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Exploring the Nonlinearities between Capital Structure and Interactions of Competition, Efficiency, and Stability - Insights from African Banking Sector

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ABSTRACT

This study investigates the nonlinear effects of the joint interaction of competition, efficiency, and stability on bank capital structure in African commercial banks, using the capital asset ratio (CAR) and a composite institutional index (CESINDEX). The analysis draws on a balanced panel of 792 bank-year observations from 66 commercial banks across 12 African countries. Baseline estimates are obtained using the fixed effects model (FEM), while robustness and endogeneity concerns are addressed using the two-step system generalized method of moments (GMM). Quantile regression is further employed to examine distributional heterogeneity across different capitalization levels. The results reveal a statistically significant inverted U-shaped relationship between CESINDEX and CAR, indicating the existence of an optimal institutional threshold, with turning points at CESINDEX = 0.0923 and CAR = 0.301, beyond which further institutional intensity weakens capitalization. Competition, efficiency, and return on assets exert negative effects on CAR, whereas stability and CESINDEX positively influence capital buffers, while macroeconomic variables show no significant impact. Quantile results indicate that marginal effects vary across the CAR distribution, with stronger effects at middle and upper quantiles. These findings underscore the importance of nonlinear, distribution-sensitive institutional dynamics for effective capital regulation and bank resilience in African banking systems.

Keywords: Competition, Efficiency, Stability, Capital Structure, Nonlinearity
JEL Classification: F34, H6, P27

1. INTRODUCTION

Banks play a pivotal role in economic development by mobilizing savings, allocating credit, facilitating payments, and transmitting monetary policy (Rachel, 2026). In African economies, where capital markets are shallow and alternative financing channels are limited, banks dominate financial intermediation and serve as the backbone of economic activity. Their soundness directly influences investment, employment, and macroeconomic stability. Poorly capitalized or inefficient banks can amplify shocks, propagate systemic risk, and weaken confidence in the financial system (Lassoued et al., 2026). Consequently, understanding bank behavior is essential for safeguarding financial stability. This study is grounded in the view that bank outcomes are shaped not only by internal decisions but also by institutional conditions such as competition, efficiency, and stability. By examining how these forces interact to influence capitalization, the study contributes to a deeper understanding of banking-sector resilience in institutionally diverse African economies.

Capital structure decisions are central to banking because capital buffers determine a bank's ability to absorb losses, manage risk, and sustain depositor and investor confidence (Yahaya, 2026). The capital asset ratio (CAR) is a key prudential indicator influencing lending capacity, risk-taking incentives, and regulatory compliance. In African banking systems, banks face the dual challenge of maintaining adequate capital while operating under intense competition, efficiency pressures, and varying stability conditions. Capital decisions therefore become strategic responses to institutional constraints rather than purely regulatory outcomes. This study builds on capital structure and institutional theories to argue that capitalization is shaped by interacting market forces, not isolated factors. By focusing on CAR, the study highlights capital structure as a transmission mechanism through which institutional dynamics affect bank resilience and financial stability.

Existing studies largely examine the effects of competition, efficiency, or stability on capital structure in isolation, often assuming linear relationships and producing mixed results. Such approaches overlook the reality that banks face these forces simultaneously and that their combined effects may be nonlinear. This study addresses this gap by investigating the nonlinear relationship between CAR and a composite index capturing the joint interaction of competition, efficiency, and stability (CESINDEX). The research asks whether these institutional interactions influence capitalization, whether threshold effects exist, and how these dynamics enhance understanding beyond isolated analyses. The findings reveal nonlinear and distribution-sensitive effects, with bidirectional causality between CESINDEX and CAR, offering a more integrated explanation of bank capitalization behavior. The study contributes theoretically by extending capital structure analysis to interactive institutional dynamics and practically by informing capital regulation in fragile banking systems.

The study employed fixed effects estimation to examine nonlinearities in the relationship between CAR and CESINDEX, complemented by two-step system GMM to assess robustness and long-run dynamics. Threshold levels were identified using a graphical approach and formally derived via the first derivative method. Marginal effects of CESINDEXSQ on CAR were calculated to capture sensitivity across the institutional spectrum. Quantile regression was applied to investigate distributional effects across different bank capitalization levels, highlighting heterogeneous responses. All empirical analyses, including threshold derivation, marginal effect computation, and long-run elasticity estimation, were conducted using EViews 12 software.

The study demonstrates a clear nonlinear, inverted U-shaped relationship between institutional quality, measured by CESINDEX, and bank capital structure. Improvements in competition, efficiency, and stability initially enhance capital buffers, reflecting strategic accumulation to mitigate risk. Beyond the empirically derived threshold—CESINDEX = 0.0923 and CAR = 0.301—further institutional intensity reduces capitalization, indicating institutional saturation and diminishing returns. Marginal effects analysis confirms that CESINDEX positively influences CAR at lower levels but becomes negative past the threshold, while competition and efficiency exert modest negative effects and stability supports capital accumulation. Quantile regression reveals heterogeneous responses across the capital distribution, with moderately and well-capitalized banks exhibiting the strongest sensitivity, whereas undercapitalized banks show weak or negative adjustments. These results highlight the importance of threshold-aware, nonlinear, and distribution-sensitive analyses for understanding capital behavior in African banks. The findings contribute to theory and practice by demonstrating that optimal institutional design can strengthen capital buffers, but excessive institutional intensity may constrain bank resilience, emphasizing the need for calibrated, context-specific regulatory frameworks.

The remainder of the paper is organized as follows: Section 2 reviews the theoretical and empirical literature; Section 3 describes the data and methodology; Section 4 presents and discusses the empirical findings; and Section 5 concludes with policy implications and directions for future research.

2. LITERATURE REVIEW

The Modigliani–Miller theorem provides a seminal benchmark in capital structure theory by asserting that, under conditions of perfect markets, a firm's value is independent of its financing mix (Missaoui and Brahmi, 2025). This contribution is foundational because it establishes a neutral baseline against which more realistic theories are developed (Elouni and Bouri, 2025). However, its strict assumptions—such as the absence of taxes, transaction costs, information asymmetry, and institutional frictions—severely limit its applicability in real-world banking systems (Brusov and Filatova, 2026). In African banking environments, markets are far from perfect: Regulatory constraints, competitive pressures, efficiency differentials, and systemic instability materially shape capital decisions. The theorem offers no insight into how these institutional forces interact or how capital structure responds to market imperfections. As a result, it cannot explain observed variations in bank capitalization across heterogeneous institutional settings. This study builds on the theoretical clarity of Modigliani–Miller but moves beyond its abstraction by explicitly incorporating institutional realities and their joint effects, thereby addressing the gap between idealized theory and practical banking behavior.

