# The Effects of Financial Development, Economic Growth, Coal Consumption and Trade Openness on Environment Performance in South Africa

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**Abstract:**

This paper explores the effects of financial development, economic growth, coal consumption and trade openness on environmental performance using annual data over the period of 1965-2008 for South African economy. ARDL bounds testing approach to cointegration has used to test the long run relationship among the variables while short run dynamics have been investigated by applying error correction method (ECM). Unit root problem is checked through Saikkonen and Lutkepohl [1] structural break unit root test.

Our findings confirmed long run relationship among the variables. Results showed that a rise in economic growth increases energy emissions while financial development lowers it. Coal consumption has significant contribution to deteriorate environment significantly. Trade openness improves environmental quality by lowering the growth of energy pollutants. EKC is also existed

Keywords: Coal Consumption, Economic Growth, Environment

## 1. Introduction

The notion that environmental degradation is the problem of developed and not of developing countries, is no more valid at least in terms of consequences. The accumulation of Green House Gases (GHGs) in the earth's surface is now adversely affecting nations across the world, both developing and developed, irrespective of who is responsible for such accumulation. The burn out of fire in Russia, the outburst of flood in Pakistan and Australia, the earthquake in Haiti, and the tsunami in Japan are some of the major catastrophes observed in the recent past which may be the consequences of environmental dilapidation. These events resulted in damages to infrastructure, natural resources such as forests and resultantly wild life, agriculture land and produce, and most importantly to precious human lives. Events like these have become a major concern, both for environmentalists and economists, for the reason that economic growth has feedback effects from environment. Grossman and Krueger [2] developed the Environmental Kuznets Curve hypothesis to demonstrate the relationship between economic growth and environment degradation.

Although environmental deterioration is a global issue and the entire world is exposed to threats arising from deterioration of environmental quality, yet the responsibility to save the world from such threats falls upon largely on countries who are the major emitters of GHGs. One of the most prominent GHG is carbon dioxide and its major emitters include China, US, India, OECD group, Russia and Brazil (World Bank, [3]). The success of international efforts to reduce world $CO_2$ emissions heavily depends on the commitment of these major emitters. However, difficulties arise for countries when the $CO_2$ emissions are related to energy production because energy works as an engine of economic growth. In such cases, curbing carbon dioxide emissions would mean to ultimately lower their economic growth, which the countries are very reluctant to accomplish. This calls for digging out the ways through which the twin objectives of higher economic growth and lower $CO_2$ emissions can be achieved. Financial development is one of the ways that could help to accomplish these objectives.

South Africa is a classic case of what has been discussed above. It contains all the contents such as high growth, monstrous energy-related emissions and strong financial base. Soon after the advent of democracy in 1994, the country economic growth shows an upward trend and remained uninterrupted until the financial crises hit the country in 2007. The average growth rate between 2001 and 2007 was 4.3%. Nonetheless, the essential feature was the continuous rise in the growth rate during this period. On the other hand, South Africa is one of the major emitter of $CO_2$ (1% of the world emissions). The obvious reason for this is the use of coal, a major ingredient of $CO_2$, in energy production. South Africa had coal reserves of 30408 million tones at the end of 2009 that constitutes 3.68% of the world coal reserves (BP Statistical Energy Survey, [4]). Almost 77% of the country's primary energy needs are provided by coal where 53% of the reserves are used in electricity generation, 33% in petrochemical industries, 12 % in metallurgical industries, and 2% in domestic heating and cooking. Similarly, financial system in South Africa is highly developed with banking regulations rank outstanding, and the sector has long been rated among the top 10 globally. These characteristics make South Africa a compelling candidate for a separate study to investigate the presence of environmental Kuznets curve (EKC) in the country and to assess the effects economic growth, financial development and coal consumption on the $CO_2$ emissions in presence of trade openness. Indeed, the study in hands is the first attempt to incorporate coal as separate determinant of $CO_2$ emissions in the analysis**.**

Rest of the study is organized as follow: section 2 gives a brief literature review. The third section talks about data and methodology used in the study. Section 4 discusses the results in detail while section 5 concludes the study with some policy implications.

## 2. Literature Review

After the seminal work of Grossman and Krueger [2], the environmental Kuznets curve (EKC) hypothesis is tested empirically for many countries and regions using different measures of environmental standards. The studies that examine relationship between economic growth and environmental quality include Shukla and Parikh [5], Shafik [6], Selden and Song [7], Jaeger et al. [8], Tucker [9], Jha [10], Horvath [11], Barbier [12], Matyas et al. [13], Ansuategi et al. [14], Heil and Selden [15], List and Gallet [16], Brandoford et al. [17], Stern and Common [18], Roca [19], Friedl and Getzner [20], Dinda and Coondoo [21], Managi and Jena [22], Coondoo and Dinda [23], and Akbostanci et al. [24]. Different indicators are used for environmental quality in these studies. For example, $CO_2$, $SO_2$, NO, etc. are used for air quality, whereas mercury, lead, cadmium, nickel are utilized for water quality. Similarly, the overall environmental quality is measured by urban sanitation, deforestation, safe drinking water and traffic volumes. Nonetheless, results differ for countries and indicators, confirming the argument that EKC is a country and/or indicator specific phenomenon.

