Economic Growth And Carbon Emissions In South Africa: An Empirical Investigation[1]

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ABSTRACT

In this paper we examine the causal relationship between CO_2 emissions and economic growth in South Africa - using the newly developed ARDL-Bounds testing approach. We incorporate energy consumption in a bivariate causality setting between CO_2 emissions and economic growth, thereby creating a simple trivariate model. Our empirical results show that there is a distinct unidirectional causal flow from economic growth to carbon emissions in South Africa. We also find that energy consumption Granger-causes both carbon emissions and economic growth. We recommend that energy conservation policies, as well as appropriate forms of renewable energy, should be explored in South Africa in order to enable the country to reduce its carbon emission footprint without necessarily sacrificing its output growth. The results apply irrespective of whether the causality is estimated in the short or in the long run.

Keywords: Africa; South Africa; CO_2 Emissions; Energy Consumption; Economic Growth

INTRODUCTION

The relationship between carbon emissions and economic growth is based on the so-called Environmental Kuznets Curve (EKC), which posits that the level of environmental degradation and income per capita resembles an inverted U-shaped curve. According to EKC hypothesis, pollution levels increase as a country develops, but begin to decrease as the rising incomes pass beyond a turning point. In other words, there is a threshold level of economic growth beyond which further increase is able to redress the environmental impacts of the early stages of economic development (see also Sun, 1999, Ferda, 2008).

Although a number of studies have examined the relationship between carbon emissions and economic growth in developing countries, the majority of these studies have mainly concentrated on the relevance of the Environmental Kuznet Curve (EKC). Very few studies have gone the full distance to examine the nexus between CO_2 emissions and economic growth. Even where such studies have been done, the focus has mainly been on Asia and Latin American countries. Studies on the causal relationship between carbon emissions and economic growth in sub-Saharan countries are very scant. In addition, the majority of the previous studies suffer from three major weaknesses; namely, 1) the use of a bivariate causality test, which may lead to the omission-of-variable bias; 2) the use of cross-sectional data, which does not satisfactorily address the country-specific effects; and 3) the use of a residual-based cointegration test associated with Engle and Granger (1987) and the maximum likelihood test based on Johansen (1988) and Johansen and Juselius (1990), which has been proven to be inappropriate when the sample size is too small (see Nerayan and Smyth, 2005). It is against this backdrop that the current study attempts to examine the inter-temporal causal relationship between CO_2 emissions and economic growth, using the newly developed ARDL-Bounds testing approach. By incorporating energy consumption as an intermittent variable in a bivariate setting between CO_2 emissions and economic growth, we develop a simple trivariate causality model between CO_2 emissions, energy consumption and economic growth.

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Co_2 Emissions And Economic Growth In South Africa

South Africa is considered to be the largest economy in Africa. The country is also ranked number 20 globally in terms of the volume of gross domestic product (GDP). The country's current GDP is about US $704 billion, which is approximately 36% of the total of sub-Saharan Africa's GDP and 69% of the total SADC's GDP. Despite the fact that South Africa's economy is the largest in Africa, economic growth has consistently shown a mixed trend, especially since the 1980s. For example, during the period 1975 to 1984, the average annual percentage growth in GDP in South Africa was 2.4%, with the highest growth rate of about 9.2% being recorded in 1980. However, this rate decreased dramatically to an average of about 1.4% during the period 1985-1989 (see African Development Indicators 2002). Between 1990 and 1992, the GDP growth rate remained negative and systematically declined to -2.1% in 1992. It was only in 1993 that the downward slide in the South African economy was reversed. In 1994, the GDP growth rate significantly increased to about 3.2% from about 1.2% in 1993. The rate later increased to 4.2% in 2000, decreased in 2003 to 2.8%, and increased again in 2004 to 4.5%. By 2005, the GDP growth rate was 5.0% - the highest rate recorded since 1984.

On the carbon emissions side, South Africa is considered to be one of the world's highest carbon dioxide emitters. The country is currently ranked 12th in terms of annual carbon dioxide emissions. By 2004, for example, the country's carbon dioxide emissions totalled 437,032,000 metric tons. Currently, its carbon emissions are estimated to be about (+/-) 451, 000, 000 metric tons." The country's carbon emissions originate mainly from coal, which provides over 70% of South Africa's energy needs and over 90% of its electricity needs. It is estimated that between 80-90% of South Africa's carbon emissions come from coal.

