







“Ensuring the balance between sustainability and profitability in the corporate financial management system: Capital adequacy, asset quality, and bank performance”

AUTHORS	Sakina Hajiyeva  Zohrab Ibrahimov  Nasirulla Nasirli  Nihad Pashazade  Marhamat Bayramov Afkhan 
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Nasirulla Nasirli, Nihad Pashazade,
Marhamat Bayramov Afkhan, 2026

Sakina Hajiyeva, Ph.D. in Economics,
Associate Professor, Head of
the Department of Economics,
Azerbaijan University of Tourism
and Management, Azerbaijan.
(Corresponding author)

Zohrab Ibrahimov, Ph.D. in Economics,
Associate Professor, Department of
Finance and Audit, Azerbaijan State
University of Economics (UNEC),
Azerbaijan.

Nasirulla Nasirli, Ph.D. in Physics and
Mathematics, Associate Professor,
Azerbaijan University of Tourism and
Management, Azerbaijan.

Nihad Pashazade, Ph.D. Student,
Azerbaijan University of Tourism and
Management, Azerbaijan.

Marhamat Bayramov Afkhan, Ph.D.
Student, Nakhchivan State University,
Azerbaijan.



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Sakina Hajiyeva (Azerbaijan), Zohrab Ibrahimov (Azerbaijan), Nasirulla Nasirli (Azerbaijan),
Nihad Pashazade (Azerbaijan), Marhamat Bayramov Afkhan (Azerbaijan)

ENSURING THE BALANCE BETWEEN SUSTAINABILITY AND PROFITABILITY IN THE CORPORATE FINANCIAL MANAGEMENT SYSTEM: CAPITAL ADEQUACY, ASSET QUALITY, AND BANK PERFORMANCE

Abstract

The balance between stability and profitability in banking systems has gained renewed urgency as rising interest rates, persistent inflation, and credit risks reshape the global financial landscape. Regulators, such as the IMF, ECB, and OECD, emphasize that while robust capital buffers are indispensable for resilience, excessive capitalization may constrain lending. In contrast, weak asset quality undermines returns regardless of capital strength. Against this backdrop, this article aims to explore how capital adequacy and asset quality jointly influence bank profitability. The analysis uses IMF Financial Soundness Indicators for 133 countries over 2010–2024 and applies two-way fixed-effects panel regressions with Driscoll-Kraay robust inference. The results reveal a consistently concave relationship: Tier 1 capital to assets is positively related to return on assets (ROA) with diminishing returns, though the turning point lies at an implausible 161.7%. In contrast, Tier 1 capital to risk-weighted assets shows an economically plausible peak around 26.3%, with gains tapering beyond that level. Within typical ranges (15–20% RWA), a one percentage point increase in capital is associated with a 0.06–0.03-point rise in ROA, but additional accumulation yields little benefit. Asset quality exerts a strong negative influence, with a 1-point increase in non-performing loans lowering ROA by 0.04–0.05 points, while liquidity remains statistically insignificant. These findings highlight that capital deepening contributes to profitability only up to moderate levels, and that poor asset quality can offset the benefits of stronger capital buffers, underscoring the need for integrated regulatory approaches to stability and performance.

Keywords

capital adequacy, bank profitability, Tier 1 capital, asset quality, non-performing loans, financial stability

JEL Classification

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INTRODUCTION

In recent years, financial regulators and institutions such as the IMF and ECB have increasingly emphasized banks' dual challenge: maintaining stability through higher capital and sound asset quality while preserving or restoring profitability in a rapidly changing economic environment. Rising interest rates in many advanced economies have improved banks' net interest income, enhancing profitability. Still, they also increase risks around credit defaults and valuation losses on fixed-income assets. For example, the IMF warns that the currently elevated profits are largely cyclical and may erode as policy rates are lowered, while impairment costs tend to lag (Chen et al., 2024).

Moreover, recent ECB Financial Stability Reviews indicate that European banks are in relatively strong condition: capital adequacy ratios and liquidity cushions remain well above regulatory minimums, and non-performing loan (NPL) ratios have declined (EIB, 2025). However, the reports also signal vulnerabilities. Asset quality deterioration remains risky if macroeconomic conditions soften, especially given inflationary pressures and the lag from monetary tightening to borrower distress. The ECB notes that while profitability (return on equity) was comfortably above 9% in 2024, its sustainability depends on managing these asset risks alongside continued prudent capital buffers (EIB, 2025).

From the IMF perspective, balancing stability and profitability is not just a banking regulatory concern but a broader policy challenge: overly stringent capital requirements or risk-weighting that disincentivize lending can restrain economic growth, yet weak capital or bad asset quality undermines financial system resilience. For example, the IMF (2025) highlights that capital adequacy ratios may be overstated when risk-weighted assets are under-assessed, creating a false sense of security. In parallel, OECD (2021) warns of a vicious circle: weak profitability leads to compromised ability to build capital buffers, which makes banks more vulnerable to shocks, which feed into worse asset quality and further profitability erosion.

Against this backdrop, the question of balancing stability and profitability in banking systems has become increasingly relevant for policymakers, regulators, and financial institutions alike. Reports from the IMF, ECB, and OECD consistently underline that while strong capital buffers are indispensable for resilience, their effectiveness depends on asset quality and broader macroeconomic dynamics. Excessive capitalization may constrain lending and erode returns, whereas weak credit portfolios undermine profitability regardless of capital strength. The ongoing interplay between regulatory capital requirements, non-performing loan management, and bank performance thus remains a critical policy concern, examining concave relationships between capital adequacy and profitability, which are timely and essential for shaping sustainable financial systems.

1. LITERATURE REVIEW

The stability and profitability of banking systems are deeply interlinked, with capital adequacy and asset quality serving as central determinants of performance. Research increasingly explores how regulatory capital, risk exposure, and external shocks shape bank outcomes, while also addressing how digitalization, corporate governance, and financial innovations alter the traditional dynamics of risk and return.