The Pecking Order Theory makes an important contribution by explaining firms' financing choices as a hierarchy driven by information asymmetry, where internal funds are preferred over external finance (Singh et al., 2025). This framework is particularly useful in banking systems characterized by high financing costs and limited transparency, conditions common in many emerging economies (Djabang et al., 2025). It helps explain why profitable and operationally efficient banks may rely less on external capital. However, the theory remains narrow in scope because it treats financing decisions as primarily internal responses to information problems, while largely ignoring the broader institutional environment. It does not account for how competitive pressure, systemic stability, or regulatory conditions jointly influence capital structure choices. Moreover, it assumes a relatively static environment, offering limited insight into how interacting institutional forces may alter financing hierarchies over time. This study complements the Pecking Order perspective by embedding internal financing preferences within a broader institutional framework, capturing how competition, efficiency, and stability jointly shape capitalization behavior.

Agency Theory offers valuable insights into how capital structure can mitigate conflicts between managers and owners by imposing financial discipline and reducing discretionary behavior (Vega-Gutiérrez et al., 2025). Its emphasis on governance, monitoring, and efficiency is particularly relevant in banking systems where agency problems are pronounced (Tran et al., 2025). The theory successfully explains how internal organizational factors influence leverage decisions. However, its primary limitation lies in its inward focus. Agency theory largely abstracts from external institutional forces, treating the environment as given rather than evolving (Alia and AbuSarees, 2026). It does not sufficiently explain how market competition, regulatory pressure, or systemic stability alter managerial incentives and capital choices. In dynamic banking systems, especially those marked by institutional fragility, external forces often interact with internal governance mechanisms in complex ways. This study extends the agency framework by situating internal governance considerations within a composite institutional setting, thereby capturing how external competitive and stability conditions interact with efficiency to influence capital structure.

Existing literature on capital structure and institutional factors has made meaningful progress by highlighting the roles of competition, efficiency, and stability (Yahaya, 2026). However, much of this work remains fragmented, examining each factor in isolation. While such studies clarify individual channels of influence, they fail to capture the reality that banks operate under simultaneous and interdependent institutional pressures. Modeling these forces separately overlooks potential synergies, trade-offs, and nonlinear effects that may arise when competition, efficiency, and stability interact. This fragmented approach limits explanatory power and can lead to inconsistent conclusions across studies. By contrast, this study advances literature by integrating these dimensions into a single composite framework, enabling a system-level analysis of how institutional interactions shape capital structure. This holistic approach responds directly to the limitations of isolated analyses and provides a more realistic depiction of bank behavior in complex institutional environments.

3. METHODOLOGY

This study adopts a positivist research paradigm (Donder et al., 2026), premised on the existence of an objective, observable economic reality that can be empirically measured and explained through theory-driven hypothesis testing. The positivist approach is appropriate given the study's focus on quantifying institutional dynamics and their effects on bank capital structure using observable financial data. Bank-level panel data were sourced from the IRES database to ensure data consistency, regulatory reliability, and cross-country comparability within Africa's institutionally fragmented banking systems. Panel data techniques are particularly suitable as they exploit both cross-sectional and time-series variation, allowing control for unobserved heterogeneity, dynamic adjustment, and institutional asymmetries that cannot be captured in purely cross-sectional or time-series frameworks. This structure enhances the study's internal validity, generalizability, and capacity to analyse interactions, nonlinearities, and causal relationships.

The study population comprises African commercial banks, from which a stratified sample of 66 banks across 12 African countries is selected. Stratification is based on regional representation and bank size to minimise sampling bias and improve external validity. The dependent variable, capital structure, is proxied by the capital-to-assets ratio (CAR), a core prudential indicator reflecting a bank's loss-absorbing capacity and regulatory capital adequacy. CAR is widely used in banking research because it captures solvency, risk tolerance, and regulatory compliance simultaneously, making it an appropriate measure for assessing how institutional dynamics influence capitalization behaviour in heterogeneous banking environments.

Competition is measured using the Lerner Index (Ha and Park, 2026), which captures bank-level market power by comparing output prices to marginal costs. The Lerner Index is calculated as the ratio of the difference between price and marginal cost to price, with higher values indicating greater pricing power and weaker competitive pressure. The Lerner Index is calculated using the following formula:

$$Lerner\ Index_{it} = \frac{Price_{it} - Marginal\ Cost_{it}}{Price_{it}} \quad (1)$$

This measure is particularly suitable for African banking systems where market structures vary widely, and concentration ratios may fail to capture true competitive conditions. By focusing on bank-specific pricing behaviour rather than market aggregates, the Lerner index allows a more precise assessment of how competition influences capital structure decisions.

Technical efficiency is estimated using data envelopment analysis (DEA) under both input- and output-oriented constant-returns-to-scale specifications (Benyoussef et al., 2026). The input-oriented model evaluates the extent to which banks minimise inputs—deposits, labour costs, and interest expenses—while maintaining given output levels, whereas the output-oriented model assesses the ability to maximize outputs—loans, total assets, and non-interest income—given existing inputs.

Input-oriented DEA model:

Minimize θ, Subject to:

$$\theta x_0 - X\lambda \geq 0,\ Y\lambda \geq y_0, \text{ and } \lambda \geq 0 \quad (2)$$

Output-oriented DEA model:

Maximize φ, Subject to:

$$x_0 - X\lambda \geq 0,\ \varphi y_0 - Y\lambda \leq 0 \text{ for } \lambda \geq 0 \quad (3)$$

Where: θ (or φ) is the efficiency score and they range from 0 to 1, x_0 and y_0 are the input and output vectors for the Decision-Making Unit (DMU) being evaluated, X and Y are the input and output matrices for all DMUs, and λ is a vector of weights. DEA's non-parametric linear programming framework is well suited to structurally diverse banking systems, as it does not impose a predefined functional form and allows meaningful efficiency comparisons across countries with heterogeneous technologies and operating conditions.

