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Sustainable FDI, green industrialization, and the macro debt-equity mix in manufacturing-led Sub-Saharan Africa: A System GMM analysis

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Abstract

This study examines how sustainable foreign direct investment (SFDI) shapes green industrialization (GIN) and the macro debt-equity ratio (DER) in manufacturing-led Sub-Saharan African economies. Using a dynamic System GMM estimator on unbalanced panel data covering 2014 to 2024, the analysis finds that SFDI is negatively associated with both GIN and DER, suggesting that foreign capital inflows in the region remain concentrated in resource-intensive activity rather than environmentally transformative production, consistent with the pollution haven hypothesis. Higher GIN is associated with a lower DER, indicating that environmental upgrading is linked to a shift toward equity-based financing and reduced debt dependence. A mediation analysis shows that GIN carries a modest but statistically significant indirect channel between SFDI and the debt equity mix, though this pathway is constrained by weak institutions and limited absorptive capacity. The results imply that SFDI alone is insufficient to drive structural transformation in SSA manufacturing economies, and that its benefits depend on complementary governance reforms, environmental regulation, and targeted green industrial policy.

***Keywords*:** Sustainable FDI, Green Industrialization, Macro Debt Equity Mix, Manufacturing-Led SSA Economies, System GMM

JEL Classification: F21, Q56, O14, O55, G32, C33

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1. Introduction

Manufacturing-led growth in Sub-Saharan Africa (SSA) encounters a twofold challenge; thus, attaining rapid industrialization while concurrently mitigating environmental externalities. SSA is marked by a continual reliance on external debt funding, underdeveloped domestic financial markets, and significant susceptibility to climate-induced disruptions. The structural characteristics render the region more susceptible to the quality and sustainability focus of foreign capital inflows. In this context, determining whether sustainable foreign direct investment (SFDI) may stimulate green industrial transformation and subsequently alter the macro debt-equity balance is a theoretically significant and policy-relevant research inquiry. The manufacturing sector in SSA constitutes a minor but expanding fraction of regional GDP, while still being excessively reliant on resource-intensive and energy-inefficient production methods (UNCTAD, 2023). Historically, foreign direct investment has been crucial to the economic growth of Sub-Saharan Africa by enabling capital accumulation, knowledge transfer, and integration into global value chains (Nsofor et al., 2024). Nonetheless, empirical evidence about the environmental impacts of FDI in the region remains ambiguous. The pollute haven hypothesis (PHH) posits that multinational corporations capitalize on less stringent regulatory frameworks in developing nations to transfer pollution-intensive manufacturing (Cole et al., 2020). The pollution halo hypothesis (PHA) posits that foreign direct investment (FDI) might enhance the environmental performance of host countries by facilitating the dissemination of cleaner technologies and management techniques (Shahbaz et al., 2022). A previously overlooked aspect in the literature centers on how the macro-financial structure of host economies, specifically the ratio of external debt to equity-like capital flows, influences or is influenced by sustainability-oriented foreign direct investment (FDI). In nations burdened by debt, the incentive framework for foreign capital typically prioritizes short-term, resource-extractive investments rather than long-term, productivity-enhancing, and ecologically transforming initiatives. The funding structure of national economies may thus serve as both a determinant and a consequence of FDI sustainability orientation.

This paper explores three interrelated relationships in manufacturing-driven SSA economies: (i) the impact of SFDI on the macro debt-equity ratio (DER); (ii) the influence of SFDI on green industrialization (GIN); and (iii) the mediating function of GIN in conveying the effect of SFDI on the macro debt-equity balance. The research utilizes a dynamic System GMM estimator using unbalanced panel data from manufacturing-led Sub-Saharan African countries spanning 2014 to 2024. Sub-Saharan Africa (SSA) is selected as the empirical context for multiple reasons: the region has the highest concentration of nations categorized as high debt-distress risk worldwide (IMF, 2022); it serves as a frontier geography for global green investment within the frameworks of the Sustainable Development Goals (SDG) and the Paris Agreement (UNCTAD, 2023); and its manufacturing transformation trajectories exhibit structural heterogeneity, providing analytical variation in the principal constructs of interest.

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The subsequent sections of the paper are structured as follows. Section 2 delineates the theoretical framework and examines the empirical literature. Section 3 delineates the methodology. Section 4 presents and analyzes the empirical findings. Section 5 concludes with policy recommendations and avenues for future research.

2. Literature Review

This section develops a comprehensive analytical framework to elucidate the effects of sustainable foreign direct investment (FDI) on green industrialization and the macro debt-equity relationship in Sub-Saharan Africa (SSA), utilizing ecological modernization theory, the pollution haven and halo hypotheses, structural transformation theory, and capital structure theories. Instead of examining each theory in isolation, the following explanation connects each theoretical strand to a particular mechanism in the sequence: SFDI leads to GIN, resulting in a Macro Debt-Equity Mix.

2.1 Theoretical Framework

2.1.1 Ecological Modernization Theory (EMT)

According to Mol and Spaargaren (2020), this theory posits that technical development, institutional reform, and green innovation can simultaneously improve economic growth and environmental sustainability. EMT forecasts that SFDI, when directed towards cleaner production methods and ESG-compliant practices, can catalyze green industrialization in SSA's energy-intensive manufacturing sector by diminishing emissions intensity and fostering the use of renewable energy. This is the principal mechanism connecting SFDI to GIN within the conceptual framework of the current study.

2.1.2 Pollution Haven and Pollution Halo Hypothesis

The Pollution Haven Hypothesis (PHH) holds that multinational firms move polluting-intensive production to countries with lax environmental regulations, increasing emissions and negative environmental externalities (Cole et al., 2020). Pollution Halo Hypothesis (PHA), on the other hand, states that FDI enhances sustainability by introducing cleaner technologies and environmental practices in the host country (Shahbaz et al., 2022). In Sub-Saharan Africa, where environmental regulations are often inadequate, FDI may demonstrate pollution-haven attributes instead of halo qualities, hence weakening the SFDI-GIN relationship. The conflicting expectations motivate the empirical enquiry of whether SFDI in SSA aligns with the PHH or PHA.

2.1.3 Structural Transformation Theory

The Structural Transformation Theory posits that enduring economic development necessitates the reallocation of resources from low-productivity to high-productivity sectors, such as manufacturing (Diao, McMillan, & Rodrik, 2019). Sustainability-focused foreign direct investment can modify these routes by incorporating host countries into environmentally friendly global value chains and promoting low-carbon industrial advancement. This delineates the process

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by which SFDI-driven GIN might modify the macro-financing landscape: economies that achieve green structural transformation encounter diminished environmental obligations, enhanced sovereign risk profiles, and increased appeal to long-term equity investors.

