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Asymmetric Effects of Fiscal and Monetary Policies on Environmental Quality in South Africa

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ABSTRACT

The effect of fiscal and monetary policies can either improve or worsen environmental quality, depending on how the policies are implemented, this may lead to asymmetrical impacts. Therefore, the aim of this study was to investigate the asymmetric effects of fiscal and monetary policies on environmental quality in South Africa from 1990 to 2023 using the nonlinear autoregressive distributed lag (NARDL) technique. The study found that a positive shock in discount rate has a positive and significant influence on carbon emissions (CO_2) in the long run however, a negative shock has an insignificant negative impact. Moreover, economic growth was reported to have a significant positive impact on carbon emissions (CO_2) in the long run. A positive shock in government expenditure was found to have a significant and negative influence on carbon emissions (CO_2), while a negative shock in government expenditure has a significant positive impact in the long run. The effect of fiscal and monetary policies on environmental quality were found to be asymmetrical in the long run. The reported findings have a significant implication for fiscal and monetary policies in South Africa and other countries with similar economic settings. Both monetary and fiscal policies have a significant influence on environmental quality, policymakers could implement strategies to enhance environmental quality by alleviating carbon emissions (CO_2). In addition, policymakers should consider coordinating fiscal and monetary policies to attain decarbonisation.

Keywords: Asymmetric, Fiscal Policy, Monetary Policy, Carbon Emissions, NARDL
JEL Classifications: E62, E52, Q53, C23

1. INTRODUCTION

Emerging economies face significant obstacles in attaining economic growth while protecting environmental performance. In the process of economic development and growth, one of the central hurdles faced by emerging economies is environmental degradation. In the course of economic growth, consumption and production activities increases the energy consumption, leading to environmental degradation (Chen et al., 2020). In addition, the central factors contributing to environmental degradation in the twenty-first century are human action and the development of economies. The discussion between environmental protection and economic growth is acute in emerging economies due to their influence on global growth trends (Lau et al., 2024). Many economies employ fiscal and monetary policies to influence economic activity and attain macroeconomic objectives such as economic growth, low inflation rate etc.

The aim of fiscal policy is to influence economic and social growth by maintaining sustainable balance spending, income and borrowing. According to Ullah et al. (2021), fiscal policy tools like government spending and income are directly and indirectly related with the size of the economy, production level, total energy usage and environmental quality. Tools of fiscal policy have numerous ways to influence environment. For instance, budget deficit stimulates the gross capital formation and accumulation, higher energy consumption and business activities (Balcilar et al., 2016). Moreover, government spending may influence environmental quality in the following channels; income effect – increase in income in relation to spending increases the demand for enhanced environmental quality; scale effect – increased spending may result in a greater pollution due to economic growth; composition effect – higher expenditure promotes human capital investment actions in contrast to physical capital investment actions that are highly detrimental to environment; and technique effect – increased spending promotes labour efficiency in health and education sectors thus reduces pollution (López et al., 2011). In term of monetary policy, central banks implement this policy to govern and control the interest rate and money supply to influence inflation. According to Mughal et al. (2021) interest rate fluctuations influence the trends in industrial innovation, energy demand and income per capita thereby contribution to environmental pollution.

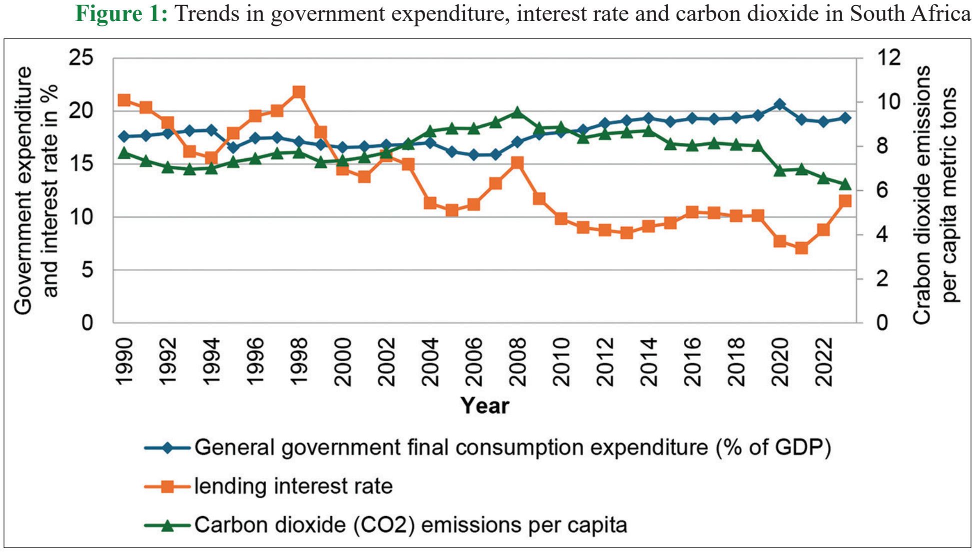
This study looks at South Africa due to its distinctive position as sizeable and fast-growing emerging economy. Moreover, the characteristics of its economy, being energy intensive and carbon-dependent distinguishes it from other emerging African economies. In addition, South Africa is among largest emitter of carbon in Africa and the world (Enerdata, 2019; Salahuddin et al., 2019). Consequently, this makes environmental quality a pressing policy matter. South Africa is coupled with high unemployment rate, poverty and inequality presenting a significant challenge to prioritise environmental matters.

