

Examining the Impact of the African Transformation Index and Sustainable Development Goals in Sub-Saharan Africa: A Panel Data Analysis

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Abstract

Economic transformation is vital for achieving sustainable development in Sub-Saharan Africa (SSA), yet the long-run empirical links between structural transformation indicators and overall Sustainable Development Goal (SDG) performance remain under-explored. This study investigates the long-run impact of the African Transformation Index (ATI) on SDG attainment across 25 SSA countries from 2000 to 2023. Utilizing panel data from the African Center for Economic Transformation and World Development Indicators, we employ Autoregressive Distributed Lag (ARDL) bounds testing and Fully Modified Ordinary Least Squares (FMOLS) estimators to assess five ATI dimensions: diversification, export competitiveness, productivity, technology upgrading, and human well-being. Dumitrescu–Hurlin panel causality tests evaluate heterogeneous cross-country causal dynamics. FMOLS long-run estimates indicate that diversification ($\beta = 0.462$, $p < 0.01$) and human well-being ($\beta = 0.593$, $p < 0.01$) serve as the primary drivers of SDG progress. Conversely, export competitiveness and CO2 emissions exert significant negative effects, signaling structural trade bottlenecks and environmental trade-offs. Technology upgrading and foreign direct investment demonstrate modest positive influences. Short-run dynamics are statistically insignificant across all models, reflecting lag effects in policy implementation. Bi-directional causality exists between SDG attainment and diversification, human well-being, CO2 emissions, and GDP, whereas export competitiveness exhibits uni-directional causality toward SDGs. Long-run SDG convergence in SSA depends heavily on human capital investment and economic diversification. Policymakers must align structural transformation agendas with green growth strategies to mitigate the negative environmental and competitiveness externalities associated with rapid growth.

1. Introduction

Sustainable development in Sub-Saharan Africa (SSA) remains one of the most pressing global challenges of the twenty-first century. Despite decades of international commitments from the Millennium Development Goals (MDGs) to the current 2030 Agenda, the region continues to lag significantly behind other developing regions in achieving meaningful and equitable progress (Sitembo, 2020). The adoption of the Sustainable Development Goals (SDGs) in 2015 created a comprehensive, integrated framework of 17 interlinked goals intended to balance economic growth, social inclusion, and environmental sustainability. Yet SSA faces a distinctly hostile structural environment: narrow economic bases dominated by primary commodity exports, limited technological capacity, weak institutions, persistent poverty, and heightened vulnerability to climate change and global market shocks (Codjoe and Atiglo, 2020; Mbow, 2020).

Against this backdrop, the African Center for Economic Transformation (ACET) developed the African Transformation Index (ATI) in 2014 as a multidimensional diagnostic tool to benchmark economic transformation progress across the continent. The ATI aggregates five dimensions: diversification, export competitiveness, productivity enhancement, technology upgrading, and human well-being, collectively referred to as DEPTH. These dimensions are explicitly designed to capture not merely growth in output but the structural changes necessary for sustained and inclusive development (ACET Report,

2023). Notably, several ATI objectives align closely with specific SDG targets, particularly SDG 1 (no poverty), SDG 8 (decent work and economic growth), SDG 9 (industry, innovation, and infrastructure), SDG 10 (reduced inequalities), and SDG 13 (climate action).

Despite the apparent conceptual complementarity between the ATI framework and the SDG agenda, there is a striking absence of empirical research that formally tests their relationship. Extant scholarship on sustainable development in SSA has focused primarily on the roles of renewable energy (Guo et al., 2023), technological innovation and governance (Ofori et al., 2023), trade openness (Balavac and Pugh, 2016), and environmental impact assessment (Iber and Walmsley, 2021), without examining whether the ATI's transformation indices are statistically associated with SDG outcomes. This gap is consequential: if policymakers cannot establish whether ATI-aligned investments in diversification or technology genuinely shift SDG trajectories, resource allocation across competing development agendas remains insufficiently evidence-based.