2.1.4 Capital Structure Theories

Two complementary theories of capital structure elucidate the link between GIN and DER. The Pecking Order Theory (POT) posits that financial hierarchies are indicative of knowledge asymmetry, favoring internal funds over external debt and equity (Frank & Shen, 2019). In Sub-Saharan Africa, where equity markets are underdeveloped, external debt prevails. Nonetheless, advancements in environmental performance and industrial productivity prompted by green transformation can bolster investor trust and draw equity-type investments, therefore diminishing reliance on debt. The Trade-Off Theory (TOT) posits that economies would transition to equity-based financing when the risk-adjusted cost of debt increases as a result of environmental liabilities and sovereign risk (Kraus & Litzenberger, 1973; De Angelo & Stulz, 2019). Consequently, both theories assert that GIN decreases debt-equity ratios by enhancing the appeal of equity.

2.1.5 Institutional Quality and Governance Theory

The Institutional Quality Theory holds that strong regulatory frameworks, rule of law, and corruption control affect investment, financial growth, and environmental standards (Kaufmann & Kraay, 2020). Countries with strong institutions are more capable of attracting sustainability-focused foreign investment and implementing environmental regulations. Institutional quality serves as a moderator of the SFDI-GIN route and strengthens the GIN-DER transmission.

2.2 Empirical Literature

2.2.1 FDI and Environmental Externalities in SSA

The empirical evidence about the relationship between foreign direct investment and the environment in Sub-Saharan Africa is inconclusive. Spatial panel analyses from 2006 to 2020 substantiate the pollution haven theory, revealing positive correlations between foreign direct investment inflows and CO2 emissions (Abbas et al., 2023). Sector-specific research demonstrates that foreign direct investment (FDI) in manufacturing exerts more detrimental environmental impacts than FDI in services, especially in economies characterized by inadequate environmental governance (Zakari et al., 2025). The findings indicate that the sustainability aspect of FDI is not inherent but dependent on the regulatory environment, prompting the development of a sustainability-adjusted FDI metric.

2.2.2 FDI, Manufacturing and Structural Transformation in SSA

Panel-ARDL analyses of Sub-Saharan African manufacturing growth demonstrate that foreign direct investment and trade liberalization foster industrial development in the long term (Nsofor et al., 2023). Nonetheless, FDI-induced manufacturing growth is not intrinsically sustainable; the

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ecological impact of industrial development hinges on the adoption of either clean or polluting production technology by multinational corporations. The lack of compulsory sustainability disclosures and ineffective carbon pricing mechanisms in Sub-Saharan Africa constrains the environmental developmental benefits of incoming foreign direct investment.

2.2.3 Financial Structure, Capital Flows and Sustainability

Numerous studies indicate a positive correlation between institutional quality and inclusive green growth in Sub-Saharan Africa at the macro-financial level (Ofori et al., 2023). The direct relationship between macro debt-equity composition and FDI sustainability remains little examined. Studies in corporate finance indicate that companies with superior ESG performance secure equity capital at cheaper costs and experience diminished borrowing expenses (Brooks & Oikonomou, 2020). This study empirically explores the movement of economies advancing green industrialization from debt-dependent to equity-oriented financing at the macro level.

2.2.4 Hypothesis Development

Based on the aforementioned theoretical framework, particularly the amalgamation of EMT, PHH/PHA, structural transformation theory, and capital structure theories, in addition to subsequent assumptions are officially articulated:

H_1: Sustainable Foreign Direct Investment (FDI) inflows are positively correlated with the Macro Debt-Equity mix in manufacturing-driven Sub-Saharan African economies.

H_2: Sustainable FDI positively correlates with Green Industrialization among Sub-Saharan markets

H_3: Green Industrialization positively correlates with Macro Deb-Equity Mix in manufacturing-driven Sub-Saharan African economies

H_4: Green Industrialization mediates the Sustainable FDI and Macro Debt-Equity Mix nexus in manufacturing-driven Sub-Saharan African economies.

2.2.5 Sustainable FDI and Environmental Performance (EMT & Pollution Hallow)

Ecological Modernization Theory suggests that sustainable foreign direct investment with cleaner technologies, energy-efficient manufacturing processes, and ESG-compliant operations can improve host economies' environmental outcomes (Mol & Spaargaren, 2020). Green technologies and advanced environmental management practices by multinationals could reduce emissions and increase renewable energy use (Gouldson et al., 2018). The Pollution Halo Hypothesis states that foreign direct investment can increase environmental efficiency when foreign investors follow global sustainability standards (Shahbaz et al., 2022). Though resource efficiency and greener output, sustainable FDI in manufacturing-led SSA economies with energy-intensive industrial processes is intended to reduce ecological externalities, the relationship is more complex. The foregoing culminates into the first and second hypotheses of this study

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2.2.6 FDI-Led Green Industrialization (EMT & Industrial Transformation Theory)

According to Diao et al., (2019), the structural transformation theory posits that technical development and increased leads to movement of capital and labor to higher-productivity sectors, such as manufacturing. Sustainable foreign direct investment is essential for access to green technologies, improved industrial facilities, and eco-friendly global value chains. Ecological Modernization Theory states that green technological spillovers from foreign direct investment can boost industrial efficiency in a low-carbon, resource-efficient approach (Zhang & Zhou, 2022). Sustainable FDI should reduce emissions, waste, and use renewable energy to improve manufacturing and green industrialization hence informing the third hypothesis of this study.

2.2.7 Green Industrialization and Macro Debt-Equity Mix (Trade-Off theory and Pecking Order Theory)

Capital structure theories explain how economic frameworks affect macro-finance. The Trade-Off Theory states that economies weigh debt's tax benefits against financial distress costs (De Angelo & Stulz, 2019). Green industrialization involves the use cleaner technology and energy efficiency to attain long-term productivity and while reducing environmental liabilities and sovereign risk. This should make equity-like flows, such as portfolio equity and reinvested earnings, more appealing than external loans. According to the Pecking Order Theory, equity investors favor information clarity and lower risk, which promote industrial growth (Frank & Shen, 2019). Green industrialization boosts creditworthiness, investor confidence, and equity over debt. This concept informed the fourth hypothesis of this study.