Despite South Africa's high level of carbon dioxide emissions, its status as a "Non-Annex 1 Country" under the Kyoto protocol implies that it has no emission reduction targets during the period 2008-2012. According to the Kyoto protocol, only industrialized and developed countries have legally binding greenhouse gas emission caps, which apply between 2008 and 2012. In other words, the Kyoto protocol exempts all developing countries, including South Africa, from taking legally binding commitments during this first commitment period up to 2012 (see Polity 2007). South Africa, however, has a non-binding commitment to mitigate emissions within its own means under the United Nations Framework Convention on Climate Change (UNFCCC). Currently, the country is pursuing a number of policies that could enable it to reduce its carbon footprint while at the same time exploring other sources of renewable energy as a means of boosting its electricity production. The country's current response to climate policy is built on a number of thematic pillars. These include, among others:

1. reducing greenhouse gas emission and limiting its growth
2. scaling up energy efficiency and electricity demand management initiatives
3. implementing the "Business Unusual" call for action in key sectors, such as the renewable energy sector and transport sector
4. increasing support for new and ambitious research, especially in the field of carbon-friendly technologies, with the focus on the renewable energy and transport sectors
5. identifying and quantifying South Africa's vulnerabilities to climate change and initiating mechanisms for interventions
6. aligning and coordinating the roles and responsibilities of all stakeholders in implementing government policies on climate change. Table 1 shows the trends of C02 emissions, energy consumption and economic growth in South Africa during the period 1990-2007, as compared to 1980

LITERATURE REVIEW

While the relationship between energy consumption and economic growth has attracted a great deal of empirical literature in recent decades, the relationship between carbon emissions and economic growth has not been extensively investigated. The majority of the empirical studies on this subject have concentrated mainly on the relevance of the Environmental Kuznets Curve (EKC). According to the Environmental Kuznets Curve (EKC) hypothesis, the relationship between environment and economic development is non-linear and resembles an inverted U-curve. That is to say, environmental damage first increases with increase in income, then stabilizes and eventually declines (see Ang, 2007). Some of the empirical studies, whose findings support the EKC hypothesis, include Hettige et al. (1992), Cropper and Griffiths (1994), Selden and Song (1994), Grossman and Kueger (1995), and Martinez-Zarzoso and Bengochea-Morancho (2004), among others. However, Dinda and Coonndoo (2006), while applying a panel data analysis in a bivariate setting to examine the relationship between income and emissions, find mixed results. In the same vein, World Bank (2007) finds that C0$_2$ emissions per capita are positively but moderately correlated with GDP per capita. The study also finds that there is no evidence of an eventual decline in emissions per capita at higher per capita income - contrary to the Environmental Kuznets Curve phenomenon. Lise (2006), while using energy consumption as an indicator of environmental degradation, concludes that the relationship between carbon emissions and income in Turkey is linear rather than following an EKC path. Agras and Chapman (1999), while examining the environmental Kuznets curve hypothesis, find that energy price - rather than income - was the significant determinant of environmental quality when both variables were included as explanatory variables. This finding raises questions as to whether income level is really an important determinant of environmental quality.

Table 1: Trends Of Co$_2$ Emissions, Per Capita GDP And Energy Consumption In South Africa

Year	CO$_2$ emissions (metric tons per capita)	Energy use (kg of oil equivalent per capita)	Per capita GDP (Rand)
1980	7.6591	2372.24	23294
1990	8.1080	2591.73	21710
1991	3.3280	2654.74	21045
1992	7.6221	2438.14	20170
1993	7.9177	2527.50	19996
1994	8.1608	2605.68	20214
1995	8.3109	2660.97	20412
1996	8.0850	2645.18	20848
1997	8.1179	2642.57	20955
1998	7.9839	2611.96	20625
1999	7.7144	2549.23	20675
2000	7.4106	2565.80	21104
2001	7.4095	2593.23	21269
2002	7.8454	2511.04	21663
2003	7.9443	2658.11	21991
2004	8.1080	2828.64	22729

Source: World Development Indicators (2007); BP Statistical Review of world Energy (2008); SARB Quarterly Bulletin (2008)