Studies on capital adequacy emphasize its role as both a prudential buffer and a determinant of bank profitability. Evidence from microfinance institutions confirms that voluntary capital buffers enhance sustainability under volatile conditions (Duho, 2023; Adhikari et al., 2024). Implementing countercyclical capital buffers is a macroprudential tool that mitigates procyclical risks and supports systemic resilience (Vasylyeva et al., 2014). The adoption of Basel III standards has been shown to positively influence the financial performance

of banks, as demonstrated in the Bangladeshi context (Yamin et al., 2025). At the same time, excessive capitalization may lead to diminishing profitability, as studies from dual banking systems reveal a trade-off between stability and competition (Ernaningsih et al., 2023). Benchmarking analyses highlight significant cross-country variation in capitalization strategies across European banks, reflecting differences in regulatory frameworks and macroeconomic stability (Krawczyk et al., 2025; Pozovna et al., 2024). The importance of capital adequacy for systemic resilience has also been underscored in Ukraine, where an indicator-based approach was used to measure systemically important banks (Buriak et al., 2015).

Asset quality is another fundamental driver of profitability. Empirical evidence from Jordan, Saudi Arabia, and the Arab Levant confirms that high NPL ratios reduce bank returns by raising provisioning costs and constraining lending capacity (Al Najjar, 2025; Altahtamouni, 2024; Alslaibi et al., 2025). Similar patterns are observed

in transitional economies, such as Ukraine, where macroeconomic instability and weak credit markets exacerbate credit risks (Dubyna et al., 2023). Comparative studies across Asian and MENA banking systems also demonstrate that macroeconomic volatility intensifies the relationship between credit risk and profitability (Aryal & Singh, 2024; Kamarudin et al., 2024). The growing literature, therefore, converges on the view that profitability gains from higher capital buffers are conditional on robust asset quality management.

Liquidity positions and efficiency factors add another dimension to bank performance. Findings from Cambodia illustrate that rising liquidity may compress profitability by reducing interest margins (Lim et al., 2025). Efficiency-oriented approaches, such as DEA-Malmquist analysis, reveal structural differences in bank productivity between advanced and developing economies (Skvarciany & Jurevičienė, 2024). Studies of deposit banks in Turkey and local government banks in Indonesia confirm that efficiency in capital allocation, investment lending, and liquidity deployment shapes performance outcomes (Tutar et al., 2025; Aswan et al., 2024). Weak profitability undermines banks' capacity to accumulate buffers, reinforcing the cyclical link between performance and stability (Kovalenko et al., 2021; Mursalov et al., 2025). Off-balance-sheet activities have also impacted technical efficiency, raising concerns about hidden risks and governance challenges (Saifi & Khouiled, 2024).

Corporate governance, technology, and innovation also affect the stability-profitability nexus. Research on insurance and banking indicates that governance practices influence profitability, risk-taking, and firm value (Noor et al., 2024; Kurniasari & Dwi Lestari, 2025). Strategic working capital management and fintech adoption have been linked to stronger financial control and resilience (Morshed, 2024; Alabdullah, 2023). Studies on enterprise risk management show that risk governance supports sustainability performance and moderates profitability outcomes (Dewi et al., 2024; Quang et al., 2024). Broader analyses of AI-based risk management, digital lending, and fintech trends confirm their growing role in shaping financial market stability and bank profitability (Kuzior et al., 2024a; Bagirzade,

2024a; Waliszewski et al., 2024; Polishchuk, 2023). Transparency and trust emerge as increasingly relevant, with cognitive mapping studies highlighting the economy of trust in financial relations (Lyeonov et al., 2024).

The geopolitical and socio-economic environment adds further complexity. Financial access and over-indebtedness of microfinance borrowers illustrate the risks of inclusive banking when regulatory oversight is weak (Budhathoki et al., 2025; Thapa et al., 2025). Research from the Arab Levant, European, and post-Soviet countries highlights the importance of macroeconomic stability for banking performance, especially in periods of crisis and recovery (Murshudli, 2022; Vysochyna et al., 2024; Kuzior et al., 2024b; Saad & Sági, 2025). Governance, transparency, and ethical considerations in banking, particularly under wartime and crisis conditions, emerge vital for sustaining trust and long-term profitability (Serpeninova et al., 2025; Hoxhaj et al., 2025; Bagirzade, 2024b; Polishchuk et al., 2024). Corruption is another dimension affecting banking outcomes, as studies on Islamic banks show that it directly undermines profitability (Sobol & Dopierała, 2025). The regulatory environment shapes financial control efficiency and systemic performance, with comparative evidence pointing to the need for more harmonized frameworks (Rekunen et al., 2025).

The literature converges on three main insights. First, capital adequacy contributes positively to profitability but with diminishing returns, suggesting an optimal range rather than a linear relationship. Second, asset quality exerts a strong and persistent negative influence on bank profitability, often offsetting the benefits of capital accumulation. Third, broader factors, liquidity, governance, technology adoption, and macroeconomic conditions, shape profitability, which interacts with core stability drivers. These findings underline the importance of integrated approaches to capital regulation, asset quality supervision, and innovation to sustain financial stability and bank profitability in diverse economic environments.

This study aims to quantify and characterize the relationship between bank capital and profitability across countries, allowing for non-linearity and for the moderating roles of liquidity and asset qual-

ity. Using IMF Financial Soundness Indicators for 2010–2024, this research estimates two-way fixed-effects panel models with robust inference to identify how capital buffers relate to return on assets over time and across jurisdictions.

2. METHODOLOGY

This study tests whether the capital-profitability link follows a U- or inverted-U shape; locate the associated turning point and report marginal effects along the capital distribution; examine how liquidity and non-performing loans shift the shape of this relationship; and verify the findings with clustered and Driscoll-Kraay standard errors, alternative capital measures (Tier-1/RWA as the primary metric and Tier-1/assets as a robustness check), and outlier-tolerant specifications. The results inform capital planning by clarifying where diminishing returns to higher capital ratios emerge.

2.1. Data and sample

The analysis draws on annual Financial Soundness Indicators from the IMF data portal (2010–2024). The sample includes only jurisdictions that reported the variables required for the baseline and moderation specifications at least once during this window, yielding an unbalanced country–year panel. The dependent variable is return on assets (ROA, %). Capital is measured primarily by Tier-1 capital to risk-weighted assets (x_2 , %) and, for robustness, by Tier-1 capital to total assets (x_1 , %). Two balance-sheet covariates enter all models: liquidity (liquid assets to short-term liabilities, x_3 , %) and asset quality (non-performing loans to total gross loans, x_4 , %). The empirical sample includes countries where consistent data were available during the study period, amounting to 133 economies worldwide. These countries are listed in Appendix A and cover a broad geographical scope, ranging from advanced economies such as the United States, Germany, and Japan to emerging and developing markets including Brazil, India, and South Africa. Including both OECD and non-OECD members ensures the results are internationally representative and capture diverse banking system structures and regulatory environments. All se-

ries follow IMF definitions and remain on their original percentage-point scale.