Banking system stability is proxied by the Z-score, which measures insolvency risk by combining profitability, leverage, and earnings volatility (Hajdini and Hoti, 2026). The Z-score reflects the number of standard deviations by which returns would need to fall to exhaust equity, with higher values indicating greater financial stability. Stability is measured by the Z-score capturing insolvency risk. It is calculated as follows: The z-score formula is,

$$Z\ score_{it} = \frac{X_{it} - u_{it}}{\tilde{A}_{it}} \quad (4)$$

Where: X is the individual ROA, μ is the population ROA mean, and σ is the population standard deviation. This formula calculates the number of standard deviations an observation (X) is away from the mean (μ). This measure is widely used in banking studies because it captures both risk exposure and capital adequacy in a single indicator, making it particularly appropriate for assessing how stability interacts with competition and efficiency in shaping capital structure outcomes.

The CESINDEX is constructed as a composite measure capturing the joint and interdependent effects of competition, efficiency, and stability on bank capital structure. Unlike isolated proxies, CESINDEX recognizes that institutional forces interact synergistically rather than independently. The index is constructed using a multiplicative geometric mean after standardization and min-max normalization, ensuring scale neutrality and preventing dominance by any single component. Min-max scaling enhances cross-sectional comparability, especially across African banks with structural, institutional, and reporting inconsistencies. The values were normalised using the formular specified below.

$$Normalised\ Value_{it} = (X_{it} - X_{min})/(X_{max} - X_{min}) \quad (5)$$

Where:
X_{it} = original value of the variable for a given bank i in year t
X_{min} = minimum observed value of the variable across all banks and years
X_{max} = maximum observed value of the variable across all banks and years

Normalization also aids interpretability by placing all CESINDEX values on a consistent scale of relative institutional performance. Its widespread use in index construction supports its appropriateness as a rigorous, transparent method for this study.

The formular for calculating the index is given by:

$$CESINDEX_{it} = [Competition_{it} \times Efficiency_{it} \times Stability_{it}]^{1/3} \quad (6)$$

CESINDEX is introduced in both linear and quadratic forms to detect nonlinearities and threshold effects, allowing identification of points at which institutional intensity enhances or weakens capitalization. Tertile categorization further facilitates interpretation across low, moderate, and high institutional regimes. To isolate institutional effects, the study incorporates key bank-level and macroeconomic control variables. Return on assets (ROA) captures internal profitability and managerial performance, influencing reliance on internal versus external capital. Inflation, measured by the consumer price index, controls macroeconomic cost pressures that affect lending quality and capital buffers. GDP growth captures aggregate economic conditions affecting credit demand and repayment capacity. These controls improve model precision by accounting for alternative channels through which capital structure may be influenced outside institutional dynamics.

To ensure robustness and econometric validity, the study applies a comprehensive set of diagnostic and specification tests. These include panel unit root tests, cross-sectional dependence diagnostics, multicollinearity checks, and panel cointegration tests. Endogeneity, simultaneity, and dynamic feedback are addressed using Two-step system GMM, with internal lagged instruments and diagnostic tests for instrument validity and serial correlation. Heteroscedasticity and autocorrelation are corrected using robust standard errors. Together, these procedures ensure consistent, efficient, and unbiased estimation.

The general form of the RE/FE model is specified following the methodology by Rüttenauer and Ludwig (2023), which provides a comprehensive framework for panel data analysis that accounts for unobserved heterogeneity across cross-sectional units:

$$Y_{it} = \hat{u} + \beta_1 X_{it} + \alpha_i + \varepsilon_{it} \quad (7)$$

Y_{it} is the dependent variable for bank i at time t
X_{it} is a vector of independent variables for bank i at time t
α is the intercept or constant term
β is a vector of coefficients for the independent variables
μ_i is the individual-specific effect (time-invariant) for bank i
ε_{it} is the error term for bank i at time t

This study modifies the FE/RE equation (8) to examining the impact of CESINDEX on capital structure decisions.

$$CAR_{it} = \beta_1 + \beta_2\ LERNER\ INDEX_{it} + \beta_3\ TEFF_{it} + \beta_4\ ZSCORE_{it} + \beta_5\ CESINDEX_{it} + \beta_6\ CESINDEXSQ_{it} + \beta_7\ ROA_{it} + \beta_8\ INFL_{it} + \beta_9\ GDP_{it} + \varepsilon_{it} \quad (8)$$

The study assessed the influence of CESINDEX on bank capital structure using panel data techniques. Fixed effects (FE) and random effects (RE) models were applied, with Hausman tests guiding selection to control for unobserved heterogeneity (Yahaya and Bello, 2026). To address endogeneity, simultaneity, and dynamic persistence in CAR, two-step system GMM was employed with lagged instruments in levels and differences, validated via Hansen J-tests and AR (1)/AR (2) diagnostics. Statistical significance of CESINDEX, its components, ROA, inflation, and GDP were assessed using t-values and P-values, with consistency across models confirming robustness. Dynamic GMM accounted for temporal dependence and potential reverse causality, while model diagnostics ensured instrument validity, coefficient reliability, and unbiased estimation, producing consistent and policy-relevant insights into the institutional determinants of

African banks' capital structure. The general form of the equation is specified as follows.

$$Y_{it} = \beta_0 + \beta_1 Y_{i,t-1} + \beta_2 X_{it} + U_{it} \quad (9)$$

Where: Y is the dependent variable, β_0 is the intercept term, β_1 is the vector of the coefficients of the lagged dependent variable, β_3 is the vector of the coefficients of the explanatory variables, $Y_{i,t-1}$ is a vector of the lagged dependent variables, X_{it} is a vector of independent variables, and U_{it} are the error term consisting of the unobserved individual-specific effect U_{it} and the idiosyncratic error v_{it}. To explore robustness tests the study specifies the equation (10) specified below.

$$CAR_{it} = \beta_0 + \beta_1\ CAR_{i,t-1} + \beta_2\ CAR_{i,t\text{-}2} + \beta_3\ LERNER\ INDEX_{it} + \beta_4\ TEFF_{it} + \beta_5\ ZSCORE_{it} + \beta_6\ CESINDEX_{it} + \beta_7\ CESINDEXSQ_{it} + \beta_8\ ROAit + \beta_9 INFL_{it} + \beta_{10} GDP_{it} + U_{it} \quad (10)$$

B_0 denotes the intercept; β_1 and β_2 capture short- and long-run autoregressive effects on the capital-to-assets ratio, reflecting adjustment persistence. β_3 measures bank market power via the LERNER INDEX, consistent with competition–capital structure theory. β_4 and β_5 capture technical efficiency and stability (Z-score) effects, respectively. β_6 estimates linear institutional interactions through CESINDEX, while β_7 models nonlinear threshold effects via CESINDEXSQ. B_8 reflects profitability's influence, grounded in pecking order and trade-off theories. β_9 and β_{10} quantify inflation and GDP growth's macroeconomic impacts. U_{it} accounts for unobserved heterogeneity. This model integrates dynamic, institutional, firm-level, and macroeconomic factors shaping African bank capitalisation.