Some of the studies that have attempted to examine the relationship between carbon emission and economic growth include Shafik (1994), Holtz-Eakin and Selden (1995), Ang (2007), Jinke et al. (2007), Soytas and Sari (2009), and Sadorsky (2009), among others. Holtz-Eakim and Selden (1995), for example, while examining the relationship between C0$_2$ emissions and economic growth using a panel data analysis, find that there is a diminishing marginal propensity to emit C0$_2$ as economies develop. Shafik (1994) also finds that pollutant emissions are monotonically increasing with income levels. In an attempt to examine the causal relationship between C0$_2$ emissions, energy consumption and economic growth, Ang (2007) finds that economic growth exerts a causal influence on growth of population and growth of energy use. However, Soytas et al. (2007), while examining the relationship between carbon emissions, energy use, and income in the US, find that there is no evidence of causality between income and carbon emissions. Similar results were found in Soytas and Sari (2009) in the case of Turkey. According to the author, the lack of a long-run causal link between income and emissions may imply that Turkey does not need to forego economic growth in order to reduce its carbon emissions. Bhattachryya and Ghoshal (2009) argue that the interrelationship between the growth rates of CO$_2$ emissions and economic development is mostly significant for countries that have a high level of CO$_2$ emissions and pollution. In an attempt to empirically examine the relationship between CO$_2$ emissions, energy consumption, income and foreign trade, Halicioglu (2009) finds that income is the most significant variable in explaining the carbon emissions in Turkey. Sari and Soytas (2009) empirically examine the relationship between carbon emissions, income, energy and total employment in five OPEC countries. The authors find that none of the countries under study need to sacrifice their economic growth in order to reduce their emission levels. Apergis and Payne (2009), while examining the relationship between CO$_2$ emissions, energy usage and output in Central America, find that in the short run there is a unidirectional causality from energy consumption and real output to emissions, but in the long run there appears to be a bi-directional causality between energy consumption and emissions.

ESTIMATION TECHNIQUES AND EMPIRICAL ANALYSIS

Cointegration – ARDL-Bounds Testing Procedure

In this study, we use the recently developed Autoregressive Distributed Lag (ARDL)-Bounds testing approach to examine the long-run relationship between carbon dioxide emissions, energy consumption, and economic growth in South Africa. The ARDL modelling approach was originally introduced by Perasan and Shin (1999) and later extended by Perasan et al. (2001). The ARDL-Bounds model used in this study can be expressed as follows:

$$\Delta InCO2_t = \alpha_0 + \sum_{i=1}^{n} \alpha_{1i} \Delta InCO2_{t-i} + \sum_{i=0}^{n} \alpha_{2i} \Delta InENC_{t-i} + \sum_{i=0}^{n} \alpha_{3i} \Delta Iny/N_{t-i} + \alpha_4 InCO2_{t-1} + \alpha_5 InENC_{t-1} + \alpha_6 Iny/N_{t-1} + \mu_t \ldots\ldots (1)$$

$$\Delta InENC_t = \beta_0 + \sum_{i=1}^{n} \beta_{1i} \Delta InENC_{t-i} + \sum_{i=0}^{n} \beta_{2i} \Delta InCO2_{t-i} + \sum_{i=0}^{n} \beta_{3i} \Delta Iny/N_{t-i} + \beta_4 InENC_{t-1} + \beta_5 InCO2_{t-1} + \beta_6 Iny/N_{t-1} + \mu_t \ldots\ldots (2)$$

$$\Delta Iny/N_t = \delta_0 + \sum_{i=1}^{n} \delta_{1i} \Delta Iny/N_{t-i} + \sum_{i=0}^{n} \delta_{2i} \Delta InCO2_{t-i} + \sum_{i=0}^{n} \delta_{3i} \Delta InENC_{t-i} + \delta_4 Iny/N_{t-1} + \delta_5 InCO2_{t-1} + \delta_6 InENC_{t-1} + \mu_t \ldots\ldots (3)$$

where $InCO_2$ = log of carbon dioxide emissions per capita; InENC = log of energy consumption per capita; Iny/N = the log of real per capita income; μ_t = white noise error term; and Δ = first difference operator.

The bounds testing procedure is based on the joint F-statistic (or Wald statistic) for cointegration analysis (see also Odhiambo, 2009a). The asymptotic distribution of the F-statistic is non-standard under the null hypothesis of no cointegration between examined variables. The null hypothesis of no cointegration among the variables in equation (1) is (Ho: $\alpha_4 = \alpha_5 = \alpha_6 = 0$) against the alternative hypothesis (H1: $\alpha_4 \neq \alpha_5 \neq \alpha_6 \neq 0$). In equation 2, the null hypothesis of no cointegration is (H_o: $\beta_4 = \beta_5 = \beta_6 = 0$) against the alternative hypothesis (H1: $\beta_4 \neq \beta_5 \neq \beta_6 \neq 0$). Finally, in equation 3, the null hypothesis of no cointegration is (Ho: $\delta_4 = \delta_5 = \delta_6 = 0$) against the alternative hypothesis (H1: $\delta_4 \neq \delta_5 \neq \delta_6 \neq 0$). Pesaran and Pesaran (1997) and Pesaran et al. (2001) report two sets of critical values for a given significance level. One set of critical values assumes that all variables included in the ARDL model are I(0), while the other is calculated on the assumption that the variables are I(1). If the computed test statistic exceeds the upper critical bounds value, then the Ho hypothesis is rejected. If the F-statistic falls into the bounds, then the cointegration test becomes inconclusive. If the F-statistic is lower than the lower bounds value, then the null hypothesis of no cointegration cannot be rejected.