South African government adopted fiscal and monetary policies to tackle economic challenges such as unemployment, poverty, inflation, and economic growth. South African government implemented expansion fiscal policy after 1994 as part of its strategy for economic recovery and consolidation. Moreover, the new administration identified a need for social expansion and ending racial inequities through the provision of public services (Calitz et al., 2014). Just like any other emerging economies, South Africa also known to be having high levels of government expenditure to tackle economic challenges face by the country. According to Figure 1, government expenditure has been increasing since 1990s, averaging 18% of GDP. However, between 2013 and 2023 the rate of government expenditure to GDP was retained to 19%. This is not surprising as the growth in government expenditure was attributed to the growth in social and economic initiatives developed to tackle unemployment and poverty, and to improve the quality of education and access to health services to disadvantaged communities.

The South African Reserve Bank (SARB) manages interest rate (repo rate) as part of its efforts maintain price stability within the target range of 3-6%. The interest rate has declined substantially since 1990s from an average of approximately 19-9% in recent years. Since 1990s, the South African carbon dioxide emissions per capita in metric tons has been oscillating between 10 and 7 tons.

Given the role that fiscal and monetary policies play on environmental quality. Few studies have investigated the impact of monetary policy on environmental quality (Pradeep, 2022), while several studies have focused on the impact of fiscal policy on environmental quality (Yuelan et al., 2019; Katircioglu and Katircioglu, 2018; Yuelan et al., 2019). However, some studies incorporated the influence of both monetary and fiscal policies on environmental quality (Lau et al., 2024; Noureen et al., 2022; Villanthenkodath et al., 2024). These studies have focused on the symmetric effects of these policies and have failed to consider the asymmetric effects. Nonetheless, limited studies have endeavoured to investigate the asymmetric effects of these policies on environmental quality. For example, Mughal et al. (2021) used panel data from ASEAN countries, Noureen et al. (2022) employed panel data from developing economies, and Ullah et al. (2021) used time series data from Pakistan. Therefore, little evidence is available on the asymmetric effects of monetary and fiscal policies on environmental quality. This empirical gap and unique characteristics of South Africa informed the reason to investigate the impact of monetary and fiscal policies on environmental quality. Consequently, this study adds to existing literature by extending the evidence on the asymmetric effects of fiscal and monetary policies on environmental quality.

Figure 1: Trends in government expenditure, interest rate and carbon dioxide in South Africa



Source: Author's plot using World Bank data

Based on the author's best knowledge, there is scanty literature in the context of South Africa, thus this study addresses the gap by investigating the asymmetric effects of fiscal and monetary policies on environmental quality in South Africa. This is to ascertain the influence of a positive and negative shock in fiscal and monetary policies on environmental quality. Moreover, this study is significant to policy makers as it provides fresh insights into the influence of fiscal and monetary policies on environmental quality. The findings of this study help policy makers to formulate programs that are environmentally friendly. In addition, the findings of this study are valuable to other economies that share similar characteristics with South Africa.

The layout of the study's other section is as follows: Literature review section discusses existing related studies while data and methodology present data description and the method employed. Results and discussion section discuss the results of the study, and conclusion section summarises the study and suggests policy implications and areas for future studies.

2. LITERATURE REVIEW

The literature review section is divided into two sub-sections: The first sub-section discusses the theoretical framework that explains the connection between fiscal and monetary policies, and environmental quality. The second sub-section contains a review of existing empirical literature on the nexus between fiscal and monetary policies, and environmental quality.

2.1. Theoretical Framework

2.1.1. Green new keynesian (GNK) framework

The Green New Keynesian framework extends on the contributions of economists as such John Maynard Keynes. The GNK framework is a theory that aims to simultaneously address all the existing issues such as unemployment and environmental issues (Kaya et al., 2024). According to the GNK framework government can use fiscal and monetary policies to stimulate economic activities while addressing environmental issues. For instance, government can implement fiscal policy to address environmental issues by directing government expenditures towards economic activities that are environmentally friendly such as investment in green infrastructure. Moreover, the GNK framework aims to generate effective demand while avoiding environmental degradation, using government authority to promote low-carbon sectors and environmentally friendly activities (Blackwater, 2012).

Although the primary focus of GNK framework is fiscal policy, it also acknowledges the role of monetary policy in influencing the overall economic landscape (Galí, 2015). In other words, the central bank can use interest rate as monetary policy instrument to control inflationary pressures. In doing so, the consumers' willingness to purchase, and aggregate demand declines, thus lowering carbon emissions (Sahuc et al., 2025). Noteworthy, the concept behind this framework is that government must use both fiscal and monetary policies to influence economic activities while addressing environmental issues. This framework is adopted in study as it highlights the implication of fiscal and monetary policies in influencing environment.