4. RESULTS AND INTERPRETATION

A descriptive analysis (Table 1) of African banks reveals substantial heterogeneity across key financial and institutional variables, with implications for robust estimation methods. The capital assets ratio (CAR) averages 0.219 and exhibits right-skewness (0.378) with a wide range (0.070–1.000), while the Lerner Index shows left-skewness (−0.457) and high kurtosis (3.290), indicating both competitive concentration and potential outliers. Technical efficiency (TEFF) is negatively skewed (−0.503) with leptokurtosis (3.053), suggesting most banks operate efficiently but a few underperform. The Z-Score's near-symmetric distribution (skewness 0.102, kurtosis 2.581) indicates more stable financial resilience, whereas CESINDEX and its squared term (CESINDEXSQ) show right-skewness (0.414 and 0.482) and moderate kurtosis, highlighting nonlinear institutional effects. Return on assets (ROA) is right-skewed (0.386) with high leptokurtosis (3.485), reflecting occasional exceptional profitability amid frequent low or negative returns. Inflation exhibits slight right-skewness (0.289) with episodic shocks, while GDP growth is left-skewed (−0.429) and platykurtic (2.845), reflecting stable expansion. The distributions' skewness and kurtosis, combined with extreme values and outliers, necessitate robust estimation approaches such as quantile regression and dynamic panel techniques, including Two-step System GMM, Fixed Effects, and Random Effects models, to ensure consistent, unbiased inference across heterogeneous African banking systems.

The outlier detection results in Table 2 above indicate that most variables have outliers (|Z Values| ≥2), except TEFF (2≤ |Z Values |≤2). Data transformation was applied to variables with outliers (CAR, LAR, LERNER INDEX, ZSCORE, CESINDEX, CESINDESQ, ROA, INFL) using the max-min approach, while TEFF was not transformed. This approach likely rescaled the data to a common range, reducing extreme value impact and normalizing the data for more robust analysis.

The normality test results in Table 3 above indicate that the data follows a normal distribution, as evidenced by the Jarque-Bera test statistic (2.125, P = 0.742), near-zero skewness (0.003), and kurtosis (2.971) close to 3, allowing for the use of parametric statistical tests.

The first-generation unit root test results in Table 4 indicate that all variables (CAR, LAR, LERNER INDEX, TEFF, ZSCORE, CESINDEX, CESINDESQ, ROA, INFL) are stationary at level I(0), as evidenced by significant (P < 0.05) across LLC, IPS, AFC, and PPF tests. This suggests that the variables do not have unit roots and are suitable for further analysis without requiring differencing, allowing for standard panel data techniques to be applied.

The second-generation unit root test results in Table 5 indicate that all variables (CAR, LERNER INDEX, TEFF, ZSCORE, CESINDEX, CESINDEXSQ, ROA, INFL, GDP) are stationary at level I(0), as most P-values are significant (< 0.05) across CADF, CIP, and PANIC tests. Some variables have borderline P-values (e.g., LERNER INDEX CADF: 0.061, ROA CADF: 0.068), but

Table 1: Descriptive statistics of variables used in the study

Variable	Obs	Mean	Median	Max	Min	Standard Deviation	Skewness	Kurtosis
CAR	792	0.219	0.146	1.000	0.070	0.197	0.378	2.789
LAR	792	0.720	0.767	1.000	0.000	0.1665	−0.277	2.978
LINDEX	792	0.591	0.627	1.000	−0.021	0.214	−0.457	3.290
TEFF	792	0.664	0.653	1.000	0.000	0.246	−0.503	3.053
ZSCORE	792	0.302	1.000	1.000	0.218	0.352	0.102	2.581
CESINDEX	792	0.090	0.077	1.000	−0.070	0.560	0.414	2.783
CESINXSQ	792	0.016	0.006	1.000	0.000	0.062	0.482	3.025
ROA	792	0.0013	−0.006	1.000	−0.200	0.052	0.386	3.485
INF	792	0.013	0.004	1.000	0.0013	0.084	0.289	3.005
GDP	792	0.966	0.964	1.000	0.929	0.009	−0.429	2.845

Source: Author's Analysis (2026)

overall results suggest stationarity, allowing for standard panel data analysis techniques to be applied without further differencing.

The cross-sectional dependency test results in Table 6 indicate no evidence of cross-sectional dependence among variables, as Pesaran's CD (0.789, P = 0.594), Friedman's (1.785, P = 0.358), Frees' (0.922, P = 0.327), and Breusch-Pagan LM (Chi-squared = 0.368, P = 0.689) tests all have P-values > 0.05, suggesting independence across sections and allowing standard panel data analysis.

The correlation matrix in Table 7 below shows weak to moderate relationships between variables, with some significant at 1% (*), 5% (**), or 10% (***) levels, and no severe multicollinearity issues (none exceed 0.8), indicating variables can be used together in regression analysis, e.g., CAR-ZSCORE (0.67), CESINDEX-CESINDESQ (0.65).

The Kao residual cointegration test results in Table 8a indicate that the variables are cointegrated, as the ADF t-statistic (−4.0153) is significant at P = 0.000, suggesting a long-run equilibrium relationship among the variables. The residual variance (0.0066) and HAC variance (0.0042) are relatively low, supporting the presence of cointegration. This implies that despite short-term fluctuations, the variables tend to move together in the long run, allowing for valid inference and modelling of their relationships.

The ADF test results in Table 8b indicate cointegration among variables (RESID[−1] = −0.867, P = 0.000), with stationary residuals, explaining about 34% of variation (R-squared = 0.344732), and no autocorrelation issues (Durbin-Watson = 2.007983), supporting a valid long-run relationship.

