ENVIRONMENT AND HEALTH: MODELLING THE RELATIONSHIP BETWEEN AIR POLLUTION AND INFANT MORTALITY IN GHANA

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ABSTRACT

The paper aims at contributing to the body of knowledge in the area of environment and health by empirically examining the stable long run relationship between carbon dioxide emissions and infant mortality, using Autoregressive Distributed Lag Model (ARDL) for the period 1961-2010 using time series data. The results indicate the series variables are unit roots in levels but attained stationarity in first difference. The cointegrationresults indicate that carbon dioxide emissions significantly influence infant mortality in the long run and short run. Policy maker should incorporate the findings into their strategies to control air pollution to avoid infant mortality resulting from carbon dioxide emissions. Income (proxied by real gross domestic product) significantly influences infant mortality negatively. Policy makers should ensure economic growth to reduce infant mortality. Public education on the control of air pollution should be intensive. Future studies should examine causality issues since the current study is descriptive in nature.

Keywords: Infant mortality; carbon dioxide emissions; real gross domestic product.

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1. INTRODUCTION

The effect of air pollution on human health has attracted attention in the literature (Caiazzo et al., 2013; Cesur et al., 2013; OECD, 2012; U.S. EPA, 2011; WHO, 2011; COMEAP, 2010; WHO, 2006). Air pollution according to the literature and reports of international bodies such as Organization for Economic Co-Operation and Development (OECD) and World Health Organization (WHO) (OECD, 2012; WHO, 2011; Laden et al., 2006; WHO, 2006; Pope et al., 2002) causes premature mortality in all economies and it is expected to continue to be one of the topical environmental issue in all economies (Fann et al., 2012).

This is an indication that the issue of air pollution has become intractable. The channel of the of air pollution on infant health and the causes of infant mortality has been explained in the literature (Siddiue et al., 2008: Choi et al., 2006; Maisonet et al., 2004; Li et al., 2003; Ha et al., 200; Dejmek, et al., 2000). According to the literature (Cesur et al., 2013), air pollution affect the health of human (infants) in various ways such impairment of fetal tissue growth; damage to the lungs and immune system of infants; smaller head circumference; lower birth weight; poorer birth outcomes and death.

The empirical findings of the effect of air pollution on health are found in the works of various researchers (Barrett et al., 2012; Cesur et al., 2013; Arceo-Gomes et al., 2012; Tanaka, 2012; U.S. Currie et al., 2011; Currie & Walker, 2011; Greenstone & Hanna, 2011; EPA, 2011; Knittel, et al., 2011; Currrie et al., 2009; Jayachandran, 2009; Jerrett et al., 2009; Krewski et al., 2009; Ratliff et al., 2009; Cooke et al., 2007; Lewtas, 2007; Laden et al., 2006; Currie &Neidell, 2005; Bell et al., 2004; Chay&Greenstone,2003). All these empirical studies have reported significant relationship between air pollution and infant mortality using different modelling approaches.

According to Cesur et al. (2013), the potential benefits associated with reducing air pollution may be greater in the developing countries than the develop countries. Accordingly, improvements in air quality are more beneficial at higher baseline levels of air pollution or these benefits are greater in environments where infants are already weakened by other factors, such as poor access to health care, weak sanitary conditions, or more widespread diseases.

The review of the literature has indicated significant impact of air pollution on infant health resulting in infant mortality using various models. The current paper examines the stable long run relationship between air pollution (proxied by carbon dioxide emissions) and infant mortality (proxied by infant mortality index) using cointegration analysis. The review of the literature indicate that significant majority of the empirical work has focused on developed economies with few works on developing economies such as Ghana (Cesur et al., 2013; Currie et al., 2011; Knittel et al., 2011; Currie & Walker, 2011; Currie et al.,2009; Currie &Neidell, 2005; Chay&Greenstone, 2003). Theresults reported by the studies from the developed economies might not properly reflect what happens in developing economies (Arceo-Gomez et al., 2012; Currie & Vogel, 2012).

Arceo-Gomez et al.(2012) states that

Estimates from developed countries may underestimate the effect in developing countries if the marginal changes in pollution are more damaging at higher levels of pollution. Alternatively, they argue that the estimates from developed countries may overstate the effect for developing countries since infants might already be weak and malnourished due to other negative health shocks.

