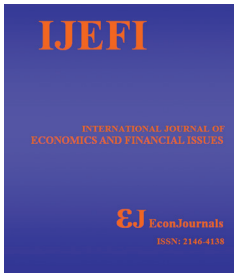

International Journal of Economics and Financial Issues

ISSN: 2146-4138

available at http: www.econjournals.com

International Journal of Economics and Financial Issues, 2025, 15(6), 218-224.

Evaluating Interaction Between Inflation and A Composite Macroeconomics Index

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Received: 25 March 2025 **Accepted:** 02 September 2025 **DOI:** https://doi.org/10.32479/ijefi.19995

ABSTRACT

This empirical investigation endeavours to elucidate the causal nexus between inflation and the dynamic confluence of money supply, interest rates, and GDP growth rate in five select African countries, leveraging annual panel data spanning the period from 2010 to 2024. Utilizing a Vector Error Correction Model (VECM) estimation paradigm, the results unveil a statistically significant long-run relationship between inflation and the Money supply-interest rate-GDP growth rate index (MIG Index). However, the MIG Index fails to Granger-cause inflation, suggesting that fluctuations in these macroeconomic variables do not exert a statistically significant long-run impact on inflation. This finding highlights the intricate interplay between inflation and macroeconomic variables, underscoring the substantial impact of inflationary pressures on salient economic indicators. The study's findings possess significant implications for policy decisions, emphasizing the imperative of mitigating potential macroeconomic instability. By grasping the long-run relationship between inflation and MIG, policymakers can devise targeted strategies to manage inflation and promote economic stability. Furthermore, the results underscore the importance of considering the autoregressive nature of inflation and the impact of past inflation levels on macroeconomic variables.

Keywords: Money Supply, Interest Rate, Gross Domestic Product, Inflation
JEL Classifications: E0, E5, E6

1. INTRODUCTION

The nexus between inflation and selected macroeconomic variables has been extensively studied, with research exploring the complex relationships between inflation and variables such as money supply (Kabundi and Muteba, 2022), interest rates (Gurkaynak et al., 2020), GDP growth rate (Ncube and Ndou, 2022), and exchange rates (Filardo and Lombardi, 2022). These studies have revealed context-specific findings that vary across different economies (Adelegan, 2021), time periods (Stock and Watson, 2020), and policy regimes (Mehrotra and Sánchez-Fung, 2021), highlighting the importance of understanding these relationships for designing effective monetary and fiscal policies to control inflation and promote economic stability (Divergences, 2023). Despite the wealth of research, the dynamic nature of economies and the constant evolution of economic conditions ensure that this area remains a vital and ongoing field of investigation (Bernanke, 2020), with new methodologies, data sets, and contexts continually shedding new light on these intricate relationships.

Recent studies on inflation have primarily focused on the isolated impact of individual macroeconomic variables, overlooking potential interactions among them (Kabundi and Muteba, 2022; Ncube and Ndou, 2022). This study addresses this gap by investigating the causal relationships between inflation and the interactions among money supply, interest rates, and GDP growth rate, using panel evidence from selected African countries. By examining these interactions, this research provides a more comprehensive understanding of the complex dynamics driving

inflation, offering valuable insights for policymakers to design more effective strategies for managing inflation and promoting economic stability in these economies (Divergences, 2023). The findings of this study can inform the development of more nuanced monetary policies that take into account the interplay between macroeconomic variables, ultimately contributing to more sustainable economic growth and development in African countries.

The majority of studies on inflation determinants have originated in developed countries, where researchers have extensively examined the causes and consequences of inflation (Gurkaynak et al., 2020; Ciccarelli and Mojon, 2019; Stock and Watson, 2020; Bernanke, 2020). Similarly, emerging market economies have also been the focus of several studies, with researchers exploring the unique challenges and characteristics of inflation in these contexts (Mehrotra and Sánchez-Fung, 2021; Filardo and Lombardi, 2022; García-Cicco, 2022; Mohanty and Klau, 2021). In contrast, the study of inflation determinants in Africa has received relatively less attention. While there have been some country-specific studies (Adelegan, 2021; Odhiambo, 2020; Kabundi and Muteba, 2022; Ncube and Ndou, 2022), these studies have often focused on individual countries, and those that do take a multi-country approach have typically examined the impact of macroeconomic variables like money supply, interest rates, and exchange rates on inflation (Kigume and Odhiambo, 2021; Sikwila and Mkhize, 2022). However, none of these studies have explored how interactions among these different variables influence inflation using panel data from African countries, highlighting a significant gap in the existing literature.

