3)*	0.0114
$\Delta \ln CA_t$	-4.2278(2)*	0.0093	-4.5730(3)*	0.0037

Note: One* asterisk and the dual asterisk ** refers to 1% and 5% level of significance. While the lag length of variables is denoted by using small parentheses.

The ADF and PP provide ambiguous empirical results due to their low explanatory power. These unit root tests also ignore the information about structural break occurring within the series. To avoid this, the study applied Zivot and Andrews (1992) unit root test that has the power of accommodating single unknown structural break in the series. The results of Zivot and Andrews (1992) unit root test are reported in Table 3. The results of the Zivot and Andrews (1992) analysis indicate the existence of structural break in 2003, 1986, 1980 and 2004 for the series of energy consumption, economic growth, trade openness, capital-labour ratio and interaction of capital-labour ratio and trade openness at level with intercept and trend. Stationarity is found for all variables at first difference. This indicates that energy consumption, economic growth, trade openness, capital-labour ratio and the interaction of capital-labour ratio and trade openness are stationary at first difference in the presence of structural breaks.

Table 3. Zivot-Andrews Unit Root Test

Variable	**At Level**		**At 1st Difference**	
	T-statistic	Time Break	T-statistic	Time Break
$\ln EC_t$	-3.084 (1)	2003	-8.176 (2)*	1985
$\ln Y_t$	-4.995 (2)	1986	-5.678 (1)*	2009
$\ln TO_t$	-4.045 (1)	1980	-8.451 (2)*	1975
$\ln CE_t$	-3.086 (3)	2004	-5.524 (1)**	2008
$\ln CA_t$	-2.898(2)	2004	-5.655 (2)**	2008
Note: One* asterisk and the dual asterisk ** refers to 1% and 5% level of significance. While the lag length of variables is denoted by using small parentheses.				

Table 4. The Lag Order Selection

VAR Lag Order Selection Criteria						
Lag	LogL	LR	FPE	AIC	SC	HQ
0	233.7718	NA	9.80e-12	-11.1596	-10.9506	-11.0835
1	440.6959	353.2850	1.39e-15	-20.0339	-18.7801*	-19.5773*
2	468.1809	40.2218*	1.30e-15*	-20.1551*	-17.8564	-19.3181
3	486.5653	22.4199	2.09e-15	-19.8324	-16.4889	-18.6149
* means lag order selected by the criterion LR: sequential modified LR test statistic (each test at 5% level) FPE: Final prediction error AIC: Akaike information criterion SC: Schwarz information criterion HQ: Hannan-Quinn information criterion						

Table 4 shows the results of the lag selection criterion, in that analysis the study find that lag 2 is suitable for this empirical analysis. The study selected the lag order of the variable following AIC due to its superior explanatory properties. Following the selection of lag length 2, the Bayer-Hanck combined cointegration test was applied. Table 5 shows the results of Bayer-Hanck combined cointegration analysis. We note that the computed Fisher F-statistic (EG-JOH, EG-JOH-BO-BDM) is more than the critical values as economic growth, trade openness, capital-labour ratio and interaction of capital-labour ratio and trade openness were used as independent variables. This leads to the rejection of the hypothesis of no cointegration among the variables. With this development, the presence of cointegration relationship among energy consumption, economic growth, trade openness, capital-labour ratio and the interaction of capital-labour ratio and trade openness in United Kingdom for the period of 1970-2013 have been established. However, the Bayer and Hanck cointegration cannot provide a dynamic explanatory position of the variables, as a result of this development and with the attainment of this result, the study proceeds to apply the ARDL bounds testing approach to cointegration in order to examine the long-run and short-run dynamics between the variables. The results of the ARDL bounds testing approach to cointegration are reported in Table 6. In that analysis the study found how the calculated F-statistics exceed upper critical bounds at 5% when energy consumption, economic growth, trade openness, labour-capital ratio were treated as the forcing variables.