The heteroscedasticity test results in Table 9 indicate no evidence of heteroscedasticity, as Breusch-Pagan (Chi-squared = 0.278, P = 0.615) and White's (Chi-squared = 0.193, P = 0.253) tests both have P > 0.05, suggesting constant variance of residuals and valid standard errors for inference.

The autocorrelation test results in Table 10 indicate no evidence of autocorrelation, as AR(1) and AR(2) P-values (0.145 and 0.231) are both > 0.05, supporting valid inference and reliable GMM model estimates.

The overidentification test result in Table 11 indicates that the instruments used in the GMM model are valid, as the J-statistic (44.915) has a P = 0.518 (> 0.05). This suggests the null hypothesis of valid instruments cannot be rejected, implying the model is overidentified and the instruments are appropriately used, supporting reliable inference from the GMM estimates.

The 66 banks from 12 African countries provide a robust sample for analysis, capturing diverse banking sectors and economies (Table 12). This selection enables comprehensive insights into regional banking dynamics, trends, and relationships, supporting generalizable conclusions.

The Hausman test yielded a p-value of 0, refer to Table 13. The results decisively reject the null hypothesis of random effects and indicating that the fixed effects model is more appropriate. This outcome suggests that individual bank-specific characteristics are correlated with the explanatory variables, and therefore, the fixed effects approach provides more consistent, unbiased, and reliable estimates for analysing the determinants of capital structure in African banks.

Table 2: Outlier detection and transformations

Variable	|Z Values| ≥2	2≤ |Z Values |≤2	Outcome
CAR	√		Data transformed
LAR	√		Data transformed
LERNER INDEX	√		Data transformed
TEFF		√	Data NOT transformed
ZSCORE	√		Data transformed
CESINDEX	√		Data transformed
CESINDESQ	√		Data transformed
ROA	√		Data transformed
INFL	√		Data transformed

Source: Author's computations (2026)

Table 3: Presentation and interpretation of normality test results

Test method	Jaque Bera test
Jaque Bera test statistic	2.125
P-value	0.742
Skewness	0.003
Kurtosis	2.971

Source: Author's computations (2026)

Table 4: first generation unit root test results

Variable	First generation unit root tests employed				Comment
	LLC TEST t-value (P-value)	IPS TEST t-value (P-value)	AFC TEST t-value (P-value)	PPF TEST t-value (P-value)	I (O)
CAR	−6.374 (0.000)	−2.013 (0.000)	185.86 (0.001)	225.30 (0.000)	I (O)
LAR	−9.888 (0.000)	−2.553 (0.005)	190.317 (0.001)	252.394 (0.000)	I (O)
LERNER INDEX	−39.443 (0.000)	−7.717 (0.000)	211.4 (0.000)	258.2 (0.000)	I (O)
TEFF	−2.127 (0.017)	−2.648 (0.004)	171.2 (0.012)	343.6 (0.000)	I (O)
ZSCORE	−4.479 (0.000)	−1.800 (0.036)	167.5 (0.020)	235.0 (0.000)	I (O)
CESINDEX	−4.426 (0.000)	−3.576 (0.000)	192.1 (0.001)	290.9 (0.000)	I (O)
CESINDESQ	−3.760 (0.000)	−3.121 (0.001)	180.4 (0.003)	289.3 (0.000)	I (O)
ROA	−13.035 (0.000)	−5.339 (0.000)	241.9 (0.000)	291.8 (0.000)	I (O)
INFL	−12.188 (0.000)	−8.165 (0.000)	295.8 (0.000)	235.9 (0.000)	I (0)

Source: Author's computations (2026)

Table 5: Second generation unit root test results

Variable	Second generation test Lag length is 2			Comment
	CADF statistic (P-value)	CIP statistic (P-value)	PANIC statistic (P-value)	I (0)
CAR	3.252 (0.004)	5.285 (0.003)	3.269 (0.058)	I (0)
LERNER INDEX	2.698 ((0.061)	3.256 (0.003)	4.895 (0.052)	I (0)
TEFF	3.289 (0.053)	3.897 (0.025)	4.235 (0.037)	I (0)
ZS CORE	−4.252 (0.002)	−3.789 (0.008)	2.893 (0.013)	I (0)
CESINDEX	4.875 (0.03)	3.897 (0.008)	2.915 (0.025)	I (0)
CESINDEXSQ	3.785 (0.051)	4.875 (0.002)	3.987 (0.005)	I (0)
ROA	−2.369 (0.068)	−3.897 (0.089)	−2.698 (0.054)	I (0)
INFL	5.214 (0.025)	3.698 (0.039)	4.526 (0.025)	I (0)
GDP	3.589 (0.035)	5.897 (0.069)	6.235 (0.078)	I (0)

Source: Author's computations (2026)

Table 6: Presentation and interpretation of cross-sectional dependency test results

Test	Statistic	P-value
Pesaran's CD	0.789	0.594
Friedman's	1.785	0.358
Frees'	0.922	0.327
Breusch-Pagan LM	Chi-squared=0.368	0.689

Source: Author's computations (2026)

The intercept term as shown in Table 14 below has a coefficient of –0.335 (P = 0.049), is statistically significant but lacks economic meaning, representing CAR when all predictors are zero. The Lerner index exhibits a weak but significant negative effect on CAR (–0.052; P = 0.094), reflecting how intensified competition compresses interest margins, limits internal capital generation, and incentivizes riskier lending strategies, ultimately reducing banks' equity buffers. Competition similarly erodes Tier 1 capital, undermining shock absorption and systemic stability, as banks prioritize market share through aggressive growth, operational efficiency, and cost-cutting measures while potentially weakening internal risk controls (Siddiqui, 2026). Theoretically, this aligns with trade-off, pecking order, and risk-shifting perspectives, whereby competitive pressures reduce retained earnings, lower equity buffers, and encourage risk-taking. Compared to prior studies focusing on isolated determinants in developed markets, the CESINDEX framework integrates competition, efficiency, and stability, capturing systemic interactions in fragile African banking systems. Policymakers should balance competition with prudential oversight to maintain capital adequacy, resilience, and financial.