2.2.8 Mediating Role of Green Industrialization

In manufacturing-led Sub-Saharan Africa (SSA), green industrialization may mediate the macro debt–equity balance and sustainable foreign direct investment (SFDI). SFDI is expected to promote cleaner technologies, efficiency gains, and structural upgrading that can reduce excessive debt dependence and strengthen equity-based financing outcomes, but empirical evidence suggests that this mediating pathway is weak due to constraints like limited absorptive capacity, policy fragmentation, and underdeveloped eco-industrial capabilities. Governance effectiveness and coherent sustainability-oriented industrial policy can help translate SFDI into meaningful green industrial transformations that can reshape capital structure dynamics in SSA (Rodrik, 2018; Dutta, Gilfillan, & Lawson, 2021).

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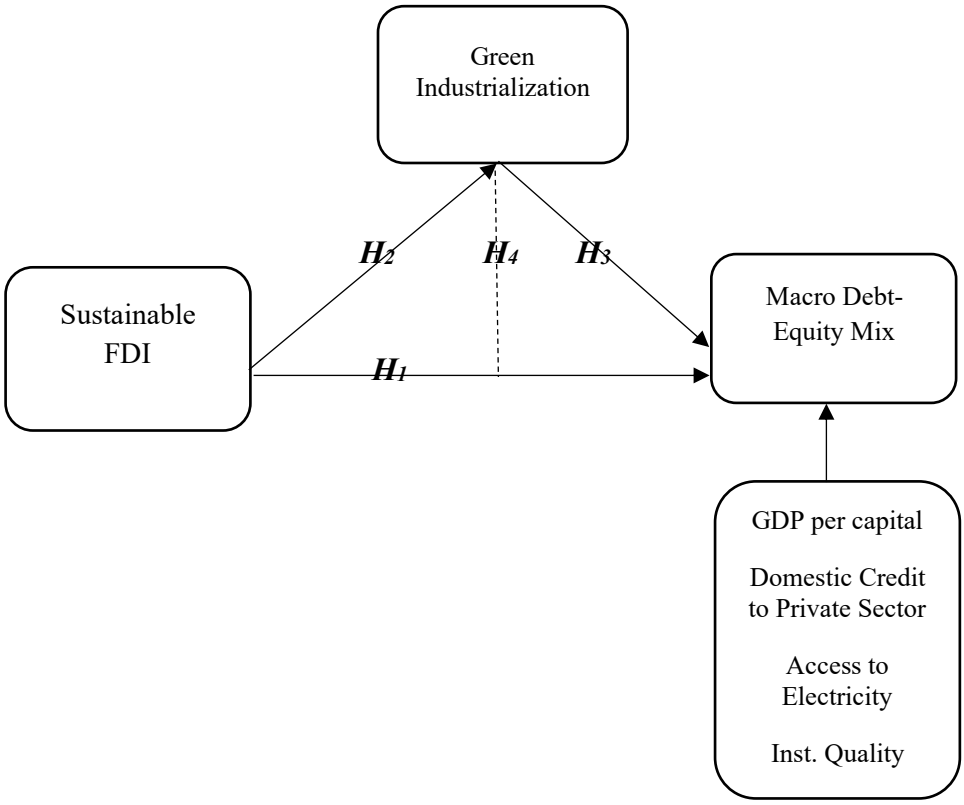
Figure 1. Conceptual Framework



Source: Author's own construct (2025)

This study's conceptual framework, as shown in Figure 1 above, asserts that sustainable foreign direct investment (FDI) is a primary catalyst for green industrialization and enhanced environmental performance, which collectively affect the macro debt-equity composition in manufacturing-oriented Sub-Saharan African economies. The framework, informed by ecological modernization and structural transformation theories, posits that foreign direct investment (FDI) associated with cleaner technologies and renewable energy can diminish emissions intensity while enhancing manufacturing value added, thus facilitating environmentally efficient industrial advancement (Diao, McMillan, & Rodrik, 2019; UNCTAD, 2023). The anticipated sustainability-enhancing impacts are likely to enhance macroeconomic risk profiles and bolster investor confidence, prompting a transition from debt-laden external financing to more stable equity-like capital inflows.

3. Methodology

The paper used System-GMM, designed to manage unbalanced panels, correct endogeneity, reduce omitted variable bias, and address dynamic persistence in macro-financial variables, resulting in consistent and efficient estimates despite missing observations. Arellano-Bond serial correlation tests and Hansen/Sargan over-identification diagnostics evaluate the instruments and

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show no second-order serial correlation, ensuring the estimations' reliability. Thus, the estimating approach is econometrically resilient and policy-relevant despite changing sample sizes. The empirical technique comprises two phases. First, a dynamic system Generalized Method of Moments (System-GMM) estimator addresses endogeneity, simultaneity, and persistence in the dependent variables. Second, interaction and mediation models evaluate green industrialization's transmission role. This comprehensive approach matches recent empirical studies on foreign direct investment, sustainability, and macro-finance in emerging economies (Acheampong et al., 2020; Shahbaz, 2022).

3.1 Sample Selection and Data Sources

The sample includes manufacturing-driven SSA economies for which data is accessible from 2014 to 2024. Countries are designated as manufacturing-led if their average manufacturing value added surpasses 10% of GDP over the study period, in accordance with the structural transformation threshold suggested in the literature (Diao, McMillan, & Rodrik, 2019). Countries that do not satisfy minimal data availability standards for core variables are omitted to ensure estimation reliability.

All primary data are derived from the World Bank's World Development Indicators (WDI) and the Worldwide Governance Indicators (WGI). These sources offer standardized, internationally comparable data and are extensively utilized in empirical sustainability and macro-finance research (World Bank, 2024). The resultant panel is unbalanced, a common occurrence in SSA empirical research because to cross-country disparities in statistical competence and reporting consistency. The estimating approach is specifically built to address unbalanced panels.

3.2 Variable Definition and Measurement

3.2.1 Environmental Performance

Environmental performance is empirically assessed by WDI-based, outcome-oriented metrics that represent both pollutant intensity and energy composition. The key metric is carbon emissions intensity, defined as CO_2 emissions per unit of GDP (kg of CO_2 per 2017 PPP USD of GDP), which directly reflects the environmental efficiency of economic activity. Additionally, CO_2 emissions per capita (metric tons) serve as an alternate statistic to indicate overall environmental strain, while renewable energy consumption (% of total final energy consumption) is utilized to assess the shift towards cleaner energy sources. Reduced CO_2 intensity and per capita emissions, coupled with an increased proportion of renewable energy, signify enhanced environmental performance.