This study is crucial because it sheds light on the intricate dynamics between inflation, money supply, interest rates, and GDP growth rate, enabling policymakers to craft targeted monetary policies that balance economic growth with price stability. By understanding the causal relationships and directions between these variables, policymakers can better navigate the complexities of inflation management, ultimately fostering economic stability and sustainable growth. The study contributes to knowledge in that it sheds light on the dynamic interactions between inflation, money supply, interest rates, and GDP growth rate, filling a significant gap in the existing literature on inflation determinants in African economies. By exploring the causal relationships between these variables, the study provides a deeper understanding of the underlying mechanisms driving inflation in these economies. The study also contributes to policy and practice in that its findings can inform the development of more effective monetary policies that take into account the complex interactions between money supply, interest rates, and GDP growth rate. Policymakers can use the study's results to design policies that mitigate the adverse effects of inflation and promote economic stability, ultimately supporting sustainable economic growth and development.

This paper is organized as follows: Section 2 outlines the literature review, Section 3 details the methodology, Section 4 presents the results, summary statistics, and diagnostic tests, and Section 5 concludes with implications and limitations.

2. LITERATURE REVIEW

The extant literature on inflation determinants has predominantly focused on the isolated impacts of macroeconomic variables, such as money supply, interest rates, and GDP growth rate, on inflation dynamics (Kabundi & Rapapali, 2019; Divergences, 2023). However, scant attention has been devoted to examining the intricate interactions among these variables and their collective influence on inflation, thereby neglecting the potential synergies and complexities that arise from these interactions (Adelegan, 2021; Odhiambo, 2020). This lacuna is particularly pronounced in the context of African economies, where the interplay between macroeconomic variables can have distinct implications for inflation dynamics (Ncube and Ndou, 2022).

Recent studies have underscored the importance of considering the interactions among macroeconomic variables in understanding inflation dynamics. For instance, research by the IMF (2023) highlights the role of monetary policy interactions with other macroeconomic factors in shaping inflation outcomes. Similarly, studies by Kabundi and Muteba (2022) and Adelegan (2021) emphasize the need for a more nuanced understanding of the relationships between macroeconomic variables and inflation. The bulk of research on inflation determinants has focused on developed and emerging markets, leaving a notable gap in the African context. Given Africa's distinct macroeconomic landscape and challenges, recent studies emphasize the need for more research on African inflation determinants, highlighting the importance of understanding unique drivers such as supply-side constraints, monetary and fiscal policy interactions, and external shocks (Kabundi & Rapapali, 2019; Divergences, 2023). Further research is needed, particularly in country-specific analyses, comparative studies, and policy-oriented research, to inform effective monetary and fiscal policy responses to African inflation. These results are crucial because they reveal that the rate of change in the interactions between money supply, interest rates, and GDP growth rate is a more significant driver of inflation than the absolute levels of these variables. This finding has important implications for policymakers, as it suggests that they should focus on monitoring and managing the dynamics of these interactions, rather than just targeting specific levels of money supply, interest rates, or GDP growth. By doing so, policymakers can develop more effective strategies to control inflation and promote economic stability, ultimately supporting sustainable economic growth and development.

The inflation and interactions of money supply, interest rate, and GDP growth rate nexus refers to the intricate relationships between these macroeconomic variables, where changes in one variable can have ripple effects on the others, ultimately influencing inflation dynamics (Kabundi and Muteba, 2022; Ncube and Ndou, 2022). Understanding these interactions is essential for designing effective monetary policies that balance economic growth with price stability (Divergences, 2023; Svensson, 2022), as changes in interest rates affect borrowing costs and aggregate demand (Mishkin, 2021a; Taylor, 2020), while money supply and GDP growth rate moderate these effects (Woodford, 2022). By recognizing these complex relationships, policymakers can

develop targeted strategies to manage inflation and promote sustainable economic growth.

