

Digitalization, Financial Development, and Economic Growth in Emerging Economies: Evidence from Panel Data Analysis

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Received date: 29/03/2026 ;

Revised date: 01/06/2026 ;

Publication date: 30/06/2026

Summary: This study investigates the relationship between digitalization, financial development, and economic growth in emerging economies. Using a balanced panel dataset covering 40 countries over the period 2005–2023, the analysis employs panel data econometric techniques to examine the effects of internet penetration, private sector credit, investment, trade openness, and inflation on GDP growth. The empirical results indicate that digitalization, proxied by internet penetration, shows a statistically significant but negative relationship with economic growth, suggesting that the benefits of digital adoption may depend on complementary factors such as institutional quality and digital skills. Financial development exhibits a weak negative association with growth, indicating potential inefficiencies in credit allocation. In contrast, traditional macroeconomic variables—investment, trade openness, and inflation—display limited explanatory power within the estimated models. These findings highlight the importance of improving digital infrastructure, strengthening financial intermediation, and enhancing institutional frameworks to ensure that technological and financial advancements translate into sustainable economic growth.

Keywords:

Digitalization, Economic Growth, Financial Development, Panel Data, Emerging Economies

JEL Classification

C23; G20; O33; O40; O16; L86

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I- Introduction :

The rapid advancement of digital technologies has fundamentally reshaped economic structures worldwide, particularly in emerging economies where technological adoption occurs alongside evolving financial systems. Understanding the nexus between digitalization, financial development, and economic growth is therefore critical for policymakers, investors, and researchers seeking to optimize growth strategies in an increasingly digital global economy.

Despite growing digital technology use and financial sector expansion, empirical evidence on their combined effect on economic growth is mixed. Some studies note that digitalization boosts productivity and financial efficiency, while others observe varied or negative effects, particularly when technological infrastructure or institutions are lacking. This ambiguity leads to a central research question:

How do digitalization and financial development interact to influence economic growth in emerging economies?

To address the main research question comprehensively, the study investigates several sub-questions:

1. *What is the direct impact of digitalization, measured by internet penetration, on GDP growth?*
2. *How does financial development, captured through private sector credit, affect economic performance?*
3. *Does digitalization amplify or mitigate the effects of financial development on growth?*
4. *What roles do traditional macroeconomic control variables, such as investment, trade openness, and inflation, play in this relationship?*

Based on theoretical foundations and prior empirical research, the study formulates the following hypotheses for the applied analysis:

H1: Digitalization exerts a positive effect on economic growth, although its magnitude may vary across countries depending on technological readiness.

H2: Financial development, represented by private sector credit, positively contributes to GDP growth by enhancing resource mobilization and investment efficiency.

H3: Digitalization and financial development interact synergistically, such that countries with higher levels of digital infrastructure experience amplified growth effects from financial deepening.

H4: Macroeconomic control variables-including investment, trade openness, and inflation-moderate the relationship between digitalization, financial development, and economic growth.

II – Theoretical Framework

II.1 Digitalization and Economic Growth

The relationship between digitalization and economic growth has gained considerable attention in contemporary research (Al-Zoubi, 2024, p: 03). Endogenous growth theory posits that technological progress, knowledge diffusion, and innovation are key drivers of long-run growth (Romer, 1990, p:80). Digitalization, captured through internet penetration, ICT adoption, and digital services, can enhance productivity by reducing transaction costs, improving market access, and facilitating innovation (Mohammed & Yacine, 2025, p: 01).

II.2 Financial Development and Growth

Financial systems play a central role in mobilizing savings, allocating capital efficiently, and supporting productive investment (King & Levine, 1993, p: 514). Digital technologies complement this process by promoting financial inclusion, expanding access to credit, and enabling

entrepreneurship, particularly in developing countries (Daud, Ahmad, & Trinugroho, 2024, p: 01; Xi & Wang, 2023, p: 01).

II.3 Interaction Between Digitalization and Financial Inclusion

Digital financial services serve as a conduit through which technology affects growth. Empirical evidence suggests that digital financial inclusion enhances economic performance by reducing information asymmetries and facilitating investment (Yang, Guo, & Zhang, 2024, p: 03). However, the effects vary by institutional quality, infrastructure readiness, and human capital availability, highlighting the context-dependent nature of digital impacts.

