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Economic Policy and Sustainable Development in Sub-Saharan Africa: The Roles of Financial Access, Green Technology, and Trade Openness

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Abstract

Achieving sustainable development remains a major challenge in Sub-Saharan Africa (SSA), despite periods of economic growth and increasing policy interventions across the region. While existing studies have examined the role of fiscal, monetary, and environmental policies independently, limited attention has been given to how these policy dimensions jointly relate to sustainable development and through which mechanisms their effects operate. Using annual panel data for five selected SSA economies from 2005 to 2020, this study examines the relationship between economic policy and sustainable development within a nonlinear and mechanism-based framework. The analysis employs hierarchical regression techniques to assess direct effects, mediation channels, and moderation dynamics. The findings indicate that fiscal and monetary policy exhibit diminishing effects on sustainable development, suggesting that the effectiveness of policy expansion may weaken as intervention intensifies. Environmental pressure, however, is positively associated with sustainable development outcomes. The results further show that access to credit partially mediates the relationship between monetary policy and sustainable development, while green technology serves as a transmission channel linking environmental pressures to sustainable development. In addition, trade openness moderates the relationship between fiscal policy and sustainable development. The findings suggest that policy effectiveness depends not only on the scale of intervention but also on financial access, technological adaptation, and external economic integration.

Keywords

Economic Policy, Sustainable Development, Fiscal Policy, Monetary Policy, Green Technology, Access to Credit, Trade Openness, Sub-Saharan Africa

1. Introduction

Sustainable development has emerged as an increasingly central policy target for both developed and developing economies. Over the past two decades, many countries have recorded improvements in economic growth, poverty reduction, education, healthcare, and environmental management. However, progress toward sustainable development remains unequal among regions, reflecting disparities in institutional capacity, policy effectiveness, and structural conditions (Bie et al., 2023; Sachs et al., 2022). While several Asian economies have achieved rapid industrial transformation alongside improvements in human development, and many European countries have strengthened environmental governance and social welfare systems, many Sub-Saharan African (SSA) economies continue to face persistent development challenges despite periods of economic expansion.

In SSA, poor infrastructure, lack of access to quality health and education, environmental degradation, financial exclusion, and institutional fragility continue to constrain development achievements. Although the region has experienced episodes of economic growth over the past two decades, this growth has not always translated into broad-based and sustainable improvements in living conditions (African Development Bank, 2018; African Development Bank Group, 2023). In many countries, rapid urbanization, dependence on primary commodity exports, exposure to climate-related shocks, and governance constraints continue to undermine long-term development prospects (Adeleye, 2023; Ulucak et al., 2020). As the global world passes the midpoint of the 2030 Sustainable Development Agenda, there is concern about the ability of many African economies to reach major sustainable development targets.

Against this backdrop, the role of economic policy has attracted increasing scholarly and policy attention. Fiscal policy, monetary policy, and environmental policy are usually considered as the three principal tools by which governments impact economic activity, financial conditions and environmental sustainability. Fiscal policy dictates public investment and resource allocation. Monetary policy regulates liquidity and credit conditions. Environmental policy aims to manage externalities to the environment and sustainable production. These policy dimensions collectively constitute a linked policy environment which can determine the path of sustainable development.

Despite the growing importance of these policy tools, the existing literature remains fragmented in several respects. First, much of the empirical literature examines fiscal, monetary, or environmental policy in isolation. Researchers have given relatively limited attention to the joint relationship between these policies and sustainable development outcomes, particularly in SSA economies (Abdullah et al., 2020; Asongu, 2018). Second, many existing studies implicitly assume a linear relationship between policy interventions and development outcomes, despite increasing evidence that policy effectiveness may weaken beyond certain levels due to institutional, financial, and structural constraints (Fotis & Polemis, 2018; Nuru & Gereziher, 2022). Third, researchers have given comparatively little atten-

tion to the mechanisms that transmit these policy effects. In particular, the mediating roles of access to credit and green technology, as well as the conditioning role of trade openness, remain insufficiently explored within the SSA context.

These gaps are particularly pertinent considering the structural features of SSA economies. In many countries within the region, weak financial systems constrain the transmission of monetary policy to productive investment, while limited technological capacity affects the adoption of environmentally sustainable production methods. At the same time, initiatives like the African Continental Free Trade Area (AfCFTA) are changing trade relations and creating new opportunities and vulnerabilities for development policy through increased regional integration (Abrego et al., 2020; African Union, 2020). As a result, understanding how policy effectiveness interacts with financial access, technological adaptation, and trade openness has become increasingly important.

This study contributes to the literature by examining the relationship between economic policy and sustainable development in selected SSA economies using a multidimensional approach. Specifically, the study considers fiscal policy, monetary policy, and environmental conditions simultaneously, while also incorporating access to credit and green technology as transmission channels and trade openness as a moderating factor. Unlike much of the existing literature, the study further considers the possibility that policy effects may be nonlinear rather than linear across all levels.

Using annual panel data for five SSA economies over the period 2005-2020, we employ a hierarchical regression framework to examine direct, mediating, and moderating relationships. The findings provide evidence that fiscal and monetary policy exhibit diminishing effects on sustainable development, suggesting that policy expansion may become less effective beyond certain levels. Environmental conditions, by contrast, are positively associated with sustainable development, possibly reflecting adaptive responses and technological adjustments. The results further show that access to credit partially mediates the relationship between monetary policy and sustainable development, while green technology serves as a transmission mechanism linking environmental conditions to development outcomes. Furthermore, trade openness plays a moderating role in the relationship between fiscal policy and sustainable development, suggesting that external economic integration partially shapes policy effectiveness.

Our study contributes to the literature in three main ways. First, it advances the growing discussion on nonlinear policy effects by showing that macroeconomic policy effectiveness may depend on scale and structural conditions. Second, it extends the literature beyond direct policy effects by incorporating financial access and green technology as transmission channels. Third, it emphasizes how trade openness plays a crucial role in influencing policy outcomes in SSA. From a policy standpoint, the findings reveal that more than simply an expansion program is required to attain sustainable development. Instead, the effectiveness of policy interventions is dependent on institutional capacity, financial inclusion, technology

adoption, and the broader external context within which policies function.

The remainder of the paper is structured as follows. Section 2 reviews the relevant literature and conceptual background. Section 3 outlines the methodology and empirical strategy. Section 4 presents and discusses the empirical findings, while Section 5 concludes with policy implications and recommendations.