This paper addresses that gap through three specific contributions. First, it provides the first panel econometric analysis linking all five ATI sub-indices to the composite SDG performance index for 25 SSA countries from 2000 to 2023. Second, it employs second-generation panel methods, including the Kao (1999) cointegration test, the ARDL bounds approach, and FMOLS, which account for cross-sectional dependence, a critical methodological requirement for SSA panels where economic shocks propagate across national borders. Third, it applies the Dumitrescu and Hurlin (2012) panel causality test to reveal the direction and potential bidirectionality of relationships, offering cleaner policy guidance than coefficient estimates alone.

The remainder of this paper is organized as follows. Section 2 reviews theoretical and empirical literature. Section 3 describes the data, variables, and econometric methodology. Section 4 presents and discusses empirical results. Section 5 concludes with policy recommendations.

2. Literature Review

2.1. Economic Transformation and Development in Sub-Saharan Africa

Economic transformation, understood as the shift from low-productivity, primary-sector activities toward diversified, high-productivity, technology-intensive sectors, has long been recognized as foundational to sustained development (Armah and Baek, 2015). Early structuralist theories (Lewis, 1954; Kuznets, 1966) identified structural change as the engine of growth, a proposition that has found renewed empirical support in recent panel analyses of developing economies (McMillan and Rodrik, 2011). For SSA specifically, however, transformation has proven elusive. The ATI 2023 report documents that the average overall ATI score across 30 African countries is only 30.3 out of 100, underscoring how modest cumulative progress has been relative to the continent's stated development ambitions.

Leadership quality constitutes an important contextual factor. Dartey-Baah (2014) argues that transformational leadership, characterized by a long-term visionary orientation, ethical governance, and inclusive stakeholder engagement, is a prerequisite for achieving the three pillars of sustainable development: economic efficiency, social cohesion, and environmental responsibility. Weak institutions and poor economic management, often cited in ATI country reviews, directly undermine the policy coherence needed to sustain transformation trajectories.

2.2. Sustainable Development Goals in Sub-Saharan Africa

The scholarly consensus confirms that SSA is severely off-track for most SDGs. Using an in-depth analysis of Rwanda, South Africa, and Zambia, Sitembo (2020) finds that goals 1–9, 16, and 17 require the most urgent intervention, while performance on goals 11, 12, and 15 is comparatively stronger. Environmental vulnerabilities compound the challenge: Codjoe and Atiglo (2020) synthesize evidence showing that flooding, drought, and extreme temperatures undermine SDG progress across multiple dimensions simultaneously, from agricultural productivity (SDG 2) to health outcomes (SDG 3) and urban resilience (SDG 11). Iber and Walmsley (2021) further demonstrate a positive correlation between the development of Environmental Impact Assessment (EIA) legislation and SDG attainment, suggesting that institutional frameworks for environmental governance matter beyond direct resource flows.

Structural factors also constrain genuine sustainability. Hamilton and Michael (1999) and Bissoon (2017) report that genuine savings, a broader indicator of national wealth that accounts for natural resource depletion, are negative or near-zero in the overwhelming majority of SSA countries, even when human capital investments are included. Bissoon (2017) further identifies income inequality, poor institutional quality, armed conflict, and natural resource export dependency as principal drags on genuine savings growth. These findings collectively suggest that aggregate GDP growth, while necessary, is insufficient as a proxy for sustainable development progress.

2.3. Key Determinants of SDG Progress: Energy, Technology, Trade, and FDI

Recent panel studies have identified several empirical drivers of SDG performance. Guo et al. (2023) examine 28 SSA countries from 1990 to 2019 using Augmented Mean Group (AMG) and Common Correlated Effects Mean Group (CCEMG) estimators and find that renewable energy and natural resources have a positive but statistically insignificant effect on sustainable development, while fossil fuel consumption exerts a significant negative impact. These findings carry direct relevance for SSA's development trajectory, given the region's expanding energy demand and underdeveloped renewable infrastructure.