The EKC literature mostly uses energy consumption and trade openness as control variable to omit any specification bias. However, studies using financial development as an important determinant of environmental performance are very rare [see, for instance, Grossman and Krueger [25]; Tamazian et al. [26]; Halicioglu [27], Tamazian and Rao [28] and Jalil and Feridun, [29]]. The most obvious reason to use financial development is that the presence of a well-developed financial sector attracts foreign direct investment (FDI), which in turns may stimulate economic growth and, hence, affect the environmental quality (Frankel and Romer, [30]). In addition, financial development results in mobilization of financial resources for environment-related projects at reduced financing costs (Tamazian et al. [26]). Regarding the concern that environmental projects are public sector activity, Tamazian and Rao [28] document that a well-functioning financial sector will especially be helpful for all tiers of government to get finances for such projects. Moreover, financial development may also lead to technological innovations (King and Levine, [31]; Tadesse, [32]) and these technological changes can then contribute significantly to reduction in emissions particularly through energy sector (Kumbaroglu et al. [33]). Likewise, Claessens and Feijen [34] consider a developed financial sector is essential for carbon trading as environmental regulators may initiate programs that are directly connected with financial markets and frequently make available the information regarding the environmental performances of firms (Dasgupta et al., [35]; Lanoie et al., [36]). Lastly, the announcements of rewards and acknowledgment of superior environmental performance have a positive effect on capital market that is a vital fraction of the financial system [see, for example, Lanoie et al., [36]; Dasgupta et al., [35]; [37]; and Tamazian et al. [26] among others]. Thus, Tamazian et al. [26] rightly points out that $CO_2$ emission can be lessened by means of a solid financial system.

Trade openness is another vital factor that could influence environmental quality. The impact of trade liberalization can be decomposed into scale, technique, and composition effects (Antweiler et al. [38]). Nevertheless, contradictory results are established in the empirical literature on the role of trade openness. Some studies such as Lucas et al. [39], Shafik and Bandyopadhyay [40], Birdsall and Wheeler [41], Ferrantino [42], and Grether et al. [43] conclude that trade is beneficial for environment. Others, however, consider trade harmful for environment [Suri and Chapman, [44]; Abler et al. [45]; Lopez, [46]; Cole et al. [47]]. Lastly, contrary to the conventional literature, we use coal consumption instead of energy consumption in our analysis.

Moreover, Dhakal [48] examines the relationship between urbanization and CO2 emissions and found that that 40% contribution in CO2 emissions is by 18 % percent increase in population in large cities of China. Similarly, Sharma [49] examined the role international trade, income, urbanization and energy consumption using dynamic panel data of countries. Findings explore that international trade, income, urbanisation and energy consumption seem to play their role to increase $CO_2$ emissions in the panels of high income, middle income, and low income countries. Finally, urbanisation, international trade and electric power consumption per capita have negative impact on energy emissions while GDP per capita and primary energy consumption has positive effect on $CO_2$. Martínez-Zarzoso and Maruotti [50] investigated the effect of urbanization on environmental degradation using data of developing economies. Their analysis indicates that there is inverted U-shaped relation found between urbanisation and energy emissions. The results show that environmental impacts of urbanisation are high in low income countries and vice versa.

## 3. Modeling and Data collection

To investigate the effects of financial development, economic growth, coal consumption and trade openness on $CO_2$ emissions along with the existence of environmental Kuznets curve, we followed Halicioglu [27] for Turkey, Menyah and Wolde-Rufael [51] for South Africa and Shahbaz et al. [52] for Pakistan. We extend the model of Menyah and Wolde-Rufael [51] by incorporating financial development (Tamazian et al. [26]), trade openness (Halicioglu, [27]) and coal consumption in case of South Africa. The relation is specified as follows[1]:

$$\ln CO2 = \beta_1 + \beta_2 \ln CO2_{t-1} + \beta_3 \ln GDPC_t + \beta_4 \ln FD_t + \beta_5 \ln CO_t + \beta_6 \ln TR_t + \mu_t \qquad (1)$$

To test the existence of environmental Kuznets curve, we included squared term of $GDPC_t$ in equation (1). The validation of EKC intimates whether or not the South African economy is attaining growth at the cost of environment. The empirical equation is modeled as following:

$$\ln CO2 = \delta_1 + \delta_2 \ln GDPC_t + \delta_3 \ln GDPC_t^2 + \delta_4 \ln FD_t + \delta_5 \ln TR_t + \delta_6 \ln URB_t + \mu_t \qquad (2)$$

where energy pollutants is shown by $CO_2$ emissions (kt) per capita, $GDPC_t$ and $GDPC_t^2$ refer to real GDP per capita and its squared term, financial development ($FD_t$) is proxied by per capita access to domestic credit of private sector, $CO_t$ refers to coal consumption per capita and $TR_t$ is trade openness which is obtained by dividing the sum of exports and imports by GDP and $URB_t$ is urban population as share of total population proxy for urbanisation.

[1] We use log-linear specification following Cameron, [53] and Ehrlich, [54] [55].