3. METHODOLOGY

This section presents the methodology of the study. The study used the VECM estimation technique to examine the causality between inflation and interactions of money supply, interest rate, and GDP growth rate. The method is most applicable because it is particularly well-suited for analyzing the relationships between multiple time series and cross-sectional variables that are cointegrated, meaning they have a long-run equilibrium relationship (Engle and Granger, 1987). In this study, VECM is most applicable because it allows for the examination of both short-run and long-run causal relationships between inflation and the interactions of money supply, interest rates, and GDP growth rate, while accounting for potential error correction mechanisms that restore equilibrium in the long run (Johansen, 1995). This makes VECM an ideal methodology for investigating the complex dynamics between these macroeconomic variables (Sims, 1980).

The study follows the causality test as done by Abel and Le Roux (2016) for panel data. Their model is modified to suite the research objective of this study of exploring the causal effect and direction between inflation and MIG Index. To test the Granger non-causality from the MIG Index to inflation, the null hypothesis is H_0: $\beta i = 0$, $forall\ i = 1$ to N. The alternative hypothesis states that there is a causality relationship from MIG Index to inflation for at least one cross-unit of the panel: H_1: $\beta i \neq 0$, for $i = N1 + 1, N1 + 2..., N$; $0 \leq N1/N \leq 1$. The study employs equation (1).

$$\text{Inflation}_{i,t} = \alpha + \sum_{k}^{K} ¥_i^k \text{Inflation}_{i,t-k} + \sum_{k}^{K} \beta_i^K \text{MIG Index}_{i,t-k} + \varepsilon_{i,t} \quad (1)$$

Where is the annual inflation rate for country i at time t, i is from 1 up to N cross units at time t which represents periods (1,2...,T), α denotes the intercept, k represents the number of lags and ε represents the error term including not only the disturbance term but also the cross-unit specific effects.

To test the Granger causality from inflation to MIG Index, the study employs equation (2).

$$\text{MIG Index}_{i,t} = \alpha + \sum_{k}^{K} ¥_i^k \text{MIG Index}_{i,t-k} + \sum_{k}^{K} \beta_i^K \text{Inflation}_{i,t-k} + \varepsilon_{i,t} \quad (2)$$

The null hypothesis is H_0: $\beta i = 0$, $forall\ i = 1$ to N. The alternative hypothesis states that there is a causality relationship from inflation to interactions for at least one cross-unit of the panel: H_1: $\beta i \neq 0$, for $i = N1 + 1, N1 + 2..., N$; $0 \leq N1/N \leq 1$.

The study's four key variables are measured as follows: Inflation is the dependent variable, measured as a percentage change in the consumer price index (CPI), capturing price increases (IMF, 2023). Money supply is measured as M3, including broad money aggregates (Kabundi & Rapapali, 2019). Interest rate is measured as a short-term or long-term rate, reflecting borrowing costs (Gurkaynak et al., 2020). GDP growth rate is measured as the percentage change in real GDP, capturing economic activity (Ncube and Ndou, 2022), while the MIG index measures interactions between money supply, interest rate, and growth rate, providing insights into their combined effects on inflation. These variables are used to examine their influence on inflation. The data is commonly available for all the variables for the years 2010 to 2024 for the five SADC countries of South Africa, Zimbabwe, Botswana, Namibia, and Zambia.

4. RESULTS PRESENTATION AND ANALYSIS

This section presents the results of the study and their interpretation. Firstly, the descriptive statistics are presented in Table 1.

The GDP growth rate data exhibits a mean of 5.969 and a median of 4.080, indicating a positive growth trend with potential skewness due to the difference between the two measures. The standard deviation of 9.405 reveals substantial variability in growth rates. The data ranges from 60.900 to −8.1, showing significant fluctuations. The positive skewness (4.185) indicates a longer tail on the right side, while the high kurtosis (23.141) suggests fat tails, deviating from normality. The Jarque-Bera test statistic (1486.598, P = 0.000) strongly rejects normality, confirming the distribution's significant deviation from normal. The study therefore recommends employing estimation techniques that are robust to non-normally distributed data.

The annual inflation rate data exhibits extreme variability and non-normality, with a mean of 24.812 and a median of 5.710, indicating significant skewness. The high standard deviation of 86.912 reflects substantial fluctuations, and the data ranges widely from −2.430 to 667.4. The positive skewness (6.016) and high kurtosis (42.301) suggest a long tail on the right side and fat tails, respectively, indicating a higher likelihood of extreme values. The Jarque-Bera test (5279.036, P = 0.000) strongly rejects normality, confirming the distribution's non-normality and potentially requiring robust or non-parametric analysis methods. In view of this, the study furthermore, recommends employing estimation techniques that are robust to non-normally distributed data.