2.2. Empirical Literature

A study by Halkos and Paizanos (2016) investigated the influence of fiscal policy on CO_2 emissions in the United States of America (U.S.A). The study employed Vector Autoregressions technique to analyse variables for the timeline from 1973 to 2013. The findings illustrated that expansionary fiscal expenditure assists in lowering emissions brought by consumption and production side. In support, Katircioglu and Katircioglu (2018) using autoregressive distributed lad (ARDL) technique to examine the link between fiscal policy and environment in Turkey for the period from 1960 to 2013. Results revealed that fiscal policy has a negative influence on CO_2 emissions. This implies that expansionary fiscal policy lowers the level of CO_2 emissions in Turkey.

In contrast, Yuelan et al. (2019) focused on China economy by using ARDL technique to analyse the link between environmental degradation and fiscal policy for the period between 1980 and 2016. Findings revealed that fiscal policy tools (revenue and expenditure) have a significant positive influence on environmental degradation in the long run. This implies that expansionary fiscal policy leads to environmental degradation in China. The study recommends that authorities should deliberate the application of upgraded and environmental-friendly production method to maintain economic growth while protecting the environment.

Pradeep (2022) investigate the role of monetary policy on CO_2 emissions in India using ARDL technique for the period from 1971 to 2014. The results indicate that interest rate has a positive and significant influence on CO_2 emissions in the short and long run. This implies that the monetary policy in India is not optimal for attaining sustainable growth. The study recommends the need to incorporate environmental consideration when formulating monetary policy. In line, Qingquan et al. (2020) noted a significant positive relationship between CO_2 emissions and expansionary monetary policy in Asian economies using panel fully-modified (PFM-LS), and panel dynamic least squares (PD-LS) techniques for the period from 1990 to 2014.

Nonetheless, some studies have considered the effects of both monetary and fiscal policies. For instance, Chishti et al. (2021) investigated the impact of fiscal and monetary policies on carbon emissions in BRICS countries between 1985 and 2014. Using the panel ARDL, ordinary least squares (OLS), fully modified OLS and dynamic OLS techniques for analysing data. The results showed that the expansionary fiscal policy has a positive influence on CO_2 emissions however, contractionary fiscal policy has a negative effect on CO_2 emissions. Moreover, the expansionary monetary policy has a positive influence on CO_2 emissions, but restrictive monetary policy has an inverse influence on CO_2 emissions. The study recommends the need to develop effective strategies and plans to curb CO_2 emissions. In line, Noureen et al. (2022) using the cross-sectional ARDL technique discovered that the expansionary fiscal and monetary policies destroy the environmental quality. However, the contractionary monetary and fiscal policies have a negative impact on methane, nitrous oxide and carbon dioxide in developing countries.

Mughal et al. (2021) examined the influence of monetary and fiscal policy on environmental quality in ASEAN economies using non-linear ARDL technique from 1990 to 2019. The results of ASEAN group-wise analysis showed that the expansionary monetary policy has a positive impact on CO_2 emissions, while contractionary monetary policy has a negative impact in the long run. In addition, the expansionary fiscal policy has a significant negative impact on CO_2 emissions in the long run, but the contractionary fiscal policy has an insignificant negative impact. The results of ASEAN country-wise analysis showed the impact of fiscal and monetary policies on CO_2 emissions differs across countries.

Focusing on BRICS countries, Lau et al. (2024) looked at the influence of monetary and fiscal policies in promoting environmental quality using panel ARDL, fully modified OLS and Driscoll-Kraay techniques from 1990 to 2018. The results showed that both fiscal and monetary policies have a significant inverse infleunce on CO_2 emissions in the long run. This shows that both monetary and fiscal policies contribute to the protection of natural environment thereby curbing CO_2 emissions.

Ullah et al. (2021) investigated the asymmetric impacts of monetary and fiscal policies on environmental quality in Pakistan using NARDL technique between 1985 and 2019. The results showed that a negative and positive change in fiscal policy tool has a positive and significant impact on CO_2 emissions in the short run however, a negative and positive change in fiscal policy tool has an inverse and significant impact on CO_2 emissions in the long run. Moreover, a positive and negative change in monetary policy tool has a significant positive impact on CO_2 emissions in the short run but a positive shock in monetary policy tool has a significant inverse effect on CO_2 emissions in the long run. The study proposed that policymakers should consider using monetary and fiscal policies to back economic growth while simultaneously curbing the environmental pollution. Challenging these findings, Nguyen and Duong (2025) found that a negative shock in fiscal policy (government expenditure) has a significant and negative impact on CO_2 emissions, while a negative shock in fiscal policy has a significant and positive influence on CO_2 emissions in Vietnam in the long run.

The above empirical works provide valuable insights into the effect of fiscal and monetary policies on environmental quality. Most studies that provided a country-specific analysis have presumed that either monetary and fiscal policy adjustments have a symmetric influence on environmental quality (Halkos and Paizanos, 2016; Katircioglu and Katircioglu, 2018; Pradeep, 2022; Yuelan et al., 2019). The assumption of a symmetrical relationship between these policies and environmental quality is overly one-dimension and does not reflect the actual complexity of this relationship. These studies failed to consider the effects of both policies as they have focused on either the impact of monetary policy or fiscal policy. Moreover, they have overlooked the asymmetric influence of these policies on environmental quality. Nonetheless, studies that have considered both policies and their asymmetric effects on environmental quality have provided a panel or group-wise analysis (Chishti et al., 2021; Mughal et al., 2021; Noureen et al., 2022). Group-wise analysis may produce confusing estimates because of differing country-specific factors. Limited evidence on the asymmetric effect of fiscal and monetary policies on environmental quality at country-level is available (Ullah et al., 2021; Nguyen and Duong, 2025). Therefore, this current study seeks to extend the literature on the asymmetric effects of fiscal and monetary policies on environmental quality at the country-level. Based on the author's best knowledge, there is scanty literature in the context of South Africa, thus this study addresses the gap by investigating the asymmetric effects of fiscal and monetary policies on environmental quality in South Africa using time series data.

