WHAT IS THE RELATIONSHIP BETWEEN CO2 EMISSIONS AND ECONOMIC GROWTH IN THE UK?

Eteng Ibiang Eteng[1]

ABSTRACT: *This research paper examines the causal relationship between carbon-dioxide emissions and economic growth in the United Kingdom using time series data covering the periods of 1980 to 2010. The variables studied are CO2 per-capita, Real Gross Domestic Product per-capita (RGDP), Final Energy Consumption (FEC) and Foreign Trade Ratio (FTR). The methodologies applied are the cointegration, error correction model and the granger causality test. The study discovers a short and long run causality running between the variables observed. It also found a unidirectional causality from CO2 to RGDP; RGDP to FTR; FTR to CO2 and FTR to FEC. The results further reveals an inverted U-shape relationship between CO2 and GDP, thus, EKC hypothesis confirmed in the UK. The conclusions, however, are a cut in CO2 emissions can affect GDP negatively and the influence of trade openness can increase CO2 emissions to have an N-shape relationship with GDP. Therefore, the paper recommends that policy makers integrate emissions and economic growth policies because of the sensitive relationship between them.*

[1]The author holds a BSc in Economics from the University of Nigeria, Nsukka and an MSc in Finance and Business Management from the University of Bedfordshire. He also has an MSc in Energy Studies with specialisation in Energy Economics from the CEPMLP, University of Dundee. Email: e_eteng@yahoo.com

Table of Contents

ABBREVIATIONS

ADF	Augmented Dickey Fuller (test)
CO2	Carbon dioxide
DECC	Department of Energy and Climate Change
DFEC	First Difference Final Energy Consumption
DFTR	First Difference Foreign Trade Ratio
DRGDP	First Difference Real Gross Domestic Production
EIA	US Energy Information Administration
EKC	Environmental Kuznets Curve
ECM	Error Correction Model
FEC	Final Energy Consumption
FTR	Foreign Trade Ratio
GHGs	Greenhouse Gases
GDP	Gross Domestic Production
IPCC	Intergovernmental Panel on Climate Change
OLS	Ordinary Least Square
PP	Phillips and Perron (test)
RGDP	Real Gross Domestic Production
VECM	Vector Error Correction Model

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

Over the past few decades, the relationship between carbon dioxide (CO2) emissions and economic growth has been the subject of intense research. Many empirical studies have suggested the existence of an inverse U-shaped relationship between economic activity and the environmental quality (Grossman and Krueger 1991; Panayotou 1993; Selden and Song 1994; and Galeotti 2003). Thus, suggesting economic growth at the early stage to increase environmental pollution as per capita income increases and then at the later stage decrease as per capita income rises beyond a turning point. This hypothesis is called the Environmental Kuznets Curve (EKC) because of the similarity between the relationship in the level of inequality and per capita income.[2]

The EKC hypothesis has been found useful because of the desire for policy makers to resolve the threat of global warming and climate change in the world today. According to the EKC assumption, growth in the economy will be the solution for environmental issues in the future. However, several empirical results and conclusions have been somewhat indefinite with the hypothesis (Cole and Elliott 2003; Soytas et al. 2007; and Akbostanci et al. 2009). Nevertheless, there have been some other empirical findings that have confirmed EKC existence in the measurements of environmental degradation (Panayotou 1993; Selden and Song 1994; Giles and Mosk 2003; Brajer et al. 2008; and Saboori et al., 2012).

This study examines the relationship between CO2 emissions and economic growth in the United Kingdom. It is imperative to understand that a developed country such as the UK is characterised with sustainability and more specifically, equipped with economic activities that drive growth in the country. More so, economic activities require an enormous amount of energy resources and material inputs which have been identified to create waste by-products in the environment. These wastes have been recognised as Greenhouse gases (GHGs) and also been attributed as being harmful to the atmosphere, causing environmental degradation.[3] According to the World Bank (2007) GHGs is largely credited to CO2 as the leading gas that causes global warming and climate change. Considerably, this research becomes very useful

[2] Kuznets (1955) suggested that as per capita income increases, income inequality also increases at first but then after a turning point starts to decline.

[3] Intergovernmental Panel on Climate Change (IPCC) reports that a possible increase from 1.1 to 6.4ºC in global temperatures and a rise from 16.5 to 53.8cm in sea level by 2100 as a result of the greenhouse gas in the atmosphere (IPCC, 2007).

because the Department of Energy and Climate Change (DECC) fact sheet suggests that the total net GHGs in the UK were 590 Mt CO2e in 2010 and CO2 accounted for 85% of the emissions, although the emissions had decreased by 23% since 1990. However, the US Energy Information Administration (EIA) ranks the UK world CO2 pollution as tenth in 2010. Resulting from this statistics, this paper investigates the relationship between CO2 emissions and economic growth in the UK by examining the causality and testing the EKC hypothesis if the assumption holds in the UK.

In other to achieve this task, the study will review a vast amount of literature from earlier scholars that considered the relationship between CO2 and economic growth. It would further adopt a cointegration and granger causality test to know the link between the variables that would be studied. Also, the ordinary least square (OLS) would be applied on the variables for the EKC hypothesis test after which the policy implication would be analysed. Finally, conclusions and possible recommendations would be highlighted.

2.0 LITERATURE REVIEW

The debate on the issue of GHGs (CO2) and economic growth has been very contentious because of the vast different literatures that have been presented in the past. Since the early 1990s, after the studies of Grossman and Krueger (1991) on the environmental impacts of the North American Free Trade Agreement, the EKC became an essential empirical research issue when studying the relationship between CO2 emissions and economic growth. Several researchers established no EKC relationship between CO2 and income, while others concluded the existence of an explicit turning point.

Holtz-Eakin and Selden (1995) in their study using global panel data to estimate the relationship between CO2 emissions and economic growth identifies the evidence of a diminishing marginal propensity to emit (MPE) CO2 as the economy develops. They concluded however, that international cooperation was needed for mitigation of global warming.

Similarly, Schmalensee et al. (1998) finds evidence of an inverted U-shape curve for the observations of 140 countries between the periods 1950 to 1990. They applied a more flexible model to evaluate the relationship between CO2 and economic growth. The model consisted of a panel fixed year and country specific effects with a piecewise linear function.

Conversely, Koop and Tole (1999) suggests a parametric model that has random coefficients which vary across countries over time and found no existence of EKC for deforestation. Despite the flexible specifications, the parametric functional forms were criticised (Azomahou and Van Phu, 2001).
Considerably, Taskin and Zaim (2000) applies a nonparametric methodology to examine the EKC existence for environmental efficiency. Cross sectional data on CO2 emissions were used to compute the environmental efficiency index for low and high income countries from 1975 to 1990. The outcome shows EKC hypothesis holds for only high income countries.