2. Literature Review and Conceptual Background

In this study, we use concepts from political economy and macroeconomic policy theory to analyze the interaction between economic policy and structural conditions as a determinant of sustainable development outcomes. At its foundation, the political economy perspective underscores that policy decisions are not neutral. Institutional quality, distributional interests, and governance structures influence policy choices, which in turn affect long-term development trajectories (Cardinale & Scazzieri, 2018; Clark, 2016). In the context of sustainable development, this perspective is particularly relevant, as it emphasizes how policy decisions balance short-term economic objectives with long-term environmental and social considerations (Jakob et al., 2020). In this sense, sustainable development is not only a matter of the intensity of the policy but also of the way policies are developed, executed, and embedded in broader institutional and economic systems. This provides the foundation for examining fiscal policy, monetary policy, and environmental conditions alongside key transmission mechanisms such as financial access, technological adaptation, and external openness.

2.1. Economic Policy and Sustainable Development

Fiscal policy remains one of the primary tools through which governments influence economic activity. Through public spending and taxation, governments can shape aggregate demand, support infrastructure development, and promote social welfare (Gupta, 2014; Samuelson & Nordhaus, 2009). A large body of empirical work suggests that well-targeted fiscal interventions can enhance development outcomes, particularly when directed toward human capital, infrastructure, and environmental sustainability (Anwar et al., 2020; Gramkow, 2020). However, the evidence varies significantly. Weak revenue mobilization, inefficiencies in public spending, and institutional limitations often constrain fiscal expansion in many developing economies (El Husseiny, 2020). For instance, fiscal policy in SSA has demonstrated procyclical behavior, resulting in limited effectiveness in stabilizing development outcomes (Lledó et al., 2011). Some studies even suggest that beyond a certain scale, fiscal expansion may lead to diminishing returns or adverse effects due to misallocation and crowding-out dynamics (Calderón & Nguyen, 2016; Nordheim & van der Wel, 2025).

Monetary policy operates through a different but complementary channel. By influencing interest rates, liquidity, and credit conditions, central banks affect investment, consumption, and financial stability (Mishkin, 2018). While expansionary monetary policy can stimulate growth in the short run, its long-term implica-

tions for sustainable development remain debated. On the one hand, accommodative conditions may support investment in productive and environmentally friendly sectors (Qingquan et al., 2020; Rehman et al., 2023). On the other hand, prolonged monetary expansion may lead to financial imbalances, inflationary pressures, or unequal distributional outcomes (Brunnermeier & Landau, 2022).

The empirical literature, therefore, suggests that the relationship between macroeconomic policy and development is not strictly linear, as policy effectiveness appears to depend on scale, context, and institutional conditions. This has led to growing interest in nonlinear and conditional relationships, particularly in emerging economies where structural constraints are more pronounced (Nuru & Gereziher, 2022; Wu et al., 2024).

This relationship is further complicated by environmental circumstances and policy actions. Environmental policies are designed to absorb externalities, increase resource efficiency, and encourage sustainable production practices (Al-Saidi, 2019; Miller et al., 2023). While some studies demonstrate that environmental regulation enhances development outcomes through improved efficiency and innovation, others report mixed or context-dependent effects (Coscieme et al., 2021; Hsu et al., 2021). In this regard, the literature increasingly recognizes that environmental challenges can induce adaptive responses that contribute to development. This perspective is closely aligned with the argument that environmental policies may stimulate innovation and structural transformation, rather than simply constrain growth (Dasgupta, 2021; Porter & Linde, 1995).

2.2. Transmission Channels: Financial Access and Green Technology

Beyond direct policy effects, recent studies emphasize the importance of transmission mechanisms through which policy influences development outcomes. Access to credit represents a key financial channel. It determines the extent to which households and firms can respond to policy signals by investing, innovating, and expanding productive activities (Pandula, 2013). In theory, expansionary monetary policy improves liquidity and reduces borrowing costs, thereby enhancing credit access and supporting economic activity (Bernanke & Gertler, 1995). Empirical evidence links improved access to credit with entrepreneurship, human capital development, and poverty reduction (Kara et al., 2021; Ratnawati, 2020). However, structural barriers such as high lending costs, collateral requirements, and financial exclusion may limit the transmission of monetary policy to real economic outcomes (Ngumbi et al., 2020). Thus, the effectiveness of monetary policy depends critically on the depth and efficiency of financial systems. This implies that access to credit could act as an intermediate mechanism linking monetary policy to sustainable development.

Green technology is another important transmission channel. Technological innovation plays a key role in improving resource efficiency, reducing environmental

degradation, and supporting sustainable production (Guo et al., 2020; Ren et al., 2022; Suki et al., 2022; Wang et al., 2021). In developing economies, however, access to such technologies remains uneven, often requiring policy support and international transfer mechanisms (Chen, 2018; Manu et al., 2024). One of the main inferences from the theoretical and empirical literature is that environmental pressures and regulatory frameworks can stimulate technology adaptability. Firms that face environmental restrictions can embrace cleaner technologies, enhance efficiency, and move towards more sustainable production practices. (Porter & Linde, 1995; Ren et al., 2022). At the same time, the impact of green technology is not universally positive, as it may involve adjustment costs, labor displacement, or uneven distribution of benefits (Aldieri & Vinci, 2018; Hafezi & Zolfagharinia, 2018). Overall, the body of literature suggests that green technology serves as a link between environmental conditions and development outcomes, mediating the broader relationship between environmental factors and sustainability.

2.3. Trade Openness and Conditional Policy Effects

Trade openness introduces an external dimension to the policy-development relationship. Openness affects resource allocation, productivity and technological diffusion through integrating domestic economies into the world markets (Fujii, 2019). The literature presents two competing perspectives. The gains-from-trade view argues that openness promotes growth, innovation, and environmental improvements through increased income and access to cleaner technologies. In contrast, the race-to-the-bottom argument suggests that countries may weaken environmental standards to attract investment, potentially worsening environmental outcomes (Branstetter & Maskus, 2022).

This tension is proven empirically. While trade can enhance efficiency and generate positive spillovers, it may also increase exposure to external shocks, environmental pressures, and structural dependence (Bombardini & Li, 2020; Hamdi & Hakimi, 2022; Lectard & Rougier, 2018; Oppong-Baah et al., 2022). Based on its detrimental effect, Yona (2021) suggests strict management in the context of liberalization to stop further resource exploitation considering its adverse effect. As result the effects of trade openness are increasingly being regarded as context-dependent, combining with domestic policy and institutional factors. In this way, trade openness should be seen rather as a conditioning element that determines how policy initiatives translate into results. External integration affects market size, competition and access to technology, and so more open economies may react differently to fiscal policy.

Figure 1 provides a comprehensive depiction of the conceptual model.