3. METHODOLOGY

This section delineates the empirical model specification informed by empirical literature revived in the previous section, data sources and timeline, and econometrics method to be utilised in this study. This study seeks to empirically investigate the asymmetric effects of fiscal and monetary policies on environmental quality in South Africa.

3.1. Model Specification

This study applies the empirical model employed by Ullah et al. (2021), their paper investigated the asymmetric effects of monetary and fiscal policies on environmental pollution in Pakistan. The empirical model is mathematically formulated as follows:

$$CO_{2,t} = \varphi_0 + \varphi_1 Gexp_t + \varphi_2 Drate_t + \varphi_3 EG_t + \varepsilon_t \quad (1)$$

Where CO_2 is carbon dioxide emissions acting as a proxy for environmental quality. Gexp denotes government expenditure, which serves as a tool for fiscal policy. Drate represents discount rate, which is used to reflect monetary policy and EG symbolises economic growth. Equation 1 indicates that environmental quality is a function of government expenditure, discount rate and economic growth.

3.2. Data Source and Timeline

This study used annual time series data 1990-2023 for the variables included in Equation 1 and 2. The period of 1990-2023 is selected on grounds that South Africa has implemented several strategies aimed at promoting environmental quality. During the 1990s the government implemented national environmental management Act to ensure cooperative environmental governance. In 2009 the government introduced the renewable energy feed-in tariff aimed at lowering carbon-based power generation and in 2019 the government introduced carbon tax Act. These developments may influence how economic indicators affect each other. Hence, this considered the selected timeline.

3.3. Econometrics Method

This study seeks to establish the asymmetric effects of fiscal and monetary policies on environmental quality in South Africa. The suitable to approach to establish this is nonlinear autoregressive distributed lags (NARDL) method. The NARDL method essentially disintegrates the variability of the variables into negative and positive partial sums. In the event that these separate elements of time series are discovered to be cointegrated, it infers the existence of a hidden cointegration (Monamodi and Choga, 2021). The NARDL method was pioneered by Shin et al. (2014) to accommodate a disintegrated partial sum elements. The NARDL method provides enhanced flexibility by granting time series variables to be integrated at different orders unlike other econometrics methods that requires time series variables to be integrated at the identical order. The NARDL model specification is expressed as follows:

$$y_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i y_{t-i} + \sum_{j=0}^{q} (\beta_j^+ x_{t-j}^+ + \beta_j^- x_{t-j}^-) + \varepsilon_t \tag{2}$$

Where:

$$x_t^+ = \sum_{j=1}^{t} \max(\Delta x_j : 0) \text{ = cumulative positive changes}$$

$$x_t^- = \sum_{j=1}^{t} \min(\Delta x_j : 0) \text{ = cumulative negative changes}$$

Equation 1 assume that a shock in any of the explanatory variable has symmetric effect on the environmental quality in South Africa. For instance, this assumption suggests that if a positive shock in government expenditure has a positive influence on environmental quality, then a negative shock must have detrimental impact. However, this is not always the case as the economic factors may react in asymmetric manner. Therefore, the fiscal and monetary policy tools in Equation 1 are disintegrated into partial sums of positive and negative changes. The disintegrated variables are as follows:

$$Gexp_t^+ = \sum_{t=1}^{t} \Delta Gexp_t^+ = \sum_{n=1}^{t} \max(\Delta Gexp_t^+, 0) \tag{3}$$

$$Gexp_t^- = \sum_{t=1}^{t} \Delta Gexp_t^- = \sum_{n=1}^{t} \min(\Delta Gexp_t^-, 0) \tag{4}$$

$$Drate_t^+ = \sum_{t=1}^{t} \Delta Drate_t^+ = \sum_{n=1}^{t} \max(\Delta Date_t^+, 0) \tag{5}$$

$$Drate_t^- = \sum_{t=1}^{t} \Delta Drate_t^- = \sum_{n=1}^{t} \min(\Delta Drate_t^-, 0) \tag{6}$$

The NARDL models to be computed establish the asymmetric long and short run effects of fiscal and monetary policies on environmental quality are formulated as follows:

$$\begin{aligned}\Delta CO_{2,t} &= \alpha_0 + \sum_{i=1}^{n1} \vartheta_i \Delta CO_{2,t-i} + \sum_{i=0}^{n2} \varphi_i \Delta Gexp_{t-i}^+ \\ &+ \sum_{i=0}^{n3} \theta_i \Delta Gexp_{t-i}^- + \sum_{i=0}^{n4} \omega_i \Delta Drate_{t-i}^+ \\ &+ \sum_{i=0}^{n5} \sigma_i \Delta Drate_{t-i}^- + \sum_{i=0}^{n6} \delta_i EG_{t-i} + \beta_1 CO_{2,t-1} + \beta_2 Gexp_{t-1}^+ \\ &+ \beta_3 Gexp_{t-1}^- + \beta_4 Drate_{t-1}^+ + \beta_5 Drate_{t-1}^- + \beta_6 EG_{t-1} + \varepsilon_t\end{aligned} \tag{7}$$