2.2. Empirical specification

To capture non-linear links between capital and profitability while absorbing time-invariant country heterogeneity and common shocks, the study estimates two-way fixed-effects models of the form

$$y_{it} = \beta_1 Cap_{it} + \beta_2 Cap_{it}^2 + \gamma_3 x_{3,it} + \gamma_4 x_{4,it} + \alpha_i + \tau_t + \varepsilon_{it}, \quad (1)$$

where i is the index of countries and t is the index of years; α_i and τ_t denote country and year effects. The preferred specification sets $Cap = x_2$ (Tier-1/RWA); parallel estimates replace x_2 with x_1 . To assess whether liquidity and asset quality shift the shape of the capital–ROA relation, moderated quadratics augment the model with interactions in both the linear and squared capital terms:

$$y_{it} = \beta_1 Cap_{it} + \beta_2 Cap_{it}^2 + \delta_1 (Cap_{it} \cdot z_{it}) + \delta_2 (Cap_{it}^2 \cdot z_{it}) + \gamma_3 x_{3,it} + \gamma_4 x_{4,it} + \alpha_i + \tau_t + \varepsilon_{it}, \quad (2)$$

with $z \in \{x_3, x_4\}$. Coefficients are interpreted as conditional associations.

2.3. Inference and diagnostics

Primary inference relies on heteroskedasticity- and autocorrelation-robust standard errors clustered by country and year. As a check for cross-sectional dependence, the study reports Driscoll-Kraay (SCC) standard errors from a two-way within estimator. Non-linearity receives formal evaluation via the Lind-Mehlum test on the observed support of capital. The turning point

$$\hat{x}^* = \frac{-\beta_1}{(2\beta_2)}, \quad (3)$$

is reported with delta-method confidence intervals, and marginal effects are evaluated at representative capital levels. In the moderation models, conditional vertices $x^*(z)$, curvature, and slopes at trimmed bounds quantify how liquidity and NPLs alter the shape of the capital–profitability curve.

2.4. Robustness

Given the heavy-tailed distributions typical of FSI ratios, the analysis

- (i) repeats estimates after light winsorization of tails;
- (ii) swaps the capital metric (x1 vs x2); and
- (iii) inspects sensitivity to influential units using leave-one-country-out re-estimation and selected subsamples.

Results are presented alongside fit statistics (adjusted and within R²) to separate variation explained by fixed effects from within-country dynamics.

3. RESULTS

The descriptive statistics indicate substantial variability and non-normal distributions across the studied variables. The dependent variable *y* (Return on Assets) has a mean of 1.73 with a relatively narrow range (−12.47 to 9.58) and moderate skewness (−0.62) but very high kurtosis (9.07), pointing to heavy tails. The explanatory variables exhibit stronger deviations. *x1* shows extreme skewness (25.15) and kurtosis (705.22), reflecting the presence of outliers and a highly non-normal distribution. *x2* is less extreme but remains positively skewed (1.22) with elevated kurtosis (4.57).

x3 and *x4* display considerable right-skewness (3.06 and 3.01, respectively) and high kurtosis (18.37 and 12.12), indicating that their distributions are heavily peaked with long tails. The descriptive statistics suggest that transformation or robust estimation techniques are necessary before applying parametric econometric models.

The Shapiro-Wilk test results confirm that all variables under study significantly deviate from normality. For *x1*, the statistic is extremely low ($W = 0.1732, p < 0.001$), indicating a highly non-normal distribution driven most likely by extreme outliers. *x2* ($W = 0.9069, p < 0.001$) and the dependent variable *y* ($W = 0.9065, p < 0.001$) also reject the null hypothesis of normality, though their distributions appear less distorted relative to *x1*. The explanatory variables *x3* ($W = 0.7303, p < 0.001$) and *x4* ($W = 0.6887, p < 0.001$) likewise demonstrate strong departures from normality, with test values suggesting heavy skewness and leptokurtosis. The uniformly significant *p*-values (< 0.001) across all tests indicate that no variable follows a normal distribution, reinforcing the necessity of applying suitable transformations (e.g., Yeo–Johnson, Box–Cox, or logarithmic adjustments) or adopting robust estimation techniques in the econometric modelling stage.

The results demonstrate that while the Yeo–Johnson transformation significantly improved normality for some variables (particularly *x3* and *x4*), others (*x1*, *y*, and *x2*) continue to deviate from

Table 1. Descriptive statistics (panel 2010–2024)

Source: Authors' calculations in R Studio.

Variable	x3	x4	y	x1	x2
n	1696	1696	1696	1696	1696
Mean	9.77	16.75	66.76	7.1	1.73
SD	10.27	5.84	51.06	8.02	1.52
Median	9.08	15.74	50.06	4.28	1.58
Trimmed mean	9.28	16.14	57.02	5.54	1.69
MAD	3.01	4.24	25.66	3.61	1.07
Min	−6.40	−17.50	11.99	0.15	−12.47
Max	317.77	55.75	690.37	61.12	9.58
Range	324.17	73.25	678.39	60.97	22.05
Skewness	25.15	1.22	3.06	3.01	−0.62
Kurtosis	705.22	4.57	18.37	12.12	9.07
SE	0.25	0.14	1.24	0.19	0.04

Notes: Variable mapping: *x3* – Liquid assets to short-term liabilities (%); *x4* – Non-performing loans to total gross loans (%); *y* – Return on assets (%); *x1* – Tier 1 capital to assets (%); *x2* – Tier 1 capital to risk-weighted assets (%). “Trimmed mean” is the 10% trimmed mean; MAD is the median absolute deviation; SE is the standard error of the mean.

the Gaussian distribution. These outcomes reinforce the necessity of robust estimation techniques in the econometric analysis, as complete adherence to normality cannot be assumed even after transformation.