A priori expectation is that current increase in energy pollutants is influenced by $CO_2$ emissions in previous period and hence $\beta_2 > 0$. Moreover, a consistent rise in economic growth is associated with more $CO_2$ emissions, $\beta_3 > 0$. The effect of financial development is ambiguous depending upon whether the maturity level is achieved by this sector. Financial sector development contributes to protection of environment by reallocating financial resources to environment friendly projects. Furthermore, this sector encourages firms to use advanced technology to enhance production level by emitting less energy pollutants (Tamazian et al. [26]). The financial sector is said to be mature if it has the will and capacity to monitor funded projects for environmental quality. On the other hand, in an immature financial sector, the sole purpose of both lending agencies and investors is to maximize profit at any cost. Consequently, they do not care about the environmental quality and as such the financial sector may contribute to deterioration of environmental (Bello and Abimbola, [56]). Therefore, we can expect $\beta_4 < 0$ or $\beta_4 > 0$. It is interesting to note that the sign of $\beta_4$ can used as an indictor for determining the maturity level of the financial sector. South Africa meets her demand for energy by using coal as 93% electricity is produced from coal. This heavy dependence on coal produces more than 90% of energy pollutants. Consequently, we can expect that $\beta_5 > 0$. Lastly, the impact of trade openness on $CO_2$ emissions is ambiguous. The sign of the trade openness coefficient can go either way. According to Antweiler et al. [38], there are three channels, namely scale, technique and composition effects, through which trade openness can result in environmental improvement or deteriorations. Scale effect implies that trade liberalization causes emissions due to economic expansion which is detrimental for environment. The technique effect is believed to reduce emissions because of import of efficient and environmental friendly technologies. Finally, the composition effect signifies that trade liberalization may reduce or increase emissions depending upon whether the country has comparative advantage in cleaner or dirty industries. Hence, the composition effect can have both positive and negative impacts. Subsequently, the sign of $\beta_6$ can be positive or negative depending on which effect is stronger and dominates the other. Finally, More urban population demands more energy which creates more environmental degradation. We expect $\delta_6$ > 0.

The data on real GDP per capita, domestic credit to private sector as share of GDP, coal consumption, trade (exports + imports) as share of GDP, urban population and $CO_2$ emissions (kt) per capita has been collected from world development indicators (CD-ROM, 2010). The study covers the period of 1965-2008.

**3.1 Saikkonen and Lütkepohl Structural Break Unit Root Test**

The standard unit root tests such as ADF and P-P may provide inefficient and bias results when shift is prevailed in the time series. To circumvent this problem, we use the test proposed by Saikkonen and Lutkepohl [1] and Lanne et al. [57]. The equation is modeled as following:

$$y = \mu_0 + \mu_1 t + f_t(\theta)' \gamma + \varepsilon_t \quad (3)$$

where $f_t(\theta)'\gamma$ indicates the shift function while $\theta$ and $\gamma$ are considered as unidentified vectors, $\varepsilon_t$ is generated by an $AR(p)$ process. A simple shift dummy variable with shift date $T_B$ is used on the basis of exponential distribution function. This function i.e. $f_t' = d_{1t}\begin{cases} 0, t < T_B \\ 1, \geq T_B \end{cases}$ does not seem to entail any parameter $\theta$ in the shift term $f_t(\theta)'\gamma$ where $\gamma$ is a scalar parameter. We follow

Lanne et al. [57] to choose the structural breaks exogenously which allows us to apply ADF-type test to check the stationarity properties of the series. Saikkonen and Lutkepohl [1] and Lanne et al. [57] also suggested of using large autoregressive in finding break date to minimize the generalized least square error of the objective function.

### 3.2 ARDL Bounds Testing Approach to Cointegration and Granger Causality

The autoregressive distributed lag (ARDL) bounds testing approach to cointegration developed by Pesaran et al. [58] is applied to test whether long run equilibrium relationship between the variables exists or not. The ARDL approach to cointegration is preferred due to its several advantages over traditional cointegration techniques. For instance, unlike other widely used cointegration techniques, ARDL bounds testing approach is applicable if variables have mixed order of integration such as I(0) or I(1) or I(0) / I(1). In addition, the unrestricted error correction model (UECM) integrates the short-run dynamics with the long-run equilibrium without losing long run information. A dynamic UECM can be derived from ARDL bounds testing through a simple linear transformation. The equation of unrestricted error correction model is modeled as following:

$$\begin{aligned}\Delta \ln CO2_t &= \alpha_1 + \alpha_T T + \alpha_{CO2} \ln CO2_{t-1} + \alpha_{GDPC} \ln GDPC_{t-1} + \alpha_{FD} \ln FD_{t-1} + \alpha_{CO} \ln CO_{t-1} \\ &+ \alpha_{TR} \ln TR_{t-1} + \sum_{i=1}^{p} \alpha_i \Delta \ln CO2_{t-i} + \sum_{j=0}^{q} \alpha_j \Delta \ln GDPC_{t-j} + \sum_{k=0}^{r} \alpha_k \Delta \ln FD_{t-k} \\ &+ \sum_{l=0}^{s} \alpha_l \Delta \ln CO_{t-l} + \sum_{m=0}^{t} \alpha_m \Delta \ln TR_{t-m} + \mu_t \end{aligned} \quad (4)$$

where difference operator is shown by $\Delta$ and $\mu_t$ is error term which is assumed to be normally distributed with zero mean and covariance. The Akaike information criteria (AIC) is used to select the appropriate optimal lag structure of the first difference regression. The lags induce when noise property in the error term[2]. To test the existence of cointegration, we followed F-test suggested by Pesaran et al. [58] for joint significance of the coefficients of the lagged level of the variables. For instance, the null hypothesis of no cointegration is tested for long run relationship in equation-4 i.e. $H_0: \alpha_{CO_2} = \alpha_{GDPC} = \alpha_{FD} = \alpha_{CO} = \alpha_{TR} = 0$ against the hypothesis of cointegration between the variables i.e. $H_A: \alpha_{CO_2} \neq \alpha_{GDPC} \neq \alpha_{FD} \neq \alpha_{CO} \neq \alpha_{TR} \neq 0$.