Where ± computes the short and long run effects of negative and positive change in discount rate and government expenditure on carbon dioxide emissions. Preliminary tests are conducted before commencing the estimation process. The initial step involves determining the nonlinear patterns in the data. As mentioned by Kantz and Schreiber (2004) the utilisation of nonlinear investigation must be informed by the evidence of nonlinearity in the data. In the following step the variables are examined for stationarity. In the third step, the variables of this study are inspected for asymmetric cointegration. After the estimation of NARDL model, the asymmetric effects of fiscal and monetary policies are verified using the Wald test. Lastly, the estimated models are diagnosed using coefficients stability test and residual diagnostic tests (Table 1).

Table 1: Data description and source

Variable	Symbol	Description	Source
Carbon dioxide emissions	CO_2	Carbon dioxide (CO_2) emissions (total) (Mt CO2e)	World development indicators
Government expenditure	Gexp	General government final consumption expenditure (% of GDP)	
Economic growth	EG	GDP growth (annual %)	
Discount rate	Drate	Policy rate	Bank for international settlements

Source: Author's own

4. EMPIRICAL RESULTS

4.1. Linearity Test

To establish whether the application of nonlinear method is appropriate, the initial step to is examine the linearity characteristics of the data employed. Therefore, to assess the linearity of variables of this study, the BDS test by Brock et al. (1996) was employed. Table 2 exhibits the BDS linearity test estimates.

Table 2 presents the estimates of BDS linearity tests, its null hypothesis states that the data is independently and identically distributed. The rejection of the null hypothesis implies the existence of nonlinearity in the data. According to the results presented in Table 2, the null hypothesis of BDS test for carbon dioxide (CO_2), government expenditure (Gexp), and discount rate (Drate) is rejected at a 1% level of significance for all dimensions. As a result, these findings confirms that CO_2, Gexp, and Drate have nonlinear characteristics. However, null hypothesis of BDS test for economic growth (EG) is not rejected for most dimensions, this implies that EG has both linear and nonlinear characteristics. Given that Gexp, and Drate show evidence of nonlinearity, employing NARDL model is reasonable, as it considers for nonlinearities in the relationships among the variables. The next step is to assess the unit root in the variables.

4.2. Unit Root Tests

This study employed the Augmented Dickey-Fuller and Kapetenios, Shin and Snell unit root tests. The null hypothesis of these tests state that there is a presence of unit root (nonstationary) in the variable. Table 3 present Augmented Dickey-Fuller unit root test results and Table 4 provides Kapetenios, Shin and Snell nonlinear unit root test estimates.

Table 3 reports that only EG is stationary at level, while other variables like CO_2, Gexp, and Drate become stationary at 1st difference. Nonetheless, the null hypothesis of nonstationary for all variables is rejected at 1% level of significance.

The results presented in Table 4 exhibit that CO_2, Gexp and EG are nonlinearly stationary using 1% and 5% level of significance,

Table 2: BDS linearity test results

BDS statistics	Dim 2	Dim 3	Dim 4	Dim 5	Dim 6
CO_2	0.18 (0.00)***	0.32 (0.00)***	0.39 (0.00)***	0.45 (0.00)***	0.47 (0.00)***
Gexp	0.12 (0.00)***	0.19 (0.00)***	0.23 (0.00)***	0.22 (0.00)***	0.21 (0.00)***
Drate	0.15 (0.00)***	0.23 (0.00)***	0.28 (0.00)***	0.32 (0.00)***	0.35 (0.00)***
EG	0.00 (0.7541)	0.00 (0.8230)	−0.00 (0.8713)	−0.18 (0.00)***	−0.17 (0.00)***

***P<0.01. The values inside the parentheses are the corresponding P-value for BDS statistics
Source: Estimation by author

Table 3: Augmented Dickey-Fuller unit root test results

Variables	At levels		At 1st difference	
	t-stat	P-value	t-stat	P-value
CO_2	−1.4557	0.5431	−5.4062	0.0001***
Gexp	−1.1147	0.6982	−6.0178	0.0000***
Drate	−1.5534	0.4938	−5.0922	0.0002***
EG	−4.1605	0.0027**	N/A	N/A

***P<0.01, **P<0.05
Source: Estimation by author

Table 4: Kapetenios, Shin and Snell (KSS) nonlinear unit root test results

Variables	KSS-stat	P-value	KSS critical value
CO_2	−2.731	0.039**	
Gexp	−3.003	0.048**	
Drate	−0.906	0.752	
EG	−5.460	0.000***	
1%			−3.322
5%			−2.625
10%			−2.304

***P<0.01, **P<0.05
Source: Estimation by author

respectively. However, Drate is not stationary at level according to the KSS nonlinear unit root test. Nonetheless, the unit root tests confirmed that the variables of this study are integrated of order zero I(0) and one I(1). Consequently, it is fitting to estimate the NARDL bound cointegration between the variables considered in this study.