Several literatures indicate that most research on the EKC applied either panel or cross-sectional data for a group of countries (developed and/or developing) to establish a connection between economic growth and environmental degradation (Panayotou 1993; Perman and Stern 2003; and Azomahou et al. 2006 amongst others). Lindmark (2002), points that a major advantage of an individual study is providing the analysis closer to the dynamic. Dinda (2004) adds that the EKC is a long run phenomenon that depicts development in a single economy through different stages of growth over time.

Consequently, Stern (2004) in an extensive research on EKC, points to a number of issues in the empirical studies. They include econometric problems ranging from the data stationarity to omitted variables as well as a weak theoretical and conceptual framework that inhibit the feedback or lag effect that run between the environmental degradation to economic growth.

The focus of research on the EKC hypothesis as a result changed to testing cointegration and causal relationship because of the enhancement of time series econometric methods. Egli (2004) suggests the importance of equations with explicit short and long run dynamics as being preferable in recognising the impact of economic growth on environmental degradation.

Considering Stern (2004) views, Dinda and Coondoo (2006) evaluates the granger causality between income and CO2 emissions in groups of countries using panel data. They maintain that the directions of the causality are unclear; stating that if there is a unidirectional causality running from CO2 emissions to income then the relationship possibly occurs during production, thus income rises. They further said that there would be a feedback effect in the existence of bidirectional causation because the variables are directly affecting each other.

However, Gubb et al. (2006) attains in their investigation that there is no unique relationship between emissions and income per capita regardless of time and place. They argue that the nature of the relationship is undoubtedly dependent on the specific circumstances and the policies adopted in each economy.

Soytas et al. (2007) in an examination of energy consumption, income and CO2 emissions in the United States discovers that the granger causality analysis shows a unidirectional link running from energy use to emissions with no causality to income. They concluded that income growth may not be a solution to environmental problems.

Following Soytas et al. (2007) studies of including other determinants that affects CO2 emissions, Halicioglu (2009) in a dynamic causal relationship between carbon emissions, energy consumption, income, and foreign trade in Turkey from the periods of 1960 to 2005 tests the interrelationship between the variables using the bounds testing to cointegration procedure. The result shows two forms of long run relationships between the variables. Firstly, CO2 emissions are influenced by energy consumption, income and foreign trade. Secondly, income is determined by CO2 emissions, energy consumption and foreign trade. The conclusion is that income was the most significant variable that explained carbon emissions in Turkey. Likewise, Akbostanci et al. (2009) reveals a monotonically increasing relationship between CO_2 and income in the long-run in Turkey using time series data. However, they both concluded that there is no inverted U-shaped relationship between emissions and income in Turkey.

Regarding the United Kingdom, there have been very few researches on the relationship between CO2 emissions and economic growth (Ubaidillah 2011; Fosten et al. 2012 and Giovanis 2013). Ubaidillah (2011) considers the relationship between income and the environment in terms of road transport sector in the UK. The study however, applies carbon monoxide emissions rather than CO2 and identifies an inverted U-shaped relationship. Thus, confirming the EKC hypothesis.

Also, Fosten et al. (2012) uses the non-linear threshold cointegration and error correction model in identifying the relationship between CO2 emissions and GDP in the UK. Applying a long dataset beginning from 1830, their study reveals an inverse U-shaped curve between per capita CO_2 and GDP per capita. They also corrected the disequilibrium from long run EKC in an asymmetric manner.

Recently, Giovanis (2013) approaches EKC hypothesis on a micro-economic level. The study views the empirical evidence between air pollution and income using social data from the British Household Panel Survey from the periods of 1991 to 2009. The fixed effect model, Arellano–Bond GMM and the binary Logit model with fixed effects were the benchmark in the test. The results show no evidence of EKC relationship in the fixed effect model. On the other hand, strong evidence of EKC hypothesis in Arellano–Bond GMM and the binary Logit model with fixed effects. Saboori et al. (2012) affirms that the empirical results of EKC hypothesis are sensitive to the chosen country/countries, time considered, estimation technique and the different variables in the model.

In a different spin, The Kyoto Protocol ratification opened up several debates on the relationship between carbon dioxide emissions and income. Some of the discussions have been centred on restricting CO_2 emissions to affect economic growth (Gubb et al. 2006). Cambridge Econometrics (2009) report to the Committee on Climate Change analyses that since the legally-binding target of a 34% reduction in greenhouse gases (GHG) by 2020 in the UK there has been an economic downturn, both globally and in the UK, has worsened considerably.

In an article from the Wall Street Journal (2009), Professor Stavins, a director of Harvard's environmental economics program suggests that a cut in the greenhouse gases will not necessarily cause a blip in the growth of an economy if smart policies are implemented. However, Steven Hayward, a fellow at the American Enterprise Institute for Public Policy Research views is contrary, adding that the Energy use and the carbon dioxide it emits is so central to the world's economy that major cuts cannot be made without significant damage (Wall Street Journal, 2009).

Several opinions rise from the relationship between CO_2 emissions and economic growth. There is a school of thought that considers the EKC hypothesis, with the assumption that economic growth would rectify environmental degradation. Another viewpoint considers the mitigation options and how it would possibly affect or not affect the economy. The next section would attempt to analyse this issue empirically.

3.0 METHODOLOGY

The purpose of this empirical analysis is to examine the relationship between CO2 emissions and economic growth and to evaluate the causal link between the various variables that would be studied. The variables investigated include CO2 emissions per capita, Real GDP per capita, final energy consumption and foreign trade ratio.[4] Although, there are other determining variables not listed above, however, this study follows Halicioglu (2009) variable choices.

The method would adopt similar approaches from previous research studies that considered the EKC hypothesis as a tool to build an econometric model (see Soytas et al. 2007; Sanglimsuwan K., 2011; Saboori et al., and 2012).

The model specification can be denoted as;

$E= f (Y, Y^2, Y^3, Z)$………………….……………………………………..……..…equation (1)

Where;

E is the environmental indicator, Y is the income, Y^2 is the squared income, Y^3 is income in cubic and Z other explanatory variables.

Thus, the relationship can be rewritten as;

$CO_{2t} = \alpha_0 + \alpha_1 Y_t + \alpha_2 Y^2_t + \alpha_3 Y^3_t + \alpha_4 FEC_t + \alpha_5 FTR_t + \mu_t$………………………equation (2)

Where;

CO_2 is carbon-dioxide emissions per capita, Y is Real GDP per capita, FEC is final energy consumption, FTR is foreign trade ratio, t is time and μ is the error term. Values of the coefficients are (α_1 to α_5) which indicates the different functional forms and α_0 is the intercept.

Further, the study would consider if the EKC hypothesis holds in the relationship between CO2 emissions and GDP in the UK for the periods under study. The decision rule is as follows;

If

$\alpha 1 = \alpha 2 = \alpha 3 = 0$ (level relationship),

$\alpha 1 < 0, \alpha 2 = \alpha 3 = 0$ (monotonically decreasing linear relationship),

[4] See definitions in Appendix A

$\alpha 1 > 0$, $\alpha 2 = \alpha 3 = 0$ (monotonically increasing linear relationship),

$\alpha 1 < 0$, $\alpha 2 > 0$, $\alpha 3 = 0$ (U-shaped relationship)

$\alpha 1 > 0$, $\alpha 2 < 0$, $\alpha 3 = 0$ (Inverted U-shaped relationship) thus EKC confirmed.