These findings are indication that further empirical studies from developing economies such as Ghana are worth doing using econometric models. The current paper fills in the literature gap by examining the relationship between carbon emissions and infant mortality. The findings serve as policy guide for policy makers dealing with air quality in relation to environmental management and health. Researchers are provided with reference material considering similar issues. Theories on air pollution and health are further understood through the findings of the current paper. The general objective of the current paper is to contribute to the body of knowledge in the area of environment and health by examining the stable long run relationship between carbon dioxides emissions and infant mortality empirically. Specifically, the paper examines

- The stationarity properties of carbon dioxide emissions and infant mortality.
- The cointegration relationship between carbon emission and infant mortality.
- The long run and short run parameter estimates of the effectof carbon emissions on infant mortality.

The study is based on the following research questions?

- What is the impact of carbon dioxide emissions on infant mortality?
- What is the nature of long run and short run relationship between carbon dioxide emissions and infant mortality?

The assumptions tested in the current research are;

- Carbon dioxide emissions and infant mortality are cointegrated.
- Carbon emission is the key factor explaining infant mortality trends.

The study is based on secondary data obtained from World Bank data base. The estimated model might suffer from errors in variables and data massaging. Causality issues are not the focus of the study. The period of study is between1961-2010. Structural breaks are not considered in the study in examining unit root properties of the series. Single country level data is used in a cross sectional study and not panel data. Other gases such as methane and carbon monoxide are not considered for non-availability of data.

The rest of the study deals with the methodology used, empirical results (unit root: cointegration results: long run results: short run results); conclusions and policy implications.

2. METHODOLOGY

The current study is trivariate, quantitative, descriptive and cross-sectional research. The study is based on annual time series data for Ghana for the period 1961-2010. The period was chosen for availability of data. Purposive sampling method used to select articles from journals on the internet for the review. The data used are air pollution (proxied by carbon dioxide emission-CO2) and infant mortality (proxied by infant mortality index).

2.1 Data Analysis models

The Kwiatkowski. D., Philips, P., Schmidt, P., Shin, Y. (1992) (KPSS) and Augmented Dicky-Fuller (1981) (ADF) test models are used to examine unit root properties of the series. The ADF model is based on the null assumption (Ho) that there is a unit root in the levels of the series. The alternative hypothesis (H1) is that the series are stationary in levels. The ADF is criticsed (Nanthakumar&Subramaniam, 2010) for having low power of tests as compared to the KPSS test. In the current study, the KPSS model is used as confirmatory test to the ADF test. The KPSS test is based on the null assumption that there is no unit root in the series variables against the alternative hypothesis that there is unit root in the series variables. Since unit rootmodels are well understood in the literature detail review of the models of unit root tests are not discussed in the current paper (Asongu, 2012).

Bound testing approach to Cointegration Model

Series variables in a model are considered to be cointegrated if they are integrated of order one, in the presence of nonzero vector, I(0). The non-stationary series with the same order of integration may be cointegrated if there exist some linear combination of the series that can be tested for stationarity. The unrestricted error-correction model (ecm) representation is specified as in equation (1) and (2).

$$\Delta x_t = \mu_{0y} + \mu_{1y} t + \delta_1 x_{t-1} + \delta_2 y_{1,t-1} + \delta_3 y_{3,t-t} + ... + \delta_k y_{k,t-1} +$$
$$\sum_{i=1}^{E-1} \gamma_i \Delta x_{1,t-1} + \sum_{i=0}^{F-1} \alpha_{ik} \Delta y_{k,t-1} + \varepsilon_{ty} \text{...}(1)$$

Variables 'x' is regress on variable 'y'. Where 'y' is a vector and the δ measure the long run effects (long run parameters). The 'y' and 'α's are the short run parameters and measure the short run effects. The F and E are the order of the lags, t is the time trend, 'k' is the number of "forcing variables in the model under estimation.

$$\Delta x_t = \sum_{i=1}^{p} \alpha_i \Delta x_{t-1} + \sum_{i=1}^{s} \beta_i \Delta y_{t-1} + \sum_{k=1}^{q} \beta_k \Delta z_{t-k} + \gamma ecm_{t-1} + e_t \text{.........................}(2)$$