4.3. Optimal Lag Section

The NARDL model necessitates the optimal lag length. Therefore, Table 5 provides the results for the selection of optimal lags for the variable considered in this study.

The results exhibited in Table 5 reflect the optimal lag length. The optimal lag length in this study was established utilising EViews 12 automatic model selection. The maximum explained variable and explanatory variables of 2 was selected for automatic model selection using AIC. The results reveal that selection criteria with the least value is AIC and hence, the optimal model to computed is NARDL(1,1,1,1,1.1).

4.4. Cointegration Test

This section outlines the results for cointegration test. As alluded by Bhatta et al. (2020) bound cointegration test should be adopted if time series are integrated at order zero and one. Therefore, the NARDL bound test was performed and the estimates are presented in Table 6.

The results outlined in Table 6 show evidence for asymmetric cointegration at 1% level of significance. This is informed on ground that the computed F statistic for NARDL bound model is higher than the critical F statistic at bound (I(1)). Noteworthy, the confirmation of asymmetric cointegration suggests that the long and short run asymmetric effects of monetary and fiscal policies on environmental quality are determined by NARDL approach.

4.5. Long and Short Run NARDL Model Results

To determine the long and short run asymmetric effects of fiscal and monetary policies on environmental quality, the model outlined in Equation 7 was estimated and results are exhibited in Tables 7 and 8.

Regarding the monetary policy, the results outlined in Table 7 exhibit that positive shock (change) in discount rate (Drate) has a significant positive effect on carbon emissions (CO_2) in the long run. That is, a one-unit increase in positive discount rate shock leads to a 0.98-unit increase in carbon dioxide emission, this implies that contractionary monetary policy (increase in interest rate) in South Africa tends to upsurge carbon emissions (CO_2). This finding indicates that an increase in discount rate deteriorate environmental quality in South Africa. Moreover, this infers that an increase in discount rate restricts the private sector to access funds, limiting their power to finance environmentally friendly technologies and thus leading to high carbon emissions (CO_2). The coefficient sign of positive shock in discount rate aligns with that of Noureen et al. (2022). However, the coefficient sign of positive shock in discount rate contradicts with that of Mughal et al. (2021) in panel analysis but it aligns with the coefficient sign for some nations in the country-wise analysis. In addition, the results showed that negative shock in discount rate has an inverse and insignificant influence on carbon emissions (CO_2). That is, a negative discount rate shock of one-unit hardly leads to a 0.05-unit decline in carbon dioxide emission, this infers that expansionary monetary policy (decrease in interest rate) in South Africa exert little influence on carbon emissions (CO_2). The economic implication associated with findings is that contractionary monetary policy deteriorates environmental while expansionary monetary policy exerts little influence. Therefore, this highlights the need to create targeted monetary policies that encourage green investment by mitigating risks associated with positive shocks in discount rate.

The findings also establish the positive and significant relationship between economic growth and environmental quality in the long run. That is, a one-unit increase in economic growth leads to 0.12-unit increase in carbon emissions (CO_2), this implies that the South Afrian's economic growth is a driver of carbon emissions. This not surprising as South African economy

Table 5: Optimal lags length results

Model	LogL	AIC	BIC	HQ	Specification
1	5.1875	0.3522	0.8511	0.52011	NARDL(1,1,1,1,1,0)
2	10.4901	0.0915*	0.6356	0.2746	NARDL(1,1,1,1,1,1)

*represents the optimal model selected
Source: Estimation by author

Table 6: NARDL bound test results

Model	f-stat	Conclusion
$CO_2 = f(Drate_-^+, Gexp_-^+, EG)$	4.6894	Asymmetric cointegration
Significance level (%)	**Critical values**	
	I(0)	**I(1)**
1	3.06	4.15
5	2.39	3.38
10	2.08	3

Source: Estimation by author

Table 7: Long run results

Variables	Long run		
	Coefficient	t-stat	P-value
CO_2 (−1)	−0.2156	−1.9953	0.0598*
Drate−	−0.0472	−0.3889	0.7015
$Drate^+$	0.9821	2.2676	0.0346**
EG	0.1208	2.4403	0.0241**
Gexp−	2.1683	1.8655	0.0769*
$Gexp^+$	−0.9248	−2.1392	0.0449**
R square	0.9782		
P (F-Stat)	0.0000***		

***P<0.01, **P<0.05, *P<0.1
Source: Estimation by author

Table 8: Short run results

Variables	Coefficient	t-stat	P-value
$D(Drate^-)$	0.0765	2.7655	0.0119**
$D(Drate^+)$	0.1173	2.5985	0.0172**
D(EG)	0.1109	6.4837	0.000***
$(Gexp^-)$	0.2036	1.9596	0.0641*
$(Gexp^+)$	0.0491	0.4018	0.6921
ECT	−0.2156	−6.5326	0.0000***

***P<0.01, **P<0.05, *P<0.1
Source: Estimation by author

depends on coal energy, infrastructure, transport activities, and mining. Consequently, economic growth leads to high carbon emissions (CO_2). This finding is consistent with that of Mughal et al. (2021), Noureen et al. (2022), Yuelan et al. (2019) and Ullah et al. (2021).