3.1. Tier-1-to-assets

The coefficients on capital indicate a concave (inverted-U) relation between ROA (y) and Tier-1-to-assets (x_1): the linear term is positive and significant (0.077, $p \approx 0.030$), while the squared term is negative and significant (-0.000239 , $p \approx 0.033$). The implied turning point is $x_1^* = -\beta_1 / (2\beta_2) \approx 161.7\%$. Although this technically lies within the sample maximum, it is far to the right of the typical range of bank capital ratios, so across most of the data, the relationship is increasing but concave: raising x_1 is associated with higher ROA, with diminishing marginal gains as x_1 rises. As a rough guide, at a conventional x_1 around 10%, the marginal effect is $\beta_1 + 2\beta_2 \cdot 10 \approx 0.073$ percentage points of ROA per 1 p.p. increase in x_1 (so $+4$ p.p. in $x_1 \rightarrow \approx +0.29$ p.p. ROA, *ceteris paribus*).

Asset quality is economically and statistically important: the NPL ratio (x_4) carries a sizeable negative effect (-0.0475 , $p \approx 0.002$), consistent with credit losses and provisioning pressure depressing profitability. Liquidity (x_3) is statistically indistinguishable from zero in this specification ($p \approx 0.804$), suggesting that, once in calculations, it holds constant country- and year-specific factors and the other covariates, cross-sectional/liquidity variation of this kind does not add explanatory power for ROA. As expected in multi-country panels, model fit is driven largely by fixed effects (Adj. $R^2 \approx 0.606$; within $R^2 \approx 0.069$).

The Lind–Mehlum test yields $p = 0.992$, indicating no evidence of a U-shaped relationship within the observed support of Tier-1-to-assets (x_1). The quadratic specification nonetheless implies concavity (positive linear term, negative squared term), with an estimated turning point at $x_1^* \approx 161.7\%$ (95% CI: 139.3%–184.1%), which lies far beyond economically plausible capital ratios for most banks. Hence, the slope remains positive over the empirically relevant range: higher capital is associated with higher ROA, but with diminishing marginal returns and no “downward” segment within the data support. This pattern is consistent with a few extreme x_1 observations shifting the vertex to the right and predominantly monotonic effects in the typical range.

The complementary inverted-U test also fails ($p = 0.992$), indicating that neither a U- nor an inverted-U shape is supported on the observed support of Tier-1-to-assets (x_1). Marginal effects remain positive and decline only slightly across the distribution of x_1 : at the 25th percentile (7.26%), $dROA/dx_1 \approx 0.0737$, at the median (9.08%) ≈ 0.0728 , and at the 75th percentile (11.33%) ≈ 0.0718 . Economically, this implies that a 1 pp increase in Tier-1/Assets is associated with roughly a 0.07 pp rise in ROA, so a 5-pp increase corresponds to about $+0.36$ pp around the median. Taken together with the quadratic estimates, the evidence points to an increasing but concave relationship – higher capital is associated with higher profitability, with modestly diminishing marginal returns and no downturn within the data range.

Applying a two-way fixed-effects estimator with Driscoll–Kraay standard errors (robust to heteroskedasticity, serial correlation and cross-sectional dependence, Table 3), the capital terms remain

Table 2. Baseline two-way FE OLS – ROA on capital, liquidity, and asset quality

Source: Authors' calculations in R Studio.

Dependent variable: ROA (y)	Estimate	Std. Error	t value	Pr(> t)
Tier-1 / Assets (x_1)	0.077180	0.031935	2.4168	0.0299*
(Tier-1 / Assets) ² ((x_1^2))	-0.000239	0.000101	-2.3620	0.0332*
Liquidity: Liquid assets / ST liabilities (x_3)	-0.000244	0.000965	-0.2532	0.8038
Asset quality: NPLs / Total gross loans (x_4)	-0.047548	0.012524	-3.7966	0.0020**

Note: Observations – 1,696; Fixed effects – country (133), year (15); Standard errors – two-way clustered (country & year); RMSE = 0.9098; Adjusted $R^2 = 0.6058$; Within $R^2 = 0.0688$; Implied turning point for x_1 : $x_1^* \approx 161.7\%$ (concave / inverted-U). Variable mapping: x_1 – Tier-1 capital to total assets; x_3 – liquid assets to short-term liabilities; x_4 – non-performing loans to total gross loans. Signif. codes: ‘***’ – 0.001; ‘**’ – 0.01; ‘*’ – 0.05; ‘.’ – 0.1; ‘no symbol’ – insignificant.

Table 3. Driscoll-Kraay robustness (two-way fixed effects)

Source: Authors' calculations in R Studio.

Variables	Estimate	Std. Error	t-value	Pr(> t)
x1	0.077180	0.026740	2.8863	0.003952**
I(x1A2)	-0.000239	0.000084	-2.8386	0.004590**
x3	-0.000244	0.000991	-0.2465	0.805307
x4	-0.047548	0.011575	-4.1080	< 0.0001***

Notes: Driscoll-Kraay standard errors with two-way fixed effects (country, year). The turning point from the quadratic fit remains $\approx 161.7\%$ (outside the economically typical range), so the effects increase but are concave over the observed support. Signif. codes: '***' – 0.001; '**' – 0.01; '*' – 0.05; '.' – 0.1; 'no symbol' – insignificant.

statistically significant and confirm concavity: the linear Tier-1/Assets coefficient is positive ($\beta = 0.077$, SE = 0.0267, $p = 0.0040$) and the squared term is negative ($\beta = -0.000239$, SE = 0.000084, $p = 0.0046$). Liquidity (x3) is not statistically different from zero ($p \approx 0.805$), while the NPL ratio (x4) is negative and highly significant ($\beta = -0.0475$, SE = 0.0116, $p < 0.001$). Combined with the Lind-Mehlum and inverted-U tests (both $p = 0.992$), the implied turning point ($\approx 161.7\%$, 95% CI: 139.3%-184.1%) lies well beyond economically plausible capital levels; within the observed range, higher capital is associated with higher ROA, with modestly diminishing marginal returns and no downturn.

As a moderator, introducing liquidity (x3) leaves the core capital-profitability pattern broadly intact (Table B1, Appendix B). The linear Tier-1/Assets term remains positive ($\beta = 0.128$, $p = 0.056$) while the squared term is negative but insignificant ($\beta = -0.000266$, $p = 0.113$). Neither interaction with liquidity is statistically different from zero. Conditional turning points move left as liquidity rises, about 190.6% at the 25th percentile, 175.7% at the median and 150.3% at the 75th percentile of x3, but all remain far above economically plausible Tier-1/Assets levels. Slopes at the lower and upper support bounds stay positive in each case, implying a practically increasing but concave relation within the observed range.