3.2.2 Macro Debt-Equity Mix (DER)

The dependent variable is the macro Debt-Equity Ratio (DER), which is defined as foreign debt stocks (% of GNI) divided by the aggregate of FDI net inflows and portfolio equity inflows (% of

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GDP). A reduced DER signifies an increased dependence on equity financing compared to debt, which is the theoretically and empirically favored macro-finance framework for long-term sustainability (UNCTAD, 2023). It is important for readers to recognize that the inclusion of FDI net inflows in the denominator of the Debt-to-Equity Ratio (DER) and their role in the construction of SFDI may create a potential mechanical inverse link between SFDI and DER. This constraint is recognized, and discussions on robustness in Section 4 address this issue. A diminished ratio signifies an increased dependence on equity compared to debt, aligning with sustainable financing standards (UNCTAD, 2023).

3.2.3 Green Industrialization

Green industrialization (GIN) is quantified by a composite index that integrates: (i) manufacturing value added as a proportion of GDP, normalized to a 0 -1 scale; and (ii) the reciprocal of CO2 emissions per unit of GDP (CO2 intensity), also normalized to a 0 -1 scale. Both sub-indicators are normalized using min-max scaling, and equal weights are assigned in the composite measure. Elevated GIN values signify concurrently increased manufacturing production and diminished emissions intensity, aligning with the OECD (2022) definition of green industrial performance. This structure specifically tackles the directional difficulty of integrating manufacturing expansion (beneficial for GIN) with the lowering of emissions intensity (a decrease in CO2 intensity is advantageous for GIN). Reduced emissions intensity coupled with increased manufacturing production is regarded as an indication of environmentally sustainable industrial advancement (OECD, 2022).

3.2.4 Sustainable FDI

In accordance with Zhang and Zhou (2022), SFDI is formulated as the product of FDI net inflows (% of GDP) and the proportion of renewable energy in total final energy consumption (%). Formally: $SFDI = FDI_{it} \times RenewableShare_{it}$. This proxy measures the extent to which foreign direct investment functions within a sustainability-focused energy framework. This measure does not explicitly identify ESG-screened or sector-specific green investment flows, a limitation common in empirical literature due to the lack of publicly accessible disaggregated sustainability-weighted FDI data for SSA. However, it offers a feasible approximation that varies by country and over time. Subsequent studies ought to utilize sector-weighted or policy-screened SFDI metrics as they become accessible.

3.2.5 Institutional Quality

Institutional quality is assessed by the composite average of three World Governance Indicators: regulatory quality, rule of law, and control of corruption. Every indicator is normalized on a scale ranging from approximately -2.5 to +2.5. The composite is normalized to a 0-1 range to enhance interpretation and interaction modeling.

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3.2.6 Control Variables

Standard macroeconomic controls are incorporated to prevent omitted-variable bias, in accordance with the FDI-environment finance literature (Acheampong, 2019; Shahbaz et al., 2022). These include the logarithm of GDP per capita (lnGDPPC) as an indicator of economic development; trade openness (% of GDP); domestic credit to the private sector (DCGDP, % of GDP) as a measure of financial development; and access to electricity (EACCESS, % of population) as a representation of infrastructure. All continuous variables are logarithmically converted as necessary to diminish skewness and facilitate elasticity comprehension.

3.2.7 Model Specification

Dynamic Panel Model

Due to the persistence of debt ratios and capital flows, together with the probable endogeneity among FDI, industrialization, and financing structure, a System-GMM estimator is employed (Arellano & Bover, 1995; Blundell & Bond, 1998). The dynamic specification is as follows:

$$DER_{it} = \gamma DER_{it-1} + \beta_1 SFDI_{it} + \beta_2 GIND_{it} + \beta_3 X_{it} + \varepsilon_{it} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

System-GMM is especially appropriate for panels characterized by relatively small temporal dimensions and bigger cross-sectional units, as commonly observed in SSA nation panels. Lagged levels and differences of endogenous regressors serve as internal instruments, mitigating bias from reverse causality and simultaneity (Roodman, 2009). The validity of the model is evaluated by the Hansen J-test for over-identifying limitations and the Arellano-Bond AR(2) test for serial correlation.

Moderation Model

The subsequent interaction model is estimated to analyze the conditioning influence of institutions.

$$DER_{it} = \gamma DER_{it-1} + \beta_1 SFDI_{it} + \beta_2 IQ_{it} + \beta_3 (SFDIit * IQ_{it}) \beta_4 X_{it} + \varepsilon_{it} \ldots\ldots\ldots\ldots\ldots(2)$$

Where institutional quality (IQ) represents the composite governance indicators index. This methodology adheres to institutional-moderation research in sustainable development financing (Kaufmann & Kraay, 2020).

4. Results And Discussions

This session presents a summary of findings and a discussion of results based on analyzed data for the study period. The descriptive data in Table 1 explain Sub-Saharan African manufacturing-driven economies' structural, institutional, and financial characteristics. Many SSA countries are debt-dependent, as the Debt-Equity Ratio (DER) ranges from 35.25 to 781.68, with a mean of 35.25 and a standard deviation of 90.38. This reinforces findings that many SSA economies rely on debt due to weak domestic capital markets and equity financing (UNCTAD, 2023; IMF, 2022).

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Zero DER shows governments relied on equity-type inflows or temporarily reduced external debt exposure.

Table 1. Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
DER	106	35.254	90.375	0	781.682
SFDI	365	.247	.13	0	.724
GIN	440	.237	.115	.012	.691
INSTQ	428	.337	.23	.008	1
INSTQxSFDI	365	.072	.049	0	.258
lnGDPPC	440	7.272	.899	5.451	9.715
TRADE OPEN	396	72.443	45.808	2.699	320.939
DCGDP	449	21.981	21.181	0	128.838
EACCESS	428	47.308	24.685	4.2	100

Source: Secondary data

Averaging 0.247% GDP with a low standard deviation of 0.13, sustainable FDI (SFDI) inflows are moderate but constant across the region. Despite a recent shift toward sustainability-linked and green investment flows, Sub-Saharan Africa still attracts foreign direct investment below global averages (UNCTAD, 2023). Despite manufacturing expansion in Sub-Saharan Africa, industrial upgrading and greening are inconsistent (African Development Bank, 2022).

Green Industrialization (GIN) averages 0.237, indicating a low-level structural shift. Governance and regulatory frameworks differ greatly across SSA economies, with Institutional Quality (INSTQ) averaging 0.337 and significant variation. Institutional capacity moderates FDI, supporting the premise that good governance boosts productivity, sustainability, and profits (Kaufmann et al., 2021). Macroeconomic and structural rules are dynamic. The mean income level (lnGDPPC) is 7.27, indicating modest improvement with large variance due to countries' economic transformation. Average trade openness is 72.44% of GDP, while volatility (Std. Dev = 45.81) indicates inconsistent global market integration.