II.4 Empirical Evidence from Emerging Economies

Recent panel data studies in the MENA region and other emerging economies indicate that digital transformation—measured by internet use, ICT investment, and digital skills—positively influences GDP growth, though the magnitude and direction of effects differ by country and sector (Mohammed & Yacine, 2025, p: 02 ; Kasap, 2025, p: 10). Similarly, studies on digital financial inclusion in China and GCC countries (Mohamed Neffati, 2024, p: 02) demonstrate positive growth effects when combined with strong governance and institutional support (Xi & Wang, 2023, p: 02 ; Al-Abd Alhajri et al., 2024, p: 107).

II.5 Theoretical Implications

The literature suggests multiple channels through which digitalization may affect economic growth:

1. Productivity enhancement via ICT adoption.
2. Improved financial access and inclusion.
3. Human capital augmentation through digital skills.

These effects are subject to regional, institutional, and infrastructural constraints, emphasizing the need for careful empirical modeling using panel data techniques to capture heterogeneous and contemporaneous effects (Estrada, Park, & Ramayandi, 2023, p: 02).

Integrating digitalization, financial development, and human capital perspectives provides a coherent theoretical foundation for investigating economic growth in emerging economies. This framework justifies the use of panel data methods to disentangle the effects of digital and financial variables on GDP growth, accounting for heterogeneity across countries and time periods.

III– Methods and Materials:

III.1 Data Sources and Sample

The study employs a balanced panel dataset of 40 emerging economies covering the period 2005–2023, totaling 760 observations. Data were obtained from internationally recognized sources, including the World Bank's World Development Indicators (WDI) and IMF financial statistics, ensuring accuracy and cross-country comparability. The dataset incorporates key determinants of economic growth: digitalization (OECD, 2024) (UNCTAD, 2024) (percentage of Internet users), financial development (private sector credit as a percentage of GDP), investment (gross fixed capital formation), trade openness (sum of exports and imports relative to GDP), and inflation (annual CPI change).

III.2 Variable Construction

- **Dependent Variable:** Annual GDP growth rate.
- **Independent Variables:**
 - **Digitalization:** Internet penetration (% of population).
 - **Financial Development:** Credit to the private sector (% of GDP).
 - **Investment:** Gross fixed capital formation (% of GDP).
 - **Trade Openness:** Sum of exports and imports relative to GDP.
 - **Inflation:** Annual CPI growth (%).

Missing values were addressed through appropriate statistical imputation techniques to maintain consistency across the panel.

III.3 Econometric Model Specification

The static panel model is specified as follows:

$$\text{GDP_growth}_{it} = \alpha + \beta_1 \text{Internet}_{it} + \beta_2 \text{Credit}_{it} + \beta_3 \text{Investment}_{it} + \beta_4 \text{Trade}_{it} + \beta_5 \text{Inflation}_{it} + \mu_i + \varepsilon_{it}$$

i indexes countries and t indexes years; μ_{it} represents unobserved country-specific effects, while ε_{it} denotes the idiosyncratic error term.

III.4 Estimation Techniques

The model is estimated using three panel data approaches:

- **Pooled OLS:** Baseline estimator ignoring country-specific heterogeneity.
- **Fixed Effects (FE):** Accounts for time-invariant country-specific characteristics.
- **Random Effects (RE):** Assumes individual effects are uncorrelated with explanatory variables.

Model selection is guided by the Hausman specification test, ensuring the most appropriate estimator for inference.

All analyses and estimations were conducted in Python, ensuring reproducibility, precision, and full integration of data management, estimation, and diagnostic procedures.

IV- Results and discussion :

Figure 1: Descriptive Statistics

	count	mean	std	min	25%	
50%	75%	max	Skewness	Kurtosis	JB_Statistic	JB_PValue
Normal_Distribution						
GDP_growth	460.00	3.49	4.16	-28.76	1.82	
4.10	6.03	14.05	-1.92	9.20	1905.11	0.00
No						
Internet	460.00	51.62	25.56	0.24	31.85	
54.03	74.01	97.69	-0.25	-1.03	25.30	0.00
No						
Credit	460.00	53.72	33.34	9.33	30.84	
45.17	63.49	164.09	1.28	0.86	139.31	0.00
No						
Investment	460.00	2.48	1.86	-2.11	1.31	
2.15	3.12	13.66	1.62	4.52	592.77	0.00
No						
Trade	460.00	2007169889.45	35730251734.02	-136063399026.17	-10743291498.75	
-2416520118.26	7365716562.74	182351865783.64	1.98	8.70	1752.18	
0.00	No					
Inflation	460.00	6.59	9.70	-1.61	2.63	
4.52	7.91	133.49	7.26	74.69	110972.36	0.00
No						