Contrastingly, concavity strengthens when asset quality (x4) moderates the relationship (Table B1, Appendix B). The linear capital term is positive ($\beta = 0.137$, $p = 0.013$) and the squared term is negative ($\beta = -0.000214$, $p = 0.023$). The interaction on the squared term is negative and significant ($I(x1^2):x4 = -0.000042$, $p = 0.014$), indicating that poorer asset quality steepens diminishing returns to capi-

tal. The conditional turning point shifts markedly left as NPLs rise, approximately 213.7% at the 25th percentile, 167.4% at the median and 106.8% at the 75th percentile of x4, yet slopes at the bounds remain positive. Overall, higher capital is associated with higher ROA, with stronger diminishing marginal returns in high-NPL environments; no downturn is detected within the data support.

3.2. Tier 1 capital to risk-weighted assets

Using Tier 1 capital to risk-weighted assets (x2) in the two-way fixed-effects regression yields a clear concave (inverted-U) relation between capital and profitability (Table 4). The linear term is positive and significant ($\beta = 0.143$, $p = 0.021$), while the squared term is negative and significant ($\beta = -0.00271$, $p = 0.033$). The implied turning point is economically plausible at approximately 26.3% of risk-weighted assets ($x2^* = -\beta_1/(2\beta_2)$). Hence, within the range typically observed for banks, the association between capital and ROA is positive but diminishing: at $x2 = 15\%$ the marginal effect is about +0.061 pp ROA per +1 pp capital; at 20% it falls to +0.034 pp; and it becomes close to zero around 25%. Liquidity (x3) remains statistically indistinguishable from zero, whereas asset quality (x4) is negative and significant ($\beta = -0.0374$, $p = 0.0115$), consistent with higher NPLs compressing profitability. Overall fit is driven largely by the fixed effects (Adjusted $R^2 \approx 0.616$; within $R^2 \approx 0.093$), as expected in multi-country panel settings.

With Tier-1 to risk-weighted assets (x2) as the capital metric, both the linear term ($\beta=0.143$, DK $p = 0.0026$) and the squared term ($\beta = -0.00271$, DK $p = 0.0045$) remain statistically significant under Driscoll-Kraay errors, confirming a concave (inverted-U) pattern that peaks at roughly 26.3%

Table 4. ROA on riskweighted capital (x2), liquidity (x3) and asset quality (x4) (baseline two-way FE OLS (SEs clustered by country & year))

Source: Authors' calculations in R Studio.

Dependent variable: ROA (y)	Estimate	Std. Error	t value	p-value
Tier1 / RWA (x2)	0.142680	0.054701	2.6084	0.0206*
(Tier1 / RWA) ² (l(x2 ²))	-0.002709	0.001146	-2.3636	0.0331*
Liquidity: Liquid assets / ST liabilities (x3)	-0.000778	0.001090	-0.7138	0.4871
Asset quality: NPLs / Total gross loans (x4)	-0.037386	0.012864	-2.9062	0.0115*

Note: Model stats: RMSE = 0.8979; Adjusted R² = 0.6160; Within R² = 0.0930; Observations = 1,696; Fixed effects: country (133), year (15). Signif. codes: '***' – 0.001; '**' – 0.01; '*' – 0.05; '.' – 0.1; 'no symbol' – insignificant.

RWA ($x2^* = -\beta_1/(2\beta_2)$) (Table 5). Within the typical range (e.g., 15-20% RWA), the marginal effect stays positive but diminishing ($\approx +0.06$ pp ROA per +1 pp capital at 15%; $\approx +0.03 - 0.04$ pp at 20%). Liquidity (x3) is again statistically indistinguishable from zero, whereas the NPL ratio (x4) is negative and highly significant (DK $p < 0.001$), underscoring the role of asset quality in depressing profitability. The DK check reinforces baseline conclusions with an inference robust to heteroskedasticity, serial correlation, and cross-sectional dependence.

The quadratic specification using the risk-weighted capital ratio yields an economically plausible vertex at $x2^* \approx 26.34\%$ (95% CI: 20.54-32.13), indicating that ROA rises with Tier-1/RWA up to the mid-twenties and then the marginal benefit fades. The Lind-Mehlum U-test returns p -value = 0.996, so there is no evidence of a U-shape on the observed support, consistent with concave (inverted-U) fit rather than a convex U. Practically, within the bulk of the data the marginal effect remains positive but diminishing; any downturn, if present, would occur only at very high capital ratios near or above the estimated vertex.

Using Tier 1 capital to risk-weighted assets (x2) as the capital measure, the quadratic specifica-

tion yields an economically plausible vertex at $x2^* \approx 26.34\%$ (95% CI: 20.54-32.13), indicating that ROA rises with capital up to the mid-twenties and then the marginal benefit fades. However, the inverted-U test on the observed support returns $p = 0.296$, so the null of no inverted-U over the realized range of x2 cannot be rejected. The evidence supports an increasing but concave association within the sample: additional risk-weighted capital tends to raise ROA, with diminishing marginal returns, and any downturn, if present, appears confined to the upper tail near the estimated vertex. This means capital deepening from typical levels (e.g., 15-20% RWA) is associated with positive but tapering gains in ROA, while movements beyond the mid-twenties yield little incremental profitability. The lack of a statistically verified inverted-U on the support is consistent with modest curvature and a peak close to the right edge of the distribution rather than a pronounced decline across commonly observed capital ratios.

Allowing liquidity (x3) to moderate the ROA-capital link leaves the basic pattern intact (Table B2, Appendix B). The linear x2 term is positive ($\beta = 0.221$, $p = 0.027$) and the squared term is negative ($\beta = -0.00408$, $p = 0.051$), implying concavity. Liquidity's direct and interaction effects are

Table 5. ROA on riskweighted capital (x2), liquidity (x3) and asset quality (x4) (Driscoll-Kraay robust inference)

Source: Authors' calculations in R Studio.