The average private sector domestic credit (DCGDP) is 21.98%, indicating undeveloped financial institutions, supporting literature that limiting domestic financing hinders Sub-Saharan African private sector and industrial growth (World Bank, 2022). Electricity access averages 47.31%, indicating infrastructure and energy concerns that hinder industrial greening and sustainable production (IEA, 2022).

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Table 2. Cross-Sectional Dependence

Variable	CD Statistic	p-value	Avg. Joint T	Mean rho	Mean abs rho
DER	1.862	0.063	4.23	0.01	0.03
SFDI	8.703	0	7.48	0.09	0.38
GIN	0.194	0.846	8.87	0	0.42
INSTQ	8.927	0	8.68	0.09	0.42
lnGDPPC	31.49	0	8.87	0.3	0.47
TRADE_OPEN	9.799	0	8.65	0.09	0.31
DCGDP	1.667	0.096	8.89	0.02	0.42
ACCESS	70.078	0	8.68	0.69	0.71

Source: Secondary Data

Table 2 above presents Pesaran's CD statistics and diagnostics for Manufacturing-Led Sub-Saharan Africa's Sustainable FDI, Green Industrialization, and Macro Debt-Equity Mix. Trade, institutional changes, regional integration, and vulnerability to global sustainability and financial shocks make cross-sectional dependence (CSD) a key issue in Sub-Saharan Africa. The macro Debt-Equity Ratio (DER) do not exhibit significant CSD, consistent with developing financial system interdependencies across nations (CD = 1.862; p = 0.063). SSA economies face global credit market constriction, development finance trends, and fiscal sustainability issues, notwithstanding their sovereign risk profiles and financing methods. SSA manufacturing economies show substantial correlations (CD = 8.703; $p < 0.001$) for sustainable FDI (SFDI), likely due to legislative reforms, green investment trends, and multinational business strategies (UNCTAD, 2023; Asongu, 2020

Green Industrialization (GIN) had no significant CSD (CD = 0.194; p = 0.846), indicating Sub-Saharan Africa's industrial transformation variability. This supports studies showing structural transformation, technical improvement, and sustainable production in African economies are country-specific (African Development Bank, 2022). Institutional Quality (INSTQ) shows significant CSD (CD = 8.927; $p < 0.001$), demonstrating AfCFTA and AU Agenda 2063 impact on regional policy harmonization, governance reform diffusion, and institutional development (Kaufmann et al., 2022). A macroeconomic control explains structural dynamics. Strong cross-sectional dependence (CD = 31.49; $p < 0.001$) suggests that commodity cycles, global crises, and coordinated policy responses impact Sub-Saharan Africa's GDP per capita logarithm.

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Trade Openness showed (CD = 9.799; p < 0.001), indicating interconnected regional and global market integration. SSA Countries differ in financial depth and banking sector growth, as shown by the poor relationship between domestic credit and GDP (CD = 1.667; p = 0.096). EACCESS dependency scores (CD = 70.078; p < 0.001) highlight the need for infrastructure investment, donor funding, and coordinated electrification measures across the continent (IEA, 2022). SFDI, institutions, macroeconomic capability, and integration variables are regionally interconnected, yet Sub-Saharan Africa's industrial development is unequal. Avoiding bias requires CSD-resistant estimate methods like Driscoll-Kraay, CCE, or second-generation panel approaches (Pesaran, 2015; Chudik & Pesaran, 2015). Sub-Saharan Africa's macro debt-equity financing is affected by sustainable foreign direct investment, institutional upgrading, and green industrial transformation.

Table 3. Correlation Matrix

Variables	1	2	3	4	5	6	7	8
(1) DER	1.00							
(2) SFDI	0.217	1.000						
(3) GIN	0.189	0.316	1.000					
(4) INSTQ	0.104	0.411	0.229	1.000				
(5) lnGDPPC	0.092	0.637	0.474	0.478	1.000			
(6) TRADE_OPEN	0.073	0.269	0.093	0.155	0.380	1.000		
(7) DCGDP	0.151	0.469	0.473	0.669	0.551	0.172	1.000	
(8) ACCESS	0.118	0.502	0.352	0.397	0.749	0.239	0.505	1.000

Source: Secondary Data

The correlation results shown in Table 3 above indicate that structural and institutional processes affect Sub-Saharan Africa's sustainable foreign direct investment, green industrialization, and financing structure. All other variables have negative relationships with DER, indicating that higher levels of these traits reduce corporate or country leverage. Sustainable Foreign Direct Investment (SFDI, = -0.217) and Green Innovation (GIN, = -0.189) have the strongest negative correlations, indicating that increased sustainable investment inflows and green innovation activities reduce debt reliance, likely due to equity-based or concessional financing options.

The negative association between Domestic Credit to GDP (DCGDP, = -0.151) and Access to Finance (ACCESS, = -0.118) suggests that resilient financial institutions reduce debt reliance through diversified funding. Institutional Quality (INSTQ, = -0.104) and GDP per capita (lnGDPPC, = -0.092) had insignificant negative associations, supporting the idea that strong

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institutions and high incomes balance capital structures. Trade Openness (TRADE_OPEN, = -0.073) has the weakest connection with leverage. All correlation values are below 0.80, indicating no multicollinearity among explanatory factors.

The negative connection between Sustainable FDI (SFDI) and Green Industrialization (GIN) (-0.316) suggests FDI may not boost green manufacturing. This supports empirical evidence that most FDI in SSA is resource- or efficiency-focused rather than sustainability-focused, limiting structural transformation without environmental and industrial policy frameworks (UNCTAD, 2023; African Development Bank, 2022).

SFDI and institutional quality (-0.411) indicate that numerous FDI inflows continue to penetrate poor governance jurisdictions, suggesting investors may take advantage of regulatory gaps or environmental enforcement in several African nations. The structural transformation metrics GIN (0.229), lnGDPPC (0.478), and DCGDP (0.669) positively correlate with institutional quality (INSTQ). Excellent governance boosts Sub-Saharan African industrial growth, investment, and financial systems (World Bank, 2022; IMF, 2022). Income levels (lnGDPPC) and access to infrastructure and energy (EACCESS = 0.749) are strongly correlated, suggesting that higher-income African economies have better electricity provision, supporting empirical studies linking infrastructure availability, industrial capacity, and sustainable growth in Africa (IEA,

Trade openness is marginally connected with green industrialization (0.093) and institutional quality (0.155), implying that structural change and sustainability require intentional policy frameworks to promote green manufacturing and enforce environmental norms (UNCTAD, 2023). The positive correlation between domestic credit (DCGDP), GIN (0.473), and ACCESS (0.505) suggests that financial deepening boosts industrial growth and infrastructure, reducing debt and stabilizing finance frameworks.