Table 5. The Bayer and Hanck Cointegration Analysis

Estimated Models	EG-JOH	EG-JOH-BO-BDM	Cointegration
$F_{EC}(EC/Y,TO,CE,CA)$	18.553*	39.566*	✓
$F_{Y}(Y/EC,TO,CE,CA)$	9.192	10.132	X
$F_{TO}(TO/EC,Y,CE,CA)$	8.845	20.109	X
$F_{CE}(CE/EC,Y,TO,CA)$	7.962	13.572	X
$F_{CA}(CA/EC,Y,TO,CE)$	7.742	14.420	X
Note: One* asterisk refers to 1% level of significance. While the critical values at 1% level are 15.845 (EG-JOH) and 30.774 (EG-JOH-BO-BDM) respectively.			

Table 6. The Results of ARDL Cointegration Test

Bounds Testing to Cointegration				Diagnostic tests		
Estimated Models	Optimal lag length	Structural Break	F-statistics	χ^2_{NORMAL}	χ^2_{ARCH}	χ^2_{RESET}
$F_{EC}(EC/Y,TO,CE,CA)$	2, 1, 2, 2, 2	2003	8.649**	1.2486	[1]: 1.4742	[1]: 1.4271
$F_{Y}(Y/EC,TO,CE,CA)$	2, 2, 2, 2, 1	1986	5.286	5.5350	[1]: 0.0995	[2]: 3.0173
$F_{TO}(TO/EC,Y,CE,CA)$	2, 2, 2, 2, 2	1980	1.872	0.5147	[1]: 0.9933	[2]: 0.0036
$F_{CE}(CE/EC,Y,TO,CA)$	2, 1, 1, 2, 2	2004	2.721	0.9877	[1]: 1.2866	[2]: 6.7414
$F_{CA}(CA/EC,Y,TO,CE)$	2, 2, 1, 2, 1	2004				
Significant level	Critical values (T= 44)					
	Lower bounds $I(0)$	Upper bounds $I(1)$				
1 per cent level	7.317	8.720				
5 per cent level	5.360	6.373				
10 per cent level	4.437	5.377				
Note: The asterisks, ** denote significance at 5% levels. While the optimal lag length is determined by AIC. [ ] is the order of diagnostic tests. Critical values are obtained from Narayan (2005).						

The results of the ARDL long-run and short-run impact of economic growth, trade openness, capital-labour ratio and the interaction of capital-labour ratio and trade openness on energy consumption are reported in Table 6. In that analysis the study discovered that economic growth has a negative and significant relationship with energy consumption in the United Kingdom. Following to this it was discovered that a 1% increase in economic growth will lead to the decrease in energy consumption in the UK by 0.5422, all else is same. In contrast to that development, Trade openness was found have a positive and significant effect on energy consumption. As a result of that a 1% increase in Trade openness is found to increases energy consumption by 0.9817% and it is statistically significant at 1% level. Composite effect was also found to affect energy consumption positively, and it is significant at 1% level. All else is same; following to this a 1% increase in capital-labour ratio increases energy consumption in the UK by 3.3906%. The relationship between comparative advantage and energy demand is negative and statistically significant at 1% level. Keeping other things constant, a 0.3159% decrease in energy demand is linked with 1% increase in comparative advantage.