The cointegrated analysis is based on the null hypothesis (H_o) that there is no cointegration among the series variables in the model against the alternative hypothesis (Ha) that the variables are cointegrated. Ho: $b_1=b_2-b_3= \dots =b_k =0$ Against the alternative hypothesis H_a: Not H_o. The ARDL model estimated is assess for goodness of fit using various diagnostic test such as J-B Normalitytest,Breusch- Godfred LM test, ARCH LM test, White Heteroskedasticity test, Ramsey RESET. The stability of the model is tested using the cumulative sum of recursive residuals (CUSUM) and the cumulative sum of squares of recursive residuals (CUSUMSQ)

2.2.3. The model

The conceptual model for the study states that infant mortality is a function of carbon dioxide emission. That is InFM=f (InCO2,InRGDP). The model is estimated in natural log form.

3 EMPERICAL RESULTS

The results are ADF; KPSS unit roots test results; cointegration test results; long run results; short run results; diagnostic test results and the stability test results.

3.3. 1. Time Series Plots of the series variables

The plots of the series variables in levels and in first difference are shown in figures 1 to 6. The plot of the series in levels indicate the series are not stationary in levels but become stationary in firstdifference. This calls for formal examination of the stationarity properties using the ADF test and the KPSS test.

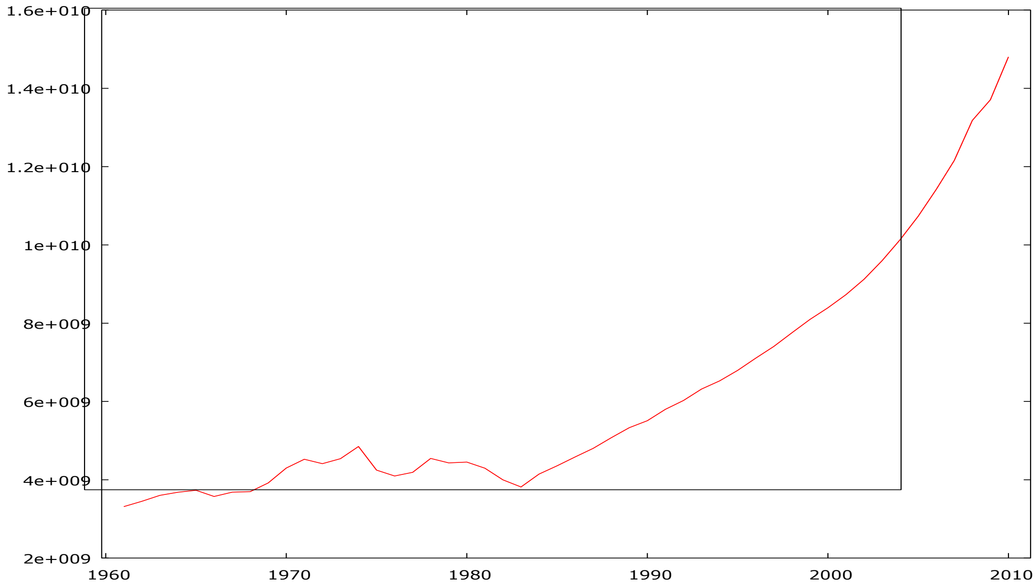

Figure 1. Plots of RGDP (levels)