3. Methodology

This section outlines the empirical approach used to examine how economic policy variables relate to sustainable development. It describes the sample, data sources, variable measurement and empirical strategy.

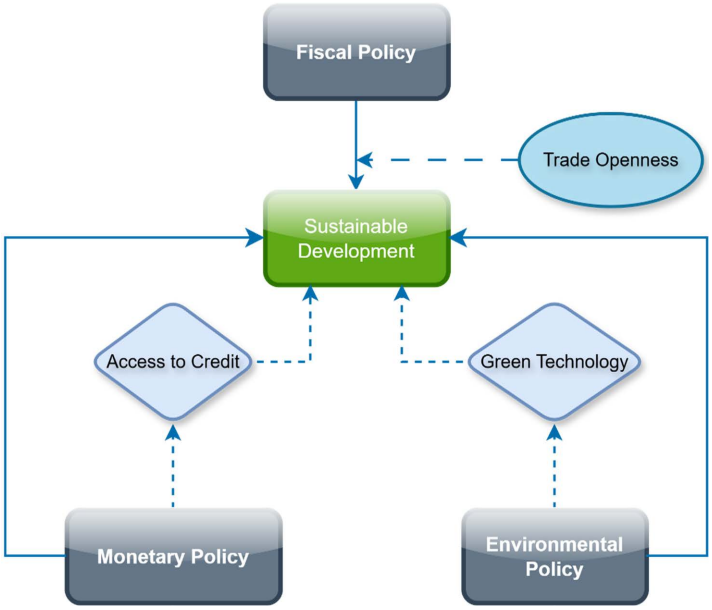

Figure 1. Conceptual framework.

3.1. Sample and Data

The study focuses on a panel of five SSA countries, namely Angola, Botswana, Ghana, Mauritius, and South Africa, over the period 2005-2020. Three considerations guide the selection of these countries. First, the sample reflects variation in income levels and economic structure, including both lower-middle-income (e.g., Ghana, Angola) and upper-middle-income economies (e.g., South Africa, Mauritius, Botswana). This allows the analysis to capture differences in policy effectiveness across development stages. Second, the selected countries represent different sub-regions within SSA, thereby improving the diversity of institutional and economic conditions considered in the analysis. This step is important given the well-documented heterogeneity within the region. Third, and more practically, the selection is constrained by data availability and consistency, particularly for variables such as human development and adjusted net savings, which are not uniformly available across all SSA countries over time. Table 1 presents the list of countries included in the analysis along with their key characteristics.

The study uses annual data covering the period 2005-2020. Most variables are obtained from the World Bank's World Development Indicators (WDI), while data on human development are sourced from the United Nations Development Programme (UNDP). The choice of the sample period is guided by data availability and consistency across countries and variables. This period also captures important structural and policy changes in SSA economies, including post-global financial crisis adjustments and increasing emphasis on sustainability.

The initial balanced panel consists of 80 country-year observations, representing five countries observed over sixteen years. However, a limited number of observations were missing for some variables. Given the small number of missing observations, linear interpolation was employed within countries to maintain

panel consistency and reduce the loss of information. This approach is commonly used in macro panel studies where variables exhibit relatively smooth temporal movements. Thus, the final estimation sample remained largely balanced over the study period.

Table 1. List of sample countries.

Country	Code	Region	Income Group	Lending Category
Angola	AGO	Central Africa	Lower middle income	IBRD
Botswana	BWA	Southern Africa	Upper middle income	IBRD
Ghana	GHA	West Africa	Lower middle income	IDA
Mauritius	MUS	East Africa	Upper middle income	IBRD
South Africa	ZAF	Southern Africa	Upper middle income	IBRD

3.2. Measurement of Variables

For the dependent variable, sustainable development (SD) is proxied using two complementary indicators: the Human Development Index (HDI) and Adjusted Net Savings (ANS). HDI captures improvements in health, education, and living standards, providing a widely used measure of social and economic development (Ofoegbu & Akwu, 2016). ANS, on the other hand, reflects long-term sustainability by accounting for resource depletion, environmental degradation, and investment in human capital (Qasim & Grimes, 2018). The combined use of these measures allows for a broader assessment of development outcomes beyond short-term economic performance.

Both variables were first standardized using z-score transformation to ensure comparability and to minimize scale-related distortions before estimation. Following standard procedures in composite index construction, the sustainable development index was computed as the equally weighted average of the standardized HDI and ANS variables:

$$SD_{it} = \frac{Z\left(HDI_{it}\right) + Z\left(ANS_{it}\right)}{2}, \tag{1}$$

where $Z(.)$ represents the standardized value of each variable for country i at time t.

The use of equal weights is justified on theoretical, empirical and methodological grounds. Theoretically, human development (HDI) and ecological sustainability (ANS) represent conceptually different dimensions with no no clear consensus in the sustainable development literature regarding their relative importance. Assigning differential weights could therefore introduce subjective bias into the index construction process (Decancq & Lugo, 2013; Hickel, 2020). Empirically, equal weighting is widely used in composite index construction because it provides a transparent and parsimonious approach when the underlying dimensions are complementary in nature (Greco et al., 2019; Nardo et al., 2005). Methodologically, given the relatively small sample size used in this study, data-driven

weighting methods such as principal component analysis or factor analysis may produce unstable or sample-sensitive weights. Consequently, equal weighting was considered the most appropriate and consistent approach for aggregating the indicators.

To measure the independent variables, the study considers three key policy-related variables. Fiscal policy (FP) is constructed as a composite measure based on government expenditure and tax revenue, both expressed as a percentage of GDP. These indicators capture the extent of government intervention in economic activity through public spending and revenue mobilization (Chugunov et al., 2021; Slepov et al., 2017).

To ensure comparability across variables with different measurement scales, the component indicators were standardized using z-score transformation prior to aggregation. The fiscal policy index was then computed as the equally weighted average of standardized government expenditure and tax revenue variables:

$$FP_{it} = \frac{Z\left(GE_{it}\right) + Z\left(TR_{it}\right)}{2}, \tag{2}$$

where GE denotes government expenditure and TR represents tax revenue.

Monetary policy (MP) is also measured using a composite indicator comprising the real interest rate and the exchange rate. These variables reflect the stance of monetary conditions and their influence on borrowing costs, liquidity conditions, and external competitiveness. Similar measures have been adopted in earlier empirical studies examining monetary conditions and macroeconomic performance (Irandoust, 2020).