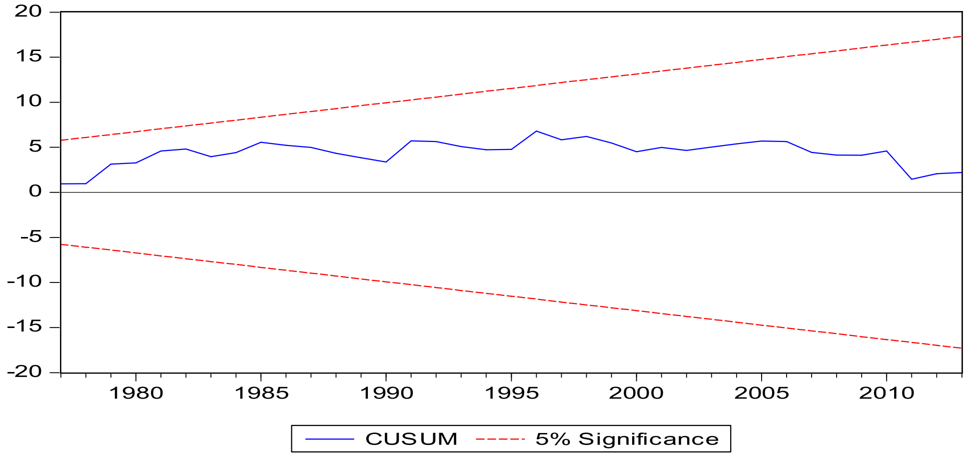
The short-run analysis is also reported in lower segment of Table 7. In the short-run perspective, the study discovered that economic growth is positively and significantly linked with energy consumption. The relationship between Trade openness and energy consumption is positive but insignificant. Capital-labour ratio was found to affect energy consumption negatively although the relationship was found to be insignificant. Comparative advantage has positive but insignificant impact on energy consumption. The value of ECM term is negative and significant which shows the convergence from short-run towards long-run equilibrium path. The estimate of ECM term is equivalent to -0.4104 which confirms that short-run deviations are corrected by 41% every year. This shows that convergence from short-run towards long-run will take 2 years and 5 months. The results of diagnostic test show the absence of serial correlation, autoregressive conditional heteroskedasticity, and white heteroskedasticity. The results of Ramsey Reset test confirm the specification of the short-run model.

Table 7. Long and Short-runs Results

Dependent variable = $\ln EC_t$				
Long-run Analysis				
Variables	Coefficient	Std. Error	t-Statistic	Prob.
Constant	2.6473	2.3849	1.110007	0.2738
$\ln Y_t$	-0.5422	0.1726	-3.1399	0.0032
$\ln TO_t$	0.9817	0.2790	3.5189	0.0011
$\ln CE_t$	3.3906	0.6902	4.9123	0.0000
$\ln CA_t$	-0.3159	0.0745	-4.2359	0.0001
Short-run Analysis				
Variables	Coefficient	Std. Error	t-Statistic	Prob.
Constant	-0.0209	0.0052	-3.9686	0.0003
$\Delta \ln Y_t$	0.8719	0.2800	3.1137	0.0036
$\Delta \ln TO_t$	0.0114	0.0553	0.2073	0.8369
$\Delta \ln CE_t$	-0.0237	0.1107	-0.2145	0.8313
$\Delta \ln CA_t$	0.3199	0.8344	0.3834	0.7036
ECM_{t-1}	-0.4104	0.0948	-4.3258	0.0001
R^2	0.5489			
F-statistic	9.0000*			
D. W	2.2700			
Short-run Diagnostic Tests				
Test	F-statistic	Prob. value		
$\chi^2 SERIAL$	1.3421	0.11247		
$\chi^2 ARCH$	0.3065	0.5829		
$\chi^2 WHITE$	0.2750	0.9917		
$\chi^2 REMSAY$	2.0196	0.1639		
Note: that the asterisk *, ** and *** denote significant at 1%, 5% and 10% level respectively.				