Pesaran et al. [58] tabulated two asymptotic critical bounds. These lower critical bound (LCB) and upper critical bound (UCB) are used to test whether cointegration between the variables exists or not. The decision is favor of cointegration if the F-statistic is more than the upper critical value. There is no cointegration found between the variables, if lower critical bound exceeds the F-statistic. The inference would be inconclusive, if the F-statistic is between lower and upper critical bunds[3]. The diagnostics tests for serial correlation, functional form, normality of error term and heteroskedasticity have been conducted to show robustness of ARDL bound testing approach to cointegration.

## 4. Empirical Results and Discussion

Table-1 describes the descriptive statistics and pair-wise correlations between the variables. The results show that positive and significant correlation exists between coal consumption and $CO_2$ emissions but association between economic growth and $CO_2$ emissions is positive and it is weak. The correlation between financial development and $CO_2$ emissions and, trade openness

[2] The mean prediction error of AIC based model is 0.0005 while that of SBC based model is 0.0063 (Shrestha and Choudhary, [59]).

[3] When the order of integration for all the series is known to be I(1), the decision is made based on the upper bound. Similarly, if all the series are I(0), then the decision is based on the lower bound.

and $CO_2$ emissions is negative. Finally, positive correlation is also found between coal consumption and economic growth, and trade openness and economic growth.

**Table-1: Summary Statistic**

| Variables | $\ln CO2_t$ | $\ln GDPC_t$ | $\ln FD_t$ | $\ln CO_t$ | $\ln TR_t$ |
|---|---|---|---|---|---|
| Mean | 12.5024 | 10.3440 | 4.4477 | 4.007582 | 3.942950 |
| Median | 12.6966 | 10.3420 | 4.2916 | 4.209160 | 3.934894 |
| Maximum | 13.0453 | 10.5237 | 5.1225 | 4.632785 | 4.302971 |
| Minimum | 11.7610 | 10.1793 | 3.8328 | 3.190476 | 3.654429 |
| Std. Dev. | 0.3886 | 0.0732 | 0.3471 | 0.465540 | 0.136403 |
| Skewness | -0.6161 | 0.1893 | 0.4570 | -0.497413 | 0.104136 |
| Kurtosis | 1.9432 | 3.0054 | 1.8456 | 1.744751 | 3.149002 |
| $\ln CO2_t$ | 1.0000 | | | | |
| $\ln GDPC_t$ | 0.2112 | 1.0000 | | | |
| $\ln FD_t$ | -0.2256 | -0.1297 | 1.0000 | | |
| $\ln CO_t$ | 0.7130 | 0.2543 | -0.1011 | 1.0000 | |
| $\ln TR_t$ | -0.1691 | 0.4242 | 0.0200 | -0.0057 | 1.0000 |

We begin our analysis through Ng-Perron [60] unit root test. However, space limitation does not allow us to report those results here but these can be obtained from authors on request. The analysis shows that all series do have unit root problem at level and the variables are stationary at 1st differenced form. It implies that all the variables are integrated at I(1). The main problem with Ng-Perron unit root is that it does not have any information about structural break points occurring in series. It is argued that in the presence of structural breaks in time series, results of Ng-Perron unit root test are inappropriate and incompatible. To overcome this issue and to check the robustness of results obtained through Ng-Perron test, we have used Saikkonen and Lutkepohl, [1] that accounts the effect of structural breaks in data. Saikkonen and Lutkepohl [1] unit root is superior to other structural break tests because this test finds dates of structural break by itself through the process and does not require any assumption about break date in series. Table-2 provides information about the results of Saikkonen and Lutkepohl, [1] unit root test.

The shift dummy is used to detect structural beaks for the concerned variables. The results of unit root test reveal that $CO_2$ emissions ($CO2_t$), economic growth ($GDPC_t$), financial development ($FD_t$), coal consumption ($CO_t$) and trade openness ($TR_t$) have unit root problem at their level while variables are found to be stationary at 1st difference or integrated at I(1). Thus unique order of integration lends a support to apply ARDL bounds testing approach to scrutinize long run relationship between the variables.

**Table 2: SL Unit root analysis**

| Unit Root Test with structural break: Constant and Time trend included | | | | | |
|---|---|---|---|---|---|
| Variables | Shift dummy and used break date is 2004 | Saikkonen and Lütkepohl (k) | Variables | Shift dummy and used break date is 2000 | Saikkonen and Lütkepohl (k) |
| $\ln CO2_t$ | Yes | -1.2739 (0) | $\ln CO_t$ | Yes | -1.8003 (0) |
| $\Delta\ln CO2_t$ | Yes | -4.7116***(0) | $\Delta\ln CO_t$ | Yes | -2.8228*(0) |
| | Shift dummy and used break date is 1987 | Saikkonen and Lütkepohl (k) | Variables | Shift dummy and used break date is 1981-82 | Saikkonen and Lütkepohl (k) |
| $\ln FD_t$ | Yes | -1.2739 (0) | $\ln TR_t$ | Yes | -1.3121 (0) |
| $\Delta\ln FD_t$ | Yes | -4.7116***(0) | $\Delta\ln TR_t$ | Yes | -3.5894***(0) |
| | Shift dummy and used break date is 1980 | | | Saikkonen and Lütkepohl (k) | |
| $\ln GDPC_t$ | Yes | | | -1.3963 (0) | |
| $\Delta\ln GDPC_t$ | Yes | | | -3.9582***(1) | |
| Note: (1) ***, ** and * denotes significance at 1%, 5% and 10% level respectively. k denotes lag length. Critical values are -3.55, -3.03, and -2.76 which are based on Lanne et al. [57] at 1%, 5%, and 10% respectively. | | | | | |