The Variance Inflation Factor (VIF) results in Table 4 indicate whether explanatory variables have multicollinearity concerns that may distort coefficient estimates or reduce inference reliability. A mean VIF of 5.154 shows moderate but acceptable multicollinearity. This is because most econometric literature allows panel estimations with VIF values under 10 (Gujarati & Porter, 2009; Wooldridge, 2015). Domestic credit to the private sector (DCGDP) has the highest VIF (12.883), indicating a strong linear association with income, institutional quality, and infrastructure. According to the World Bank (2022), countries with strong financial systems have higher incomes, better governance, and better industrial and infrastructure performance. This suggests caution when interpreting the independent marginal influence of DCGDP.

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Table 4. Multicollinearity Result (Variance Inflation Factor)

	VIF	1/VIF
DCGDP	12.883	.078
lnGDPPC	5.866	.17
GIN	5.848	.171
cINSTQ	4.37	.229
ACCESS	3.894	.257
cINSTQxSFDI	3.668	.273
c SFDI	3.243	.308
TRADE OPEN	1.459	.685
Mean VIF	5.154	.

Source: Secondary Data

All the other key structural transformation and sustainability variables have moderate VIFs: lnGDPPC (5.866), GIN (5.848), and institutional quality (4.37). While these factors are naturally related, as higher-income economies frequently have stronger institutions and advanced industrial frameworks, the collinearity is not enough to compromise the estimations. Empirical evidence shows that governance quality, economic growth, and industrial advancement in Sub-Saharan Africa move together (IMF, 2022; UNCTAD, 2023).

The interaction term INSTQ × SFDI (3.668) and primary SFDI variable (3.243) remain within acceptable ranges, showing no unstable collinearity from the moderating specification. This study clearly shows how institutional quality affects sustainable foreign direct investment on green industrialization and the macro debt-equity ratio, and the diagnostic confirms this interaction modeling (Baltagi, 2021). Electricity access (EACCESS = 3.894) and trade openness (1.459) are consistently included in the regression, supporting the idea that infrastructure and external integration explain independently without overlap.

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Table 5. Systems GMM Regression (Main Model)

	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
DER	.404	.061	6.61	0	.271	.537	***
SFDI	-19.727	9.759	-2.02	.066	-40.989	1.536	*
GIN	-102.08	49.851	-2.05	.063	-210.696	6.536	*
lnGDPPC	5.958	3.332	1.79	.099	-1.301	13.217	*
TRADE_OPEN	-.016	.033	-0.50	.628	-.087	.055	
DCGDP	.053	.057	0.92	.373	-.071	.176	
ACCESS	-.102	.218	-0.47	.648	-.577	.373	
Mean dependent var		29.402	SD dependent var			54.730	
Number of obs		39	F-test			142391852.419	

*** $p<.01$, ** $p<.05$, * $p<.1$

Source: Secondary Data

GMM results in Table 5 above show dynamic macro debt-equity mix (DER) factors in manufacturing-led Sub-Saharan African economies. The positive lagged dependent variable (DER = 0.404; $p < 0.01$) suggests that countries with high debt-to-equity ratios tend to sustain their financing strategies over time. This supports empirical findings that SSA economies have structural borrowing limits, restricted equity markets, and continuing debt financing (IMF, 2022; UNCTAD, 2023).

A significant negative influence of SFDI on DER ($\beta = -19.727$; $p < 0.10$) indicates that higher SFDI inflows reduce macro debt dependency, consistent with the first hypothesis (H_1) of the study. According to UNCTAD (2023) and the World Bank (2022), quality FDI improves long-term capital formation, risk-sharing, and financing stability by providing equity-like financing that reduces sovereign and corporate borrowing. This reinforces the study's main finding that sustainability-aligned FDI improves SSA economies' financial structures.

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Green Industrialization (GIN) has a significant negative effect on DER (β = –102.08; p < 0.10), supporting the third hypothesis (H_3): countries with higher GIN exhibit lower debt dependency. This is consistent with the theoretical hypothesis that environmental-industrial upgrading improves sovereign risk profiles and attracts equity-type investments. Ecological modernization holds that green industrial development boosts productivity, export competitiveness, and creditworthiness, eliminating excessive borrowing (African Development Bank, 2022; OECD, 2022). It suggests that green structural changes stabilize finances, strengthening the sustainability-finance nexus among SSA countries.

While SSA economies grow, they may initially accumulate more debt due to economic development, as evidenced by (lnGDPPC) (β = 5.958; p < 0.10). This is consistent with evidence that development transitions in low- and middle-income economies often involve increased borrowing before stabilizing financing structures (IMF, 2022). However, this emphasizes the need to fund growth with equity and sustainable investment rather than debt. Three principal policy-relevant insights emerge overall: The structural persistence of debt dependence in Sub-Saharan Africa necessitates intentional reforms in financing and industrial policy; Sustainable foreign direct investment diminishes dependence on macroeconomic debt, hence underscoring the strategic significance of attracting environmentally conscious, equity-based foreign investment; and Green industrialization enhances financial stability, validating the notion that environmental improvement and financial resilience are interdependent, hence rationalize policy frameworks that incorporate sustainability, industrial enhancement, and financial structural change to establish robust manufacturing-driven economies in Sub-Saharan Africa.

Table 6. GMM Instrument Structure and Diagnostic Test (Main Model)

Section	Item	Details
Instruments (First-differences equation)	Standard IV instruments	D.(SFDI, INSTQ, lnGDPPC, TRADE_OPEN, ACCESS)
	GMM-type instruments (collapsed)	L(3/5).DCGDP (collapsed); L(4/10).L.DER (collapsed)
Instruments (Levels equation)	Standard IV instruments	SFDI, INSTQ, lnGDPPC, TRADE_OPEN, ACCESS
	GMM-type instruments (collapsed)	DL2.DCGDP (collapsed); DL3.L.DER (collapsed)
Serial correlation tests (Arellano–Bond)	AR(1) in first differences	z = −0.91; p = 0.361
	AR(2) in first differences	z = 0.72; p = 0.474