Similarly, the component variables for monetary policy were standardized prior to aggregation to ensure consistency and interpretability of the index. The monetary policy index was computed as:

$$MP_{it} = \frac{Z\left(RIR_{it}\right) + Z\left(EXR_{it}\right)}{2}, \tag{3}$$

where RIR refers to the real interest rate and EXR represents the exchange rate.

CO_2 emissions per capita serve as a proxy for environmental pressures (EP). CO_2 emissions remain one of the most widely used indicators of environmental pressure in the climate and sustainability literature due to their close association with industrial activity, energy consumption, and environmental degradation (Andriamahery et al., 2022; Donkor et al., 2022, 2024). In addition, the use of CO_2 emissions improves comparability with existing international studies. While this measure reflects environmental pressure rather than environmental policy directly, it provides a useful indication of the environmental context within which economic policies operate, and sustainable development outcomes evolve.

We consider two mediating variables for the study. Access to credit (AC) is measured as domestic credit to the private sector by banks (% of GDP). This variable captures the extent to which financial systems support investment and economic activity. Green technology (GT) is proxied by renewable energy consumption (% of total energy use). This reflects the adoption of cleaner technologies and

sustainable energy practices.

Trade openness (TO) is used as the mediating variable for the fiscal policy-sustainable development nexus. In line with previous empirical studies by Agyei & Idan (2022) and Malefane (2018), we measure trade openness as total trade (exports plus imports) as a percentage of GDP. This captures the degree of integration into the global economy and its potential role in shaping policy effectiveness.

The model also includes GDP growth, inflation, and political stability as control variables. GDP growth captures overall economic performance, while inflation reflects macroeconomic stability. Political stability is included to account for institutional quality and governance, which are important determinants of development outcomes (Asongu & Odhiambo, 2021). **Table 2** presents the variables and their measurement methods.

Table 2. Description of variables.

Variable	Abbreviation	Measurement	Source
Sustainable Development	SD	Composite of HDI and ANS	UNDP, WDI
Fiscal Policy	FP	Tax revenue (% GDP) and Government expenditure (% GDP)	WDI
Monetary Policy	MP	Real interest rate and exchange rate	WDI
Environmental Policy	EP	CO_2 emissions (metric tons per capita)	WDI
Access to Credit	AC	Domestic credit to private sector by banks (% GDP)	WDI
Green Technology	GT	Renewable energy consumption (% total energy use)	WDI
Trade Openness	TO	Trade (% of GDP)	WDI
GDP Growth	GDP_G	Annual GDP growth rate (%)	WDI
Inflation	INF	Consumer price index (annual %)	WDI
Political Stability	Pol_S	Political stability index	WGI

3.3. Empirical Strategy and Model Specification

To examine the relationship between economic policy and sustainable development, we employ a hierarchical regression approach. This approach is suitable given the multidimensional nature of the analysis, which involves nonlinear effects, mediation mechanisms, and moderation dynamics.

The use of hierarchical regression offers several advantages. First, it allows variables to be introduced sequentially, making it possible to observe how the inclusion of additional explanatory factors alters the estimated relationships between economic policy and sustainable development. This staged estimation process is useful for identifying the incremental explanatory contribution of mediating and moderating variables (Aiken et al., 1991; Hayes, 2022). Second, the approach provides a flexible framework for examining potential nonlinear relationships through

the inclusion of squared terms. The literature suggests that macroeconomic policy effects may not be strictly linear, particularly in developing economies where institutional and structural constraints may weaken policy effectiveness beyond certain levels (Nuru & Gereziher, 2022; Wu et al., 2024). The inclusion of squared fiscal and monetary policy terms therefore allows the analysis to capture possible diminishing effects associated with policy expansion. The squared environmental term (EP^2) is introduced in the mediation analysis to examine whether environmental conditions influence green technology adoption in a nonlinear manner. This specification is theoretically plausible because lower levels of environmental pressure may generate limited incentives for technological adjustment, whereas higher levels of environmental stress may induce stronger responses through cleaner production methods, renewable energy adoption, and green innovation. Third, studies involving mediation and moderation analysis widely use hierarchical regression because it systematically introduces explanatory mechanisms across estimation stages. In the present study, access to credit and green technology are introduced as mediating variables to examine the channels through which monetary policy and environmental conditions influence sustainable development. Similarly, interaction terms are incorporated to assess whether trade openness conditions the relationship between fiscal policy and sustainable development.

In estimating the models, we include country fixed effects and year fixed effects to control for unobserved country-specific heterogeneity and time-specific shocks that may affect sustainable development across countries. This approach helps reduce omitted variable bias arising from time-invariant country characteristics such as institutional structure, geographical conditions, and historical differences. In addition, we employ robust standard errors clustered at the country level to address potential heteroskedasticity and serial correlation within countries over time.

In line with these objectives, the baseline model is specified as follows:

$$SD_{it} = \beta_0 + \beta_1 FP_{it} + \beta_2 FP_{it}^2 + \beta_3 MP_{it} + \beta_4 MP_{it}^2 + \beta_5 EP_{it} + \beta_6 CV_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (4)$$

where SD_{it} represents sustainable development for country i at time t, FP denotes fiscal policy, MP captures monetary policy, EP represents environmental conditions, and CV refers to the vector of control variables, including GDP growth, inflation, and political stability. μ_i captures country-specific fixed effects, while λ_t represents year-specific effects.

To examine the mediating roles of access to credit and green technology, the study estimates the following mediation equations:

$$AC_{it} = \alpha_0 + \alpha_1 MP_{it} + \alpha_2 MP_{it}^2 + \alpha_3 CV_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (5)$$

$$GT_{it} = \alpha_0 + \alpha_1 EP_{it} + \alpha_2 EP_{it}^2 + \alpha_3 CV_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (6)$$

where AC represents access to credit and GT denotes green technology. The first model examines whether monetary policy influences access to credit, while

the second model investigates whether environmental conditions affect green technology adoption through nonlinear effects. The inclusion of the squared environmental term (EP^2) is intended to capture the possibility that higher levels of environmental pressure may create stronger incentives for cleaner production methods, green innovation, and renewable energy adoption.

To examine mediation effects, the mediating variables are introduced into the baseline specification in subsequent stages of estimation. Moderation effects are assessed through interaction terms between trade openness and fiscal policy variables. Given the inclusion of squared and interaction terms, all nonlinear variables are mean-centered prior to estimation to reduce potential multicollinearity and improve coefficient interpretability, following standard practice in nonlinear modeling (Aiken et al., 1991). Finally, to address potential endogeneity concerns, the study employs a Two-Stage Least Squares (2SLS) approach as a robustness check, using GDP growth and its squared term as instrumental variables.