**Table-3: Lag Length Selection Criteria**

| VAR Lag Order Selection Criteria | | | | | | |
|---|---|---|---|---|---|---|
| Lag | LogL | LR | FPE | AIC | SC | HQ |
| 0 | 170.0898 | NA | 2.65e-10 | -7.8614 | -7.6545 | -7.78559 |
| 1 | 381.0886 | 361.7121 | 3.81e-14 | -16.7185 | -15.4773* | -16.2635* |
| 2 | 408.9194 | 41.0836* | 3.51e-14* | -16.8533* | -14.5777 | -16.0192 |

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

The selection of appropriate lag length is necessary to apply ARDL bounds testing approach to cointegration. It is experienced that the calculation of ARDL F-statistic is quite sensitive to the selection of lag order. As can be seen in Table-3, several selection criteria have been considered but the appropriate lag length selected on the basis of AIC statistics is 2. Lütkepohl, [61] pointed out that AIC criterion is superior for small sample data set.

**Table-4: The Results of ARDL Cointegration Test**

| Panel I: Bounds testing to cointegration | | |
|---|---|---|
| Estimated Equation | $\ln CO2_t = f(\ln GDPC_t, \ln FD_t, \ln CO_t, \ln TR_t)$ | |
| Optimal lag structure | (2, 2, 1, 2 , 1) | |
| F-statistics (Wald-Statistics) | 7.852** | |
| Significant level | Critical values ($T$ = 44)# | |
| | Lower bounds, $I(0)$ | Upper bounds, $I(1)$ |
| 1 per cent | 7.313 | 8.720 |
| 5 per cent | 5.360 | 6.373 |
| 10 per cent | 4.437 | 5.377 |
| Panel II: Diagnostic tests | Statistics | |
| $R^2$ | 0.8807 | |
| Adjusted- $R^2$ | 0.7576 | |
| F-statistics (Prob-value) | 7.7773 (0.00014)* | |
| Durbin-Watson | 2.1836 | |
| J-B Normality test | 2.5831 (0.2741) | |
| Breusch-Godfrey LM test | 0.5008 (0.6142) | |
| ARCH LM test | 0.0241 (0.8774) | |
| White Heteroskedasticity Test | 0.3681 (0.9831) | |
| Ramsey RESET | 1.5091 (0.3163) | |

Note: The asterisk * and ** denote the significant at 1% and 5% level of significance. The optimal lag structure is determined by AIC. The probability values are given in parenthesis. # Critical values bounds computed by (Narayan, [62]) following unrestricted intercept and unrestricted trend.

Table-4 demonstrates the results of ARDL bounds test approach to cointegration and suggests that hypothesis of cointegration may be accepted at 5% level of significance when economic growth, financial development, coal consumption and trade openness are used as forcing variables. It is found from Table-4 that estimated F-statistic is more than upper critical bound (UCB) tabulated by Narayan [62] at 5% level. The critical bounds tabulated by Pesaran et al. [58] are not suitable for small sample data set. The empirical exercise shows that cointegration is confirmed which validates the long run relationship between economic growth, financial development, coal consumption, trade openness and $CO_2$ emissions in case of South Africa for the period of 1965-2008.

The long run results are illustrated in Table-5. The results show that $CO_2$ emissions in previous period contribute to deterioration of environment in next period. In other words, there is inertia in emissions. It is noted that a 1% increase in $CO_2$ emissions is linked with 0.294% increase in $CO_2$ in future. Similarly, rise in economic growth has positive effect on carbon dioxide emissions. It is evident from the table that 1% increase in GDP leads to 0.223% increase in emissions. The statistics show that growth rate of income per capita in South Africa is 41% and $CO_2$ emissions per capita growth is 47% over the period of analysis. This reveals that South Africa is achieving growth at the cost of environment. It implies that environmental quality is associated with cost of economic growth that provides support to Menyah and Wolde-Rufael [51] who indicates that South Africa has to sacrifice economic growth to lower $CO_2$ emissions.