$\alpha 1 > 0$, $\alpha 2 < 0$, $\alpha 3 > 0$ (N-shaped relationship)

$\alpha 1 < 0$, $\alpha 2 > 0$, $\alpha 3 < 0$ (Reverse N-shaped relationship)

The turning point of per capital real GDP is $Y^* = - \alpha 1/2\ \alpha 2$; Log term will be exp ($Y^*$).

In line with the above specification, the methodological approach would be structured by first understanding the properties of the series considered for analysis. This can be achieved by first presenting the variables graphically to illustrate the intercept and trend behaviour. Afterwards, test for stationarity of the data, if they have a unit root. This is to ensure that the regression is not spurious.[5] The Augmented Dickey Fuller (1979) and Phillips and Perron (1988) tests would be applied to examine the integration order of the data. Both tests model can be expressed as;

$$\Delta y_t = \alpha + \beta\ t + \gamma\ y_{t-1} + \sum_{I=1}^{p} \delta_i\ \Delta y_{t-i} + \varepsilon_t \text{ ....equation (3)}$$

Where Y is the variable under examination, ε is the random error term and P is the lag number which is chosen with the use of the Akaike Information Criterion (Akaike, 1973). This corrects the possibility of a serial correlation. The null hypothesis is $\gamma = 0$ implies that the time series have a unit root and the alternative hypothesis is $-2<\rho<0$ indicates stationarity. However, Akaike information criterion is only used in the ADF test at lag 7. PP test uses a non-parametric correction (Newey and West, 1987) for serial correlation and the Bartlett kernel spectral estimation method.

The next step is the cointegration test by Johansen (1988, 1995). This would show the long run association between the variables. Should the variables be cointegrated, the error correction model (ECM) would be applied on equation 2 and the ordinary least square (OLS) would be used to generate the estimate of the coefficients. The estimate is used to know the short and long run causality between the variables and to confirm the EKC hypothesis. The model would be indicated as;

---

[5] Stern (2004) earlier mentioned that the use of non-stationary data in the EKC hypothesis made the results inaccurate.

$DCO_{2t} = \alpha_0 + \alpha_1 DYt + \alpha_2 DY^2t + \alpha_3 DY^3t + \alpha_4 DFECt + \alpha_5 DFTRt + \alpha_6 \mu_{t-1} + V$….equation (4)

Where V is the white noise error term, D represents the first differenced variables; α_1 to α_5 is the short run coefficient and α_6 is the long run coefficient if it is negative and significant.

The final step is the Pairwise Granger Causality Tests on the variables to know how they influence each other in terms of their contributions structurally. This indicates causality in the prediction sense. Granger (1969) initiated this statistical hypothesis to test whether a particular series is useful in predicting another. It starts with an assumption that the future cannot influence the past; if X occurs after Y, then X cannot granger cause Y. A time series is said to granger cause if the X values provide statistically significant information about the future of Y values. The T-test and F-test on lagged values are used to reveal the interpretation. If the P-value is less than 5percent reject the null hypothesis that "X does not granger cause Y."

3.1 DATA ANALYSIS

The time series samples under investigations are 31 observations which cover the periods of 1980 to 2010.[6] The CO2 emissions data is derived from IEA database, RGDP and FTR data are retrieved from the World Bank[7] and FEC collected from DECC database. The data are in normal form and the use of e-view 7.1 and MS Excel are applied on the data for analysis.

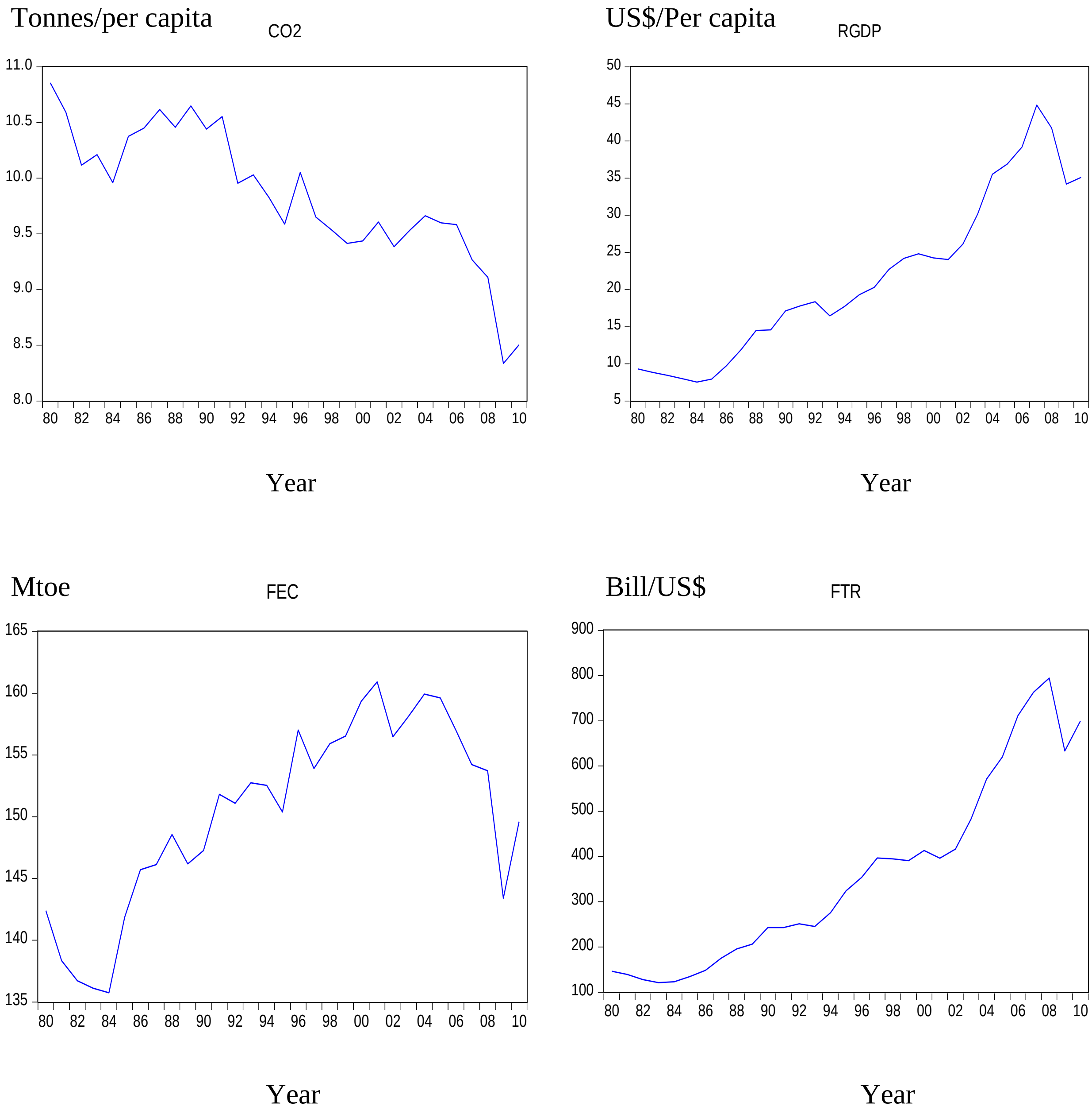
3.2 SIMPLE TREND INDICATORS

Figure 1 shows the trend movements of the variables graphically that will be analysed in the course of this analysis. The data suggests an intercept and trend behaviour. Nonetheless, this will be tested in the next section.