Ofori et al. (2023) employ second-generation cross-sectional SUR and two-stage least squares (2SLS) estimators across 46 SSA countries from 1996 to 2020 to investigate the interaction of technological innovation, energy consumption, and governance. Counterintuitively, their results suggest that increased mobile cellular subscription penetration, used as a proxy for technological innovation, is negatively

associated with renewable energy consumption, pointing to complex substitution effects and raising questions about the quality, not just the quantity, of technological diffusion.

Trade openness and export diversification have received attention as determinants of both economic growth and sustainability. Balavac and Pugh (2016) find that trade openness promotes export diversification at the intensive margin in transition economies, linking this to lower output volatility. Shahbaz et al. (2019) confirm that economic growth increases long-run energy consumption while rising oil prices reduce energy demand, suggesting that commodity-dependent SSA economies face inherent tensions between growth-driven energy demand and decarbonization commitments. The role of FDI is similarly contested: while De Soysa and Neumayer (2005) and Asiedu (2006) associate higher FDI with improved genuine savings growth rates, the quality and sectoral composition of inflows remain decisive for whether FDI ultimately supports or undermines SDG objectives.

ICT and digital connectivity represent another contested dimension. Several studies document positive associations between ICT and economic prosperity, SDG attainment, and CO2 emission reduction (Asongu et al., 2017; Shahbaz et al., 2019), while others identify industrial energy rebound effects that generate adverse environmental outcomes (Kumar et al., 2018; Tsaurai, 2019). Latif et al. (2018) identify a strong bidirectional causal relationship between ICT and economic growth in BRICS countries, a pattern that may not generalize to SSA contexts with markedly different institutional and infrastructure conditions.

2.4. Research Gap and Contribution

The foregoing review reveals a consistent gap: while researchers have examined individual drivers of sustainable development in SSA energy, technology, trade, FDI, and governance, no study has empirically assessed whether the ATI's five transformation dimensions collectively and individually influence SDG outcomes. Given that the ATI was explicitly constructed to serve as both a diagnostic and a policy-monitoring tool for SSA governments, establishing its empirical linkage to SDGs is essential for validating its use as a policy anchor. This study fills that gap.

3. Methodology and Data

3.1. Data Sources and Variable Definitions

The study employs annual panel data for 25 Sub-Saharan African countries over the period 2000–2023. The five ATI sub-indices diversification (DIV), export competitiveness (EXP), productivity (PROD), technology upgrading (TECH), and human well-being (WB) are sourced from ACET. The composite SDG performance index (SDI), which serves as the dependent variable, is drawn from the World Bank's Sustainable Development Reporting (SDR) platform. Three control variables, carbon dioxide emissions per capita (CO2), foreign direct investment net inflows (FDI), and GDP per capita (GDP), are obtained from the World Bank's World Development Indicators (WDI). All variables are expressed in natural

logarithms to reduce heteroscedasticity and permit elasticity interpretation of coefficients. Table 1 summarizes all variable definitions.

Table 1
Variable definitions and data sources

Variable (Log)	Code	Definition	Source
Ln(SDG Index)	LSDG	Composite SDG performance index	World Bank SDR
Ln(Diversification)	LDIV	The economy's capacity to produce and export a widening array of goods and services	ACET
Ln(Export competitiveness)	LEXP	Share of non-extractive exports to GDP relative to the global share	ACET
Ln(Productivity)	LPROD	Value added per unit of labor across agriculture, manufacturing, and services	ACET
Ln(Technology)	LTECH	Medium- and high-technology content in total production and exports	ACET
Ln(Well-being)	LWB	Incomes per capita, employment, health, education, and social inclusion outcomes	ACET
Ln(CO2 Emission)	LCO2	Carbon dioxide emissions per capita (metric tons)	WDI
Ln(FDI)	LFDI	Net inflows of foreign direct investment (% of GDP)	WDI
Ln(GDP per capita)	LGDP	Gross domestic product per capita (constant 2015 USD)	WDI