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Overidentification tests	Sargan test (not robust)	$\chi^2(5) = 0.26$; $p = 0.998$
	Hansen test (robust)	$\chi^2(5) = 3.98$; $p = 0.553$
Difference-in-Hansen (instrument subsets)	GMM instruments for levels	Excluding group: $\chi^2(3) = 2.07$; $p = 0.558$; Difference: $\chi^2(2) = 1.91$; $p = 0.385$
	gmm(L.DER, collapse lag(4 .))	Excluding group: $\chi^2(2) = 3.54$; $p = 0.170$; Difference: $\chi^2(3) = 0.44$; $p = 0.932$
	gmm(DCGDP, collapse lag(3 5))	Excluding group: $\chi^2(1) = 0.26$; $p = 0.607$; Difference: $\chi^2(4) = 3.71$; $p = 0.446$
	iv(SFDI INSTQ lnGDPPC TRADE_OPEN ACCESS)	Excluding group: $\chi^2(0) = 0.00$; $p =$. ; Difference: $\chi^2(5) = 3.98$; $p = 0.553$

Table 6 above shows the primary Regression instrument structure and diagnostic results suggest that System GMM estimation is well-specified and statistically robust for exploring how sustainable FDI and green industrialization dynamics affect manufacturing-driven Sub-Saharan Africa's macro debt-equity composition. To address endogeneity, unobserved heterogeneity, simultaneity bias, and persistence in macro-financial variables, the Arellano-Bover/Blundell-Bond approach uses lagged levels to instrument initial differences and levels. GMM-type instruments like lagged DER and DCGDP, along with conventional IVs like Sustainable FDI (SFDI), institutional quality (INSTQ), openness, access, and income, reliably identify how structural sustainability and green industrial pathways affect sovereign leverage structures and equity financing capabilities in manufacturing. The residuals demonstrate no first- or second-order autocorrelation in Arellano-Bond serial correlation tests (AR(1) = 0.361, AR(2) = 0.474) as shown in Table 6 above. This indicates the dynamic specification is correct and residual persistence and misspecification do not affect debt-equity dynamics. The Sargan ($p = 0.998$) and Hansen ($p = 0.553$) tests show that the instruments are valid and uncorrelated with the error term, which is important when policy-relevant macro variables are weakly identified or overfitted (Roodman, 2009 Difference-in-Hansen tests show that limited GMM and IV subsets are valid, proving no subset bias of Sustainability-related financial indicators and macro-control devices are structurally linked to debt-equity and statistically exogenous.

Diagnostics show the model's statistical reliability and estimates. Sustainable FDI flows and green industrialization dynamics considerably alter macro debt-equity structures in SSA manufacturing

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economies, increasing green finance, structural competitiveness, and sovereign balance-sheet management policy discussions.

Table 7. System GMM Regression Result of the Mediation Effect

	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
lGIN	.914	.033	27.79	0	.847	.981	***
SFDI	-.103	.023	-4.45	0	-.15	-.055	***
lnGDPPC	.009	.002	3.59	.001	.004	.014	***
TRADE_OPEN	0	0	-1.71	.097	0	0	*
DCGDP	-.001	0	-4.51	0	-.001	0	***
ACCESS	0	0	0.89	.383	0	0	

Mean dependent var	0.255	SD dependent var	0.108
Number of obs	155	F-test	8341.121

*** p<.01, ** p<.05, * p<.1

Source: Secondary Data

Table 7 above presents the SFDI effects on macro-financial structure and debt-equity equilibrium in manufacturing-driven SSA economies, which are explored using the mediation model. A positive L.GIN coefficient of 0.914 ($p < 0.01$) suggests considerable persistence in green industrial performance. This aligns with structural changes and green transition theories, emphasizing technological transfer and capability building for path-dependent and progressive green industrial transformation. SFDI significantly lowers GIN (coef. = -0.103; $p < 0.01$), thus aligns with the second hypothesis (H_2) and the pollution-haven hypothesis: the SFDI measured in this study correlates with diminished, rather than enhanced, green industrialization in SSA manufacturing economies. FDI in Sub-Saharan African manufacturing may be resource-seeking or pollution-intensive rather than environmentally transformative, illustrating "pollution haven" and "brown FDI dominance" in jurisdictions with weak regulatory frameworks (Eskeland & Harrison, 2023; Cole et al., 2020).

Given that SFDI decreases GIN (β = -0.103) and GIN decreases DER (β = -102.08), the indirect effect is calculated as: -0.103 x (-102.08) = +10.51. The positive indirect effect indicates that SFDI enhances GIN through GIN's DER-reducing mechanism; however, as SFDI initially diminishes GIN, the overall indirect effect on DER is upward, implying that SFDI exacerbates DER through

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the GIN pathway. The direct impact of SFDI on DER is negative (-19.727), resulting in a net total effect that somewhat counterbalances this indirect route. This represents partial mediation, wherein GIN conveys a compensatory indirect impact. The mediation is limited due to the minor magnitude of the SFDI-GIN coefficient, affirming the fourth hypothesis (H_4) with the caveat that the mediation pathway is poor and hindered by deficiencies in institutional and absorptive ability.

This shows that foreign direct investment may not encourage green industrial advances without rigorous environmental legislation and green investment plans, damaging the sustainability pathway that may make finance frameworks less debt-dependent and more productivity-focused. Proper macroeconomic controls function. Green industrialization is significantly favored by income growth (lnGDPPC) (coef. = 0.009; $p < 0.01$), supporting the Environmental Kuznets-structural upgrading theory with cleaner technologies and sustainable production systems (Grossman & Krueger, 1995; Domestic credit negatively correlates with GDP (DCGDP) (coef. = -0.001; $p < 0.01$), showing Sub-Saharan Africa may prioritize traditional manufacturing and brown production over green advancement. This suggests many African financial and capital markets do not have sufficient options for sustainability financing and green funding (UNEP, 2018; Demirgüç-Kunt et al., 2022). Trade openness reduces integration-led greening's direct benefits without industrial policy ($p = 0.097$). The mediation model suggests GIN mediates considerably but limitedly. SFDI does not necessarily improve green industrial outcomes, demonstrating a low indirect influence on macro debt-equity pressure through productivity-enhancing green transformation. This argues that Sub-Saharan African states require better institutional frameworks, environmental laws, and green-industrial plans to attract foreign direct investment and transition from debt to equity-based sustainable growth. The model's expected signals and statistical significance (F-statistic = 8341.121) support these claims.