[6] See data in Appendix B

[7] RGDP is deflated to 2010 constant terms and FTR is exports plus imports divided by GDP.

Figure 1: Graphical illustration of the variables



3.3 UNIT ROOT TESTS

Table 1 presents the unit root tests results and both ADF and PP test show all the variables significant in the first order of integration. All the data were 5% statistically significance. This implies that the data analysis will be analysed in the first difference of the variables.

Table 1: Stationarity test results

ADF Test					PP Test				
Variables	Level		1st order		Level		1st order		Decision
	C	C & T	C	C & T	C	C & T	C	C & T	
CO_2	0.02	-2.47	-6.95	-6.97	-0.63	-2.44	-6.95	-6.97	I(1)
RGDP	-0.49	-3.35	-4.42	-3.80	-0.49	-2.54	-3.80	-3.71	I(1)
RGDP2	2.14	-3.82	-3.41	-3.91	-0.67	-2.28	-3.99	-3.88	I(1)
RGDP3	2.14	-5.38	-3.78	-4.44	-1.12	-2.27	-4.16	-4.07	I(1)
FEC	-1.51	-0.30	-6.30	-6.72	-1.43	-1.35	-6.32	-7.22	I(1)
FTR	2.86	-0.72	-4.12	-5.23	0.10	-2.49	-4.92	-4.96	*I(1)*

Note: C (constant) & T (Trend)

3.4 COINTEGRATION TEST

The unrestricted cointegration tests result is illustrated in table 2. Trace test indicates 5 cointegrating equations while Max-Eigen reveals 3 cointegrating equations at the 0.05 level of significance in lag 2. This shows that at most three of the variables have a long run association or equilibrium between each other.

Table 2: Unrestricted Cointegration Test Results

Hypothesized	**Trace**	**0.05**		**Max-Eigen**	**0.05**		**Hypothesized**
No. of CE(s)	**Statistic**	**Critical Value**	**Prob.****	**Statistic**	**Critical Value**	**Prob.****	**No. of CE(s)**
None *	237.92	95.75	0.0000	105.28	40.08	0.0000	None *
At most 1 *	132.65	69.82	0.0000	63.97	33.88	0.0000	At most 1 *
At most 2 *	68.68	47.86	0.0002	35.68	27.58	0.0037	At most 2 *
At most 3 *	33.00	29.80	0.0207	16.58	21.13	0.1930	At most 3
At most 4 *	16.42	15.49	0.0362	15.85	14.26	0.0278	At most 4 *
At most 5	0.57	3.84	0.4493	0.57	3.84	0.4493	At most 5

* denotes rejection of the hypothesis at the 0.05 level

**MacKinnon-Haug-Michelis (1999) p-values

3.5 CAUSALITY TESTS

The results of the cointegration enable this research to conduct an error correction model on the variables. This is a restrictive test that considers the error term which possibly could have occurred in the process of testing the long run relationship between the variables. This test would further expose the short run causality between the variables. The equation is built from a vector error correction model (VECM)[8] to reveal the transmission channel between the dependent and independent variables.

Table 3 shows the outcome of the estimates. The long run association is revalidated with the error term indicating a negative sign and statistically significant p-value. The short run causality is not statistically significant for RGDP, but FEC and FTR reveals short run causality with CO2 emissions.[9] However, the coefficient result of the error term indicates the speed at which the disequilibrium in the model can be resolved. This suggests that the system is rectified at 102% speed annually.

The diagnostic checks in table 4 further verify the accuracy of the model.[10] This explains that the data are normally distributed, no serial correlation and free from the ARCH effect. Also, the R-squared being less than Durbin Watson statistics and explaining 87% makes it a valid regression. Finally, the P-value is statistically significant.

Table 3: Error Correction Model

Variables	Coefficient	Std. Error	t-Statistic	Prob.
μ-1	-1.025	0.266	-3.857	0.002
V-1	0.031	0.097	0.321	0.754
V-2	0.003	0.006	0.535	0.602
CO2-1	0.254	0.253	1.005	0.335
CO2-2	0.793	0.297	2.667	0.021
DRGDP-1	0.402	0.192	2.092	0.058
DRGDP-2	-0.015	0.298	-0.049	0.962
$DRGDP^2$-1	-0.021	0.009	-2.411	0.033
$DRGDP^2$-2	0.005	0.015	0.357	0.727

[8] See model in Appendix C
[9] See Wald test in Appendix D
[10] See full details in Appendix E

$DRGDP^3$-1	0.000	0.000	2.052	0.063
$DRGDP^3$-2	0.000	0.000	-0.499	0.627
DFEC-1	-0.026	0.032	-0.809	0.434
DFEC-2	-0.062	0.025	-2.520	0.027
DFTR-1	0.010	0.003	3.738	0.003
DFTR-2	0.001	0.004	0.133	0.897
α0	-0.078	0.077	-1.016	0.330
R-squared	0.874516	Durbin-Watson stat	2.302323	
Adjusted R-squared	0.717662	F-statistic	0.002379	
	Prob(F-statistic)	0.002379		

Table 4: Diagnostic Checks

Tests	Jarque-Bera	Obs*R-squared	Probability
Normality	3.877774		0.143864
Breusch-Godfrey Serial Correlation LM		5.243174	0.0727
Heteroskedasticity Test: ARCH		0.099563	0.7524

3.6 EKC HYPOTHESIS

The hypothesis is derived from the coefficient estimates in table 3. RGDP-1 is 0.402, $RGDP^2$-1 is -0.021 and $RGDP^3$-1 is 0.000. These estimates confirm the EKC hypothesis relationship between CO2 emissions and GDP in the UK. In summary, the EKC hypothesis can be confirmed through this decision rule ($\alpha1 > 0$, $\alpha2 < 0$, $\alpha3 = 0$ (Inverted U-shaped relationship) thus EKC confirmed). Where α1 is RGDP-1, α2 is $RGDP^2$-1 and α3 is $RGDP^3$-1.

3.7 GRANGER CAUSALITY TESTS

Table 5 explains the granger causality test at lag three. The results indicate a unidirectional causality running from CO_2 to RGDP. Likewise FTR to CO_2 suggests a unidirectional link. Also, RGDP is found to granger cause FTR. Finally, a unidirectional relationship is revealed from FTR to FEC.