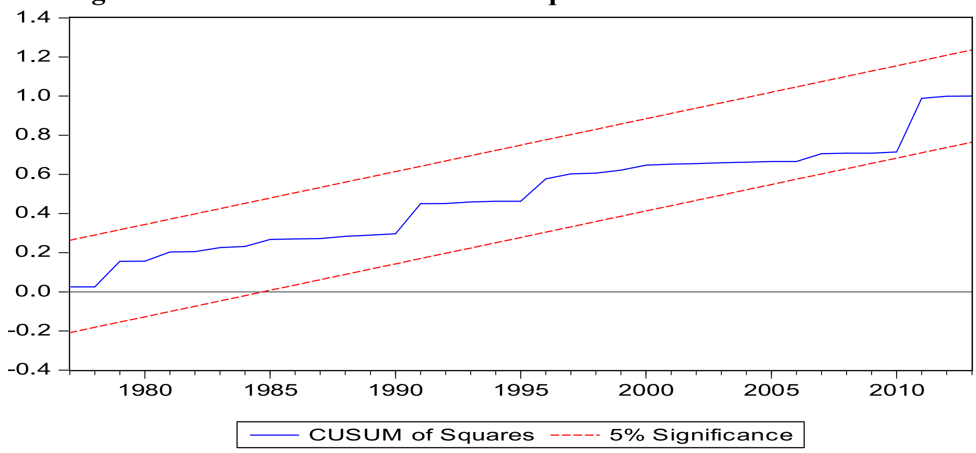
The study has applied the CUSUM and CUSUMsq tests to examine the parameters stability. In that regard, Brown *et al*. (1975) exposed that these tests help in understanding the gradual changes in parameters. The expected value of recursive residual is found to be zero and this leads to the acceptance of the null hypothesis of parameter constancy to be correct, otherwise not. The plots of both CUSUM and CUSUMsq are shown by Figure 3 and 4 at 5% level of significance. The empirical findings indicate that plots of both tests are within critical bounds at 5% level of significance. This confirms the stability of long-run as well as short-run parameters under survey.

Figure 3. Plot of Cumulative Sum of Recursive Residuals



The straight lines represent critical bounds at 5% significance level

Figure 4. Plot of Cumulative Sum of Squares of Recursive Residuals



The straight lines represent critical bounds at 5% significance level

Following the attainment of cointegration among the variables in table 5, the study proceeds to apply the VECM Granger causality which is suitable in examining the causal relationship between the variables. The results are presented in Table 8. The study discovered that trade openness and energy consumption cause each other in the Granger sense while economic growth is found to Granger-cause energy consumption. Unidirectional causality is found running from composite effect to energy consumption. Energy consumption, on the other hand, is found to Granger cause comparative advantage effect. In the short-run, the bidirectional causality is found between economic growth and energy consumption. Economic growth is the Granger cause of trade openness, capital-labour ratio and comparative advantage effect. Capital-labour ratio and comparative advantage effect Granger cause trade openness and capital-labour ratio is the Granger cause of trade openness. Comparative advantage is Granger cause of capital-labour ratio and trade openness.

Although, the VECM Granger causality test provides the direction of causality between the variables in the long-run as well as in the short-run but this test does not inform us ahead with respect to how the sample period behave particularly on the information about causal relationship provided by the VECM Granger causality test and how it lies within the selected time period. In such situation, variance decomposition approach is more suitable in examining the direction of causality among the series[1]. The result of variance decomposition approach is reported in Table 9, and this indicates that a 41.52% portion of energy consumption is explained by its own innovative shocks. The analysis confirms how economic growth contributes to energy consumption by 7.94%.

[1] Further details about innovative accounting approach are available in (Shan, 2005).

Table 8. The VECM Granger Causality Analysis

Dependent Variable	Direction of Causality					
	Short-run					Long-run
	$\Delta \ln EC_{t-1}$	$\Delta \ln Y_{t-1}$	$\Delta \ln TO_{t-1}$	$\Delta \ln CE_{t-1}$	$\Delta \ln CA_{t-1}$	ECT_{t-1}
$\Delta \ln EC_t$	….	8.3852* [0.0012]	0.1947 [0.8240]	0.0991 [0.9058]	0.2123 [0.8098]	-0.5238* [-4.2631]
$\Delta \ln Y_t$	7.2071* [0.0026]	….	2.2080*** [0.0775]	2.0553*** [0.0935]	2.7171*** [0.0813]	….
$\Delta \ln TO_t$	1.0665 [0.3565]	0.2771 [0.7628]	….	3.6570** [0.0500]	5.3773* [0.0078]	-0.2266*** [-1.8735]
$\Delta \ln CE_t$	0.1387 [0.8710]	0.4673 [0.6309]	3.6089*** [0.0623]	….	10.0067* [0.0010]	….
$\Delta \ln CA_t$	0.2508 [0.7797]	0.4698 [0.6294]	5.1145* [0.0098]	10.6800* [0.0009]	….	….
Note: * and ** show significance at 1% and 5% respectively.						