Granger Non-Causality Test

Once the long-run relationships have been identified in the previous section, the next step is to examine the short-run and long-run Granger-causality between carbon dioxide emissions, energy consumption, and economic growth using the following trivariate model (see also Odhiambo, 2009a; Odhiambo, 2009b; Narayan and Smyth, 2008).

$$\Delta InCO2_t = \alpha_0 + \sum_{i=1}^{n} \alpha_{1i} \Delta InCO2_{t-i} + \sum_{i=0}^{n} \alpha_{2i} \Delta InENC_{t-i} + \sum_{i=0}^{n} \alpha_{3i} \Delta Iny / N_{t-i} + ECM_{t-1} + \mu_t ...(4)$$

$$\Delta InENC_t = \beta_0 + \sum_{i=1}^{n} \beta_{1i} \Delta InENC_{t-i} + \sum_{i=0}^{n} \beta_{2i} \Delta InCO2_{t-i} + \sum_{i=0}^{n} \beta_{3i} \Delta Iny / N_{t-i} + ECM_{t-1} + \mu_t ....(5)$$

$$\Delta Iny / N_t = \delta_0 + \sum_{i=1}^{n} \delta_{1i} \Delta Iny / N_{t-i} + \sum_{i=0}^{n} \delta_{2i} \Delta InCO2_{t-i} + \sum_{i=0}^{n} \delta_{3i} \Delta InENC_{t-i} + ECM_{t-1} + \mu_t ....(6)$$

where ECM_{t-1} = the lagged error-correction term obtained from the long-run equilibrium relationship.

Although the existence of a long-run relationship between CO_2, ENC and y/N suggests that there must be Granger-causality in at least one direction, it does not indicate the direction of temporal causality between the variables. The direction of the causality, in this case, can only be determined by the F-statistic and the lagged error-correction term. While the t statistic on the coefficient of the lagged error-correction term represents the long-run causal relationship, the F-statistic on the explanatory variables represents the short-run causal effect (see Odhiambo, 2008; Narayan and Smyth, 2006). It should, however, be noted that even though the error-correction term has been incorporated in all the equations (4) – (6), only equations where the null hypothesis of no cointegration is rejected will be estimated with an error-correction term (see Narayan and Smyth, 2006; Morley, 2006; Odhiambo, 2009a).

DATA SOURCE AND DEFINITION OF VARIABLES

Data Sources

Annual time series data, which covers the 1970 and 2007 period, has been used in this study. The data has been largely obtained from various issues of the International Financial Statistics (IFS) Yearbook and World Development Indicators.

Definitions Of Variables

- CO_2 emissions variable is expressed as metric tons per capita.
- Energy Consumption is expressed as Kg of oil equivalent per capita.
- Real GDP per capita: The real per capita GDP is computed as follows: Real GDP per capita (y/N) = Real GDP (y) / Total population (N).

EMPIRICAL ANALYSIS

Stationarity Tests

Just like in other time series data, the current study performed appropriate tests for stationarity of all variables used in order to avoid misleading statistical inferences. The results of the stationarity tests in levels (not presented here) show that all variables are non-stationary in levels. Having found that the variables are not stationary in levels, the next step is to difference the variables once in order to perform stationarity tests on differenced variables. The results of the stationarity tests on differenced variables are presented in Table 2.

The results reported in Table 2 show that after differencing the variables once, all the variables were confirmed to be stationary. The Phillips-Perron and DF-GLS tests applied to the first difference of the data series reject the null hypothesis of non-stationarity for all the variables used in this study. Therefore, it is worth concluding that all the variables are integrated of order one.

Table 2: Stationarity Tests of Variables on First Difference

Variable	No Trend	Trend
Phillips-Perron (PP) Test		
$DLCO_2$	-9.599607***	-9.426128***
DLENC	-5.188037***	-5.244287***
DLy/N	-4.106690***	-4.308916***
Dickey-Fuller - GLS Test		
$DLCO_2$	-8.521515***	-8.764371***
DLENC	-5.169684***	-5.112923***
DLy/N	-3.363047***	-3.7224060**

Notes:

1. The truncation lag for the PP tests is based on Newey and West (1987) bandwidth.
2. *** denotes 1% level of significance.
3. Critical values for Dickey-Fuller GLS test are based on Elliot-Rothenberg-Stock (1996, Table 1).