Variable	Estimate	Std. Error	t value	Pr (> t)
x2	0.14268026	0.04725381	3.0194	0.0025739**
l(x2 ²)	-0.00270873	0.00095181	-2.8459	0.0044876**
x3	-0.00077795	0.00102816	-0.7566	0.4493799
x4	-0.03738630	0.01117901	-3.3443	0.0008446***

Notes: Two-way fixed effects absorb time-invariant country heterogeneity and common year shocks. Panel A uses standard errors clustered by country and year; Panel B reports Driscoll-Kraay (SCC) standard errors. Variable mapping: x2 – Tier1. Signif. codes: '***' – 0.001; '**' – 0.01; '*' – 0.05; '.' – 0.1; 'no symbol' – insignificant.

not statistically different from zero. Conditional turning points lie around 26.7%, 26.5% and 26.0% at the 25th, 50th and 75th percentiles of x_3 , respectively; curvature remains negative (concave). Slopes at the lower support bound are positive. In contrast, at the upper bound, they turn slightly negative for medium-to-high liquidity, suggesting a modest inverted-U within the observed support at higher x_3 , albeit without significant interaction coefficients, so this should be interpreted as suggestive rather than definitive.

When asset quality (x_4) moderates the relationship (Table B2, Appendix B), the concave pattern persists (x_2 : $\beta = 0.215$, $p = 0.014$; x_2^2 : $\beta = -0.00428$, $p = 0.024$). Neither interaction is significant, and the conditional turning point is tightly clustered near 25-26% across x_4 quartiles. Importantly, the slopes at both bounds remain positive for all x_4 levels reported, indicating an increasing but concave association throughout the observed range, even in weaker credit quality environments. Capital deepening up to the mid-twenties (per cent of RWA) is associated with higher ROA, with diminishing marginal returns; liquidity and NPL levels shift the vertex's location only slightly in these specifications.

4. DISCUSSION

The empirical findings of this study confirm that capital adequacy is positively related to bank profitability but with diminishing returns, which is consistent with the broader body of literature emphasizing the concave nature of this relationship. The evidence that Tier-1 capital to assets exhibits a positive but tapering association with ROA, though with an implausibly high turning point, resonates with the view that excessive capitalization may constrain lending and reduce profitability, as documented in studies of dual banking systems (Ernaningsih et al., 2023). By contrast, the turning point for Tier-1 capital to risk-weighted assets at around 26.3% is economically meaningful and supports earlier findings on the existence of an optimal capital range, beyond which additional capital deepening yields limited benefits (Yamin et al., 2025; Vasylyeva et al., 2014). These findings provide quantitative confirmation of the hypothesis that capital strengthens profitability up to a moderate threshold, after which its marginal effect diminishes.

The results also highlight asset quality's strong and persistent negative effect on profitability, with a 1-percentage-point increase in NPLs reducing ROA by 0.04-0.05 points. This is in line with the evidence from Jordan, Saudi Arabia, and the Arab Levant, where high levels of non-performing loans erode returns by raising provisioning costs and weakening lending capacity (Al Najjar, 2025; Altahtamouni, 2024; Alslaibi et al., 2025). The moderation analysis further confirms that poor asset quality intensifies diminishing capital returns, echoing findings from transitional and emerging economies where weak credit markets amplify systemic vulnerabilities (Dubyna et al., 2023; Pozovna et al., 2024). These outcomes suggest that while capital buffers play a stabilizing role, their effectiveness is conditional on sound asset quality. This supports the argument that profitability gains from capital accumulation are undermined in high-NPL environments.

Liquidity, by contrast, was found to be statistically insignificant in explaining profitability across specifications, even when tested as a moderating factor. This finding partially diverges from studies showing that higher liquidity can compress profitability, such as in Cambodia (Lim et al., 2025), and from efficiency-based analyses that stress the importance of liquidity allocation for performance (Skvarciany & Jurevičienė, 2024). The discrepancy may be explained by the stronger role of fixed effects in the present multi-country panel, which absorbs much of the macroeconomic and institutional variation underlying liquidity effects. Still, the results resonate with literature highlighting that weak profitability rather than liquidity positions primarily constrain banks' ability to build capital buffers (Mursalov et al., 2025).

These findings reinforce the multi-dimensional nature of the stability-profitability nexus. The quantitative evidence presented here complements earlier research that underscores the importance of balancing prudential regulation with performance outcomes (Krawczyk et al., 2025; Buriak et al., 2015). Moreover, the lack of strong liquidity effects, combined with the dominant role of capital and asset quality, aligns with studies that place greater emphasis on governance, technology, and transparency as additional performance drivers (Alabdullah, 2023; Kuzior et al., 2024a; Lyeonov

et al., 2024). The discussion, therefore, highlights that while capital and asset quality remain fundamental, future strategies to balance stability and profitability must also consider efficiency, governance, and innovation.

This research is subject to several limitations that open avenues for further investigation. First, although the dataset covers 133 countries from 2010 to 2024, heterogeneity in regulatory environments, accounting practices, and financial reporting quality may have influenced the comparability of results. Second, while fixed-effects and Driscoll-Kraay estimators address unobserved heterogeneity and cross-sectional dependence, they cannot fully eliminate endogeneity concerns arising from

reverse causality between capitalization and profitability. Third, liquidity measures and asset quality indicators were included, but other relevant dimensions such as bank size, ownership structure, or macroeconomic volatility were not explicitly modelled, potentially omitting important channels. Future research should therefore incorporate dynamic panel methods or instrumental variables to address endogeneity more rigorously, extend the analysis to alternative profitability metrics such as net interest margin or return on equity, and explore cross-regional differences in capital-profitability dynamics. In addition, linking bank-level findings to broader financial stability outcomes could provide valuable insights for regulators and policymakers.

CONCLUSION

This article aimed to investigate the relationship between bank capital adequacy and profitability, measured through the impact of Tier 1 capital ratios on ROA, while accounting for liquidity conditions and asset quality. Focusing on an international panel of banks from 2010 to 2024, the analysis sought to clarify whether higher capitalization strengthens profitability or imposes diminishing returns once regulatory thresholds are exceeded.

Methodologically, the study employed two-way fixed-effects panel regressions with robustness checks using Driscoll-Kraay errors, based on a balanced dataset of 1,696 bank-year observations retrieved from the International Monetary Fund. The explanatory variables included Tier 1 capital to assets, Tier 1 capital to risk-weighted assets, liquidity ratios, and non-performing loan shares, with transformations and robustness procedures applied to address strong deviations from normality.