4. Results and Discussion

4.1. Descriptive Statistics and Correlation Analysis

Table 3 presents the descriptive statistics and pairwise correlations for all variables included in the analysis. The summary statistics show moderate variation across variables, with standard deviations that are generally comparable to their respective means, suggesting reasonable dispersion without extreme volatility in the data. The correlation coefficients are also below conventional thresholds of concern, indicating that multicollinearity is unlikely to pose a serious problem in the regression analysis.

Concerning central tendency, trade openness records the highest mean value (1.265), followed by fiscal policy (1.084) and green technology (1.011), while sustainable development exhibits a relatively low mean (0.073). The relatively large

Table 3. Descriptive statistics and correlation coefficients.

Variables	SD	FP	MP	EP	AC	GT	TO
SD	1.00						
FP	0.264**	1.00					
MP	0.331**	0.217**	1.00				
EP	0.378**	0.188**	0.310**	1.00			
AC	0.286**	0.293*	0.285**	0.332**	1.00		
GT	0.242*	0.326**	0.192*	0.173**	0.218**	1.00	
TO	0.187*	0.412**	0.418**	0.204**	0.184**	0.476**	1.00
Mean	0.073	1.084	0.793	0.685	.0904	1.011	1.265
Std. Dev.	0.801	0.763	0.643	0.913	0.805	0.733	0.707

Note: ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively; Std.Dev. = Standard Deviation; SD = Sustainable Development; FP = Fiscal Policy; MP = Monetary Policy; EP = Environmental Policy; AC = Access to Credit; TO = Trade openness.

standard deviations observed for environmental pressure (0.913) and access to credit (0.805) indicate notable cross-country and temporal variation within the sample.

Turning to the correlation matrix, the results indicate that sustainable development is positively associated with all key explanatory variables. Fiscal policy (r = 0.264), monetary policy (r = 0.331), and environmental pressure (r = 0.378) all exhibit positive and statistically significant relationships with sustainable development. These correlations are consistent with previous assumptions, but they are simple pairwise associations and do not establish causation. The intermediary variables also display meaningful associations with policy indicators. Access to credit is positively correlated with both fiscal policy (r = 0.293) and monetary policy (r = 0.285), suggesting that expansion in policy instruments may coincide with improved financial access. Similarly, green technology shows a positive relationship with environmental pressure (r = 0.173), although the magnitude of this association is relatively modest. Trade openness is positively correlated with fiscal policy (r = 0.412) and monetary policy (r = 0.418), indicating that more open economies tend to exhibit stronger policy activity. Its direct correlation with sustainable development is positive but weaker (r = 0.187), suggesting that its role may be more relevant through interaction effects rather than direct influence.

4.2. Policy Effects on Sustainable Development

Table 4 presents the baseline results from the hierarchical regression model used to examine the nonlinear effects of fiscal policy on sustainable development. To reduce potential multicollinearity, all interaction and squared terms were mean-centered prior to estimation. The analysis follows a hierarchical approach, where variables are introduced in stages to assess their incremental contribution to explaining variations in sustainable development outcomes.

The baseline results provide initial evidence on how key policy variables relate to sustainable development. Beginning with fiscal policy, Model 1 shows that the squared term of fiscal policy (FP^2) carries a negative and statistically significant coefficient ($\beta = -0.019$, $p < 0.05$). Model 2 also reveals a similar pattern for monetary policy, where the squared term (MP^2) carries a negative and significant coefficient ($\beta = -0.325$, $p < 0.05$). These findings suggest the presence of diminishing returns to both fiscal and monetary policy in relation to sustainable development. In practical terms, policy expansion may initially support development outcomes, but further intensification appears to yield smaller gains and may eventually become counterproductive. It is important to note, however, that the current specification relies primarily on squared terms. As such, the results should be interpreted as indicative of nonlinear effects rather than conclusive evidence of a precise inverted U-shaped relationship or a clearly defined optimal threshold. This interpretation is consistent with the broader fiscal literature. For instance, excessive fiscal expansion can lead to inefficiencies, misallocation of resources, and crowding-out of private investment, particularly in economies with limited insti-

tutional capacity (Park & Meng, 2024; Zhang et al., 2022). In a similar vein, prolonged accommodative monetary policy may support short-term growth but can generate inflationary pressures or financial imbalances that weaken long-term sustainability (Brunnermeier & Landau, 2022). In this sense, the results suggest that policy effectiveness is a function of direction, scale and context.

Table 4. Hierarchical regression results.

	SD								
Variables					AC		GT		TO
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
FP^2	−0.019**								
MP^2		−0.325**							
EP			0.662***						
MP^2	−0.291**				−0.165*	−0.179**			
EP^2	0.245**						0.211***	0.301**	
AC	0.152	0.386	0.351						
GT	0.279**	0.416	0.183*						
TO									
TO × FP									−0.106**
TO × FP^2									0.164*
Pol_S				.503***					
GDP_G				.153**					
INF				−.150**					
R^2	0.522	0.314	0.412	0.080	0.498	0.527	0.060	0.496	0.387
Adjusted R^2	0.517	0.312	0.410	0.093	0.498	0.029	0.060	0.435	0.384

***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Turning to the environmental factor, Model 3 indicates that environmental pressure is positively and significantly associated with sustainable development (β = 0.662, $p < 0.01$). This finding suggests that higher levels of environmental-related activity are correlated with improved development outcomes within the sample. One possible explanation is that countries facing environmental pressures may respond through targeted adaptive strategies. These include public and private investments in clean technologies, stricter enforcement of emissions standards, and policy incentives for energy efficiency. Over time, such measures can induce process innovation, encourage resource productivity, and redirect investment toward sustainable sectors. This aligns with the Porter hypothesis, which

posits that well-designed environmental regulation stimulates technological change and enhances competitiveness (Porter & van der Linde, 1995). More recent empirical evidence from developing economies further supports this mechanism, showing that environmental stress, when met with institutional responsiveness, can catalyze green structural transformation and contribute to improved economic and social outcomes (Manu et al., 2024; Marimuthu et al., 2021).

Model 4 introduces the control variables, and the results behave largely as expected. Political stability is positively associated with sustainable development ($\beta = 0.503$, $p < 0.01$), highlighting the importance of institutional quality and governance in supporting long-term development. This finding is in line with the view that stable political environments reduce uncertainty, improve policy implementation, and encourage investment (Bilal, 2019; North, 2018). GDP growth also shows a positive and significant relationship ($\beta = 0.153$, $p < 0.05$), indicating that economic expansion remains an important driver of development outcomes in emerging economies. In contrast, inflation is negatively associated with sustainable development ($\beta = -0.150$, $p < 0.05$), reflecting the widely held view that macroeconomic instability can erode welfare and distort investment decisions.