Table 5: Pairwise Granger Causality Test Results

Sample: 1980 2010

Lags: 3

Null Hypothesis:	Obs	F-Statistic	Prob.
DRGDP does not Granger Cause DCO2	27	2.12166	0.1295
DCO2 does not Granger Cause DRGDP		5.52745	0.0063
DFEC does not Granger Cause DCO2	27	1.15519	0.3514
DCO2 does not Granger Cause DFEC		0.24835	0.8615
DFTR does not Granger Cause DCO2	27	5.43047	0.0067
DCO2 does not Granger Cause DFTR		0.43323	0.7315
DFEC does not Granger Cause DRGDP	27	0.82483	0.4956
DRGDP does not Granger Cause DFEC		2.88797	0.0610
DFTR does not Granger Cause DRGDP	27	1.02167	0.4040
DRGDP does not Granger Cause DFTR		4.41223	0.0155
DFTR does not Granger Cause DFEC	27	4.08434	0.0205
DFEC does not Granger Cause DFTR		1.49760	0.2457

4.0 FINDINGS AND POLICY IMPLICATION

The findings above indicate that at first difference CO_2 emissions would relate to the economic growth in the UK in a short and long term. Differently, it exposes a short and long run causality running between CO_2 and the economy in UK. More so, the result reveals that in the event of disequilibrium in the relationship, it would be rectified at a speed of 102%. This is found to be statistically significant. This implies that there is a strong association between CO_2 emissions and economic growth in the UK between the periods 1980 to 2010.

Further, the EKC hypothesis is confirmed in the UK for the periods observed. This validates earlier studies conclusions about EKC hypothesis in UK and other developed countries. This means that initially GDP growth caused CO_2 emissions to rise beyond a turning point, before a fall in CO_2 resulting from a further growth in the GDP. This is evident in the negative sign in FEC which is statistical significant in table 3. This depicts a more efficient energy consumed in UK which reduces CO_2 emissions in the environment. However, the trade openness positively affects CO_2 emissions in the UK.

The granger causality tests further reveals trade openness influencing CO_2 emissions increase in the UK. The implication of RGDP granger causing FTR and FTR causing CO_2 emissions simply means there is a chance of an N-shaped EKC, if better policies to curb emissions from trade openness are not considered. Also, the effect of CO_2 granger causing GDP means a cut in emissions will have an adverse impact on GDP. Finally, FTR causes FEC indicating further CO_2 emissions concerns are needed on final energy consumed in the UK.

5.0 CONCLUSIONS AND RECOMMENDATIONS

This study examined the relationship between CO_2 emissions and economic growth in UK. The paper identified the existence of a short and long run causality between the variables. It further confirmed the EKC hypothesis and found a unidirectional causality running from CO_2 to GDP; FTR to CO_2; GDP to FTR and FTR to FEC.

Considerably, the implications of these results were analysed and there was an assumption of a possible N-shaped relationship running between CO_2 and economic growth if cautious policies are not implemented to regulate trade openness in UK. Also, a cut in CO_2 emissions was discovered to possibly affect GDP negatively.

In line with the above conclusions, the study recommends the need for policy makers to integrate emissions regulations with economic growth policies. They should also consider educating the masses on energy efficiency. More so, the trade regulations should be firm about environmental friendly supplies. Finally, there should be a joint venture between the public and private sector in clean energy investment because it is capital intensive.

REFERENCE LIST

SECONDARY SOURCES

Journals

Akbostanci, E., Türüt-Asik, S., & Tunc, I.G., *The relationship between income and environment in Turkey: is there an environmental Kuznets curve?* Energy Policy, 37 (2), 861-867 (2009) at http://dx.doi.org/10.1016/j.enpol.2008.09.088 (Last visited 20/01/13).

Azomahou, T., Laisney, F., Van, P.N., *Economic development and CO2 emissions: a nonparametric panel approach*, Journal of Public Economics 90, 1347–1363 (2006) at http://ideas.repec.org/p/zbw/zewdip/4282.html (Last visited 21/01/13).

Brajer, V., Mead, R.W., Xiao, F., *Health benefits of tunneling through the chinese environmental Kuznets curve*, Ecological Economics 66 (4), 674–686 (2008) at http://www.sciencedirect.com/science/article/pii/S0921800907005277 (Last visited 20/01/13).

Cole, M.A., Elliott, R.J.R., *Determining the trade–environment composition effect: the role of capital, labor and environmental regulations*, Journal of Environmental Economics and Management 46 (3), 363–383 (2003) at http://www.sciencedirect.com/science/article/pii/S0095069603000214 (Last visited 20/01/13).

Dickey, D.A. and Fuller,W.A., *Distribution of the estimators for auto-regressive time series with a unit root*, Journal of American Statistical Association 74, 427–431 (1979) at http://www.jstor.org/discover/10.2307/2286348?uid=3738032&uid=2&uid=4&sid=21101698480417 (Last visited 21/01/13).

Dinda, S., *Environmental Kuznets Curve hypothesis: a survey*, Ecological Economics 49, 431–455 (2004) at http://www.sciencedirect.com/science/article/pii/S0921800904001570 (Last visited 21/01/13).

Dinda, S., Coondoo, D., *Income and emission: a panel data-based cointegration analysis*, Ecological Economics 57, 167-181 (2006) at http://www.sciencedirect.com/science/article/pii/S0921800905001692 (Last visited 21/01/13).

Fosten, J., Morley, B., Taylor, T., *Dynamic misspecification in the environmental Kuznets curve: evidence from CO2 and SO2 emissions in the United Kingdom*, Ecological Economics 76, 25–33 (2012) at http://www.sciencedirect.com/science/article/pii/S0921800912000468 (Last visited 21/01/13).

Galeotti, M., Lanza, A., *Richer and cleaner? A study on carbon dioxide emissions in developing countries*, Energy Policy 27, 565–573 (1999) at http://www.sciencedirect.com/science/article/pii/S0301421599000476 (Last visited 20/01/13).

Granger, C. W. J., *Investigating Causal Relations by Econometric Models and Cross-spectral Methods*, Econometrica, Vol. 37, No. 3., pp. 424-438 (1969) at http://www.sonoma.edu/users/c/cuellar/econ411/Granger.pdf (Last visited 21/01/13).

Grossman, G.M., Krueger, A.B., *Environmental Impacts of a North American free trade agreement*, NBER Working Paper 3914. NBER, Cambridge (1991) at http://ideas.repec.org/p/nbr/nberwo/3914.html (Last Visited 20/01/13).

Holtz-Eakin, D.,Selden,T.M., *Stokingthefires?: CO2 emissions and economic growth*, Journal of Public Economics 57, 85–101 (1995) at http://www.ingentaconnect.com/content/els/00472727/1995/00000057/00000001/art01449 (Last visited 21/01/13).