The findings demonstrate a concave (inverted-U) relationship between capital ratios and profitability. For Tier-1-to-assets, the association is positive with diminishing returns, though the turning point ($\approx 161.7\%$) lies far beyond economically relevant levels. In contrast, Tier 1-to-risk-weighted assets shows an economically plausible vertex at approximately 26.3%, with ROA rising to that threshold and marginal benefits tapering thereafter. Asset quality exerts a strong and consistently negative effect: a 1-percentage-point increase in non-performing loans reduces ROA by roughly 0.04-0.05 points. Liquidity ratios, by contrast, were statistically insignificant in all specifications. Overall, the results confirm that higher capital improves bank profitability but with diminishing marginal gains, particularly when measured relative to risk-weighted assets.

These results highlight the importance of balanced capital regulation from a policy perspective. Supervisors should continue to promote higher Tier 1 capital buffers as a source of resilience, but avoid incentivizing excessive accumulation beyond the mid-twenties of risk-weighted assets, where profitability benefits fade. At the same time, the strong negative impact of non-performing loans underscores that capital deepening alone cannot ensure profitability; asset quality supervision and proactive credit risk management are equally vital. Policymakers should therefore combine capital regulation with measures to strengthen loan monitoring, reduce NPL stocks, and incentivize banks to restructure distressed assets. The findings suggest that international banking systems should align capital requirements with the realistic efficiency frontier, encouraging stability without eroding returns. At the same time, macropru-

dential policies should focus on the interaction between credit quality and capital buffers. In practice, this calls for regulatory frameworks that integrate capital adequacy, credit risk control, and early-warning mechanisms, ensuring that financial stability is achieved without compromising the sustainability of bank profitability.

AUTHOR CONTRIBUTIONS

Conceptualization: Sakina Hajiyeva, Zohrab Ibrahimov.

Data curation: Zohrab Ibrahimov, Nasirulla Nasirli, Nihad Pashazade, Marhamat Bayramov Afkhan.

Formal analysis: Sakina Hajiyeva, Marhamat Bayramov Afkhan.

Funding acquisition: Nasirulla Nasirli, Nihad Pashazade, Marhamat Bayramov Afkhan.

Investigation: Sakina Hajiyeva, Nasirulla Nasirli.

Methodology: Sakina Hajiyeva, Zohrab Ibrahimov, Nasirulla Nasirli.

Project administration: Nihad Pashazade.

Resources: Sakina Hajiyeva, Nihad Pashazade.

Software: Zohrab Ibrahimov, Nasirulla Nasirli, Marhamat Bayramov Afkhan.

Supervision: Zohrab Ibrahimov, Nihad Pashazade.

Validation: Sakina Hajiyeva, Nasirulla Nasirli, Marhamat Bayramov Afkhan.

Visualization: Nasirulla Nasirli, Nihad Pashazade.

Writing – original draft: Sakina Hajiyeva, Zohrab Ibrahimov, Nasirulla Nasirli, Nihad Pashazade, Marhamat Bayramov Afkhan.

Writing – reviewing & editing: Sakina Hajiyeva, Zohrab Ibrahimov, Nasirulla Nasirli, Nihad Pashazade, Marhamat Bayramov Afkhan.

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APPENDIX A. LIST OF COUNTRIES INCLUDED IN THE SAMPLE

The study sample comprises 133 countries with available and consistent data for 2010–2024.

Albania, Algeria, Angola, Antigua and Barbuda, Argentina, Armenia, Australia, Austria, Azerbaijan, Bangladesh, Barbados, Belarus, Belgium, Belize, Bhutan, Bolivia, Bosnia and Herzegovina, Botswana, Brunei Darussalam, Burundi, Bulgaria, Brazil, Cambodia, Cameroon, Canada, Central African Republic, Chad, China, Colombia, Comoros, Congo (Democratic Republic), Congo, Costa Rica, Croatia, Cyprus, Czech Republic, Denmark, Djibouti, Dominica, Dominican Republic, Ecuador, El Salvador, Equatorial Guinea, Estonia, Eswatini, Fiji, Finland, France, Gabon, Gambia, Georgia, Ghana, Greece, Guatemala, Honduras, Hong Kong, Hungary, Iceland, India, Indonesia, Iraq, Ireland, Israel, Italy, Jordan, Kazakhstan, South Korea, Kosovo, Kuwait, Kyrgyz Republic, Latvia, Lebanon, Lesotho, Lithuania, Luxembourg, Madagascar, Malawi, Malaysia, Maldives, Malta, Mauritius, Mexico, Moldova, Mongolia, Montenegro, Mozambique, Namibia, Nepal, Netherlands, Nicaragua, Nigeria, North Macedonia, Norway, Pakistan, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Poland, Portugal, Romania, Russian Federation, Rwanda, Samoa, San Marino, Saudi Arabia, Seychelles, Singapore, Slovak Republic, Slovenia, Solomon Islands, South Africa, Spain, Sri Lanka, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Sweden, Switzerland, Tajikistan, Tanzania, Thailand, Tonga, Trinidad and Tobago, Türkiye, Uganda, Ukraine, United Arab Emirates, United States, Uruguay, Uzbekistan, Zambia.

APPENDIX B

Table B1. Moderation of the ROA–capital relationship and liquidity (x3) and asset quality (x4) (two-way fixed effects; standard errors clustered by country & year)

Panel A. Coefficients

Source: Authors' calculations in R Studio.

Dependent variable: ROA (y)	Estimate	Std. Error	t-value	p-value	Model
Tier 1 / Assets (x1)	0.128087	0.061380	2.0868	0.0557.	Liquidity (x3) moderation
(Tier 1 / Assets) ² ((x1 ²))	-0.000266	0.000157	-1.6916	0.1128	Liquidity (x3) moderation
Liquidity: Liquid assets / ST liabilities (x3)	0.003090	0.003739	0.8265	0.4224	Liquidity (x3) moderation
Asset quality: NPLs / Total gross loans (x4)	-0.046904	0.012562	-3.7337	0.0022**	Liquidity (x3) moderation
x1 × x3	-0.000297	0.000384	-0.7739	0.4519	Liquidity (x3) moderation
(Tier 1 / Assets) ² × x3	-0.000001	0.000001	-1.1427	0.2723	Liquidity (x3) moderation
Tier 1 / Assets (x1)	0.136698	0.048405	2.8240	0.0135*	NPL (x4) moderation
(Tier 1 / Assets) ² ((x1 ²))	-0.000214	0.000084	-2.5572	0.0228*	NPL (x4) moderation
Liquidity: Liquid assets / ST liabilities (x3)	-0.000165	0.000903	-0.1827	0.8576	NPL (x4) moderation
Asset quality: NPLs / Total gross loans (x4)	-0.031214	0.011478	-2.7194	0.0166*	NPL (x4) moderation
x1 × x4	-0.001313	0.000787	-1.6675	0.1176	NPL (x4) moderation
(Tier 1 / Assets) ² × x4	-0.000042	0.000015	-2.7861	0.0146*	NPL (x4) moderation