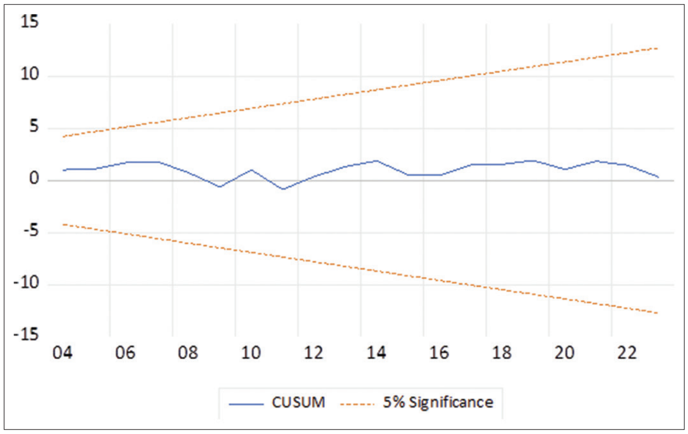
In terms of fiscal policy, the results show that the coefficient of positive shock in government expenditure (GEXP) is negative and statistically significant in the long run. That is, a one-unit increase government expenditure leads to 0.92-unit decrease in carbon emissions (CO_2), this implies that expansionary fiscal policy (increase in government expenditure) in South Africa tends to diminish carbon emissions (CO_2). This finding reinforces the idea of technique effect, which highlights that increased government expenditure promotes labour efficiency in education and health sectors thus reduces pollution and improves environmental quality. Conversely, the results show that the coefficient of negative shock in government expenditure is positive and statistically significant in the long. That is, a negative shock of one-unit lead to 2.17-unit increase in carbon emissions (CO_2), this infers that contractionary fiscal policy (decrease in government expenditure) is associated with high carbon emissions (CO_2) in South Africa. This could be attributed to a decline in government expenditure, which impedes investment in infrastructure, environmentally friendly technologies, education and healthcare, thereby affecting government's capacity to effectively tackle environmental issues. These findings align with those of Nguyen and Duong (2025), who reported that positive shock in government expenditure alleviates carbon emissions while negative shock exacerbates environmental quality in Vietnam. The result of the current study also demonstrates that fiscal policy in South Africa is effective in influence the environmental quality. This supports the Green New Keynesian (GNK) framework, which argue that government can use fiscal policy to influence economic activities while addressing environmental issues. However, these findings does not align with the results by Ullah et al. (2021) and Mughal et al. (2021), which indicate that both positive and negative shock in government expenditure have a negative influence on carbon emissions (CO_2).

The coefficient of R square is statistically significant at 1% level of significance. This suggests that 97.82% of variation in carbon emissions (CO_2) is explained by economic growth, the negative and positive disintegration of economic growth and fiscal policy. The estimated NARDL model is highly fitted since 97.82% is higher than 50%, and the explanatory variables are jointly significant at 1% level of significance.

Table 8 presents the short run coefficient estimations. Regarding the monetary policy, the positive and negative shock in discount rate exert a significant and positive effect on carbon emissions (CO_2) in the short run. That is, a positive shock of one-unit leads to 0.08-unit decrease in environmental quality and negative shock of one-unit leads to 0.11-unit decrease in environmental quality. The results presented in Table 8 also reveal that economic growth has a significant and positive impact on carbon emissions (CO_2) in the short run. That is, in response to a one-unit increase in economic growth, carbon emissions (CO_2) upsurges by 5.38-unit. Regarding the fiscal policy, the negative and positive shock in government expenditure exert positive influence on carbon emissions (CO_2) but a positive shock is insignificant in the short run.

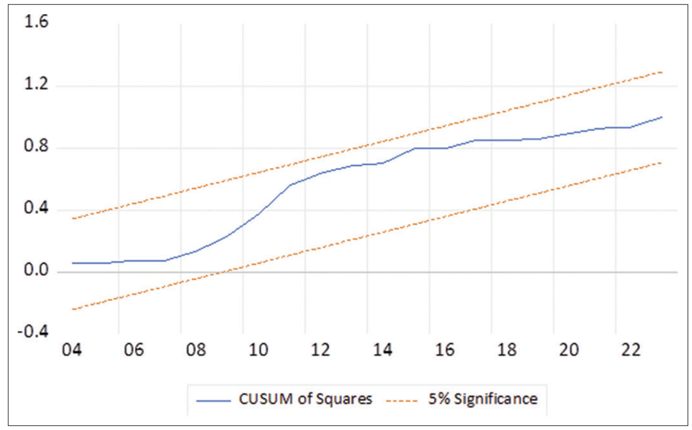
The computed error correction term (ECT) is −0.2156 and statistically significant. This infers that 21.56% of imbalance in the model is amended in the year, thus the NARDL adjust slowly to reach equilibrium steady state. This is due to the spend of adjustment, which is <50%. This adjustment would take 4 years and 6 months (i.e. 1/0.2156 = 4.6382).