Halicioglu, F., *An econometric study of CO2 emissions, energy consumption, income and foreign trade in Turkey*, Energy Policy, Elsevier, vol. 37(3), pages 1156-1164 (2009) at http://ideas.repec.org/p/pra/mprapa/11457.html (Last visited 21/01/13).

Giovanis E., *Environmental Kuznets curve: Evidence from the British Household Panel Survey, Economic Modelling*, Vol. 30, Pages 602–611 (2013) at http://www.sciencedirect.com/science/article/pii/S0264999312003501 (Last visited 21/01/13).

Johansen, S., *Statistical analysis of Cointegration Vectors*, Journal of Economics Dynamics Control, Volume 12, Pages 231–254 (1988) at http://www.researchgate.net/publication/223143152_Statistical_analysis_of_cointegration_vectors (Last visited 20/01/13).

Johansen, S., *Identifying restrictions of linear equations with applications to simultaneous equations and cointegration*, Journal of Econometrics, Elsevier, vol. 69(1), pages 111-132 (1995) at http://ideas.repec.org/a/eee/econom/v69y1995i1p111-132.html (Last visited 20/01/13).

Koop, G., Tole, L., *Is there an Environmental Kuznets Curve for deforestation?* Journal of Development Economics 58, 231–244 (1999) at http://ideas.repec.org/a/eee/deveco/v58y1999i1p231-244.html (Last visited 21/01/13).

Kuznets, S., *Economic growth and income inequality*, American Economic Review 45, 1–28 (1955) at http://courses.nus.edu.sg/course/ecshua/eca5374/Economics%20growth%20and%20income%20inequality_Kuznets_AER55.pdf (Last visited 20/01/13).

Lindmark, M., *An EKC-pattern in historical perspective: carbon dioxide emissions, technology, fuel prices and growth in Sweden, 1870–1997*, Ecological Economics 42, 333–

347 (2002) at http://www.sciencedirect.com/science/article/pii/S0921800902001088 (Last visited 21/01/13).

Phillips, P.C.B. and Perron, P., *Testing for unit root in time series regression*, Biometrica 75, 335–346 (1988) at http://biomet.oxfordjournals.org/content/75/2/335 (Last visited 19/01/13).

Perman, R., Stern, D.I., *Evidence from panel unit root and cointegration tests that the environmental Kuznets curve does not exist*, The Australian Journal of Agricultural and Resource Economics 47, 325–347 (2003) at http://ageconsearch.umn.edu/bitstream/116988/2/1467-8489.00216.pdf (Last visited 21/01/13).

Saboori, B., Sulaiman, J., Mohd, S., *Economic growth and CO2 emissions in Malaysia: A cointegration analysis of the Environmental Kuznets Curve*, Energy Policy 51,184–191 (2012) at http://www.sciencedirect.com/science/article/pii/S0301421512007471 (Last visited 19/01/13).

Sanglimsuwan, K., *Carbon Dioxide Emissions and Economic Growth: An Econometric Analysis*, International Research Journal of Finance and Economics, ISSN 1450-2887 Issue 67 (2011) at http://www.eurojournals.com/IRJFE_67_09.pdf (Last visited 23/01/13).

Schmalensee, R.L., Joskow, P.L., Ellerman, A.D., Montero, J.P., Bailey, E.M., *An interim evaluation of sulfur dioxide emissions trading*, Journal of Economic Perspectives 12 (3), 133–148 (1998) at http://ideas.repec.org/a/aea/jecper/v12y1998i3p53-68.html (Last Visited 21/01/13).

Selden, T., Song, D., *Environmental quality and development: is there a Kuznets Curve for air pollution emissions?* Journal of Environmental Economics and Management 27, 147–162 (1994) at http://ideas.repec.org/a/eee/jeeman/v27y1994i2p147-162.html (Last visited 20/01/13).

<u>OTHER</u>

Internet

Akaike,H., *Information theory and an extension of the maximum likelihood principle*, Proc. 2nd Inter, Symposium on Information Theory, 267-281 (1973) at http://www.sortie-nd.org/lme/Statistical%20Papers/Akaike_1973%20with%20commentary.pdf (Last visited 21/01/13).

Azomahou T. and Van Phu, N., *Economic growth and CO2 emissions: a nonparametric approach*, BETA-Theme, Université Louis Pasteur, (2001) at http://ideas.repec.org/p/ulp/sbbeta/2001-01.html (Last visited 21/01/13).

Cambridge Econometrics, *An Impact Assessment of the Current Economic Downturn on UK CO2 Emissions*, A final report for the Committee on Climate Change (2009) at http://downloads.theccc.org.uk/docs/CE%20Final%20Report_110809.pdf (Last visited 21/01/12).

Department of Energy and Climate Change (DECC), Overview, GHG Inventory summary Factsheet at http://www.decc.gov.uk/assets/decc/Statistics/climate_change/1227-ghg-inventory-summary-factsheets-amalgamated-doc.pdf (Last visited 20/01/13).

Energy Information Administration (EIA) at http://www.eia.gov/cfapps/ipdbproject/iedindex3.cfm?tid=90&pid=45&aid=8&cid=regions&syid=1980&eyid=2010&unit=MMTCD (Last Visited 20/01/13).

Egli, H., *The Environmental Kuznets Curve-evidence from time series data for Germany*, Working Paper Series 04–33, Institute of Economic Research (2004) at http://ideas.repec.org/p/eth/wpswif/03-28.html (Last visited 21/01/13).

Giles, D.E., Mosk, C., *Ruminant eructation and a long-run environmental Kuznets curve for enteric methane in New Zealand: Conventional and fuzzy regression*, Econometrics Working Paper, vol. 0306 (2003) at http://ideas.repec.org/p/vic/vicewp/0306.html (Last visited 20/01/13).

Grubb, M.,Butler, L. and Feldman, O., *Analysis of the Relationship between Growth in Carbon Dioxide Emissions and Growth in Income*, (2006), available at http://www.econ.cam.ac.uk/rstaff/grubb/publications/GA12.pdf(Last visited 21/01/12).

Intergovernmental Panel on Climate Change (IPCC), *Climate Change Synthesis Report* (2007) at http://www.ipcc.ch/S (Last visited 20/01/13).

Newey, K. W. and West K. D., *A Simple, Positive Semi-definite, Heteroskedasticity and Autocorrelation Consistent Covariance Matrix*, Econometrica, vol. 55, issue 3, pages 703-08 (1987) at http://www.ssc.wisc.edu/~kwest/publications/1980/A%20Simple%20PSD%20HAC%20Covariance%20Matrix.pdf (Last visited 21/01/13).

Panayotou, T., *Empirical tests and policy analysis of environmental degrada- tion at different stages of economic development*, Working Paper WP238, Technology and Environment Programme, International Labour Office, Geneva (1993) at http://www.econbiz.de/en/search/detailed-view/doc/all/empirical-tests-and-policy-analysis-of-environmental-degradation-at-different-stages-of-economic-development-pana%C4%ADotou-todor/10000989773/?no_cache=1 (Last visited 20/01/13).