The contribution of Trade openness and capital-labour ratio is found to be minimal i.e. 13.80% and 5.58% respectively. Innovations in comparative advantage explain energy consumption by 31.15%. Energy consumption was also found to contribute to economic growth by 43.42% in the UK. Following to this an 8.29%, 1.60% and 5.08% of economic growth is contributed by trade openness, capital-labour ratio and comparative advantage respectively. Trade openness is explained by energy consumption (21.17%) and economic growth (43.56%). Innovations in capital-labour ratio and comparative advantage effect explain economic growth by 4.71% and 3.27%. A 40.34% and 43.57% of capital-labour ratio is contributed by innovative shocks arising in energy consumption and economic growth. Trade openness and comparative advantage effect was also found to contribute minimally, in this respect the contribution of energy consumption and economic growth to comparative advantage is 42.73% and 41.60% respectively. Trade openness and capital-labour ratio was also found to contribute to comparative advantage minimally.

Table 9. Variance Decomposition Approach

Variance Decomposition of $\ln EC_t$						
Period	S.E.	$\ln EC_t$	$\ln Y_t$	$\ln TO_t$	$\ln CE_t$	$\ln CA_t$
1	0.0262	100.0000	0.0000	0.0000	0.0000	0.0000
2	0.0360	81.1338	7.5327	6.9000	0.3174	4.1159
3	0.0419	76.5052	8.3677	8.1177	2.0205	4.9887
4	0.0470	66.3869	9.6169	9.2986	3.5969	11.1005
5	0.0512	59.6804	10.0362	9.8917	4.5949	15.7966
6	0.0546	53.6263	9.9563	11.0997	4.9967	20.3207
7	0.0573	49.1392	9.3975	12.2183	5.3450	23.8997
8	0.0594	45.5847	8.7527	13.0716	5.5267	27.0641
9	0.0613	43.0976	8.2476	13.5726	5.5987	29.4831
10	0.0630	41.5201	7.9452	13.8016	5.5808	31.1521
Variance Decomposition of $\ln Y_t$						
Period	S.E.	$\ln EC_t$	$\ln Y_t$	$\ln TO_t$	$\ln CE_t$	$\ln CA_t$
1	0.0223	41.6462	58.3537	0.0000	0.0000	0.0000
2	0.0374	43.4521	54.0345	2.3283	0.1158	0.0690
3	0.0478	46.0285	49.5881	4.0320	0.2519	0.0992
4	0.0554	47.6849	46.6297	4.9729	0.5958	0.1164
5	0.0617	48.5069	44.5697	5.4916	1.0430	0.3884
6	0.0672	48.3307	43.3485	5.9764	1.3737	0.9704
7	0.0719	47.4988	42.6705	6.4976	1.5233	1.8096
8	0.0760	46.2564	42.2575	7.0654	1.5724	2.8481