These findings emphasize the importance of creating policies that are configured to specific situations and context. For instance, fiscal policy is likely to be more effective when aligned with long-term development priorities such as infrastructure, human capital, and sustainable technologies (Anwar et al., 2020; Gramkow, 2020). However, beyond a certain scale, such interventions may face diminishing returns if governance constraints, absorptive capacity, or fiscal sustainability are not adequately addressed. A similar argument applies to monetary policy. While expansionary monetary conditions can support sustainable development through improved liquidity and credit access, excessive easing may reduce effectiveness over time. This aligns with the financial intermediation perspective, where lower interest rates stimulate investment, including in environmentally friendly sectors, but may also lead to credit misallocation if maintained for prolonged periods (Oyetade et al., 2022; Qingquan et al., 2020). In addition, monetary policy can support sustainable development by promoting financial inclusion and improving access to finance for underserved groups, thereby strengthening the social and economic dimensions of development. This finding is consistent with the argument advanced by Zaei et al. (2018), who contend that improved financial access can enhance welfare, stimulate productive investment, and reduce socio-economic inequalities. However, the extent of these benefits largely depends on the structure, efficiency, and depth of the financial system.

Overall, the baseline results point to a conditional and nonlinear relationship between macroeconomic policy and sustainable development. Moderate policy intervention appears beneficial, but excessive expansion may weaken the sustainability of outcomes. At the same time, environmental pressures and institutional conditions play a complementary role in shaping development trajectories.

4.3. Mediating Role of Access to Credit and Green Technology

To examine the potential transmission channels through which policy variables influence sustainable development, we apply a stepwise mediation approach following the logic of Baron & Kenny (1986). This allows us to assess whether access to credit and green technology serve as intermediate pathways linking monetary and environmental variables to sustainable development outcomes.

From **Table 4**, the results in Model 5 show that the squared term of monetary policy (MP^2) is negatively and significantly associated with access to credit ($\beta = -0.165$, $p < 0.05$). This suggests that as monetary policy expands, access to credit initially improves but may weaken beyond a certain point, reflecting possible diminishing effectiveness of monetary expansion in deepening financial access. It is important to interpret this result cautiously. While the negative squared term points to potential nonlinearity, the model does not fully establish a complete inverted relationship. Thus, the evidence suggests that the impact of monetary policy on credit access may vary depending on its intensity.

Building on this, model 6 incorporates access to credit into the sustainable development equation. The coefficient of MP^2 remains statistically significant, although its magnitude declines (from $\beta = -0.291$ to $\beta = -0.179$). This suggests that access to credit accounts for part of the relationship between monetary policy and sustainable development, indicating partial mediation.

The results regarding the mediating role of access to credit show that monetary policy has direct and indirect effects on sustainable development through its effect on financial access. This is consistent with the financial intermediation view, which holds that monetary policy affects real economic outcomes through the credit channel by altering borrowing conditions and liquidity in the economy. For emerging economies, improved access to credit can support investment in productive sectors, enhance entrepreneurship, and facilitate human capital development, thereby contributing to general development outcomes (Kara et al., 2021; Ratnawati, 2020). However, the weakening effect observed at higher levels of monetary expansion may reflect structural constraints within the financial system, such as limited absorptive capacity, inefficiencies in credit allocation, or increased financial risks. As a result, the effectiveness of monetary policy in promoting sustainable development through credit access appears to depend on the strength and depth of financial institutions.

The mediation analysis for environmental factors follows a similar logic for green technology. Based on **Table 4**, model 7 shows that the squared term of environmental pressure (EP^2) is positively associated with green technology ($\beta = 0.211$, $p < 0.01$). This implies that higher levels of environmental pressure may encourage the adoption of cleaner technologies, possibly as a response to environmental constraints or regulatory pressures. When green technology is introduced into the sustainable development model (Model 8), the coefficient of EP^2 increases (from $\beta = 0.245$ to $\beta = 0.301$), while remaining statistically relevant. This pattern is evidence of partial mediation, showing that green technology is one of the path-

ways that link environmental circumstances to sustainable development outcomes. This finding is consistent with the argument that environmental pressures can stimulate technological adaptation and innovation. As firms and governments respond to environmental challenges, they may adopt cleaner production methods, invest in renewable energy, or improve resource efficiency, all of which contribute to sustainable development (Ren et al., 2022; Yuan & Zhang, 2020). In this sense, green technology acts as a bridge between environmental conditions and long-term development outcomes. At the same time, the relatively moderate strength of the mediation effect suggests that green technology is only one part of a broader adjustment process. Other factors, such as institutional quality, regulatory effectiveness, and access to finance, are likely to influence how environmental pressures translate into technological change.

The mediation results overall confirm a channel-based understanding of policy effects. Monetary policy appears to influence sustainable development partly through access to credit, whereas environmental factors operate partly through green technology. Importantly, the evidence supports partial rather than full mediation, indicating that these channels complement rather than fully explain the observed relationships. Hence, sustainable development outcomes are a mixture of the direct policy effects and indirect transmission routes. These findings are consistent with the notion that sustainable development cannot be achieved by policy growth alone. It also depends on the efficacy of supporting institutions (notably financial markets and technological capability) that transform policy initiatives into actual economic and environmental results.

4.4. Moderating Role of Trade Openness

The final stage of the analysis examines whether trade openness conditions the relationship between fiscal policy and sustainable development. To this end, Model 9 introduces interaction terms between trade openness (TO) and both the linear and squared components of fiscal policy. The results from **Table 4** indicate that the interaction between trade openness and fiscal policy (TO × FP) is negative and statistically significant ($\beta = -0.106$, $p < 0.05$), while the interaction between trade openness and the squared fiscal term (TO × FP^2) is positive and significant ($\beta = 0.164$, $p < 0.10$). These coefficients demonstrate that the fiscal policy influence is not merely strengthened or weakened by trade openness. Instead, it modifies how fiscal policy and sustainable development are related. The trend of coefficients therefore indicates that trade openness moderates the nonlinear component of fiscal policy, influencing how the marginal effect of fiscal policy evolves across different levels of policy intensity. In other words, the degree of external economic integration affects fiscal policy's efficacy in addition to its scope, as was previously mentioned.

To provide a clearer interpretation, we evaluate the marginal effects at different levels of trade openness (mean, mean minus one standard deviation, and mean plus one standard deviation), following the approach suggested by Aiken et al.