**Table-5: Long Run Results**

| Dependent Variable = $\ln CO2_t$ | | | | |
|---|---|---|---|---|
| Variable | Coefficient | T-Statistic | Coefficient | T-Statistic |
| Constant | 4.8052 | 3.9844* | -33.8705 | -4.4492* |
| $\ln CO2_{t-1}$ | 0.2940 | 4.2759* | … | … |
| $\ln GDPC_t$ | 0.2230 | 2.1341** | 4.2637 | 3.4476* |
| $\ln GDPC_t^2$ | … | … | -0.1211 | -1.7807*** |
| $\ln FD_t$ | -0.0273 | -1.8637*** | -0.1370 | -0.6762 |
| $\ln CO_t$ | 0.5694 | 10.5348* | -0.5746 | … |
| $\ln TR_t$ | -0.1102 | -1.7971*** | -0.0575 | -2.3761** |
| $\ln URB_t$ | -0.1102 | -1.7971*** | 0.4595 | 5.0868* |
| Diagnostic Test | | | | |
| R-squared | | 0.9952 | 0.8633 | |
| Adjusted R-squared | | 0.9944 | 0.8449 | |
| F-statistics | | 1337.212* | 46.7713* | |
| Normality LM Test | | 0.4088 (0.8151) | 1.4073(0.4947) | |
| ARCH LM Test | | 0.01341(0.7164) | 0.5762 (0.8037) | |
| W. Heteroskedasticity Test | | 0.4261 (0.8270) | 2.9010 (0.0258) | |
| Ramsey RESET | | 0.4186 (0.5224) | 1.2320 (0.2742) | |
| Note: *, ** and *** indicates significance at 1%, 5% and 10% respectively while Prob-values are shown in parentheses in lower segment. | | | | |

The effect of financial development on $CO_2$ emissions is negative and statistically significant at conventional level of significance. The results demonstrate that a 0.0273% reduction in $CO_2$ emissions would result from 1% increase in financial development. The negative sign of the coefficient of this variable confirms the fact that the financial sector in South Africa has achieved the maturity level as the this sector allocate resources to environment-friendly projects and also supports the firms to use advanced technology in production to enhance output levels. This result is in line with Tamazian and Rao [28] who surfaced the importance of financial and institutional developments in improving environmental quality.

Coal consumption is positively associated with $CO_2$ emissions and its coefficient is highly significant. The results highlight that coal consumption is a major contributor to deterioration of environmental quality as South Africa is the 6th biggest country which heavily consumes coal to meet energy demand. It is observable that a 1% increase in coal use raises $CO_2$ emissions by 0.569%. South Africa is heavily dependent on energy sector where coal consumption is dominant in production activity. Almost 70% primary energy supply and 93% electricity production are from coal reserves. This heavy reliance on coal use is leading factor in $CO_2$ emissions as compared to population as well as size of economy (Winkler, [63]). In case of South Africa, coal sector produces 87% of $CO_2$ emissions, 96% of sulfur dioxide ($SO_2$) and 94% of nitrogen oxide emissions in terms of energy pollutants (Menyah and Wolde-Rufael, [51]).

The sign of $\ln TR_t$ is negative and significant at 10% level of significance. It implies that trade openness improves environmental quality (i.e. decreases $CO_2$ emissions). The coefficient value of trade openness reveals that 1% increase in trade openness reduces $CO_2$ emissions by 0.1102%. This relationship between trade openness and energy pollutants can be justified by scale, technique, and composition effects. Scale effect hypothesizes that trade liberalization boosts exports volume of the country that results in an increase in economic growth. This rise in economic growth improves the income level of an economy, which leads the country to import environmental-friendly technology to enhance output levels (i.e. technique effect). Moreover, trade openness is a source of competition among local producers, which encourages them to use advanced technology to minimize per unit cost and thereby emitting less energy pollutant during production. The composition effect implies that the industrial structure of an economy is changed by trade liberation. Subsequently, a country specializes in production of goods following comparative advantage theory of international trade. The composition effect also reduces $CO_2$ emissions when country has comparative advantage in environment friendly industries.

We now explain the results of the second model in Table-5. The signs of $\ln GDPC_t$ and $\ln GDPC_t^2$ are positive and negative respectively, and both are statistically significant at 1% level of significance. The negative sign of $\ln GDPC_t^2$ confirms delinking of $CO_2$ emissions and higher level of per capita GDP. The threshold point is US$ 3463 in South Africa for the period of 1965-2008. The findings validate the existence of so-called Environmental Kuznets Curve (EKC) that states that CO2 emissions increase with economic growth at initial stages and start to declines after stabilization point as economy achieves a sustainable level of economic growths. These results are consistent with Halicioglu [27], Fodha and Zaghdoud [64], Shahbaz et al. [52] and Nasir and Rehman [65]. Further, the impact of urbanization on environment degradation is positive and significant. The results posit that urbanization increase energy consumption. A 1 % rise in urbanisation leads to an increase in environmental pollutants by 0.4595%, on an average and all else same. This finding is in line with literature such as Dhakal [48] who reported that that 40% contribution in $CO_2$ emissions is by 18 % percent increase in population in large cities of China. An exercise of diagnostic tests confirms the goodness fit of the models and the stability of long run empirical evidence.

We have also conducted pair-wise Granger causality test to analyse the direction of causal relationship between the variables. These results are reported in Table 6. The unique order of integration leads a support to examine the direction of causality between economic growth and $CO_2$ emissions through Granger causality test. The same approach is applied for short run causality without the level feedback. The results reported in Table-6 indicate that real GDP and its squared term Granger causes $CO_2$ emissions in long run at 5% level of significance[4]. The causality results also confirm the existence of EKC in long run. This finding is consistent with Maddison and Rehdanz [66] for North America, Zhang and Cheng [67] and Jalil and Mahmud [68] for China and Ghosh [69] for India.