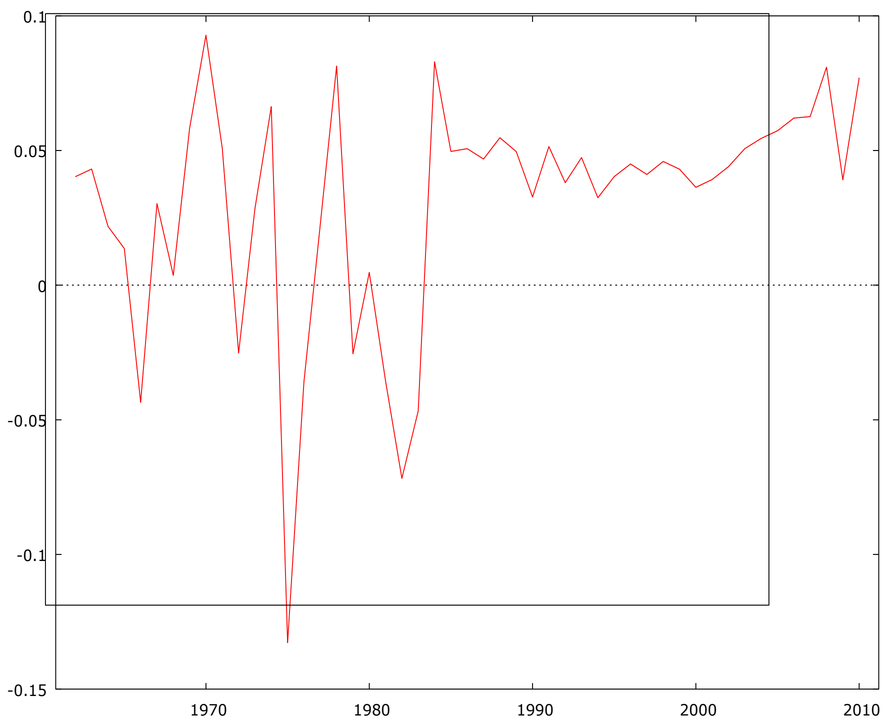

Figure 2. Plots of RGDP (First difference of logarithm)

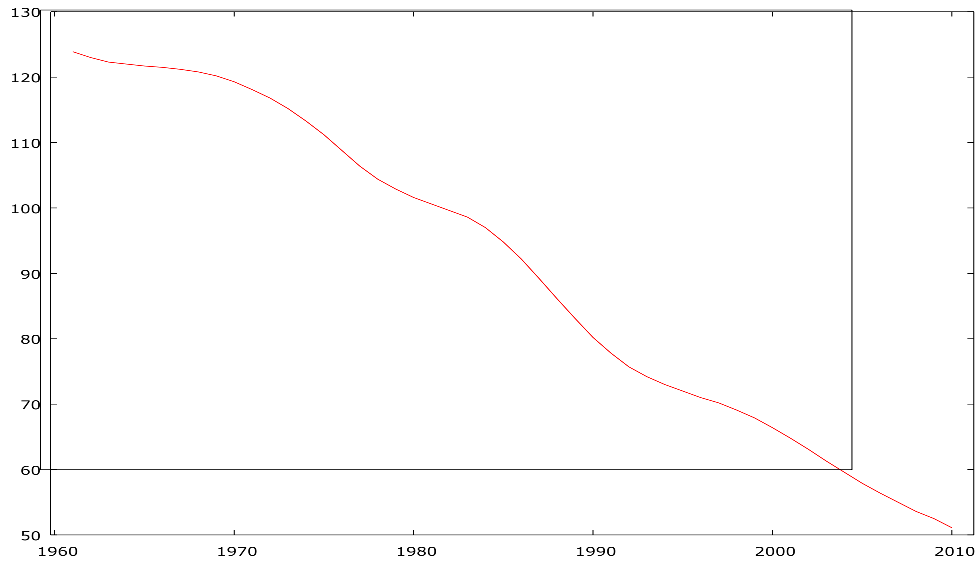

Figure 3. Plots of FM (levels)