(1991). The interaction plot (**Figure 2**) shows that, at higher levels of trade openness, the relationship between fiscal policy and sustainable development becomes more pronounced and exhibits a stronger curvature. By contrast, at lower levels of openness, the effect appears weaker and more dampened. This suggests that trade openness enhances the responsiveness of sustainable development outcomes to fiscal policy changes. One possible explanation is that more open economies are better able to translate fiscal interventions into productive outcomes due to access to larger markets, technology transfer, and greater competitive pressures. As a result, sectors that support long-term development, such as infrastructure, innovation, and environmental sustainability, may more effectively channel public spending and fiscal incentives. This interpretation is consistent with the literature that suggests that trade openness can improve resource allocation and productivity by exposing domestic firms to international competition and facilitating knowledge spillovers (Apergis & Cooray, 2016; Branstetter & Maskus, 2022). In addition, openness may expand the fiscal space available to governments by increasing economic activity and broadening the tax base, thereby enabling more effective policy implementation.

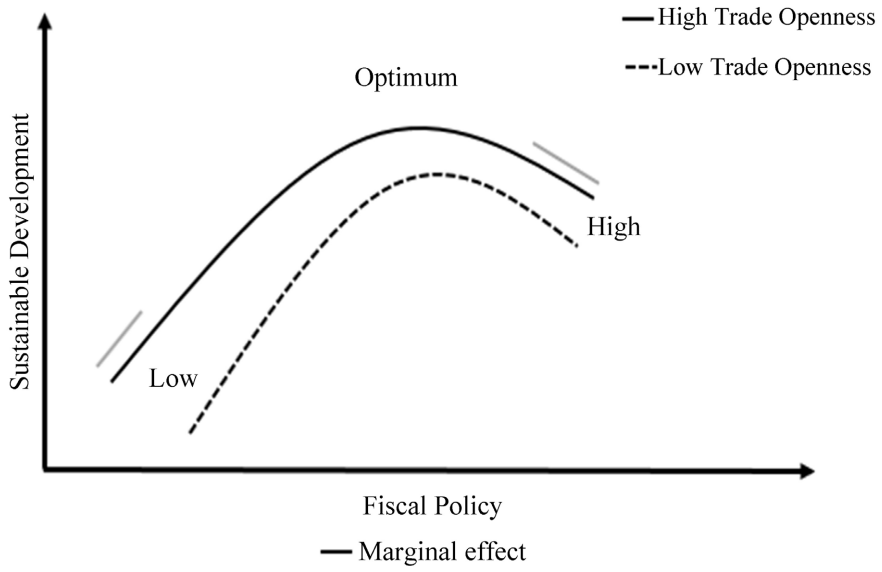

Figure 2. Interaction graph.

Concurrently, the results also suggest that greater openness may amplify both the positive and negative aspects of fiscal policy. While moderate levels of fiscal intervention may yield stronger development gains in open economies, excessive policy expansion may also lead to sharper declines in effectiveness. This reinforces the earlier finding that policy outcomes are conditional and context dependent. Therefore, the evidence offers qualified support for trade openness's moderating role. Trade openness seems to change the link between fiscal policy and development, making policy effects more context- and scale-sensitive rather than universally increasing it. Policymakers should design fiscal strategies aimed at promot-

ing sustainable development with careful attention to the external economic environment. In more open economies, well-targeted fiscal interventions may generate stronger development outcomes. However, policymakers must also remain mindful of the risks associated with overexpansion, particularly in settings where openness exposes the economy to external shocks and competitive pressures.

4.5. Endogeneity Test

A potential concern in the analysis is the possibility of endogeneity between economic policy variables and sustainable development. To address this issue, we employ a Two-Stage Least Squares (2SLS) approach, using GDP growth (GDP_G) and its squared term as instruments. The rationale is that macroeconomic performance may influence the scale and orientation of policy decisions, while its direct link to sustainable development is more indirect and operates through policy channels. Table 5 reports the results of the endogeneity test.

Table 5. Endogeneity test.

Dependent variables	FP	FP^2	MP^2	EP	SD		
	Model 10	Model 11	Model 12	Model 13	Model 14	Model 15	Model 16
Methods	1st Stage				2nd Stage		
GDP_G	0.098** (0.097)		−0.159* (0.262)	0.238*** (0.754)			
GDP_G^2		−0.214** (0.104)					
FP^2					−0.318** (0.213)		
MP^2						−0.204** (0.144)	
EP							0.188** (0.098)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	16	16	16	16	16	16	16

Notes: ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. The numerical value enclosed in parentheses represents the standard deviation. GDP_G = GDP growth.

It is important to acknowledge that the validity of any instrumental variable depends on two key conditions: relevance and exogeneity. The first-stage results (Models 10 - 13) provide evidence on relevance. GDP growth and its squared term show statistically significant associations with the endogenous policy variables. For example, GDP growth is positively related to fiscal policy ($\beta = 0.098$, $p < 0.05$) and environmental pressure ($\beta = 0.238$, $p < 0.01$), while its squared term is negatively associated with fiscal policy squared ($\beta = -0.214$, $p < 0.05$). These patterns

suggest that the instruments are correlated with the policy variables, satisfying the relevance condition. However, it is equally important to interpret the exogeneity assumption with caution. While GDP growth may influence sustainable development through policy adjustments, it may also be directly related to development outcomes, particularly in emerging economies. As such, the instrument should be viewed as a practical approximation rather than a strictly exogenous source of variation. This limitation is acknowledged when interpreting the results.

Turning to the second-stage estimates (Models 14 - 16), the core relationships remain broadly consistent with the baseline findings. The coefficient on fiscal policy squared (FP^2) remains negative and statistically significant ($\beta = -0.318$, $p < 0.05$), reinforcing the earlier evidence of diminishing returns to fiscal policy. A similar pattern is observed for monetary policy squared (MP^2), which also retains a negative and significant coefficient ($\beta = -0.204$, $p < 0.05$). These results suggest that, even after accounting for potential endogeneity, the nonlinear relationship between macroeconomic policy and sustainable development persists. In addition, environmental pressure continues to exhibit a positive and statistically significant association with sustainable development ($\beta = 0.188$, $p < 0.05$). This finding is consistent with the earlier interpretation that environmental challenges may induce adaptive responses, including investment in cleaner technologies and improvements in resource efficiency, which support development outcomes. The 2SLS results therefore provide supporting evidence for the baseline findings, indicating that the observed relationships are not solely driven by reverse causality or omitted variable bias.