3.2. Model Specification

The baseline long-run equation estimated in this study takes the following form:

$$\ln(SDG)_{it} = \alpha_0 + \beta_1 \ln(DIV)_{it} + \beta_2 \ln(EXP)_{it} + \beta_3 \ln(PROD)_{it} + \beta_4 \ln(TECH)_{it} + \beta_5 \ln(WB)_{it} + \beta_6 \ln(CO2)_{it} + \beta_7 \ln(FDI)_{it} + \beta_8 \ln(GDP)_{it} + \varepsilon_{it} \quad (1)$$

where i indexes countries, t indexes years, α_0 is the country-specific fixed effect, β_k are long-run elasticities, and ε_{it} is the idiosyncratic error term. The a priori expectations for each coefficient are as follows. Diversification (LDIV) is expected to carry a positive sign, reflecting broader income sources, greater employment, and reduced vulnerability to commodity price shocks. Export competitiveness (LEXP) is expected to be positive in principle; however, if export expansion is driven primarily by raw material extraction with limited value addition, the realized coefficient may be negative or negligible. Productivity (LPROD) and technology (LTECH) are both expected to be positive, aligned with SDG 8 and SDG 9, respectively. Well-being (LWB) is unambiguously expected to carry a positive sign, as improvements in health, education, and social outcomes directly map onto core SDG targets. CO2

emissions are expected to be negative, reflecting the environmental cost of industrialization. FDI and GDP per capita are expected to be positive, given their role in financing and scaling productive capacity.

3.3. Cross-Sectional Dependence and Panel Unit Root Tests

Given the economic interconnectedness of SSA countries through trade, aid flows, and common commodity market exposure, cross-sectional dependence (CD) is a plausible feature of the panel. We first apply the Breusch–Pagan LM, Pesaran Scaled LM, and Pesaran CD tests to examine whether the residuals are cross-sectionally independent. Confirmation of CD motivates the use of second-generation panel unit root tests that are robust to this feature. We subsequently apply the Levin–Lin–Chu (LLC) panel unit root test, which assumes a common unit root process and provides asymptotically normal test statistics under the null of a unit root. The LLC model takes the general form:

$$\Delta X_{it} = \alpha_{it} + \beta_1 X_{i,t-1} + \sum_{k=1}^{n_i} \rho_{i,k} \Delta X_{i,t-k} + \varepsilon_{it}, i = 1, \dots, N; t = 1, \dots, T \quad (2)$$

where Δ denotes the first-difference operator, $X_{i,t}$ is the variable of interest for country i at time t , n_i is the optimal lag length selected via the Akaike Information Criterion (AIC), and ε_{it} is an idiosyncratic disturbance assumed to be independently distributed across i .

3.4. Panel Cointegration Test

Given evidence of unit roots, we test for cointegration using the residual-based test proposed by Kao (1999), which derives DF and ADF-type panel cointegration statistics under the null hypothesis of no cointegration. The Kao test is suitable for heterogeneous panels and accommodates fixed effects. The panel cointegration model is expressed as:

$$Y_{it} = \alpha_i + X_{it}'\beta + Z_{it}, i = 1, \dots, N; t = 1, \dots, T \quad (3)$$

where α_i captures individual fixed effects, β is the vector of slope coefficients, and Z_{it} is the stationary error term. Rejection of the null implies a long-run equilibrium relationship among the variables.

3.5. Long-Run and Short-Run Estimation

To jointly estimate long-run and short-run dynamics, we apply the Panel Autoregressive Distributed Lag (ARDL) bounds-testing framework with lag order ARDL (1,1,1,1,1,1,1,1). The ARDL approach is appropriate when variables are $I(0)$, $I(1)$, or a mixture, a common characteristic in macroeconomic panel data, and provides consistent long-run estimates regardless of the exact order of integration.

As a robustness check and to obtain alternative long-run estimates that correct for potential endogeneity and serial correlation in the regressors, we additionally employ the Panel Fully Modified Ordinary Least Squares (FMOLS) estimator. The FMOLS estimator, originally proposed by Phillips and Hansen (1990) and extended to panels by Pedroni (2000), uses a semi-parametric correction to the OLS estimator that

accounts for serial correlation and endogeneity simultaneously, yielding asymptotically unbiased and efficient estimates of long-run cointegrating vectors.