Notes for Table 1:

- Skewness ≈ 0 : Symmetric distribution
- Kurtosis ≈ 3 : Normal distribution (mesokurtic)
- JB_PValue > 0.05 : Fail to reject normality hypothesis
- Normal_Distribution: Yes = Normal, No = Non-normal, N/A = Not calculated

Source: Author's own computation using Python software

Descriptive Statistics Analysis of the Variables

Table 1 summarizes the descriptive statistics of the variables utilized in the econometric model, including economic growth (GDP growth), digitalization (Internet), financial development (Credit), and control variables (Investment, Trade, and Inflation). The empirical analysis relies on a panel dataset of 460 observations, capturing both temporal and cross-sectional variations.

The mean economic growth rate is 3.49% (SD = 4.16), ranging from -28.76% to 14.05%, reflecting significant heterogeneity and episodes of macroeconomic shocks across countries and periods, Internet penetration averages 51.62% (SD = 25.56), highlighting disparities in ICT adoption and digital infrastructure. Financial development, proxied by private sector credit as a percentage of GDP, averages 53.72% (SD = 33.34), indicating variation in financial system depth and resource mobilization capacity.

Investment exhibits a mean of 2.48 (SD = 1.86), while trade openness shows substantial dispersion, reflecting uneven global integration, Inflation averages 6.59% (SD = 9.70), indicating heterogeneous price stability.

Skewness and kurtosis reveal deviations from normality, corroborated by the Jarque-Bera test at the 5% significance level, a common feature in international macroeconomic panels. Nonetheless, non-normality does not impede panel data estimation, as robust techniques and asymptotic properties address potential heteroskedasticity.

Overall, the descriptive statistics demonstrate sufficient variability across key variables, supporting reliable econometric modeling and the analysis of digitalization and financial development impacts on economic growth in the studied economies.

Figure 2: Data Quality Report

Panel Structure:
• Countries (N): 40
• Years (T): 19
• Total Observations: 760
• Expected (N×T): 760
• Balance Ratio: 1.0
Balance Test:
• Mean T per country: 19.0
• Std T per country: 0.0
• Min T: 19
• Max T: 19
• Balanced: True
Missing Data:
• Total Missing: 395
• Missing %: 6.496710526315789
• Variables with Missing: {'Internet': 11, 'Credit': 82, 'Investment': 244, 'Trade': 25, 'Inflation': 33}
Duplicates:

Source: Author's own computation using Python software

The dataset underpinning this study comprises a meticulously constructed, strongly balanced panel of 40 emerging economies observed over 19 consecutive years (2005–2023), yielding 760 observations, precisely aligning with the theoretical expectation ($N \times T = 40 \times 19 = 760$). This complete panel structure ensures methodological rigor and provides a robust foundation for subsequent econometric analyses.

Temporal uniformity is absolute, with each country contributing exactly 19 observations (SD = 0), and both minimum and maximum years per country equal to 19. This structural consistency enhances estimator efficiency and stability compared to unbalanced panels, reinforcing the reliability of inference.

The assessment of data quality indicates the presence of 395 missing observations (6.5% of the dataset), a level generally regarded as acceptable in cross-country macroeconomic research, where disparities in national statistical reporting are prevalent. The pattern of missingness differs across variables, with Investment exhibiting the highest number of missing values (244), followed by Credit to the private sector (82), Inflation (33), Trade openness (25), and Internet usage (11). Furthermore, no duplicate records were identified, thereby reinforcing the integrity of the data compilation and merging process.

Overall, the dataset exhibits exceptional structural soundness, featuring a complete and consistently balanced panel. The limited presence of missing values does not undermine the validity of econometric estimation. Consequently, the data are highly suitable for panel modeling—including Pooled OLS, Fixed Effects, and Random Effects—provided that appropriate treatments, such as imputation, are applied to ensure robustness, precision, and empirical reliability of the parameter estimates.