COINTEGRATION RESULTS

In this study, the long-run relationship between [CO_2, ENC and y/N] is examined using the ARDL-Bounds testing procedure. The ARDL-Bounds testing procedure involves two steps. In the first step, the order of lags on the first differenced variables in equations (1) - (3) is obtained from the unrestricted models by using the Akaike Information Criterion (AIC) and the Schwartz Bayesian Criterion (SBC). The results of the AIC and SBC tests (not reported here) show that while in the case of CO_2 and ENC equations the optimal lag is lag 1, in y/N equation, the optimal lag is lag 3. In the second step, we apply bounds F-test to equations (1) – (3) in order to establish whether there exists a long-run relationship between the variables under study. The results of the bounds test are reported in Table 3.

Table 3: Bounds F-Test For Cointegration

Dependent Variable	Function		F-test Statistic		
$\Delta In\ CO_{2\ t}$	CO_2 (ENC, y/N)		7.0589***		
$\Delta InENC_t$	ENC(CO_2, y/N)		2.3934		
$\Delta Iny/N_t$	y/N (CO_2, ENC)		6.8218***		
Asymptotic Critical Values					
	1 %		5%		10%
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
Pesaran et al (2001), p. 300, Table CI(ii) Case II	4.94	5.58	3.62	4.16	3.02	3.51

Note: * denotes statistical significance at the 10% level.

The results reported in Table 3 show that there is evidence of cointegration when CO_2 and y/N are taken as a dependent variable, but not when ENC is taken as a dependent variable. This is supported by the calculated F statistics and the error-correction term, which are found to be statistically significant in both CO_2 and y/N equations, but not in the ENC equation.

Analysis Of Causality Test Based On Error-Correction Model

Having found that there is a long-run relationship between CO_2, ENC and y/N, the next step is to test for the causality between the variables used by incorporating the lagged error-correction term into equations (4), (5) and (6), respectively. The causality, in this case is, examined through the significance of the coefficient of the lagged error-correction term and joint significance of the lagged differences of the explanatory variables using_the Wald test. The results of these causality tests are reported in Table 4.

Table 4: Granger Non-Causality Test

F-statistics [P-value]				**t - statistics**
Dependent Variable	**$\Delta InCO_{2\,t}$**	**$\Delta InENC_t$**	**$\Delta Iny/N_t$**	**ECM $_{t-1}$**
$\Delta InCO_{2\,t}$	-	4.5558[0.0092]***	4.3825[0.0054]***	-0.8802*** [-4.736]
$\Delta InENC_t$	0.46535[0.8732]	-	0.80998[0.6163]	-
$\Delta Iny/N_t$	0.64094[0.7474]	3.6248[0.0246]**	-	-4.212*** [-0.4979]

The empirical results reported in Table 4 show that there is both a short-run and a long-run unidirectional causal flow from economic growth to CO_2 emissions in South Africa. The short-run causality is supported by the corresponding F-statistic in the CO_2 emissions equation, which is statistically significant, while the long-run causality is supported by the lagged error-correction term, which is found to be negative and statistically significant. The results also show that energy consumption Granger-causes CO_2 emissions without a feedback. This finding is supported by the corresponding F-statistic and the lagged error-correction term, which are statistically significant in the CO_2 equation. Other results show that energy consumption Granger-causes economic growth both in the short run and in the long run. This is supported by the F-statistic and the coefficient of the lagged error-correction term, which are statistically significant in the economic growth equation, but insignificant in the energy consumption equation.

CONCLUSION

In this paper, we examine the causal relationship between CO_2 emissions and economic growth in South Africa using the newly introduced ARDL-Bounds test. Specifically, we incorporate energy consumption in a bivariate setting between CO_2 emissions and economic growth, thereby creating a simple trivariate model. Our empirical results show that there is a distinct unidirectional causal flow from economic growth to CO_2 emissions in South Africa without a feedback. The results also show that energy consumption Granger-causes CO_2 emissions and economic growth in South Africa. The results, however, failed to find any causal flow from CO_2 emissions to either economic growth or energy consumption. The results apply irrespective of whether the causality is estimated in the short run or in the long run. The study, therefore, recommends that energy conservation policies, as well as appropriate forms of renewable energy, should be explored in South Africa in order to enable the country to reduce its carbon emission footprint without necessarily sacrificing its output growth.

AUTHOR INFORMATION

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NOTES