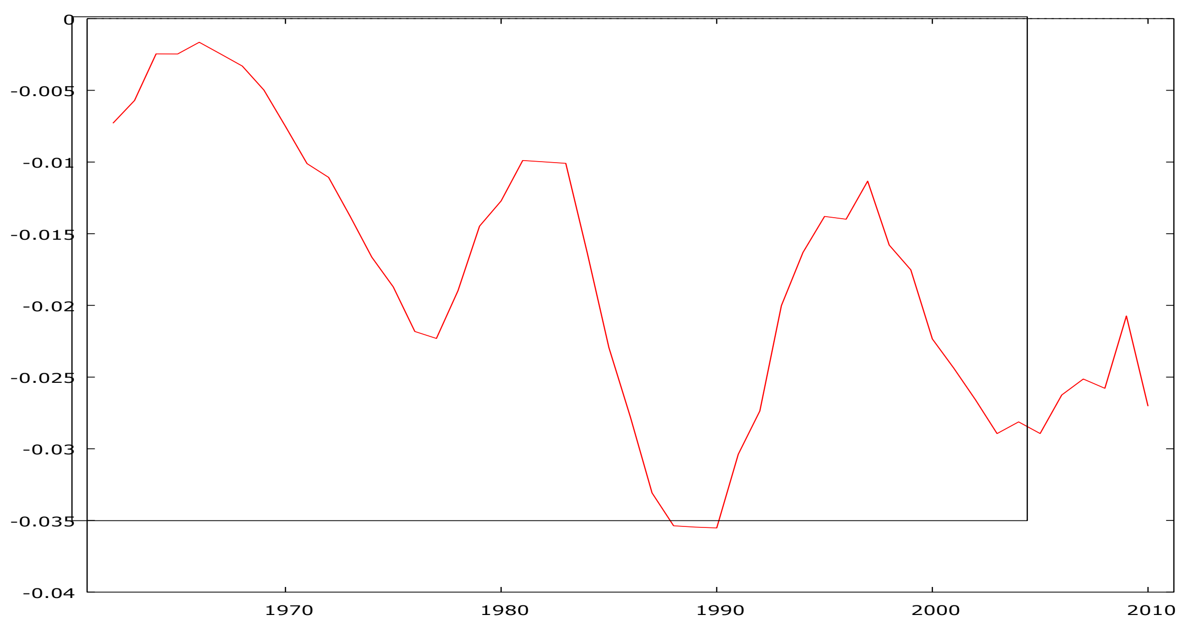

Figure 4. Plots of FM (First difference of logarithm)

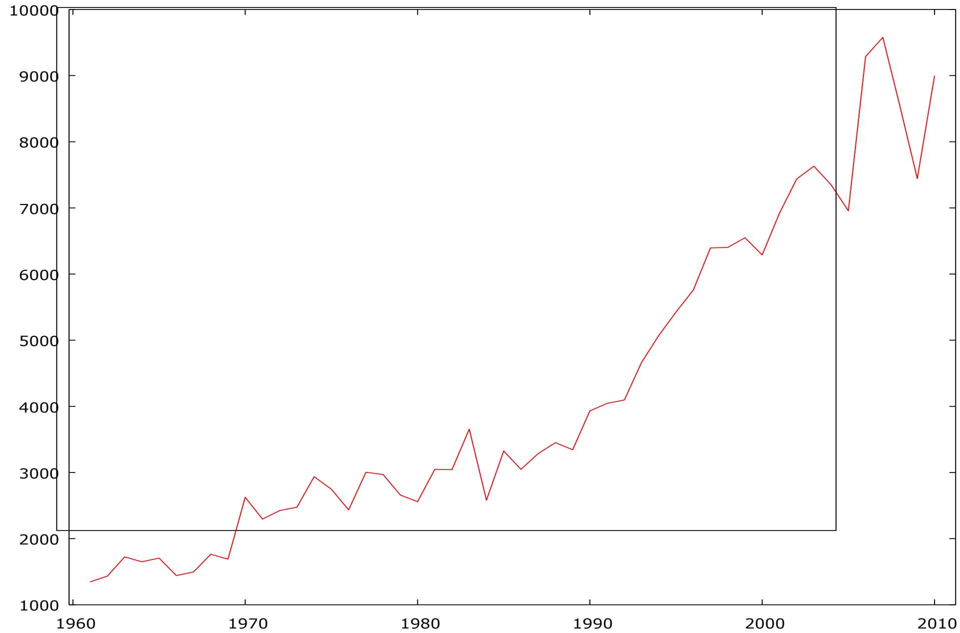

Figure 5. Plots of CO_2 (Levels)