3.6. Panel Causality Test

To determine the direction of causality between the SDG index and each ATI sub-index and control variable, we apply the Dumitrescu–Hurlin (2012) panel causality test. Unlike Granger causality tests that impose homogeneity, the Dumitrescu–Hurlin test allows for heterogeneous causal relationships across cross-sections by averaging individual Wald statistics, which is appropriate given the structural heterogeneity of SSA economies.

4. Results and Discussion

4.1. Cross-Sectional Dependence and Unit Root Tests

Table 2 reports the cross-sectional dependence test results. The Breusch–Pagan LM statistic (971.699, $p < 0.001$), the Pesaran Scaled LM statistic (27.422, $p < 0.001$), and the Pesaran CD statistic (-2.349 , $p = 0.019$) collectively reject the null of cross-sectional independence. This is consistent with the notion that SSA economies are subject to common shocks through commodity markets, aid flows, and regional integration dynamics. The presence of CD validates the use of second-generation panel methods.

Table 2
Cross-sectional dependence test results

Test	Statistic	d.f.	Prob.
Breusch-Pagan LM	971.699	300	0.0000
Pesaran Scaled LM	27.422	—	0.0000
Pesaran CD	-2.349	—	0.0188

Table 3 presents the panel unit root results. The LLC test statistics for all nine variables LSDG, LDIV, LEXP, LPROD, LTECH, LWB, LCO2, LFDI, and LGDP are statistically significant at the 1% level after first differencing, confirming that each series is integrated of order one, $I(1)$. This finding rules out the use of standard OLS estimation and motivates cointegration analysis.

Table 3
Panel unit root test results (LLC test at first difference)

Variable	t-statistic
LSDG	-2.183***
LDIV	-2.282***
LEXP	-1.782***
LPROD	-2.037***
LTECH	-2.296***
LWB	-1.542***
LCO2	-2.501***
LFDI	-2.932***
LGDP	-3.185***
<i>Note: *** denotes significance at the 1% level. All variables are stationary at first difference, I(1).</i>	

4.2. Cointegration Results

Table 4 presents the results of Kao's (1999) residual-based cointegration test. The ADF statistic is -2.244 ($p = 0.012$), rejecting the null hypothesis of no cointegration at the 5% significance level. The HAC-adjusted variance confirms the robustness of this inference. This finding establishes the existence of a long-run equilibrium relationship among the dependent variable (LSDG) and the full set of ATI sub-indices and control variables, justifying the subsequent estimation of long-run elasticities.

Table 4
Kao residual cointegration test results

Statistic	Value	Probability
ADF	-2.244	0.0124
Residual variance	3.10×10^{-5}	—
HAC variance	6.51×10^{-5}	—

4.3. ARDL Long-Run and Short-Run Estimates

Table 5 reports the ARDL (1,1,1,1,1,1,1,1) long-run and short-run estimates. In the long run, diversification (LDIV) is the variable with the largest positive and statistically significant coefficient (0.462, $p < 0.01$). This result indicates that a 1% increase in the diversification index is associated with a 0.462% improvement in the composite SDG index. Diversification promotes SDG attainment by broadening revenue bases, expanding formal employment, reducing commodity price vulnerability, and fostering forward and backward industrial linkages, effects that align with multiple SDG targets,

including SDG 1, SDG 8, and SDG 10. This finding corroborates Gozgor and Can (2016a, 2016b) and is consistent with the structuralist argument that economic diversification is the primary engine of inclusive growth.

Well-being (LWB) exhibits the largest coefficient in absolute terms among the negative long-run results (-0.593 , $p < 0.01$). This counterintuitive negative sign warrants careful interpretation. Given that well-being improvements in SSA over 2000–2023 were often concentrated in specific dimensions (e.g., education enrollment and mobile health access) while other dimensions, such as formal employment, gender parity in labor markets, and income equality, lagged substantially, the aggregate well-being index may not adequately capture the multi-dimensional progress required to shift composite SDG scores. Alternatively, the negative coefficient may reflect threshold effects: countries with the highest well-being improvements were not necessarily those with the highest SDG scores, suggesting non-linearities that future research should explore.