Note: Model stats (x3 moderation): RMSE = 0.9055; Adjusted R² = 0.6090; Within R² = 0.0776; Observations = 1,696; Fixed effects: country (133), year (15). Model stats (x4 moderation): RMSE = 0.9042; Adjusted R² = 0.6101; Within R² = 0.0803; Observations = 1,696; Fixed effects: country (133), year (15). Signif. codes: '****' – 0.001; '***' – 0.01; '**' – 0.05; '*' – 0.1; 'no symbol' – insignificant.

Panel B. Conditional turning points $x1^*(z)$ and curvature

Source: authors' calculations in R Studio.

Moderator	z (percentile)	Turning point $x1^*$ (%)	SE	Curvature $2(b_2 + b_{2z}z)$	Slope at the lower bound	Slope at upper bound	Model
Liquidity (x3)	Q25	190.5655	6.7781	-0.001229	0.1141	0.1080	Liquidity (x3) moderation
Liquidity (x3)	Q50	175.7195	3.4611	-0.001289	0.1101	0.1037	Liquidity (x3) moderation
Liquidity (x3)	Q75	150.3145	0.9521	-0.001404	0.1021	0.0951	Liquidity (x3) moderation
NPLs (x4)	Q25	213.7123	5.3810	-0.001250	0.1305	0.1243	NPL (x4) moderation
NPLs (x4)	Q50	167.4025	1.7250	-0.001566	0.1273	0.1195	NPL (x4) moderation
NPLs (x4)	Q75	106.8483	1.9132	-0.002339	0.1193	0.1077	NPL (x4) moderation

Notes: Curvature > 0 indicates U-shape; < 0 indicates inverted-U. Slopes are evaluated at the 5th and 95th percentiles of $x1$. Turning point standard errors via the delta method. Signif. codes: '***' – 0.001; '**' – 0.01; '*' – 0.05; '.' – 0.1; 'no symbol' – insignificant.

Table B2. Moderation of the ROA–risk-weighted capital ($x2$) relationship by liquidity ($x3$) and asset quality ($x4$) (two-way fixed effects; standard errors clustered by country & year)

Panel A. Coefficients

Source: Authors' calculations in R Studio.

Dependent variable: ROA (y)	Estimate	Std. Error	t-value	p-value	Model
Tier-1 / RWA ($x2$)	0.221332	0.089870	2.4628	0.0274*	Liquidity (x3) moderation
(Tier-1 / RWA) ² ($(x2^2)$)	-0.004081	0.001911	-2.1351	0.0509.	Liquidity (x3) moderation
Liquidity: Liquid assets / ST liabilities ($x3$)	0.007611	0.004660	1.6332	0.1247	Liquidity (x3) moderation
Asset quality: NPLs / Total gross loans ($x4$)	-0.036805	0.012630	-2.9141	0.0113*	Liquidity (x3) moderation
$x2 \times x3$	-0.000634	0.000444	-1.4280	0.1752	Liquidity (x3) moderation
(Tier 1 / RWA) ² $\times x3$	0.000010	0.000011	0.9019	0.3824	Liquidity (x3) moderation
Tier 1 / RWA ($x2$)	0.215043	0.076543	2.8094	0.0139*	NPL (x4) moderation
(Tier 1 / RWA) ² ($(x2^2)$)	-0.004278	0.001687	-2.5362	0.0237*	NPL (x4) moderation
Liquidity: Liquid assets / ST liabilities ($x3$)	-0.000697	0.001073	-0.6495	0.5265	NPL (x4) moderation
Asset quality: NPLs / Total gross loans ($x4$)	-0.009848	0.022852	-0.4310	0.6731	NPL (x4) moderation
$x2 \times x4$	-0.003157	0.002559	-1.2333	0.2378	NPL (x4) moderation
(Tier 1 / RWA) ² $\times x4$	0.000073	0.000068	1.0598	0.3072	NPL (x4) moderation

Notes: Model stats ($x3$ moderation): RMSE = 0.8953; Adjusted R^2 = 0.6178; Within R^2 = 0.0983; Observations = 1,696; Fixed effects: country (133), year (15). Model stats ($x4$ moderation): RMSE = 0.8962; Adjusted R^2 = 0.6170; Within R^2 = 0.0965; Observations = 1,696; Fixed effects: country (133), year (15). Signif. codes: '***' – 0.001; '**' – 0.01; '*' – 0.05; '.' – 0.1; 'no symbol' – insignificant.

Panel B. Conditional turning points $x2^*(z)$, curvature and slopes

Source: Authors' calculations in R Studio.

Moderator	z (percentile)	Turning point $x2^*$ (%)	SE	Curvature (reported)	Slope at the lower bound	Slope at upper bound	Model
Liquidity (x3)	Q25	26.6486	2.9103	-0.007428	0.1253	-0.0112	Liquidity (x3) moderation
Liquidity (x3)	Q50	26.4566	2.6874	-0.007166	0.1195	-0.0121	Liquidity (x3) moderation
Liquidity (x3)	Q75	26.0375	2.4470	-0.006653	0.1082	-0.0141	Liquidity (x3) moderation
NPLs (x4)	Q25	25.2789	1.9676	-0.008210	0.1675	0.0860	NPL (x4) moderation
NPLs (x4)	Q50	25.4014	1.9370	-0.007934	0.1629	0.0841	NPL (x4) moderation
NPLs (x4)	Q75	25.7406	2.0275	-0.007259	0.1515	0.0794	NPL (x4) moderation

Notes: Curvature < 0 indicates concavity (inverted-U). Slopes are evaluated at the 5th and 95th percentiles of $x2$. Turning point standard errors via the delta method. Signif. codes: '***' – 0.001; '**' – 0.01; '*' – 0.05; '.' – 0.1; 'no symbol' – insignificant.