5. Conclusion and Policy Implications

This study set out to examine how components of the economic policy mix relate to sustainable development in selected Sub-Saharan African (SSA) economies. Specifically, it considered the roles of fiscal policy, monetary policy, and environmental conditions, alongside the mediating effects of access to credit and green technology and the moderating role of trade openness.

The findings reveal several important insights. First, fiscal and monetary policy exhibit signs of nonlinear and diminishing effects on sustainable development. While policy expansion appears to support development outcomes at lower levels, further intensification yields smaller gains and may weaken effectiveness over time. Second, environmental pressure is positively associated with sustainable development, suggesting that environmental challenges may induce adaptive responses such as technological adjustment, regulatory action, and shifts toward more sustainable production practices. Third, the results highlight the importance of transmission channels. Monetary policy appears to influence sustainable development partly through access to credit, while environmental conditions operate partly through green technology. The results indicate that the transmission of policy impacts is neither direct and equal but depends on the underlying financial and technological frameworks. Fourth, trade openness has a conditioning func-

tion in terms of the translation of fiscal policy into development outcomes. Openness seems to change the response of sustainable development to fiscal policy. This makes the results more sensitive to the intensity of policy and the larger external environment.

5.1. Theoretical Implication

The findings offer important contributions to the growing literature on economic policy and sustainable development. Existing studies provide mixed evidence regarding the developmental effects of fiscal, monetary, and environmental policies. While some studies argue that policy interventions stimulate sustainable development, others suggest that excessive or poorly coordinated interventions may generate inefficiencies and weaken long-term outcomes. The present study contributes to this debate by providing evidence that the relationship between economic policy and sustainable development is nonlinear and conditional rather than purely linear or deterministic.

More specifically, the results suggest that the effectiveness of fiscal and monetary policy depends on their scale, composition, and wider institutional environment. The negative and significant coefficients associated with the squared terms indicate diminishing returns to policy expansion, implying that policy interventions may initially enhance sustainable development but become less effective when policy intensity exceeds the absorptive capacity of the economy. In this regard, the study extends traditional Keynesian and growth-based perspectives by showing that macroeconomic interventions alone do not automatically translate into sustainable outcomes. Instead, developmental gains appear to depend on complementary institutional and structural conditions, including governance quality, financial depth, and productive capacity.

The study also contributes to the literature by going beyond a narrow emphasis on direct policy effects. The analysis shows that the transmission of policy effects is transmitted through major structural channels by including mediation and moderation processes. In particular, the mediating role of access to credit refines financial intermediation theory by showing that the effectiveness of monetary policy depends on the ability of the financial system to channel resources toward productive and socially beneficial activities. Similarly, the findings relating to green technology provide support for ecological modernization theory and the Porter hypothesis. The positive mediating role of green technology suggests that environmental pressure and environmentally oriented policies may stimulate innovation, technological adaptation, and cleaner production processes, which subsequently improve sustainable development outcomes. However, the findings also indicate that environmental regulation alone may not be sufficient. Its effectiveness appears to depend on complementary conditions such as technological readiness, financing capacity, and institutional enforcement mechanisms.

Furthermore, trade openness plays a moderating role, reinforcing the argument that external integration and structural readiness shape policy outcomes. The re-

sults suggest that openness to trade can strengthen the developmental effects of fiscal policy by improving market access, encouraging technology transfer, enhancing competition, and expanding productive opportunities. This supports institutional and endogenous growth perspectives, which argue that external integration can enhance policy effectiveness when supported by appropriate domestic structures and governance systems.

5.2. Policy Implication

The findings carry several practical implications for policymakers and economic actors in SSA. First, the results suggest that policy effectiveness depends on balance rather than scale alone. Fiscal and monetary policies can support sustainable development when appropriately calibrated, but excessive expansion may reduce their effectiveness. This implies that policymakers should adopt a measured and context-sensitive approach, considering institutional capacity, macroeconomic stability, and long-term sustainability objectives. In the case of fiscal policy, this means prioritizing productive and targeted expenditures, particularly in areas such as infrastructure, human capital, and sustainable technologies. However, policymakers must also focus on fiscal sustainability and efficiency, as poorly designed or excessive spending can result in diminishing returns.

Second, the role of monetary policy emphasizes the importance of financial system development. While accommodative monetary conditions can improve access to credit and stimulate investment, their effectiveness depends on the depth and efficiency of financial institutions. Strengthening financial inclusion, improving credit allocation, and reducing structural barriers in lending markets can enhance the transmission of monetary policy to sustainable development outcomes.

Third, the mediation results emphasize the importance of supporting mechanisms. Expanding access to credit and promoting green technology adoption can amplify the positive effects of policy interventions. This suggests the need for complementary policies that encourage financial access, support innovation, and facilitate the diffusion of environmentally friendly technologies.

Fourth, the moderating role of trade openness indicates that external integration shapes policy outcomes. More open economies may be better positioned to translate policy interventions into development gains due to access to larger markets, technology transfer, and increased competition. However, openness may also expose economies to external shocks, requiring careful policy coordination. Therefore, policymakers must ensure that supportive domestic policies accompany trade liberalization, strengthening productive capacity, institutional quality, and economic resilience. Governments should prioritize investments in infrastructure, export diversification, industrial upgrading, and human capital development to enable domestic firms to compete effectively in international markets. Strengthening regional trade integration initiatives such as the AfCFTA may also help African economies expand market opportunities while reducing excessive dependence on volatile external markets.

5.3. Limitations and Directions for Future Research

The study acknowledges some limitations despite its insightful information. First, the analysis is based on a relatively small sample of five countries. Although the selected countries provide variation in economic structure and institutional conditions, the findings may not fully capture the broader heterogeneity across SSA economies. Second, the study relies on composite indicators for fiscal policy, monetary policy, and sustainable development. While this approach allows for a broader representation of multidimensional concepts, it may hide the individual effects of specific policy instruments and development indicators. Future studies may therefore consider disaggregated analysis of individual fiscal, monetary, and sustainability components. Third, although the study incorporates nonlinear specifications through squared terms, the current estimation primarily emphasizes the nonlinear components without jointly estimating all corresponding linear terms in the main models. As a result, the findings should be interpreted as indicative of nonlinear or diminishing effects rather than definitive evidence of precise inverted U-shaped relationships or optimal policy thresholds. Future research may extend the analysis by jointly estimating both linear and nonlinear terms to identify turning points more accurately.

Author Contributions

Conceptualization, writing, and original draft preparation: C. L. Supervision and approval for submission: Y. K. Data Analysis and Methodology: C. L. Review and editing: C.L. and J.Y.

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Data Availability Statement

The analysis in this study is based on publicly available data.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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