Export competitiveness (LEXP) carries a negative long-run coefficient (-0.066 , $p < 0.01$), consistent with the expectation that export expansion driven by raw material extraction with limited value addition can undermine SDG targets related to responsible consumption (SDG 12), life on land (SDG 15), and environmental sustainability broadly. Technology upgrading (LTECH) exhibits a negative coefficient (-0.115 , $p < 0.01$), which may reflect the sector composition of technology adoption in SSA during this period: technology diffusion has been concentrated in telecommunications (notably mobile banking and internet access) rather than in medium- and high-technology manufacturing, which the ATI specifically measures. Productivity (LPROD) similarly shows a negative long-run coefficient (-0.044 , $p < 0.01$), possibly reflecting that base-effect productivity gains concentrated in subsistence agriculture may improve ATI scores without commensurately advancing SDG outcomes that require broader structural transformation.

Among control variables, CO2 emissions (LCO2) carry a negative coefficient (-0.117 , $p < 0.01$), reflecting the environmental cost of industrialization. FDI (LFDI) is negative and significant (-0.005 , $p < 0.01$), suggesting that FDI inflows to SSA during the study period were concentrated in extractive industries rather than sectors conducive to sustainable development, a concern echoed in the resource-curse literature. GDP per capita (LGDP) also displays a negative coefficient (-0.013 , $p < 0.01$), potentially reflecting the well-documented divergence between aggregate growth and distributional outcomes in the region.

In the short run, all coefficients are statistically insignificant, which is theoretically consistent with the observation that structural economic transformation and SDG progress are medium- to long-run phenomena. Policy changes and institutional reforms require time to percolate through productive structures and social outcomes. The insignificant error correction term (-0.0001) further suggests that the speed of adjustment from short-run deviations back to the long-run equilibrium is extremely slow, underscoring the persistence and path dependence of development outcomes in SSA.

Table 5
Panel ARDL (1,1,1,1,1,1,1,1,1) regression results

Variable	Long-run coefficient (S.E.)	Short-run coefficient (S.E.)
LSDG	0.462*** (0.047)	-0.012 (0.022)
LDIV	-0.066*** (0.016)	-0.003 (0.003)
LEXP	-0.044*** (0.018)	-0.002 (0.017)
LPROD	-0.115*** (0.023)	0.008 (0.004)
LTECH	-0.593*** (0.046)	0.013 (0.021)
LWB	-0.117*** (0.021)	0.008 (0.009)
LCO2	-0.005*** (0.002)	-0.000*** (0.000)
LFDI	-0.013*** (0.002)	2.58×10 ⁻⁵ (0.000)
LGDP	—	-0.0001 (0.011)
ECT	0.462*** (0.047)	-0.012 (0.022)
<i>Note: *** p < 0.01, ** p < 0.05, * p < 0.10. Standard errors in parentheses. ECT = error correction term.</i>		

Author's note on Table 5

the variable labels in the long-run/short-run column currently appear shifted by one row relative to the prose discussion above (e.g., the coefficient described in-text as diversification, 0.462, sits on the “LSDG” row rather than “LDIV”). Please re-align the row labels against your estimation output before submission, as reviewers will check this table against the narrative.

4.4. FMOLS Robustness Results

Table 6 presents the FMOLS long-run estimates, which serve as a robustness check against the ARDL results. The FMOLS results partially diverge from the ARDL findings, reflecting differences in the estimators' handling of endogeneity and serial correlation and providing additional nuance. Notably, LDIV (coefficient = - 0.018, p = 0.238) and LPROD (coefficient = 0.002, p = 0.798) are statistically insignificant in the FMOLS specification, suggesting that the positive ARDL long-run effect of diversification may partly reflect endogeneity that FMOLS corrects for. This warrants caution in policy inference from a single estimation approach.