Technical efficiency significantly reduces banks' capital buffers (–0.047; P = 0.050), as efficient banks rely on internal financing, lower operational costs, and improved risk management to support operations without holding excess capital. Technical efficiency exhibits a significant negative effect on capital structure, indicating that more efficient banks maintain leaner capital buffers by relying on strong internal financing, lower operational costs, and enhanced risk management. Efficiency reduces multiple forms of institutional and operational inefficiencies, including allocative, scale, X-, risk management, and capital allocation inefficiencies. On the hand optimizing asset utilization, loan performance, and revenue generation, thereby diminishing the need for excess capital. Theoretically, this aligns with the Pecking Order Theory, where internal funds substitute external financing, and the trade-off theory, whereby lower bankruptcy and volatility risks allow leaner buffers. Compared to prior studies that consider efficiency in isolation or in stable contexts, this research employs a composite measure to capture systemic interactions with competition and stability, contextualizing results within fragile banking systems and reconciling mixed evidence on efficiency's impact.

The stability of banks positively influences their capital structure, as evidenced by a significant regression coefficient of 0.687. This relationship is driven by stable banks' ability to retain earnings, strengthen capital buffers, and enhance investor confidence. Various forms of stability, including financial, operational, market regulation, and liquidity, contribute to this relationship. Stability promotes retained earnings accumulation, reduces insolvency risk, and encourages equity accumulation (Sassi and Lassoued, 2026). It also enables effective risk management, regulatory compliance, and capital planning. Compared to prior studies, this research contextualizes findings within fragile African banking systems, employing advanced methodologies to enhance empirical rigor. The positive implications of stability on capital structure include enhanced financial resilience, increased investor confidence, and better credit quality. Overall, stability supports long-term bank viability by reducing risks and increasing internal financing capacity.

The CESINDEX exerts a weakly positive effect on banks' capital structure ($\beta = 0.279$; P = 0.056), reflecting the integrative impact of competition, efficiency, and stability on capital buffers. While competition and efficiency individually tend to reduce CAR, stability offsets these effects by lowering volatility and enhancing risk management. Stability enables banks to retain earnings and optimize internal capital generation. CESINDEX captures nonlinear and synergistic interactions, supporting adaptive capital structures aligned with institutional quality, innovation, and operational efficiency. Theoretically, findings align with the Trade-Off Theory, where banks balance capital costs and insolvency risk, and system-wide interaction models, illustrating how combined institutional strengths outweigh individual weaknesses. Unlike prior studies in developed markets that examine isolated determinants, CESINDEX contextualizes capital structure within fragile banking systems, reflecting regulatory fragmentation, shallow markets, and volatility. Positive CESINDEX effects encourage strategic bank behaviour, including retention of earnings, prudent leverage management, operational efficiency, innovation-driven responses to competition, and strengthened investor confidence, promoting

Table 7: Presentation and discussion of multicollinearity test results

	LAR	CAR	LINDEX	TEFF	ZSCORE	CESINDEX	CESINDEXSQ	ROA	INFL	GDP
LAR	1									
CAR	−0.41*	1								
L INDEX	0.21*	−0.35*	1							
TEFF	0.37*	−0.35*	0.031	1						
ZSCORE	−0.19*	0.67*	−0.17*	−0.41*	1					
CESINDEX	−0.26*	0.218	0.398	0.298	0.358	1				
CESINDESQ	−0.30*	0.25*	0.15*	0.17*	0.33*	0.65*	1			
ROA	−0.30*	0.19*	0.05	−0.19*	0.40*	0.11*	0.15*	1		
INFL	−0.06***	0.02	−0.01	0.01	0.10	0.05	0.006**	0.07	1	
GDP	0.09*	−0.08*	0.13*	−0.01	−0.10	0.04	0.002	−0.01	−0.03	1

Source: Author's computations (2026). Key: (*), (**), and (***) means 1%, 5%, and 10% respectively

Table 8a: Kao residual cointegration test results

Method	Statistic (t, probability, and variance)
ADF	t-statistic=−4.0153
ADF	Probability=0.000
Residual variance	Residual variance=0.0066
HACC variance	Residual variance=0.0042

Source: Author's computations (2026)

Table 8b: ADF results after 562 adjustments

Variable	Coefficient	Standard error	t-statistic	Probability
RESID (−1)	−0.867	0.058	−14.856	0.000
D (RESID [−1])	0.215	0.050	4.350	0.000
D (RESID [−2])	0.129	0.041	3.121	0.002
R-squared	0.344732	Mean dependent var		−0.002699
Adjusted R-squared	0.342387	Standard deviation dependent var		0.085941
S.E. of regression	0.069692	Akaike info criterion		−2.484129
Sum squared resid	2.715075	Schwarz criterion		−2.461007
Log likelihood	701.0403	Hannan-Quinn criter.		−2.475102
Durbin-Watson stat	2.007983			

Source: Author's computations (2026)

Table 9: Presentation and interpretation of heteroscedasticity results

Test method employed	Statistic	P-value
Breusch Pagan	Chi-squared (1)=0.278	0.615
White's	Chi-squared (1)=0.193	0.253

Source: Author's computations (2026)

Table 10: Presentation and interpretation of autocorrelation results

GMM model of estimation	Probability value	Interpretation
AR (1)	0.145	No autocorrelation
AR (2)	0.231	No autocorrelation

Source: Author's computations (2026)

Table: 11: Presentation and interpretation of over identification test

Test method	J-statistic	Prob (J statistic)
GMM test	44.915	0.518

Source: Author's computations (2026)

Table 12: List of banks in the sample

Country	Number of banks in sample	Bank name in the sample
Ghana	8	ADB, Cal, Ecobank, GCR, Republic Bank, SCB, and Trust Bank
Botswana	4	Absa, FNB, Investec, and SCB
Kenya	8	Stanbic, NCBA, KCB, Equity, DTKL, COBK, SCB, and Absa
Malawi	5	FNB, National Bank, NIT, NBS, and Standard Bank
Mauritius	2	Fincorp and NIT
Namibia	8	Capricon, First Rand, Investec, NAM, Nedbank, Standard Bank, Trustco, and Vikile
Nigeria	12	Abbey, Access, Ecobank, FCMB, Fidelity, Guaranty, Stanbic, Union, United, Unity, Wema, and Zithin
Rwanda	3	Equity, BK, and KCB
South Africa	7	Absa, Capitec, FINBOND, First Rand, Investec, Nedbank, and Standard Bank
Tanzania	2	CRDB and KCB
Zambia	2	SCB and ZNC
Zimbabwe	7	CBZ, NMBZ, ZB, Nedbank, Stanbic, and Agribank

Source: Author's computations (2026)

Table 13: Presentation of Hausman test results-impact of CESINDEX on CAR

Test summary	Chi-square statistic	Chi-square, df	Probability
Cross section random	51.834	8	0.000

Source: Author's computations (2026)

sustainable growth, regulatory compliance, and resilience in underdeveloped financial systems where external funding is costly and markets are constrained.