9	0.0795	44.8497	41.9222	7.6686	1.5893	3.9700
10	0.0824	43.4238	41.5873	8.2944	1.6077	5.0865
Variance Decomposition of $\ln TO_t$						
Period	S.E.	$\ln EC_t$	$\ln Y_t$	$\ln TO_t$	$\ln CE_t$	$\ln CA_t$
1	0.0584	3.8341	12.9171	83.2486	0.0000	0.0000
2	0.0816	7.8480	36.0534	53.1033	2.1347	0.8604
3	0.0936	12.3463	42.5208	41.2150	2.1317	1.7859
4	0.0985	13.3665	44.7547	37.2550	2.0823	2.5412
5	0.1015	14.6335	44.8334	35.0717	2.3018	3.1594
6	0.1045	15.9999	44.4366	33.1001	3.0637	3.3995
7	0.1075	17.5041	43.8492	31.2748	3.8165	3.5552
8	0.1102	18.8233	43.5630	29.7672	4.3083	3.5380
9	0.1128	20.0569	43.4944	28.4527	4.5721	3.4236
10	0.1154	21.1755	43.5633	27.2715	4.7144	3.2751
Variance Decomposition of $\ln CE_t$						
Period	S.E.	$\ln EC_t$	$\ln Y_t$	$\ln TO_t$	$\ln CE_t$	$\ln CA_t$
1	0.0525	22.5828	47.4428	0.0894	29.8849	0.0000
2	0.0843	29.2134	49.4073	2.2028	18.7590	0.4173
3	0.1066	37.5792	45.2989	4.1555	12.6646	0.3013
4	0.1216	42.2362	41.6822	5.9501	9.7438	0.3875
5	0.1321	44.8497	39.0659	6.9820	8.2877	0.8145
6	0.1404	45.5894	37.4707	7.6655	7.3879	1.8863
7	0.1475	45.1389	36.4806	8.2261	6.7152	3.4390
8	0.1535	43.9172	35.7918	8.8244	6.1934	5.2730
9	0.1587	42.4014	35.1858	9.4697	5.7990	7.1439
10	0.1630	40.8684	34.5775	10.1354	5.5018	8.9167
Variance Decomposition of $\ln CE_t$						
Period	S.E.	$\ln EC_t$	$\ln Y_t$	$\ln TO_t$	$\ln CE_t$	$\ln CA_t$
1	0.5753	21.4640	49.0815	9.0545	20.0789	0.3208
2	0.9262	28.0931	57.0533	3.5175	10.942	0.3933
3	1.1732	36.4490	52.8269	3.2361	7.1448	0.3429
4	1.3271	40.7060	49.2433	4.1890	5.5891	0.2723
5	1.4334	43.6602	46.4114	4.7312	4.9025	0.2944
6	1.5187	45.0195	44.5998	5.1369	4.5466	0.6970
7	1.5919	45.3315	43.4488	5.5227	4.2478	1.4490
8	1.6556	44.8063	42.7151	5.9947	3.9697	2.5140
9	1.7104	43.8619	42.1422	6.5307	3.7334	3.7315
10	1.7569	42.7377	41.6096	7.1146	3.5474	4.9905

Overall, we find that the feedback effect exists between energy consumption and economic growth. The unidirectional causal relationship was also found to exist and running from energy consumption and economic growth to trade openness, capital-labour ratio and comparative advantage.

5. Conclusion and Policy Implications

This study investigated the linkages between economic growth, trade openness and energy consumption using energy demand function in the case of the United Kingdom. This is in a bid to find whether the expanding economic growth prospects of the UK may add to its energy predicaments or otherwise. To ensure this, the study used annual data over the periods of 1970-2013. The unit root properties of the data were investigated using the traditional, as well as the standard structural break unit root tests. These results from the structural break unit root analysis were then used in the Bayer-Hank combined cointegration approach in order to examine the cointegration relationship between the variables. The ARDL bounds test approach was also used to examine the dynamics of the long-run and short-run relationship, while the VECM Granger causality approach was then used to determine the causal relationship between the series, and this was validated using the innovation accounting test. The results confirmed the existence of cointegration among the variables. Following to this, the study discovered that in the long-run economic growth is negatively linked with energy demand in the UK while Trade openness was found to add to energy consumption. The Capital-labour ratio was discovered to have a composite effect, and it influence energy consumption significantly. Our investigation on the comparative advantage, on the other hand, was found to decline energy demand. Following to this, the study found the existence of bidirectional causal relationship between energy consumption and Trade openness; as a result of this, economic growth was found to Granger cause energy consumption; energy consumption is Granger cause of composite effect and comparative advantage effect. To support the claims made, the result of this study established that a 1% increase in economic growth decreases energy consumption by 0.5422%. By this finding, it means that the UK energy predicaments cannot be aggravated by the country's economic growth prospects all things being equal. However, Ferguson *et al* (2000) argued that for the global economy as a whole, there is a stronger inter-relation between electricity consumption and the creation of wealth (economic growth) than that connecting total use of energy and wealth (economic growth). The author continue to insist that, in the same rich nations like the UK, the rise in economic growth with time will correlate with the rise in the amount of energy that is used and this will modestly make energy consumption as a root cause to economic growth. Meaning energy will in due course become the Granger cause to economic growth in rich countries.