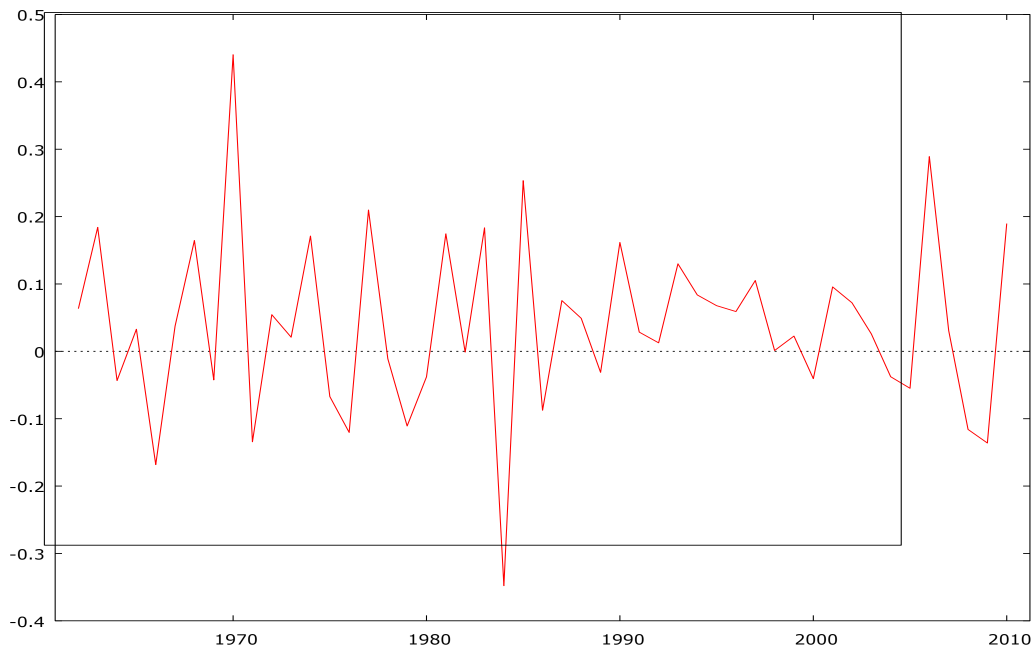

Figure 6. Plots of CO_2 (first difference in logarithm)

3.3.2. The ADF Model

The unit root testsresults are based on the ADF test are reported in table 1 and 2. The results of the ADF test for unit root is logarithm, shows that the series are non-stationary in intercept and trend. The null hypothesis of unit root was accepted for the series variables.

Table 1; ADF stationarity test results with a constant and Time trend

Variables (logarithm)	T-ratio	ADF P-Value	Results
CO2	-0.523027	0.9826	Not stationary
FM	-0.618924	0.9775	Not stationary
RGDP	0.0578461	0.9969	Not stationary

Source; Author's computation 2013

Taking the logarithm of the first difference of the series and testing these with intercept and time trends do make the series stationary. That is, the null hypothesis of unit root was rejected. The series become stationary after first difference. These results indicate that the series exhibits unit root processes and are integrated of order one, 1(1) and zero, 1(0). The results are reported in table 3

Table 2:ADF Stationarity test results with a constant and Time trend

Variables (1st diff. of logarithm)	T-ratio	ADF P-Value	Results
InCO2	-6.01131	1.089e-006	Stationary
InFM	-2.2513	0.4603	Not stationary
InRGDP	-4. 7488	0.0005364	Stationary

Source; Author's computation, 2014

3.3.3. The KPSS Model

The KPSS test results arepresented intable 4. The KPSS is reversed test for unit root. It isused in thecurrent study for confirmation of the stationarity properties of the series. The series were examined in their logarithm form. The results confirm that of the ADF test results.

Table 3; KPSS stationarity test results with a constant and a time trend

Variables (logarithm)	T-stats	Results
CO2	0.288047(0.01)	Not stationary
FM	0.147933(0.051)	Not stationary
RGDP	0.306493(0.01)	Not stationary

Source; Author's computation, 2014; NB; 1%; 5% and 10% Critical values are 0.213, 0. 149 and 0.121 respectively

Table 4; KPSS stationarity test results with a constant and a time trend

Variables (1st diff. of the logarithm)	T- stats	Results
InCO2	0.065819(0.1)	Stationary
InFM	0.0907909(0.1)	Stationary
InRGDP	0.100559(0.1)	Stationary

Source; Author's computation, 2014:NB; 1%; 5% and 10% Critical values are 0.212, 0.149 and 0.122 respectively

In summary, the test results from the ADF and the KPSS indicates that the series exhibits unit root processes and are integrated of order one, 1(1) and order zero, 1(0). The detection of unit roots in the series indicates that shocks to the series will have permanent effects and not transitory effects. The results indicate that cointegration analysis can be performed.

3.3.4. Cointegration Analysis using Autoregressive Distributed Lag (ARDL) Model/Bound Approach to Cointegration

In this section of the paper the results of the relationship between carbon dioxide emissions, Infant mortality and real gross domestic product are presented. The dependent variables are infant mortality where as carbon dioxide emissions and real gross domestic product are the independent variables. The results on the bound test, long run and short run parameters are presented in Table 5, Table 6 and Table 7

3.3.3.1. Bound Approach to Cointegration for infant mortality (FM)

The results reported in the Table 5 indicate significant cointegration between carbon dioxide emission (CO2); infant mortality (FM) and real gross domestic product (RDDP) in models 1, 2 and 3. In model 1, the F-statistics value of 360.2900 is greater than the critical value of the upper bounds at the 90% levels of significance which is an indication of cointegration between carbon dioxide emissions, infant mortality and real gross domestic product with infant mortality as the dependent variable.