The money supply growth rate (M3) data exhibits a mean of 0.582 and a median of 0.550, indicating relatively stable growth. The standard deviation of 0.229 suggests moderate variability, with growth rates ranging from 0.210 to 1.050. The data shows slight

Table 1: Descriptive statistics results

Statistic	GDPGR	INFL	M3	MIG Index
Mean	5.969	24.812	0.582	0.369
Median	4.080	5.710	0.550	0.200
Maximum	60.900	667.400	1.050	2.800
Minimum	−8.100	−2.430	0.210	−0.370
Standard deviation	9.405	86.912	0.229	0.511
Skewness	4.185	6.016	0.281	2.844
Kurtosis	23.141	42.301	1.962	12.259
Jarque-Bera	1486.598	5279.036	4.353	369.037
Probability	0	0.000	0.113	0.000
Observations	75	75	75	75

right-skewness (0.281) and platykurtosis (1.962). The Jarque-Bera test (4.353, P = 0.113) fails to reject normality, suggesting the data does not significantly deviate from a normal distribution, potentially allowing for normality assumptions in further analyses.

The MIG Index data shows a mean of 0.369 and a median of 0.200, indicating positive central tendency with potential skewness. The standard deviation of 0.511 suggests notable variability, with data ranging from −0.370 to 2.80. The distribution is positively skewed (2.844) with fat tails (kurtosis of 12.259), indicating a higher likelihood of extreme values. The Jarque-Bera test strongly rejects normality (P = 0.000), confirming significant deviation from normality and potentially requiring robust or non-parametric analysis methods.

Table 2 presents the correlation coefficients of the variable which is used to cross check for multicollinearity among the independent variables. The study employed the Pearson correlation method) to test for the problem of multicollinearity, the results are in Table 2. The results are rounded to three decimal places.

The Pearson correlation matrix reveals that most variables have coefficients below 0.8, suggesting relatively low multicollinearity among the variables. This indicates that the variables are not highly correlated, reducing concerns about redundancy or inflated variance in regression analysis. However, any coefficients above 0.8 should be examined further to ensure they do not pose issues for the analysis.

Given the cointegration between inflation (I[0]) and interactions of money supply, interest rate, and GDP growth rate (I[1]), VECM is more appropriate than standard VAR as it captures the long-run equilibrium relationship and dynamic adjustment process through the error correction term, while also modeling short-run dynamics (Engle and Granger, 1987; Johansen, 1991). Although VECM is typically used for I(1) variables, its application here can be justified by the strong cointegration relationship, allowing for insights into both short-run and long-run causal relationships (Pesaran and Shin, 1998), but requires careful interpretation due to the mixed orders of integration.

The results suggest that there is a significant long-run relationship between inflation and the interactions of money supply, interest rate, and GDP growth rate (Table 3). The adjustment coefficient of −602.381 for the interactions variable indicates that when the system is out of equilibrium, the interactions variable adjusts to correct the deviation. Specifically, for every unit deviation from the long-run equilibrium, the interactions variable adjusts by −602.381 units. Given the statistically significant t-value (−6.686), this adjustment is significant, suggesting that the interactions variable responds strongly to restore equilibrium. The negative sign implies a corrective mechanism towards the long-run relationship. This result implies that changes in inflation have a significant long-run impact on the interactions of money supply, interest rate, and GDP growth rate, and the interactions variable plays a crucial role in adjusting to maintain the long-run equilibrium.

Table 2: Results for pearson correlation matrix

Variable	INFL	GDPGR	MS	INTR	MIG
INFL	1.00				
GDPGR	−0.03	1.00			
MS	0.11	−0.13	1.00		
INTR	0.56	−0.06	−0.15	1.00	
MIG	0.25	0.86	0.02	0.31	1.00

Source: Owners computation

Table 3: Results for the cointegration equation

Variable	Cointegration Eq	After adjustments standard error	t- statistic.
IINF (−1)	1		
MIG (−1)	602.381	90.094	−6.686

Source: Owners computation

The VECM results provide insights into the causal relationships between inflation and the interactions of money supply, interest rates, and GDP growth rate. The Error Correction Term (ECT) coefficient is −0.041 with a t-value of 0.969, indicating no statistical significance. This suggests that there is no significant long-run causality from the interactions variable to inflation. The coefficients of inflation lagged by one and two periods are −0.778 and −1.488, respectively, both statistically significant (t-values of −6.516 and −5.823). This indicates that past inflation values have a significant negative effect on current inflation changes, suggesting mean-reversion or a self-correcting mechanism in inflation. In contrast, the coefficients for the interactions variable lagged by one and two periods (−11.125 and 11.080) are not statistically significant.