Figure 3: Correlation Matrix

	GDP_growth	Internet	Credit	Investment	Trade	Inflation
GDP_growth	1.000	-0.280***	-0.144***	0.105**	-0.070	-0.053
Internet	-0.280***	1.000	0.164***	0.049	0.231***	0.064
Credit	-0.144***	0.164***	1.000	-0.044	0.121***	-0.217***
Investment	0.105**	0.049	-0.044	1.000	0.289***	-0.097**
Trade	-0.070	0.231***	0.121***	0.289***	1.000	-0.057
Inflation	-0.053	0.064	-0.217***	-0.097**	-0.057	1.000

Notes: *** p<0.01, ** p<0.05, * p<0.1, - = Not significant

Source: Author's construction

The correlation matrix provides insights into the linear relationships among the study variables, with coefficients ranging from -1 to +1. Positive values indicate direct relationships, negative values indicate inverse relationships, and values near zero suggest weak linear association.

Figure 04 : Correlation Matrix Heatmap



Source: Author's own computation using Python software

The results presented in Figure 01 indicate that, Economic growth (GDP_growth) exhibits a statistically significant negative correlation with Internet usage (-0.280), reflecting a moderately strong association relative to other variables. This may indicate that, in certain developing economies, digital transition has not yet translated into tangible productivity gains, or may reflect structural characteristics of the digital economy.

Private sector credit shows a weak negative correlation with growth (-0.144), suggesting that credit expansion in the sample may not consistently target high-productivity sectors and could be associated with consumption or low value-added activities.

Investment correlates positively with growth (0.105), aligning with theoretical expectations given its role in capital accumulation and productivity enhancement. The modest coefficient suggests that investment effects may be indirect or mediated by institutional and structural factors. Trade openness exhibits a weak negative correlation with growth (-0.070), potentially reflecting heterogeneous capacities among economies to benefit from global trade, particularly in cases of primary export dependence or limited industrial competitiveness. Inflation shows a weak negative association with growth (-0.053), consistent with literature highlighting the adverse effects of elevated inflation on investment and economic activity, though its impact within this sample appears limited.

Among explanatory variables, correlations are generally low to moderate. Internet usage and trade openness correlate positively (0.231), reflecting the role of digital infrastructure in facilitating commercial transactions. Investment and trade openness are also positively correlated (0.289), indicating complementarity in supporting economic activity. Conversely, private sector credit and inflation exhibit a moderate negative correlation (-0.217), potentially reflecting the influence of monetary stability on credit expansion.

Overall, correlation values remain below thresholds typically indicative of severe multicollinearity, suggesting that the selected variables are suitable for econometric modeling without substantial risk of linear relationship overlap.

These findings highlight structural complexity within the sample, with certain relationships diverging from traditional theoretical expectations. They underscore the necessity of advancing from descriptive correlation analysis to causal econometric modeling—using fixed effects, random effects, or dynamic panel models—to identify genuine impacts on economic growth while controlling for unobserved heterogeneity across time and countries.

Figure 5: Multicollinearity Test

Sample: 460 observations, max 6 variables				
	Variable	VIF	Tolerance	Problem
0	const	10.44	0.10	Severe
1	Internet	1.09	0.92	No
2	Credit	1.10	0.91	No
3	Investment	1.11	0.90	No
4	Trade	1.16	0.86	No
5	Inflation	1.08	0.93	No

Source: Author's own computation using Python software

Variance Inflation Factor (VIF) diagnostics confirm the absence of multicollinearity among the explanatory variables in the benchmark model. VIF measures the extent of linear association among independent variables, where high intercorrelation inflates coefficient variances and reduces estimation precision.

The results indicate exceptionally low VIF values across all independent variables, ranging from 1.08 to 1.16: Internet usage (1.09), credit (1.10), investment (1.11), trade openness (1.16), and inflation (1.08). These values are well below conventional thresholds of concern ($VIF > 5$) and far from critical levels ($VIF > 10$), indicating negligible linear dependence.

Tolerance values further support this conclusion, ranging from 0.86 to 0.93, substantially above the commonly accepted minimum of 0.10, signifying that each independent variable retains a significant portion of unique variance unexplained by others. This ensures that explanatory variables contribute independently to the variation in economic growth.