Stern, D., *The rise and fall of the Environmental Kuznets Curve*, World Development 32, 1419–1439 (2004) at http://www.sciencedirect.com/science/article/pii/S0305750X04000798 (Last visited 21/01/13).

Soytas, U., Sari, R. and Ewing, B.T., *Energy Consumption, Income, and Carbon Emissions in the United States*, 62, 482-489 (2007) at http://dx.doi.org/10.1016/j.ecolecon.2006.07.009 (last visited 19/01/13).

Taskin, F., Zaim, O., *Searching for a Kuznets curve in environmental efficiency using kernel estimation*, Economics Letters 68, 217.223 (2000) at http://directory.umm.ac.id/Data%20Elmu/jurnal/E/Economics%20Letters/Vol68.Issue2.Aug2000/1767.pdf (Last visited 21/01/13).

The World Bank, *Growth and CO2 emissions: how do different countries fare?* Environment Department, Washington, DC (2007) at http://siteresources.worldbank.org/INTCC/214574-1192124923600/21511758/CO2DecompositionfinalOct2007.pdf (Last visited 20/01/13).

The Wall Street Journal, *Can Countries Cut Carbon Emissions Without Hurting Economic Growth?* (September 13, 2009) at http://online.wsj.com/article/SB10001424052970203440104574406681308037234.html (Last visited 21/01/12).

Ubaidillah, N.Z., *The relationship between income and environment in UK's road transport sector. Is there an EKC?* International Conference on Economics and Finance Research IPEDR 4, pp. 100–103 (2011) at http://www.ipedr.com/vol4/20-F00040.pdf (Last visited 21/01/13).

APPENDIX A – DEFINITION OF VARIABLES

CO2 emissions (metric tons per capita)

Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring. Per capita refers to emissions per unit/person (World Bank).

Gross Domestic Product (Constant 2010 US $)

GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is measured in 2010 real terms (World Bank).

Final energy consumption (Mtoe)

Final energy consumption is the total energy supplied to the final consumers in the UK for all energy uses. Examples are coal, coke and breeze, other solid fuels, coke oven gas, Town gas, natural gas, electricity, heat, bioenergy and waste and petroleum (DECC website). It is measured in million tonnes of oil equivalent.

Foreign Trade Ratio (US $)

Foreign trade ratio is the sum of all the exports and imports in the UK to the gross domestic product (GDP).

APPENDIX B – DATA PRESENTATION

Year	CO2 (tonnes per capita)	RGDP (US$)	$RGDP^2$ (US$)	$RGDP^3$ (US$)	FEC (Mtoe)	FTR (billion US$)
1980	10.86	9.32	86.78	808.40	142.39	146.32
1981	10.59	8.85	78.33	693.25	138.35	139.06
1982	10.12	8.44	71.23	601.16	136.73	127.65
1983	10.21	8.00	64.04	512.47	136.11	121.08
1984	9.96	7.53	56.69	426.82	135.75	122.87
1985	10.37	7.95	63.16	502.00	141.87	134.64
1986	10.45	9.74	94.91	924.68	145.72	148.31
1987	10.62	11.94	142.54	1701.84	146.13	175.14
1988	10.46	14.47	209.48	3031.90	148.57	195.76
1989	10.65	14.58	212.46	3096.92	146.18	206.26
1990	10.44	17.12	293.18	5020.08	147.27	243.02
1991	10.55	17.80	316.81	5638.95	151.82	242.84
1992	9.95	18.35	336.90	6183.67	151.09	251.10
1993	10.03	16.45	270.76	4455.42	152.75	245.27
1994	9.83	17.74	314.81	5585.63	152.55	275.75
1995	9.59	19.31	372.75	7196.50	150.38	323.99
1996	10.05	20.30	411.95	8361.03	157.02	353.67
1997	9.65	22.71	515.76	11712.98	153.90	396.75
1998	9.53	24.20	585.51	14167.87	155.92	394.72
1999	9.41	24.81	615.37	15265.20	156.53	390.98
2000	9.44	24.26	588.41	14273.09	159.37	413.20
2001	9.61	24.04	578.06	13898.34	160.93	396.37
2002	9.38	26.13	683.01	17850.25	156.48	416.42
2003	9.53	30.16	909.49	27428.25	158.15	482.47
2004	9.66	35.52	1261.88	44825.47	159.94	571.18
2005	9.60	36.90	1361.89	50258.69	159.63	619.88
2006	9.58	39.19	1535.68	60179.90	157.00	711.36
2007	9.27	44.85	2011.54	90217.93	154.22	762.89
2008	9.11	41.77	1744.61	72869.48	153.73	794.68
2009	8.34	34.20	1169.82	40010.80	143.40	633.32
2010	8.50	35.10	1231.85	43235.36	149.60	699.44

Data Sources: The World Bank, Department of Energy and Climate Change and International Energy Administration.

APPENDIX C – ERROR CORRECTION MODEL

Dependent Variable: D(CO2)
Method: Least Squares
Date: 01/22/13 Time: 21:08
Sample (adjusted): 1983 2010
Included observations: 28 after adjustments
D(CO2) = C(1)*(CO2(-1) - 4.82503670844E-05*RGDP3(-1) - 0.0633127557697*FEC(-1) + 0.00977784335397*FTR(-1) - 2.91083427084) + C(2)*(RGDP(-1) - 0.000328593695078*RGDP3(-1) - 0.615628175362*FEC(-1) + 0.000550091835002*FTR(-1) + 76.8721238661) + C(3)*(RGDP2(-1) - 0.0202865039432*RGDP3(-1) - 11.1497905184*FEC(-1) - 0.0949100323246*FTR(-1) + 1499.97668068) + C(4)*D(CO2(-1)) + C(5)*D(CO2(-2)) + C(6)*D(RGDP(-1)) + C(7)*D(RGDP(-2)) + C(8)*D(RGDP2(-1)) + C(9)*D(RGDP2(-2)) + C(10)*D(RGDP3(-1)) + C(11)*D(RGDP3(-2)) + C(12)*D(FEC(-1)) + C(13)*D(FEC(-2)) + C(14)*D(FTR(-1)) + C(15)*D(FTR(-2)) + C(16)

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-1.025002	0.265732	-3.857277	0.0023
C(2)	0.031002	0.096625	0.320849	0.7538
C(3)	0.003364	0.006285	0.535185	0.6023
C(4)	0.254257	0.252939	1.005207	0.3346
C(5)	0.793304	0.297444	2.667073	0.0205
C(6)	0.401996	0.192188	2.091684	0.0584
C(7)	-0.014559	0.297604	-0.048920	0.9618
C(8)	-0.020750	0.008608	-2.410561	0.0329
C(9)	0.005321	0.014892	0.357268	0.7271
C(10)	0.000233	0.000114	2.051539	0.0627
C(11)	-9.52E-05	0.000191	-0.499234	0.6266
C(12)	-0.025887	0.031994	-0.809125	0.4342
C(13)	-0.062249	0.024705	-2.519685	0.0269
C(14)	0.009802	0.002622	3.738103	0.0028
C(15)	0.000503	0.003796	0.132614	0.8967
C(16)	-0.078031	0.076822	-1.015739	0.3298