The analysis demonstrates a clear nonlinear, inverted U-shaped relationship between institutional dynamics, as measured by CESINDEX, and bank capital structure. Initially, improvements in governance, competition, efficiency, and stability enhance capital buffers, reflecting strategic capital accumulation to mitigate systemic and idiosyncratic risks. Beyond a critical CESINDEX threshold of approximately 0.309, additional institutional gains reduce capital levels as banks prioritize internal financing and efficiency over buffer accumulation. This pattern reflects adaptive capital management, where institutional support initially fosters resilience but later encourages leaner, profitability-driven strategies. By integrating CESINDEX as a composite index rather than examining isolated components, the analysis captures threshold effects and systemic interactions that conventional linear approaches overlook. Economically, these results suggest that institutional improvements exhibit diminishing marginal returns, and excessive regulatory layering may constrain capital adequacy. The findings underscore the need for balanced institutional strengthening that promotes operational flexibility, allowing banks to optimize both risk absorption and capital efficiency within structurally heterogeneous banking systems.

Table 14: Presentation of regression results using FEM-impact of CESINDEX on CAR

Variable	Coefficient	Standard error	t statistic	Probability
C	0.044	0.338	−0.685	0.494
LERNER INX	−0.052	0.031	−1.680*	0.094
TEFF	−0.047	0.023	−1.965**	0.050
ZSCORE	0.687	0.075	9.118*	0.000
CESINDEX	0.279	0.146	1.911**	0.056
CESINDEXSQ	−0.451	0.158	−2.185***	0.085
ROA	−0.175	0.069	−2.547*	0.011
INFLATION	−0.028	0.035	−0.800	0.424
GDP	0.292	0.344	0.850	0.397

Source: Author's computations (2026). Key: *1% level of significance, **5% level of significance, and ***10% level of significance

Table 15: Extract of the CESINDEX And CESINDEXSQ results

Variable	Beta coefficient	Mean	Median	Standard deviation	Min	Max
Competition	−0.052	0.591	0.627	0.214	−0.021	1.000
Efficiency	−0.047	0.664	0.653	0.246	0.000	1.000
Stability	0.687	0.302	1.000	0.352	0.218	1.000
CESINDEX	0.279	0.090	0.077	0.560	−0.070	1.000
CESINDEXSQ	−0.451	0.016	0.006	0.0062	0.000	1.000

Source: Author's computations (2026)

Table 16: Marginal effects (ME) on different values

Variable	ME mean	ME median	ME standard deviation	ME min	ME max
Competition	−0.0175	−0.1053	−0.1704	−0.052	−0.675
Efficiency	−0.0257	−0.1040	−0.1755	−0.047	−0.670
Stability	0.7330	0.5592	0.5030	0.687	0.0640
Cesindex	0.1978	0.2095	−0.2261	0.3421	−0.6230

Source: Author's computations (2026)

Marginal effects analysis reveals that individual institutional components exert predictable influences on capital structure, with stability supporting buffer accumulation, while competition and efficiency have modest negative effects. In contrast, the composite CESINDEX exhibits a pronounced nonlinear effect: initial improvements increase capital ratios, but beyond a critical threshold, marginal benefits decline sharply and become negative (Table 15).

This pattern reflects threshold transmission mechanisms, where early institutional gains reduce market frictions and perceived risk, encouraging capital accumulation, while excessive institutional intensity introduces complexity, compliance burdens, and operational constraints. Banks respond adaptively, balancing internal financing, risk management, and regulatory obligations to optimize leverage under evolving institutional conditions.

The observed nonlinear response aligns with dynamic trade-off and adaptive pecking order principles, highlighting that capital is first accumulated to mitigate risk and subsequently adjusted downward as perceived risk declines and internal resources become sufficient. Modelling CESINDEX interactions captures these compounded, threshold-sensitive effects, providing a more nuanced understanding than analyses of isolated institutional factors (Table 16).

Empirical threshold analysis identifies CESINDEX = 0.309 and CAR = 9.23% as critical points where the inverted U-shaped relationship manifests. Below this threshold, strengthened governance, operational efficiency, and financial stability reduce risk and support capital accumulation. Beyond the threshold, institutional overreach, regulatory congestion, and compliance fatigue generate operational inefficiencies, elevate capital costs, and shift bank behaviour toward strategic capital substitution.

The results in Graph 1 indicate that banks replace equity with hybrid instruments or securitized forms to meet regulatory targets without increasing core buffers, reducing overall capital quality. Concurrently, moral hazard and regulatory complacency incentivize risk-taking, weakening market discipline and discouraging capital retention. These mechanisms collectively explain why excessive institutional strength constrains long-term capital formation. The findings highlight the necessity of threshold-sensitive regulatory frameworks that optimize institutional quality while preserving capital adequacy and resilience in structurally fragile banking systems.

Quantile regression analysis confirms heterogeneous and nonlinear

Table 17: Quantile regression results

	Quantiles: CESINDEXSQ						
Measure	5%	10%	25%	50%	75%	90%	95%
Coefficient	−0.080	0.045	0.619	1.458	4.319	5.723	4.322
Standard error	0.126	0.0133	0.111	0.367	2.379	4.036	6.018
t-statistic	−0.633	0.339	5.533*	3.969*	1.802***	1.418	0.173
Probability	0.527	0.735	0.000	0.000	0.072	0.157	0.473

Source: Author's computations (2026)

Table 18: Long run results: CAR and CESINDEXSQ nexus

Variable	Coefficient	Calculation of long run effect (LRE)	LRE
CESINDEXSQ	−0.006	LRE of CESINDEXSQ on CAR=−0.006/ (1-0.406)=−0.010	−0.010