**Table-6: Pair-wise Granger Causality Analysis**

| Pair-wise Granger Causality Tests | | |
|---|---|---|
| Null Hypothesis | F-Statistic | Prob. value |
| $\ln GDPC_t$ does not Granger Cause $\ln CO2_t$ | 3.6515 | 0.0357 |
| $\ln CO2_t$ does not Granger Cause $\ln GDPC_t$ | 1.1562 | 0.3258 |
| $\ln GDPC_t^2$ does not Granger Cause $\ln CO2_t$ | 3.6701 | 0.0352 |
| $\ln CO2_t$ does not Granger Cause $\ln GDPC_t^2$ | 1.1611 | 0.3243 |
| $\ln FD_t$ does not Granger Cause $\ln CO2_t$ | 1.4136 | 0.2561 |
| $\ln CO2_t$ does not Granger Cause $\ln FD_t$ | 2.0281 | 0.1459 |
| $\ln CO_t$ does not Granger Cause $\ln CO2_t$ | 4.7024 | 0.0151 |
| $\ln CO2_t$ does not Granger Cause $\ln CO_t$ | 1.8556 | 0.1706 |
| $\ln TR_t$ does not Granger Cause $\ln CO2_t$ | 2.8476 | 0.0707 |
| $\ln CO2_t$ does not Granger Cause $\ln TR_t$ | 0.1251 | 0.8827 |
| $\ln FD_t$ does not Granger Cause $\ln CO_t$ | 0.5212 | 0.5981 |
| $\ln CO_t$ does not Granger Cause $\ln FD_t$ | 2.6546 | 0.0837 |

Further, no causal relationship is found between financial development and environmental degradation while unidirectional causality is found running from coal consumption to $CO_2$ emissions providing support to the view that coal consumption is major contributor to energy pollutants in case of South Africa in long-run. Trade openness Granger causes energy emissions, which implies that trade, improves environmental quality by having comparative advantage in environment friendly industries. Unidirectional causal relation is found from coal consumption to financial development.

[4] Findings are same at lag 2 and 3.

Table-7 provides the details of short run results. The results show that a 0.3701% of energy emissions in current period is linked with a 1% rise in $CO_2$ emissions in previous period. It is statistically significant at 1% level. Similarly, economic growth leads to energy emissions and the results reveal that a 1% increase in economic growth is associated with 0.2566% in $CO_2$ emissions. Financial development has negative and significant effect on carbon dioxide emissions. Likewise, coal consumption has positive and statistically significant effect on $CO_2$ emissions. Hence, these results confirm that coal consumption play an important role in environmental degradation in the short-run as well. Nonetheless, the impact of trade openness on emissions is negative but insignificant statistically in the short-run.

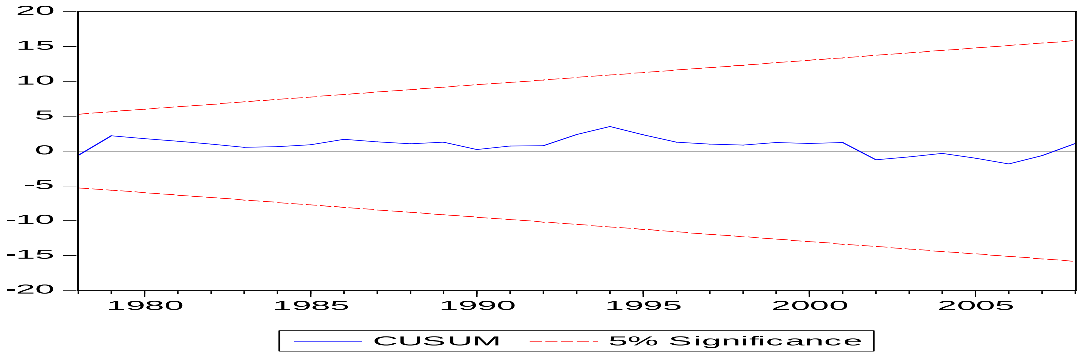
**Table-7: Short Run Results**

| Dependent Variable = $\Delta \ln CO2_t$ | | | |
|---|---|---|---|
| Variable | Coefficient | T-Statistic | Prob-value |
| Constant | -0.0018 | -0.4076 | 0.6864 |
| $\Delta \ln CO2_{t-1}$ | 0.3701 | 3.1696* | 0.0034 |
| $\Delta \ln GDPC_t$ | 0.2566 | 2.0478** | 0.0491 |
| $\Delta \ln FD_t$ | -0.0348 | -1.7729*** | 0.0861 |
| $\Delta \ln CO_t$ | 0.6030 | 9.4814* | 0.0000 |
| $\Delta \ln TR_t$ | -0.0581 | -1.0306 | 0.3107 |
| $ECM_{t-1}$ | -0.9651 | -4.6018* | 0.0001 |
| Diagnostic Test | | | |
| R-squared | 0.7393 | | |
| Adjusted R-squared | 0.6889 | | |
| F-statistics | 14.6589* | | |
| Durbin-Watson | 1.6304 | | |
| Normality Test | 0.1033 (0.9496) | | |
| Breusch-Godfrey LM Test | 1.8814 (0.1091) | | |
| ARCH LM Test | 0.0907 (0.7650) | | |
| W. Heteroskedasticity Test | 0.3753 (0.8890) | | |
| Ramsey RESET | 0.0003 (0.9869) | | |
| Note: *, ** and *** indicates significance at 1%, 5% and 10% respectively while Prob-values are shown in parentheses in lower segment. | | | |