In model 2, the F-calculated value of 6.2038 is greater than the critical values of the upper bounds at the 90% and 95% levels of significance which are an indication of cointegration between carbon dioxide emissions, infant mortality and real gross domestic product with carbon emissions as the dependent variable.

In model3, the F-calculated value of 3.5443 is less than thecriticalvalues of the upper bounds at the 90%,95% and 99% levels of significance which is not an indication of cointegration between carbon dioxide emissions, infant mortality and real gross domestic product with real gross domestic product as the dependent variable. The null assumption of no cointegration is rejected in models 1 and 2. The null assumption of no cointegration is not rejected in model 3. Model 1 is estimated for the long run and short run parameters.

Table 5; Test for cointegration relationship

Critical bounds of the F-statistic: intercept and trend						
	90%level		**95% level**		**99% level**	
	I(0	**I(1)**	**I(0)**	**I(1)**	**I(0)**	**I(1)**
	2.913.695		**3.538**	**4.428**	**5.155**	**6.265**
Model	**Computed F-Stats**		**Decision**			
1.F_{lnFM}(lnFM/lnCO_2,lnRGDP)	360.2900(0.000)***		Cointegrated			
2.F_{lnCO2}(lnCO_2/lnFM, lnRGDP)	6.2038(0.013)**		Cointegrated			
3.F_{lnRGDP}(lnRGDP/lnFM, lnCO_2)	3.5443(0.060)*		Not cointegrated			

Source; Author's computation, 2013; Note: critical values are obtained from Pesaran et al., (2001) and Narayan, (2004): NB *** and ** denote significance at 1% and 5% levels

3.3.3.2. Results of Long-Run Elasticities of ARDL Model

The long-run relationship between carbon dioxide emissions, infant mortality and real gross domestic product was estimated with infant mortality as the dependent variable. The results are reported in Table 6. The results indicate that carbon emissions are significant (at 10% level) determinant of infant mortality in the long run. The results indicate that increase in carbon dioxide emissions (CO2) by 1% will lead to an increase in infant mortality by about

13.64%.There is significant long run relationship between infant mortality (FM) and real gross domestic product (RGDP) in the model estimated. The results indicate that increase in real gross domestic product (RGDP) by 1% will lead to a decrease in infant mortality by about 11.75%.

Table 6: Estimated long-run coefficients, Dependent variables isInFM

Variables	Coefficient	Std. Error	T-ratio	P-value
Constant	4.5379	0.52355	8.6674	0.000***
Trend	-0.023971	0.0029041	-8.2544	0.000***
InCO2	0.13639	0.069628	1.9588	0.057*
InRGDP	-0.11746	0.046454	-2.5286	0.016**

Author's computation, 2014; ARDL (2) selected based on Akaike Information Criterion.

Note: ***, ** and * denotes statistical significance at the 1%, 5% and 10% levels

3.3.3.3. Results of Short-Run Elasticities of ARDL Model

The results of short-run dynamic equilibrium relationship coefficients estimated with trend and error correctionterm(ecm) are reported in Table 7. The results on the nature of the short run coefficients are not different form that of the long run parameters. The results indicate that carbon dioxide emissions are statistically significant determinants of infant mortality in the short run. The results indicate that increase in carbon dioxide emissions (CO2) by 1% will lead to an increase in infant by about 1.14%. There is significant short run relationship between infant mortality (FM) and real gross domestic product (RGDP) by 1% will lead to a decrease in infant mortality by about 0.09%. The error correction term is statistically significant and does have the theoretical expected sign which is negative. The coefficient of -0.083276 indicates that, after 1 percent deviation or shock to the system, the long-run equilibrium relationship of infant mortality is quickly re-established at the rate of about 8% per annum. The value does not indicate faster adjustment rate.