In contrast to the earlier finding, this study discovered Trade openness of the UK to have a positive and significant effect on energy consumption. As a result of this development, the study found that a 1% increase in trade openness increases energy consumption by 0.9817% in the UK, and it is significant at 1% level. Following to this development and according to the report from the UK Office for National Statistics, (2014) it is asserted that international Trade represents almost 60% of the UK's GDP. This development positioned the country to assume the world's second biggest exporting nation and the third biggest importer of commercial services, as well as the tenth biggest exporter and the sixth biggest importer of goods in the world. Despite this vibrant position, yet, the United Kingdom has experienced huge trade deficit. For example in 1998, the UK's trade deficit was estimated to be about US$ 3.5 billion or 1.5 percent of its GDP. To show that the figure did not improve but rather worsened, in February, 2014 the UK recorded a Trade deficit of £9.1 billion which is almost 4.4% of its GDP (Office for National statistics, 2014). The more compounding issue with this development which is the key policy implication that this study was able to identify is that the UK operates 7 free trade zones in Birmingham, Humberside, Liverpool, Prestwick, Sheerness, Southampton, and Tilbury. By this development, it means a strong pressure to the country's energy sector. This is in the sense that the greater the energy consumption of the UK's 7 free trade zones, the more stressing this may be to the energy consumption of the country, particularly when considering the rising trade deficit, from this operation and also when considering the huge volume of trading activities of the country i.e. 60% of the GDP.

In another related development, the composite effect of energy consumption was found to have a positive and significant effect on energy demand in the UK; as a result of this, the study discovered that a 1% increase in capital-labour ratio increases energy consumption in the UK by 3.3906% from these developments, the UK energy predicaments could only worsen if electricity generation should fall below the expected requirement of these and other existing energy requirement statistics as well as key potential once. More so, that energy consumption was found to contribute 43.42% to the UK economic growth prospects as found in this study. Following to this and in order to ameliorate the issue of energy predicaments, and place the UK economy towards a sustainable path of affluence already attained, we argue for strong commitment on the side of policy makers to embrace alternative long-run and short-run measures of energy provisions by pursuing mix energy policies and strategies that will ensure the exclusive use of renewable energy at the household level. This can be ensured by encouraging heavy investments in renewable energy source. In addition to that, this study is also of the belief that when the UK economy continue to grow from its current position the stress on energy demand will undoubtedly be high and could exert more on the energy predicaments of the country particularly if the minimum electricity supply could not be met. To further mitigate this effect we argue for the adoptions of those policies and strategies that will ensure the use of advanced technology at the industrial level. This development will not only palliate the UK's energy predicaments but will equally prevent environmental degradation by lessening the extent of energy consumption and also sustain the welfare position of the UK citizens through reduction in carbon dioxide emission particularly if the use of renewable energy is prioritized. This development if implemented will also enable the UK to be in track with the 2007 white Paper that is aimed at "Meeting the Energy Challenge" of the country as well as keeping abreast with the EU vision 20/20/20.

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