The results suggest no long-run causality from the interactions variable to inflation, given the insignificance of the ECT. Similarly, there is no strong evidence for short-run Granger causality from the interactions variable to inflation, as indicated by the insignificance of the lagged coefficients of the interactions variable. However, inflation's past values significantly influence its current changes.

The VECM results examine the causal relationship between inflation and the interactions of money supply, interest rates, and GDP growth rate, with interactions as the dependent variable. The Error Correction Term (ECT) coefficient is 0.001 with a t-value of 5.295, indicating statistical significance and suggesting long-run causality from inflation to the interactions variable. Inflation's lagged effects on the interactions variable show mixed results. The coefficient of inflation lagged by one period is not significant, but the coefficient of inflation lagged by two periods is significant with a t-value of 2.589. This suggests that inflation has a delayed impact on the interactions variable. The interactions variable's own lagged effects also show significance for the one-period lag, indicating short-run dynamics within itself. The results indicate long-run causality from inflation to the interactions variable, given

Table 4: Causality test results

Error correction model	After adjustment	Standard error	t-value
Cointegration equation	−0.041	0.042	0.969
D (Inf [−1])	0.778	0.119	−6.516
D (Inf [−2])	1.488	0.255	−5.823
D (MIG[−1])	−11.125	25.747	−0.432
D (MIG[−2])	11.080	20.278	0.546
C	12.675	9.358	1.354

the significance of the ECT. In the short run, there is evidence of Granger causality from inflation to the interactions variable, particularly with a two-period lag. This suggests that inflation plays a role in influencing the interactions between monetary policy and economic activity.

The findings of this study, which reveal causality from inflation to interactions of money supply, interest rates, and GDP growth rate, align with the results of several notable studies. For instance, Friedman and Schwartz (1963) demonstrated a significant relationship between inflation and monetary policy variables in their seminal work on monetary history. Similarly, Taylor (1998) emphasized the importance of inflation in determining interest rates and economic activity through his research on monetary policy rules. Mishkin (2007b) also explored the role of inflation targeting in monetary policy, highlighting its impact on economic stability. Furthermore, Bernanke and Gertler (1995) examined the relationship between inflation and economic activity, providing insights into the mechanisms through which inflation influences monetary policy decisions. . Other studies have also contributed to the understanding of inflation's role in shaping economic outcomes. These studies collectively support the notion that inflation plays a crucial role in influencing the interactions between monetary policy variables and economic activity, consistent with the findings of this analysis.

The study conducted robustness tests using the robust ordinary least squares (ROLs) method, which is robust to deviations from normality and heteroscedasticity in the data. This approach helped ensure the reliability of the estimates, given the specific characteristics of the data used in this study.

The robustness findings corroborate the initial results presented in Table 6, reinforcing the notion that inflation exhibits persistence, driven by past inflation experiences and expectations, while the interactions of money supply, interest rates, and GDP growth rate have an inconsequential impact on inflation. This consistency across results lends credence to the conclusion that policymakers should prioritize managing inflation expectations and addressing persistence drivers, rather than relying solely on traditional macroeconomic variable manipulation, thereby informing a more effective policy approach to mitigate inflationary pressures.

The robustness analysis in Table 7 provides compelling evidence that past inflation, lagged by two periods, significantly influences the interactions of money supply, interest rate, and GDP growth rate. Notably, the interactions lagged by one and two periods have an insignificant impact. While the results in Table 7 differ slightly from those in Table 5, which show that the MIG index lagged by one period influences the current MIG index, both sets of results corroborate the existence of causality from inflation to interactions which aligns with the study's primary theme, underscoring the significant role of inflation in shaping the interactions of key macroeconomic variables.