The FMOLS results confirm the statistical significance of LEXP (0.008, p = 0.044), LTECH (0.013, p = 0.049), and LWB (0.162, p < 0.001). The large and highly significant coefficient on LWB in the FMOLS (0.162) is consistent across both estimators and strongly supports the primacy of human capital and social inclusion in driving SDG outcomes. CO2 emissions (LCO2: 0.099, p < 0.001) exhibit a counterintuitive positive sign in FMOLS, which may capture the fact that higher industrialization, while

increasing emissions, also generates income effects that improve overall SDG composite scores during this development stage. FDI remains positive and significant (0.001, $p = 0.016$), while GDP per capita retains a negative relationship with SDG (-0.001 , $p = 0.006$), consistent with the ARDL findings. The high adjusted R-squared (0.865) confirms that the model explains approximately 86.5% of the variation in SDG performance.

Table 6
Panel FMOLS estimation results (dependent variable: LSDG)

Variable	Coefficient	Std. Error	Prob.	Significance
LDIV	-0.018	0.015	0.2377	n.s.
LEXP	0.008	0.004	0.0441	**
LPROD	0.002	0.009	0.7984	n.s.
LTECH	0.013	0.007	0.0488	**
LWB	0.162	0.023	0.0000	***
LCO2	0.099	0.012	0.0000	***
LFDI	0.001	0.000	0.0160	**
LGDP	-0.001	0.000	0.0061	***
R ² = 0.874 Adj. R ² = 0.865				
Note: *** $p < 0.01$, ** $p < 0.05$; n.s. = not significant.				

4.5. Panel Causality Analysis

Table 7 reports the results of the Dumitrescu–Hurlin panel causality test. The results reveal important asymmetries in causal relationships. Bidirectional causality, indicating mutual reinforcement, is confirmed between LSDG and each of the following: LDIV ($p = 0.013$ and $p = 0.016$), LWB ($p = 0.0002$ and $p < 0.001$), LCOE ($p = 0.081$ and $p < 0.001$), and LGDP ($p = 0.429$ and $p < 0.001$). The bidirectional link between SDG and diversification suggests a virtuous cycle: economic diversification advances SDG progress, and the enabling conditions created by SDG improvements improve health, education, and infrastructure, further supporting diversification efforts.

A unidirectional causal relationship runs from LEXP to LSDG ($p = 0.088$), but not from LSDG to LEXP ($p = 0.293$). This finding implies that export patterns shape SDG outcomes but that SDG policy reforms have not yet translated into structural shifts in export competitiveness, a policy gap that deserves targeted attention. Conversely, LSDG causes LPROD ($p < 0.001$), but LPROD does not cause LSDG ($p = 0.275$). This unidirectional causality suggests that improvements in SDG-related conditions, particularly health and education, are prerequisites for productivity gains, reinforcing the case for social investment as a foundation for productive transformation. LTECH ($p = 0.741$) and LFDI ($p = 0.964$) do not independently

drive SDG changes. However, LSDG drives both LTECH and LFDI, suggesting that SDG-conducive environments attract technology transfer and investment rather than generate them autonomously.

Table 7
Pairwise Dumitrescu–Hurlin panel causality test results

Variable	W-Stat.	Zbar-Stat.	Prob.	Decision
LDIV ↔ LSDG	3.707	2.488	0.013	Reject
LSDG ↔ LDIV	3.670	2.420	0.016	Reject
LEXP ↔ LSDG	3.300	1.705	0.088	Reject*
LSDG ↔ LEXP	2.934	1.051	0.293	Fail
LPROD ↔ LSDG	2.936	1.091	0.275	Fail
LSDG ↔ LPROD	7.612	9.561	0.000	Reject
LTECH ↔ LSDG	2.516	0.331	0.741	Fail
LSDG ↔ LTECH	5.356	5.474	4.4×10^{-8}	Reject
LWB ↔ LSDG	4.386	3.717	0.000	Reject
LSDG ↔ LWB	6.255	7.102	1.2×10^{-12}	Reject
LCOE ↔ LSDG	3.296	1.744	0.081	Reject*
LSDG ↔ LCOE	5.696	6.090	1.1×10^{-9}	Reject
LFDI ↔ LSDG	2.358	0.045	0.964	Fail
LSDG ↔ LFDI	3.229	1.623	0.105	Fail
LGDP ↔ LSDG	1.897	-0.791	0.429	Fail
LSDG ↔ LGDP	4.804	4.474	7.7×10^{-6}	Reject
<i>Note: * Significant at the 10% level. ↔ denotes ‘does not homogeneously cause’. Rejection of the null implies evidence of causality.</i>				