The coefficient of $ECM_{t-1}$ has negative sign and significant at 1% level of significance. The significance of lagged error term corroborates the established long run association between the variables. Furthermore, the negative and significant value of $ECM_{t-1}$ implies that any change in $CO_2$ emissions from short run towards long span of time is accurated by 96.51% every year. Sensitivity analysis indicates that short run model passes all diagnostic tests i.e. LM test for serial correlation, ARCH test, normality test of residual term, White heteroskedasticity and model specification successfully. The results are shown in lower segment of Table-7. It is found that short run model does not show any evidence of non-normality of residual term and implies that error term is normally distributed with zero mean and covariance. Serial correlation does exist between error term and $CO_2$ emissions. There is no autoregressive conditional heteroscedisticity and same inference is drawn about white heteroscedisticity. The model is well specified proved by Ramsey RESET test.

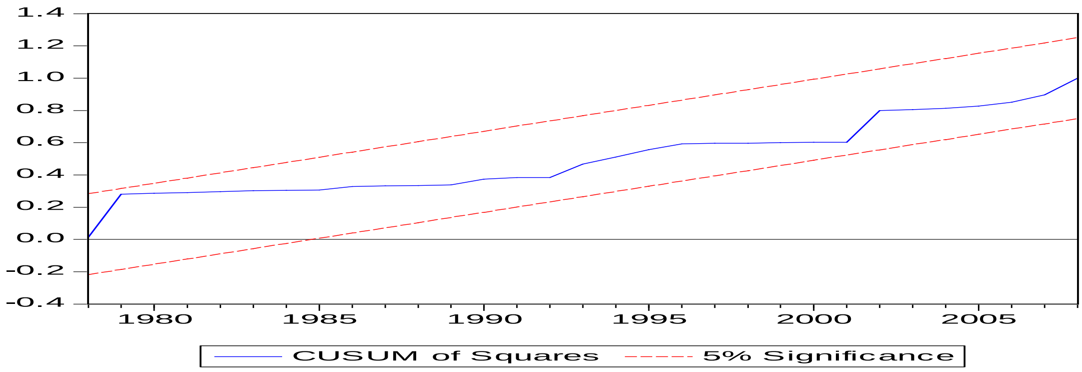
The stability of long run parameters is tested by applying the CUSUM and CUSUMSQ tests. The plots of both CUSUM and CUSUMSQ statistics are reported in Figure 1 and Figure 2. These figures demonstrate that plots are of both tests are within the critical bounds and, therefore, confirm the stability of long-run estimates.

Figure 1 Plot of Cumulative Sum of Recursive Residuals




The straight lines represent critical bounds at 5% significance level.

Figure 2 Plot of Cumulative Sum of Squares of Recursive Residuals




The straight lines represent critical bounds at 5% significance level.

**5. Conclusions and Policy Implications**

South Africa is a classic case and contains all the contents such as high growth, monstrous energy-related emissions, and strong financial base. Soon after the advent of democracy in 1994, the country economic growth shows an upward trend and remained uninterrupted until the financial crises hit the country in 2007. The average growth rate between 2001 and 2007 was 4.3%. Nonetheless, the essential feature was the continuous rise in the growth rate during this period. On the other hand, South Africa is one of the major emitter of $CO_2$ (1% of the world emissions). The obvious reason for this is the use of coal, a major ingredient of $CO_2$, in energy production. Coal consumption is major contributor in environmental degradation.

The study assessed the effect of financial development on energy pollutants in the presence of coal consumption and trade openness. Our empirical exercise pointed out that rise in financial development is linked with environmental quality i.e. financial development lowers energy pollutants. Particularly, we find that banking sector development that is per capita access to domestic credit of private sector help to achieve lower $CO_2$ per capita emissions. This implies that financial development can be used as an instrument to keep the environment clean by introducing financial reforms. Coal consumption has major contribution to deteriorate environment while trade openness improves it. Further, our results confirmed the existence of environmental Kuznets curve (EKC) in case of South Africa and urbanisation also deteriorates environment.

In this regard, the government can help the markets by establishing a strong policy framework that creates long-term value for green house gas emissions reductions and consistently supports the development of new technologies that leads to a less carbon-intensive economy. In addition to this, development of efficient capital market might be another useful policy option that can be adopted. This is because firms can reduce the liquidity risk and can mobilize the required funds through portfolio diversification that is extremely useful in developing sound technology base in the long run particularly. Another, interesting observation of our finding is that policies directed to financial openness and liberalization to attract higher levels of R&D related foreign direct investment can decrease the environmental degradation as our evidence show that trade openness reduces environmental degradation. This is important because the higher degree of economic and financial openness strengthens the institutional framework creating incentives for the firms to act upon. Therefore, addressing these issues might lead to higher energy efficiencies through technological advances as suggested by Blanford [70] and possibly reduce the $CO_2$ emissions in South Africa. Further, we argue with respect to financial development and environment degradation that higher degree of financial system development and trade openness prop up technological innovations by increasing spending on energy conservation R&D which results in energy efficiency and hence it may lower emissions. However, our study is limited to not to provide the analysis at disaggregate i.e., at the firm level in that one might answer how financial development/development of well-established capital market can improve the environment performance or how openness polices can motivate firms to use environment friendly and more efficient technologies.

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