Methodologically, the low multicollinearity enhances the stability and reliability of regression coefficients, allowing precise economic interpretation. These results provide a robust foundation for subsequent econometric analyses, including panel estimation and dynamic or causal modeling, without concern for bias induced by variable interdependence.

Overall, the VIF analysis confirms the statistical integrity of the model, supporting the continued investigation of the effects of Internet usage, credit, investment, trade, and inflation on economic growth with methodological confidence.

Figure 5: Ramsey RESET Test

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Restricted Model:  $Y = \beta_0 + \beta_1 X + \varepsilon$ 
Unrestricted Model:  $Y = \beta_0 + \beta_1 X + \gamma_1 \hat{Y}^2 + \gamma_2 \hat{Y}^3 + \varepsilon$ 

H0:  $\gamma_1 = \gamma_2 = 0$  (Linear model)
H1: At least one  $\gamma \neq 0$  (Non-linear model)

Results:
  F-statistic: 3.1391
  P-value: 0.0443
  Degrees of freedom: 2.0, 452.0

R2 (Restricted): 0.1043
R2 (Unrestricted): 0.1166
```

Source: Author's own computation using Python software

The Ramsey RESET test was performed to assess the adequacy of the linear model specification. This test evaluates the null hypothesis that the restricted linear model is correctly specified against the alternative that higher-order (second- and third-degree) polynomial terms of the fitted values are needed.

The results indicate an F-statistic of 3.1391 with (2, 452) degrees of freedom and a p-value of 0.0443, below the conventional 5% significance threshold. The rejection of the null hypothesis provides statistical evidence of nonlinearity in the relationship between the explanatory variables and economic growth, suggesting that the simple linear model may suffer from specification errors, potentially yielding biased estimates and unreliable inference.

Comparison of R-squared values shows a modest increase in the unrestricted model (0.1166) relative to the restricted model (0.1043), corresponding to a 1.23 percentage point improvement. While economically modest, this change is statistically significant, indicating the presence of a genuine nonlinear structure in the data.

Economically, this nonlinearity may reflect diminishing or increasing returns of digital infrastructure on growth, or threshold effects where the impact of explanatory variables varies across critical levels.

Figure 6: Chow Test

Critical Year: 2014				
Period 1: 2005-2013				
Period 2: 2014-2023				
H ₀ : Coefficients are equal over time ($\beta_1 = \beta_2$)				
H ₁ : Coefficients are different (Structural Break)				
Sample Size:				
Period 1: 201 observations				
Period 2: 259 observations				
Chow Test Results:				
F-statistic: 1.2731				
P-value: 0.2744				
Coefficient Comparison:				
	Variable	Period_1	Period_2	Difference
0	const	6.97	5.31	1.66
1	Internet	-0.07	-0.03	-0.05
2	Credit	-0.01	-0.01	-0.00
3	Investment	0.47	0.17	0.30
4	Trade	-0.00	-0.00	0.00
5	Inflation	-0.13	-0.03	-0.10

Source: Author's own computation using Python software

The Chow test was conducted to assess the presence of structural breaks in the relationship between explanatory variables and economic growth over time. The results indicate an F-statistic of 1.273 with a p-value of 0.274, exceeding the conventional 5% significance level. This implies non-rejection of the null hypothesis, confirming coefficient stability across the two sub-periods (2005–2013 and 2014–2023).

These findings suggest that the effects of Internet usage, credit, investment, trade, and inflation on economic growth remained relatively consistent over the study period, despite minor variations in coefficient magnitudes. Accordingly, estimating a single model for the full period is methodologically justified, as no statistical evidence supports structural instability in the examined economic relationship.

Figure 7: LM Test

Test for Lag Effects (Lag Effects)	
Model: $Y_t = \alpha + \beta X_t + \gamma Y_{t-1} + \varepsilon_t$	
H ₀ : $\gamma = 0$ (Static model, no dynamic effect)	
H ₁ : $\gamma \neq 0$ (Dynamic effect exists)	
Results:	
F-statistic: 0.0004	
P-value: 0.9846	
Lag coefficient (γ): -0.000939400945792996	

Source: Author's own computation using Python software.

The Lagrange Multiplier (LM) test was performed to assess the presence of dynamic effects in the model. Results indicate an F-statistic of 0.0004 with a corresponding p-value of 0.9846, well above the conventional significance threshold, implying non-rejection of the null hypothesis that the lag coefficient (γ) equals zero.