Figure 2: CUSUM test



Source: Author's plot

Figure 3: CUSUM of squares test



Source: Author's plot

Table 9: Long and short run asymmetric effects

Asymmetric null hypothesis	Long run		Short run	
	F-stat	P-value	F-stat	P-value
$Drate^{-}=Drate^{+}$	3.5154	0.0492**	0.1945	0.6619
$Gexp^{-}=Gexp^{+}$	3.4200	0.0792*	0.8012	0.3707

*P< 0.1, **P<0.05

Source: Estimation by author

Table 10: Residuals and coefficients stability tests results

Test	Null hypothesis	P-value (F. stat)	Conclusion
Heteroscedasticity	Homoscedasticity	0.5982	Fail to reject null hypothesis
Breusch–Godfrey LM	No serial correlation	0.2323	Fail to reject null hypothesis
Normality (Jarque–Bera test)	Normal distribution	0.0731	Fail to reject null hypothesis
Ramsey RESET (stability)	The model is correctly specified	0.4989	Fail to reject null hypothesis

Source: Estimation by author

4.6. Wald Test Results

The Wald test is performed in this study to ascertain the long and short run asymmetric effects of fiscal and monetary policies on environmental quality. The Wald test results are outlined in Table 9.

The results exhibited in Table 9 establish that in the long run the effects of discount rate and government expenditure on carbon emissions (CO_2) are asymmetric but in the short run are symmetric. These results are in line with that of Nguyen and Duong (2025), who reported that government expenditure has asymmetric effects in the long run. In addition, Ullah et al. (2021) and Mughal et al. (2021), highlighted that discount rate has asymmetric effects in the long run.

4.7. Residual and Coefficients Stability Test

Several diagnostic examinations were performed to assess NARDL estimates. The Breusch–Godfrey LM, heteroscedasticity, normality and Ramsey RESET tests were performed and the result are outlined in Table 10.

Table 10 exhibits the model's weakness and strengthen. All the tests that were performed rejected the null hypotheses, implying that there is homoscedasticity, no serial correlation, normal distribution and the model was correctly specified. Therefore, the computed model is reliable.

Stability approaches were utilised to assess the structural stability of the model. Figure 2 exhibits the cumulative sum (CUSUM). The results offered in Figure 2 demonstrate the CUSUM statistic for the computed model, the CUSUM statistic is significant at 5% given that the statistic is within the 5% critical level. As a result, this infers that there is no evidence of instability in the model coefficients.

Figure 3 exhibits the cumulative sum of square (CUSUMSQ). The results presented in Figure 3 demonstrate the CUSUMSQ statistic for the computed model, the CUSUMSQ statistic is significant at 5% given that the statistic is within the 5% critical level. Thus, the computed model remains stable over the study period (1990-2023).

5. CONCLUSION AND POLICY IMPLICATIONS

The effect of fiscal and monetary policies can either improve or worsen environmental quality, depending on how the policies are implemented, this may lead to asymmetrical impacts. Moreover, previous studies have mostly focused on the symmetric influence of either monetary policy or fiscal policy on environmental quality. Few studies have considered the asymmetric effects of fiscal and monetary policies on environmental quality. Mixed results have been reported in these studies. Therefore, the purpose of this study is to assess the asymmetric effects of fiscal and monetary policies on environmental quality in South Africa (1990-2023) utilising NARDL technique. The study found that a positive shock in discount rate has a positive and significant impact on carbon emissions (CO_2) in the long run however, a negative shock has an insignificant negative impact. Moreover, economic growth was reported to have a significant positive impact on carbon emissions (CO_2) in the long run. A positive shock in government expenditure was found to have a significant and inverse influence on carbon emissions (CO_2), whereas a negative shock in government expenditure has a significant effect on carbon emissions (CO_2) in the long run. The effect of fiscal and monetary policies on environmental quality were found to be asymmetrical in the long run.

The reported findings have a significant implication for fiscal and monetary policies in South Africa and other countries with similar economic settings. Both monetary and fiscal and policies have a significant impact on environmental quality; policymakers could implement strategies to enhance environmental quality by alleviating carbon emissions (CO_2). Implementing monetary policy strategies is important, increased in discount rate have increases carbon emissions (CO_2), thus this study recommends that policymakers should design dual rate policy. This could be achieved by offering lower discount rates for environmental-friendly projects while maintaining higher rates for environmental damaging projects. In the long run, this may discourage the financing of environmental damaging projects and investors may opt to invest in environmental-friendly projects as these will be granted lower interest rates. In addition, implementing fiscal policy is also imperative, policymakers should implement measures that direct government investment and expenditures to sectors that environmental-friendly such as education and health. This could result in low carbon emissions (CO_2) compared to spending on heavy sectors. Moreover, policymakers should also adopt measures that encourages investment in renewable energy and efficiency projects. This would stimulate economic growth while addressing environmental issues. Policymakers should consider coordinating fiscal and monetary policies to attain decarbonisation. This can be accomplished by integrating climate-aware frameworks such as carbon taxes, dual rates and green subsidies.

This study provides valuable insight into the asymmetric effects of fiscal and monetary policies on environmental quality in South Africa. Nevertheless, certain drawbacks of this study should be taken into account in the future research. This study relied on discount rate and government expenditure as proxies for fiscal and monetary policies, future studies should consider including more fiscal and monetary policy indicators to provide more comprehensive analysis. In addition, future studies should consider expending the evidence by investigating this topic for African countries. Moreover, future study should investigation this topic by using other environmental quality proxies than carbon emissions (CO_2) such as air quality indicators, water quality indicators and noise pollution indicators.

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