R-squared	0.874516	Mean dependent var	-0.057577
Adjusted R-squared	0.717662	S.D. dependent var	0.275054
S.E. of regression	0.146151	Akaike info criterion	-0.712788
Sum squared resid	0.256323	Schwarz criterion	0.048472
Log likelihood	25.97903	Hannan-Quinn criter.	-0.480063
F-statistic	5.575330	Durbin-Watson stat	2.302323
Prob(F-statistic)	0.002379		

APPENDIX D - SHORT RUN CAUSALITY TESTS

Foreign Trade Ratio (FTR)

Wald Test:
Equation: Untitled

Test Statistic	Value	df	Probability
F-statistic	9.276378	(2, 12)	0.0037
Chi-square	18.55276	2	0.0001

Null Hypothesis: C(14)=C(15)=0
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
C(14)	0.009802	0.002622
C(15)	0.000503	0.003796

Restrictions are linear in coefficients.

Real Gross Domestic Product (RGDP)

Wald Test:
Equation: Untitled

Test Statistic	Value	df	Probability
F-statistic	2.268363	(2, 12)	0.1460
Chi-square	4.536725	2	0.1035

Null Hypothesis: C(6)=C(7)=0
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
C(6)	0.401996	0.192188
C(7)	-0.014559	0.297604

Restrictions are linear in coefficients.

Final Energy Consumption (FEC)

Wald Test:
Equation: Untitled

Test Statistic	Value	df	Probability
F-statistic	3.785200	(2, 12)	0.0531
Chi-square	7.570400	2	0.0227

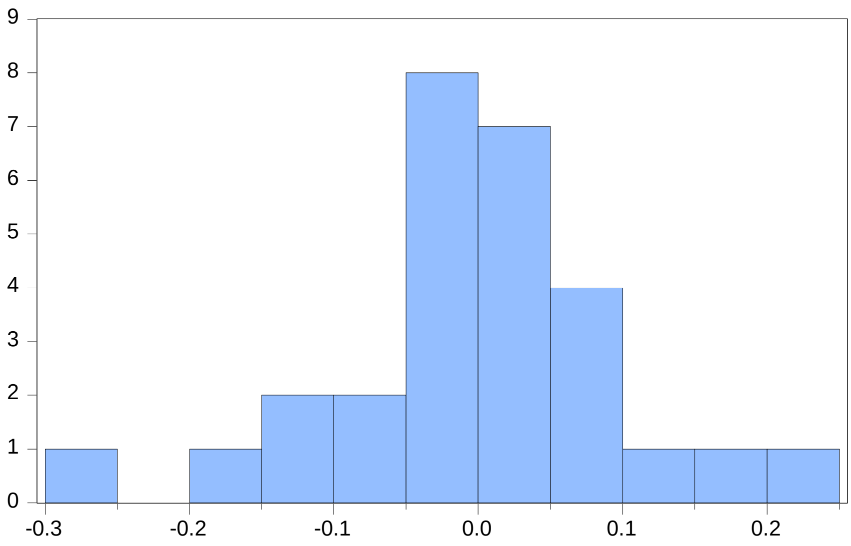
Null Hypothesis: C(12)=C(13)=0
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
C(12)	-0.025887	0.031994
C(13)	-0.062249	0.024705

Restrictions are linear in coefficients.

APPENDIX E – DIAGNOSTIC CHECKS

i) Normality Tests



Series: Residuals	
Sample 1983 2010	
Observations 28	
Mean	-5.98e-16
Median	-0.003990
Maximum	0.227406
Minimum	-0.281829
Std. Dev.	0.097434
Skewness	-0.398887
Kurtosis	4.639318
Jarque-Bera	3.877774
Probability	0.143864

ii) Breusch-Godfrey Serial Correlation LM Test:

F-statistic	1.152000	Prob. F(2,10)	0.3546
Obs*R-squared	5.243174	Prob. Chi-Square(2)	0.0727

Test Equation:
Dependent Variable: RESID
Method: Least Squares
Date: 01/22/13 Time: 21:50
Sample: 1983 2010
Included observations: 28
Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	0.241742	0.366767	0.659116	0.5247
C(2)	-0.030391	0.100972	-0.300989	0.7696
C(3)	0.000163	0.008666	0.018832	0.9853
C(4)	0.021472	0.270794	0.079293	0.9384
C(5)	0.004219	0.318236	0.013257	0.9897
C(6)	0.142458	0.227050	0.627428	0.5444
C(7)	-0.139986	0.447084	-0.313108	0.7606
C(8)	-0.003098	0.010572	-0.293072	0.7755
C(9)	0.006069	0.022007	0.275776	0.7883
C(10)	3.12E-05	0.000143	0.217776	0.8320
C(11)	-6.20E-05	0.000278	-0.223205	0.8279
C(12)	-0.003910	0.039777	-0.098309	0.9236
C(13)	0.000845	0.030811	0.027437	0.9787
C(14)	-0.003701	0.004438	-0.833938	0.4238
C(15)	-0.003325	0.005474	-0.607528	0.5570
C(16)	0.055481	0.107498	0.516110	0.6170
RESID(-1)	-0.677833	0.601611	-1.126697	0.2862
RESID(-2)	-0.479078	0.487631	-0.982462	0.3490

R-squared	0.187256	Mean dependent var	-5.98E-16
Adjusted R-squared	-1.194408	S.D. dependent var	0.097434
S.E. of regression	0.144335	Akaike info criterion	-0.777270
Sum squared resid	0.208325	Schwarz criterion	0.079147
Log likelihood	28.88178	Hannan-Quinn criter.	-0.515455
F-statistic	0.135529	Durbin-Watson stat	2.051629
Prob(F-statistic)	0.999812		

iii) Heteroskedasticity Test: ARCH

F-statistic	0.092529	Prob. F(1,25)	0.7635
Obs*R-squared	0.099563	Prob. Chi-Square(1)	0.7524

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 01/22/13 Time: 21:54
Sample (adjusted): 1984 2010
Included observations: 27 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.008836	0.004015	2.200741	0.0372
RESID^2(-1)	0.060824	0.199957	0.304186	0.7635

R-squared	0.003688	Mean dependent var	0.009412
Adjusted R-squared	-0.036165	S.D. dependent var	0.018070
S.E. of regression	0.018393	Akaike info criterion	-5.082456
Sum squared resid	0.008458	Schwarz criterion	-4.986468
Log likelihood	70.61315	Hannan-Quinn criter.	-5.053913
F-statistic	0.092529	Durbin-Watson stat	1.987737
Prob(F-statistic)	0.763504		