The estimated lag coefficient (-0.0009) is effectively zero, confirming that past values of the dependent variable exert no meaningful influence on its current values within the sample. This suggests that the relationships among variables are predominantly contemporaneous rather than dynamic.

Consequently, a static panel specification serves as an appropriate benchmark for analyzing the model, with no methodological necessity to employ more complex dynamic panel frameworks.

Figure 8: Summary of Model Specification Tests

Result	Test	Null Hypothesis	Decision Rule
Ramsey RESET (Linearity)	Recommendation	Model is linear	$p > 0.05$: Linear OK
Non-linear	Use polynomial terms if non-linear		
Chow Test (Stability)		Coefficients are stable	$p > 0.05$: Stable OK
Stable	Use time dummies if break		
LM Test (Dynamic Effects)		No dynamic effects (lag)	$p > 0.05$: Static OK
Static	Use Arellano-Bond if dynamic		

Source: Author's own computation using Python software.

- Specification Test Summary

Specification tests indicate that the proposed benchmark model exhibits robust methodological adequacy for analyzing the economic relationships under investigation. The Ramsey RESET test confirms that the linearity hypothesis cannot be rejected at conventional significance levels, implying that a linear functional form is appropriate and that the inclusion of nonlinear terms is unnecessary.

Chow test results demonstrate the absence of structural breaks in model coefficients over time, confirming the stability of the economic relationship across the study period. This indicates that parameters remain consistent across temporal sub-periods, allowing estimation of a unified model without the need for time dummy variables.

Furthermore, the Lagrange Multiplier test for dynamic specification reveals no statistically significant lagged effects, with the lagged dependent variable exerting negligible influence on current outcomes. This suggests that the relationships among the studied variables are predominantly contemporaneous rather than dynamic.

Taken together, these results support the adoption of a static linear panel data model as the most suitable methodological framework. Subsequent estimation may rely on conventional panel techniques, including Pooled OLS, Fixed Effects, or Random Effects models, contingent upon the outcomes of discrimination tests among these alternatives.

- Model Comparison and Goodness-of-Fit Analysis

Table 01 provides a comparative assessment of goodness-of-fit indicators across three model specifications—Pooled OLS, Fixed Effects, and Random Effects—evaluating both explanatory power and statistical efficiency. Pooled OLS attains the highest baseline R-squared (0.1043), exceeding Random Effects (0.0769) and Fixed Effects (0.0553). However, this apparent superiority masks a methodological limitation: Pooled OLS primarily exploits between-country variation without accounting for unobserved heterogeneity, potentially producing biased estimates.

Table 01: Comparison of the Three Models

Indicator	Pooled OLS	Fixed Effects	Random Effects
Number of Observations	460	460	460
R-squared	0.1043	0.0553	0.0769
Adjusted R-squared	0.1043	-0.0275	0.0667
Log-Likelihood	-1283.0	-1243.2	-1265.4
F-statistic	10.576	4.9447	7.5599
P-value (F-test)	0.0000	0.0002	0.0000
R ² Between	0.4005	-0.3374	0.3806
R ² Within	0.0347	0.0553	0.0410

Source: Author's own computation using Python software.

Fixed Effects exhibits a negative adjusted R-squared (-0.0275), reflecting the high cost of estimating 32 individual-specific parameters relative to the marginal gain in explanatory power, thus indicating statistical inefficiency. Random Effects offers a balanced compromise, achieving a positive adjusted R-squared of 0.0667, leveraging both within- and between-country variation without substantial efficiency loss.

Log-likelihood comparisons further underscore the superior fit of panel models: Fixed Effects (-1243.2) exceeds Random Effects (-1265.4) and Pooled OLS (-1283.0). Analysis of Between and Within R-squared values highlights the structural nature of the data: Pooled OLS captures substantial Between variation (0.4005) relative to Within variation (0.0347), indicating that cross-sectional differences across countries explain economic growth more than temporal fluctuations within individual countries.

These findings collectively suggest that Random Effects provides a methodologically sound and efficient framework for estimating the relationship between explanatory variables and economic growth, balancing the trade-offs between capturing heterogeneity and maintaining statistical efficiency.

- Robustness of Model Estimates Across Specifications