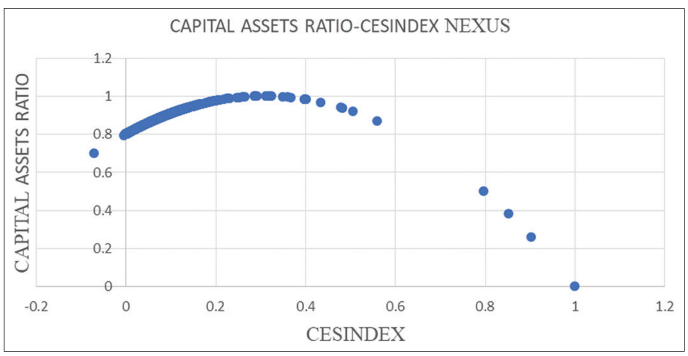
Source: Author's computations (2026)

Table 19: Impact of CESINDEX on CAR-robustness results using system dynamic GMM

Variable	Coefficient	Standard error	t-statistic	Probability
CAR (−1)	0.406	0.014	30.000*	0.000
LERNER INDEX	−0.281	0.027	−10.505*	0.000
TEFF	−0.166	0.014	−11.884*	0.000
ZSCORE	0.370	0.070	5.251*	0.000
CESINDEX	1.350	0.137	8.851*	0.000
CESINDEXSQ	−0.006	0.001	−9.526*	0.000
ROA	−0.007	0.035	−1.854	0.064
INFLATION	−0.003	0.032	−0.086	0.932
GDP	0.088	0.201	4.371*	0.000

Source: Source: Author's computations (2026)

Graph 1: Graphical representation of the CAR and CESINMDEX nexus



Source: Author's computations (2026)

CESINDEX effects on capital structure across capitalization levels, reinforcing the inverted U-shaped relationship. Moderately capitalized banks (25th-50th quantiles) exhibit strong, positive, and statistically significant responses, adjusting capital efficiently to balance regulatory requirements, financing costs, and risk exposure (Table 17).

The results in Table 17 reveals that well-capitalized banks (75th-90th quantiles) maintain positive but diminishing responsiveness, reflecting institutional saturation and reduced regulatory pressure. Undercapitalized banks (5th-10th quantiles) display weak or negative reactions due to operational constraints and limited capital access. These findings demonstrate threshold sensitivity, where institutional improvements enhance capital only up to critical points, beyond which overreach, and compliance burdens reduce effectiveness. The distributional perspective emphasizes that institutional benefits are unevenly transmitted, necessitating differentiated interventions tailored to bank capitalization, absorptive capacity, and institutional maturity. Quantile-based insights thus advance understanding of heterogeneous capital responses and inform targeted, context-specific policy design in complex banking systems.

The long-run analysis results in Table 18 above reinforces the inverted U-shaped CESINDEX–CAR relationship, showing that institutional improvements initially strengthen capital buffers, while saturation (~CESINDEX 0.301) erodes them over time. The negative long-run CESINDEXSQ elasticity (−0.010) reflects persistent overregulation, compliance burdens, and institutional congestion, slowing convergence to optimal capital levels. Partial adjustment behaviour and hysteresis effects indicate that past institutional intensity shapes present capital dynamics, while structural constraints such as market imperfections, enforcement gaps, and volatile governance further impede normalization. Threshold effects illustrate diminishing prudential returns, prompting strategic capital substitution and cautious risk-taking. African banks display sharper nonlinearities and greater sensitivity to institutional saturation compared to emerging and advanced systems, highlighting the need for phased, tiered, and context-specific regulatory frameworks. Overall, sustainable capital formation requires balancing institutional strengthening with banks' absorptive capacity, mitigating overreach, and designing macroprudential policies that accommodate heterogeneity, structural rigidity, and long-run institutional persistence.

Return on assets (ROA) shows a significant negative effect, consistent with the pecking order theory, whereby more profitable banks rely on internal funds, lowering reliance on external capital and maintaining leaner capital structures, particularly in contexts with costly or constrained financing. In contrast, macroeconomic controls such as inflation and GDP are statistically insignificant, suggesting that bank-specific and industry-level factors dominate capital structure decisions. These findings underscore the importance of considering nonlinear institutional interactions, internal profitability, and contextual factors in banking, while advocating for stronger regulatory frameworks and improved external financing access to balance financial flexibility with systemic stability.

The results in Tables 14 and 19 demonstrate robustness. The signs and significance of most coefficients are consistent across both models. In both tables, Lerner index, technical efficiency scores, CESINDEXSQ, and ROA are negatively related to capital levels, while Zscore and CESINDEX are positively related. The dynamic Two step System GMM estimation uses 55 instruments for 66 groups. Overall, the consistency across both models confirms robust relationships between the variables and capital levels. The GDP coefficient varies—positive and significant in Table 19 but positive and insignificant in Table 14. This suggests the GDP-capital link is sensitive to model specification or estimation technique. The system dynamic GMM results in Table 19 offer stronger robustness. This method controls for endogeneity and persistence in capital levels. Most variables retain their expected signs and significance under this model. These results strengthen confidence in the study's empirical findings.

5. CONCLUSION

This study set out to determine whether the joint interaction of competition, efficiency, and stability influences bank capitalization, whether nonlinear threshold effects exist, and whether such an integrated framework enhances understanding beyond isolated institutional analyses. The findings provide clear affirmative answers to these questions. The results demonstrate that institutional interactions, captured by the CESINDEX, significantly shape the capital structure of African commercial banks. CESINDEX and financial stability positively influence capital buffers, while competition, technical efficiency, profitability, and the quadratic CESINDEX term exert negative effects, reflecting strategic trade-offs between efficiency, profitability, and resilience. The presence of a significant quadratic term confirms threshold effects, indicating that institutional quality enhances capitalization only up to an optimal point, beyond which intensified pressures weaken capital buffers. These dynamics reveal that banks adjust leverage strategically in response to systemic institutional conditions rather than isolated market forces. By moving beyond fragmented, single-variable approaches, this study offers a more comprehensive explanation of capitalization behaviour in institutionally heterogeneous banking systems.

For policymakers and bank managers, the findings highlight the need to promote balanced competition, sustainable efficiency gains, and financial stability to support resilient capitalization. Despite data and methodological limitations, the CESINDEX framework provides a robust, context-sensitive lens for analysing capital structure in emerging markets and offers a foundation for future research incorporating governance and macroeconomic shocks.

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