4.1. Diagnostic Tests

The results revealed non-constant variance, indicating the presence of heteroscedasticity (Table 8). Despite this, VECM remains a viable option due to its estimators' retained asymptotic properties, such as consistency and asymptotic normality (Hamilton, 1994; Johansen, 1995). Additionally, VECM exhibits robustness, particularly with large sample sizes, enabling it to handle some degree of heteroscedasticity. The model's emphasis on cointegration relationships yields valuable insights, and employing robust standard errors, like White's heteroscedasticity-consistent standard errors (White, 1980), effectively mitigates the impact on inference.

The normality test results show a P = 0.000, which is less than the typical significance level of 0.05, indicating that the null hypothesis of normality is rejected (Table 9). This suggests that the data does not follow a normal distribution, but this might not be a major issue for VECM estimation, especially with a large sample size (Hamilton, 1994; Johansen, 1995). Robust standard errors can be considered to ensure reliable inference (White, 1980).

Table 5: Causality test results-dependent variable is MIG index

Error correction model	After adjustment	Standard error	t-value
Cointegration equation	0.001	0.000	5.295
D (Inf [−1])	−0.0003	0.001	−0.480
D (Inf [−2])	0.003	0.001	2.589
D (MIG [−1])	−0.286	0.117	−2.449
D (MIG [−2])	0.131	0.092	1.423
C	−0.049	0.043	−1.143

Table 6: Robustness causality results from inflation to MIG index

Variable	Coefficient	Standard error	Z statistic	Prob.
C	2.2008	0.484	4.550	0.000
INFL(−1)	0.511	0.005	109.164	0.000*
INFL(−2)	0.043	0.010	4.227	0.000*
MIG(−1)	−0.331	0.760	−0.435	0.663
MIG(−2)	−0.028	0.727	−0.038	0.970

Source: Owners computation

Table 7: Robustness results from MIG index to inflation

Variable	Coefficient	Standard Error	Z statistic	Prob.
C	0.155	0.028	5.455	0.000
MIG (−1)	0.054	0.045	1.232	0.218
MIG (2)	−0.001	0.043	−0.026	0.979
INF(−1)	0.000	0.000	0.776	0.438
INF(−2)	0.003	0.001	4.447	0.000*

Source: Owners computation

Table 8: Results for heteroskedasticity using the Breusch-pagan test

Chi-squared statistic	60.358
Degrees of freedom	60
Probability value	0.000

Source: Owners computation

Table 9: Normality test results

Jarque-bera test	Value
Test statistic	232.291
Degrees of freedom	2
P-value	0.000

Source: Owners computation

5. CONCLUSION

This study's empirical findings substantiate the paramount importance of inflation dynamics in precipitating consequential alterations in the interplay of pivotal macroeconomic variables, namely money supply, interest rates, and GDP growth rate, in the selected African countries, thereby underscoring the imperative of prioritizing inflation control as a policy desideratum. The unequivocal revelation of a unidirectional causal nexus from inflation to the MIG Index, wherein past inflation levels significantly influence current interactions of these macroeconomic variables, highlights the need for policymakers to adopt a proactive and inflation-targeting approach to monetary policy. By doing so, policymakers can mitigate the deleterious effects of inflationary pressures on macroeconomic stability, foster a propitious environment for sustainable economic growth and development, and ultimately enhance the efficacy of macroeconomic management in the region. The long-run relationship between MIG and inflation implies that monetary policy can be an effective tool for managing inflation. Central banks can use monetary policy instruments, such as interest rates and money supply, to influence inflation expectations and achieve long-term inflation targets. By adjusting MIG, policymakers can mitigate the risks of high inflation and promote economic stability. This relationship highlights the importance of careful consideration and strategic decision-making in monetary policy to balance economic growth and price stability. The implications of these results suggest that policymakers should prioritize inflation control, adopting a proactive approach to manage inflationary pressures, as high inflation can have a ripple effect on other macroeconomic variables, including money supply, interest rates, and GDP growth rate.

Notwithstanding the contributions of this study, several limitations warrant acknowledgment. Firstly, the study's focus on selected African nations precludes generalizability to other regions or countries, thereby necessitating caution in extrapolating the findings. Secondly, the employment of dynamic panel data analysis assumes linearity and temporal stability in the relationships between variables, which may not always obtain.

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