Table 8. System GMM Instrument and Diagnostic Test (Mediation Effect)

Section	Item	Details
Instruments (First-differences equation)	Standard IV instruments	D.(SFDI, lnGDPPC, TRADE_OPEN, ACCESS, FDI, PORT)
	GMM-type instruments (collapsed; lags as specified)	L(2/10).DCGDP (collapsed); L(3/10).L.GIN (collapsed)
Instruments (Levels equation)	Standard IV instruments	SFDI, lnGDPPC, TRADE_OPEN, ACCESS, FDI, PORT
	GMM-type instruments (collapsed)	DL.DCGDP (collapsed); DL2.L.GIN (collapsed)

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Serial correlation tests (Arellano-Bond)	AR(1) in first differences	z = −2.60; p = 0.009
	AR(2) in first differences	z = −1.50; p = 0.134
Overidentification tests	Sargan test (not robust)	$\chi^2(14) = 6.83$; p = 0.941
	Hansen test (robust)	$\chi^2(14) = 17.06$; p = 0.253
Difference-in-Hansen (instrument subsets)	GMM instruments for levels	Excluding group: $\chi^2(12) = 9.59$; p = 0.651; Difference: $\chi^2(2) = 7.46$; p = 0.024
	gmm(L.GIN, collapse lag(3 .))	Excluding group: $\chi^2(8) = 6.95$; p = 0.542; Difference: $\chi^2(6) = 10.11$; p = 0.120
	gmm(DCGDP, collapse lag(2 .))	Excluding group: $\chi^2(6) = 4.76$; p = 0.574; Difference: $\chi^2(8) = 12.30$; p = 0.139
	iv(SFDI lnGDPPC TRADE_OPEN ACCESS FDI PORT)	Excluding group: $\chi^2(8) = 4.23$; p = 0.835; Difference: $\chi^2(6) = 12.83$; p = 0.046

Table 8 above shows the instrument and diagnostic test results, which show that the System GMM framework is suitable and reliable for studying the interaction between Sustainable FDI (SFDI) and green industrialization (GIN) with macro-financing structures like the debt-equity mix in manufacturing-driven Sub-Saharan African economies. Difference and system GMM instruments, orthogonally transformed variables, and collapsed lag structures are needed for dynamic panel models with limited temporal dimensions and probable endogeneity (Arellano & Bond, 1991; Blundell & Bond, 1998; Roodman, 2009). Instrument sets include GMM instruments from lagged endogenous variables like DCGDP and GIN, and IV instruments (exogenous regressors in levels and starting differences). Supporting the premise that SSA's FDI, debt dynamics, and environmental performance are endogenous and path-dependent, lagged macro-financial determinants and sustainability performance are persistent and valid predictors of present dynamics (UNCTAD, 2023; Demirgüç-Kunt et al., 2022). The strong Sargan test p-value ($\chi^2(14) = 6.83$; p = 0.941) suggests that homoskedasticity cannot be employed to eliminate over-identifying constraints as shown in Table 8. Resilience to heteroskedasticity and autocorrelation is indicated by the Hansen J-test ($\chi^2(14) = 17.06$; p = Valid instruments that do not overfit endogenous variables or correlate with the error term meet the GMM estimation criterion (Roodman, 2009; Blundell & Bond, 1998).

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Serial Arellano-Bond correlations indicate model specification: As expected, first-differencing causes negative first-order serial correlation, making the AR(1) term significant (p = 0.009) and the AR(2) statistic insignificant (p = 0.134), indicating no second-order serial correlation, which is necessary for GMM estimator consistency. The fact that the differenced residuals are free from higher-order serial dependency validates the dynamic structure, and that model estimates represent structural links rather than contrived persistence.

Instrument subset validity is tested by difference-in-Hansen. Instrument dependability and proliferation issues are essential in SSA macro-panel setups where excessive instrumentation can influence estimations (Roodman, 2009). The level and differenced moment requirements are met in most subgroups, proving validity. The Difference test for all GMM instruments reveals p = 0.024, showing slight sensitivity. The instruments are mainly valid, but the sustainability channel is statistically weak, reflecting real-world uncertainty about SFDI's impact on green transformation and financing restructuring in SSA (UNCTAD, 2023; Stern, 2017).

5. Conclusion And Recommendations

This study analyzed the interrelationships among sustainable foreign direct investment (SFDI), green industrialization (GIN), and the macro debt-equity ratio (DER) in manufacturing-driven Sub-Saharan African economies from 2014 to 2024. The empirical data derived from a System GMM framework reveal three primary discoveries.

Firstly, SFDI exhibits a negative correlation with the macro debt-equity ratio (DER), indicating that sustainability-adjusted FDI inflows are linked to enhancements in the macro-financing framework of SSA economies. This outcome is contingent upon the methodological caveat that FDI is incorporated in both SFDI (numerator) and DER (denominator), potentially creating a spurious negative correlation. Subsequent investigations ought to develop SFDI and DER from non-overlapping data sources to address this identification issue.

Secondly, SFDI has a substantial negative impact on GIN, aligning with the pollution haven hypothesis. Without rigorous environmental regulations and sustainable industrial policies, foreign direct investment in Sub-Saharan African manufacturing is typically allocated to resource-intensive and carbon-intensive endeavors rather than to ecologically transformative initiatives. This discovery contests the presumption that sustainability-labeled foreign direct investment inherently produces green industry spillovers and emphasizes the need for evaluating foreign investment based on its environmental impact.

Third, GIN has a negative and significant correlation with DER, suggesting that nations attaining green industrial advancement gain from increased equity-focused macro-financing. This corroborates the theoretically anticipated transmission mechanism by which environmental enhancement diminishes sovereign risk, bolsters investor confidence, and draws equity-type capital inflows.

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The mediation study indicates that GIN partially mediates the association between SFDI and DER; however, the indirect pathway is weak and limited by institutional deficiencies. This indicates that SSA economies cannot depend exclusively on obtaining SFDI to initiate green transformation and financial restructuring; intentional policy involvement is necessary.

The policy implications are evident. Governments in SSA should: (i) establish green FDI screening mechanisms to guarantee that incoming foreign investments adhere to minimum environmental performance standards; (ii) enhance institutional capacity especially regulatory quality and environmental governance to ensure that multinational investors' sustainability commitments result in genuine green industrial advancement; (iii) create domestic green finance instruments, such as sustainability bonds and concessional equity financing vehicles, to diminish dependence on external debt; and (iv) synchronize industrial policy with climate transition strategies to align structural transformation pathways with long-term environmental and financial sustainability goals.

The study's limitations encompass a small effective regression sample (n = 39), mechanical overlap between SFDI and DER, cross-sectional dependence inadequately handled by System GMM, and the lack of direct sector-level SFDI data. Subsequent study ought to broaden the sample size, utilize sector-specific FDI data where available, integrate firm-level microdata, and evaluate the model using other estimators like Driscoll-Kraay or Common Correlation Effect (CCE) to confirm the robustness of the results. Sustainable foreign direct investment (FDI) is an environmental imperative and an economic and financial stabilization strategy that can help manufacturing-oriented Sub-Saharan Africa (SSA) transform green and improve macro debt-equity.

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