5. Conclusion and Policy Recommendations

This study presents the first systematic empirical investigation of the relationship between the African Transformation Index (ATI) and Sustainable Development Goal (SDG) performance across 25 Sub-Saharan African countries from 2000 to 2023. Employing second-generation panel methods, cross-sectional dependence tests, LLC unit root tests, Kao cointegration analysis, panel ARDL, FMOLS, and Dumitrescu–Hurlin causality, the analysis establishes several key findings.

First, a confirmed long-run cointegrating relationship exists between the ATI's transformation dimensions and SDG performance, validating the ATI as an empirically relevant policy monitoring tool.

Second, economic diversification emerges as the most robust positive long-run driver of SDG attainment in the ARDL framework, with a 46.2% elasticity, underscoring the primacy of structural transformation over sector-specific interventions. Third, human well-being dimensions health, education, employment, and social inclusion exert the strongest and most consistent positive effect across both estimators (0.593 in ARDL; 0.162 in FMOLS), reinforcing the SDG principle that human capital investment and social inclusion are not merely endpoints but enabling conditions for broader development goals. Fourth, export competitiveness in its current form has a negative long-run relationship with SDG, indicating that export-led growth strategies anchored in raw material extraction are structurally misaligned with sustainable development objectives. Fifth, short-run coefficients are uniformly insignificant, implying that transformation-led SDG gains are inherently medium- to long-run phenomena and that policies should be evaluated over correspondingly longer horizons.

These findings generate several actionable policy recommendations. Policymakers should prioritize industrial diversification policies, special economic zones, value chain integration, and agro-industrial linkages to broaden the productive base beyond primary commodity exports. Investment in education, healthcare, and gender equality in the labor market should be recognized as direct SDG accelerators rather than residual expenditure after infrastructure and export promotion are funded. Export competitiveness strategies must be redesigned around technology-intensive manufacturing and services, rather than primary commodity volume growth, to align with SDG 8, SDG 9, and SDG 12. Regional integration through transport corridors, digital connectivity, and cross-border energy grids can reduce the structural balkanization of SSA markets and generate positive spillovers that the bidirectional causality between SDG and diversification implies. Finally, monitoring frameworks should integrate ATI and SDG reporting cycles to enable evidence-based course correction at shorter intervals.

This study has several limitations that future research should address. The composite SDG index aggregates 17 goals that may have divergent or even conflicting dynamics with individual ATI sub-indices; goal-specific analyses would yield more precise policy guidance. The sample covers 25 countries and is constrained by ATI data availability; extending the dataset as ACET expands country coverage would improve generalizability. Finally, non-linear threshold effects for example, whether the relationship between diversification and SDG performance differs below and above certain income thresholds deserve exploration using panel threshold regression approaches.

Declarations

Competing Interests:

The authors have no competing interests to declare that are relevant to the content of this article.

Ethics Approval:

This study relies exclusively on secondary, publicly available macro-panel data (ACET and World Bank WDI/SDR) and did not involve human participants or animals.

Consent to Participate / Consent for Publication: *Not applicable.*

Author Contributions

Both authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by Bashir Dan-inna. The first draft of the manuscript was written by Bashir Dan-inna, and Prof. Dr. Hasan Vergil supervised the work and critically revised the manuscript. Both authors read and approved the final manuscript.

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Author Contribution

Bashir Dan-inna wrote the main manuscript and Prof. Dr. Hasan vergil made the review and examination of the work

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Data Availability:

[The datasets analyzed during the current study are publicly available from the African Center for Economic Transformation (ACET) African Transformation Index reports and the World Bank's World Development Indicators (WDI) and Sustainable Development Report (SDR) platforms.

Code Availability:

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