Table 7: Short-run representation of ARDL model. ARDL (2) selected based on Akaike Information Criterion. Dependent variable; InFM

Variables	Coefficient	Std. Error	T-ratio	P- value
Trend	-0.0019962	0.5084E-3	-3.9266	0.000***
Constant	0.37789	0.15267	2.4752	0.018**

InCO2	0.011358	0.0045599	2.4908	0.017**
InFM-1	1.6633	0.089538	18.9813	0.000***
InFM-2	-0.74660	0.089538	-8.3383	0.000***
InRGDP	-0.0097819	0.0051958	-1.8826	0.067*
Ecm(-1)	-0.0832276	0.026455	-3.1479	0.003***

Ecm= InMOR+0.023971TREND-4.5379InPT-0.13639InCO2+0.11746InRGDPP……(3)

R- Squared	0.99984	R-Bar-Squared	0.99982
S.E. of Regression	0.0033367	F-Stat. F(5,40)	49582.4[0.000]
Mean of Dependent Variable	4.4111	S.D. of Dependent Variable	0.24768
Residual Sum of Squares	0.4453E-3	Equation Log-likelihood	200.2710
Akaike Info. Criterion	194.2710	Schwarz Bayesian Criterion	188.7851
DW-statistic	2.0886		

Source;Author's computation, 2014. Note:***, ** and * denotes statistical significance at the 1%, 5% and 10% levels significantly

3.3.3.4. Results of Diagnostic Tests

The diagnostic tests of the short-run estimation to examine the reliability of the results of the error correction model are reported in Table 8. The null hypothesis of no serial correlation is not rejected using the Lagrange multiplier test and the F-statistics. The RESET test showed evidence of correct functional specification of the model. The estimated model did not passed the normality test. The model passed Heteroscadasticity test indicating the variances are constant over time. The R(0.99984) and the adjusted R(0.99982) in the Table 7 are indications of a very well behave model. The coefficient indicate approximately 99.98% of the variations in infant mortality are attributed to carbon dioxide emissions and real gross domestic product.

Table 8: Short-Run DiagnosticTests of ARDL Model

Test Statistics	LM Version	F Version
A: Serial Correlation	CHSQ0.17435[0.676]	F(1,39) = 0.14838[0.702]
B: Functional Form	CHSQ(1) = .026535[0.606]	F(1,39) = .22627[0.637]
C: Normal	CHSQ(2) = 10.9981[0.004]	Not applicable
D: Heteroscedasticity	CHSQ(1) = .98194[0.322]	F(1,44) = .95973[0.333]

A: Lagrange multiplier test of residual serial correlation

B: Ramsey's RESET test using the square of the fitted values

C: Based on a test ofskewness and kurtosis of residuals

D: Based on the regression of squared residuals on squared fitted values

Source: Author's computation, 2014.

The stability of the long-run estimates was determined by employing the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMG) procedures. This was determined using the residuals of the error-correction model indicated by equation (3). The CUSUM test of stability determines the methodological arrangements of the estimates and its null hypothesis states the coefficients are stable. The null assumption is rejected when the CUSUM surpasses the given critical boundaries which demonstrate unstable nature of the estimates. The CUSUMG determines the stabilityof the variance. Both test revealed that the estimates and the variance were stable as the squared residuals fall within the various 5% critical boundaries. The null assumptions are rejected in both tests.

4. CONCLUSIONS AND POLICY RECOMMENDATIONS

The objectives of the paper have been achieved. The variables in the series are cointegrated. The long run and short run elasticities are statistically significant though the values of the parameters are small in magnitude. The findings of the current study are in support of the findings of previous studies reported in the literature (Barrett et al., 2012; Cesur et al., 2013; Arceo-Gomes et al., 2012; Tanaka, 2012; U.S. Currie et al., 2011; Currie & Walker, 2011; Greenstone & Hanna,2011; EPA, 2011; Knittel, et al., 2011; Currie et al., 2009; Jayachandran, 2009; Jerrett et al.,2009; Krewski et al., 2009; Ratliff et al.,2009) that carbon dioxide emissions affect infant health and infant mortality.

The results indicate that carbon dioxide emissions should be reduced in order to prevent infant mortality. Policy makers should ensure that air pollution is reduce to avoid its negative effect on health. Institutions such as Environmental Protection Agency (EPA) should intensive their regulatory activities to control air pollution. Public education on the control of air pollution should be intensified so that the citizens will reduce their emissions. The results indicate that increase in income is associated with reduction in infant mortality. Policy makers should put in place policies to ensure economic growth in order to reduce infant mortality. Future studies should examine causality issues since the current study is descriptivein nature.

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