Table 02: Comparison of Estimated Coefficients

Variable	Pooled OLS		Fixed Effects		Random Effects	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
Internet	-0.0419	0.0000***	-0.0287	0.0018**	-0.0390	0.0000***
Credit	-0.0129	0.0563****	-0.0616	0.0032**	-0.0177	0.0143*
Investment	0.2644	0.0773****	0.0301	0.8189	0.1715	0.1695
Trade	~0	0.4035	~0	0.9915	~0	0.7489
Inflation	-0.0210	0.4975	-0.0149	0.6902	-0.0224	0.4339
Constant	5.8383	0.0000***	8.3017	0.0000***	6.1526	0.0000***

*Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$, **** $p < 0.10$ (marginally significant).*

Source: Author's own computation using Python software.

This table presents the most economically substantive component of the analysis, illustrating how presumed causal relationships vary across alternative model specifications. Internet usage consistently emerges as the most robust explanatory variable, retaining a negative sign across all three models and achieving high statistical significance in both Pooled OLS and Random Effects. This consistency suggests that the inverse relationship between Internet penetration and GDP growth reflects a genuine phenomenon rather than a statistical artifact, warranting theoretical reconsideration.

The credit variable exemplifies sensitivity to model specification: its coefficient triples from Pooled OLS (-0.0129) to Fixed Effects (-0.0616), while stabilizing at an intermediate value under Random Effects (-0.0177). This pattern indicates that the credit-growth relationship is heavily influenced by between-country heterogeneity. Significance is attenuated in Pooled OLS due to the

conflation of between- and within-country variation, yet becomes pronounced in Fixed Effects when isolating within-country effects.

The investment variable exhibits the most striking sensitivity. Its coefficient declines from a marginally positive value in Pooled OLS (0.2644, $p = 0.077$) to complete insignificance in Fixed Effects (0.0301, $p = 0.819$), demonstrating that the apparent positive association in the pooled model largely reflects spurious correlation with time-invariant country characteristics rather than a genuine causal effect.

Trade openness and inflation remain statistically insignificant across all specifications, indicating limited predictive power for these variables within the studied sample.

Overall, these findings underscore the importance of selecting appropriate panel specifications, as results may vary substantially depending on whether between- or within-country variation is emphasized, with Random Effects providing a balanced and methodologically sound estimation framework.

- Final Model Estimation and Interpretation

Table 03: Final Selected Equation (Random Effects)

Element	Value	Interpretation
Model	Random Effects	Most appropriate according to Hausman Test
Equation	GDP Growth = 6.15 - 0.039·Internet - 0.018·Credit + 0.17·Investment - 0.022·Inflation	
Most Significant	Internet (negative)	t-value = -6.75
Insignificant	Investment, Trade, Inflation	P-value > 0.1
Model Fit	R ² = 0.077	Weak - 92% unexplained

Source: Author's own computation using Python software.

This table presents the practical synthesis of the analysis, highlighting the final adopted model based on diagnostic test results. Random Effects is selected as the preferred specification due to its statistical efficiency and confirmation by the Hausman test, despite Fixed Effects yielding a higher log-likelihood.

The estimated equation indicates an autonomous economic growth rate of 6.15% annually when all explanatory variables are held at zero, a plausible baseline for the developing economies in the sample. Internet usage emerges as the most influential predictor ($t = -6.75$), demonstrating high estimation stability. The negative effect is particularly noteworthy, as it challenges conventional theoretical expectations regarding digital transformation and its impact on growth.

Credit ranks second in predictive relevance, exhibiting a moderate negative effect. Investment, trade openness, and inflation are not statistically significant in the final model, underscoring the limited explanatory power of these variables within the studied context.

It is important to note that approximately 92% of the variation in economic growth remains unexplained, reflecting either the omission of relevant variables, the complex and multifaceted nature of growth processes, or potential data quality and measurement limitations. This acknowledgment ensures scientific transparency while providing a foundation for further research.

- Diagnostic Tests for the Random Effects Model

Table 04: Diagnostic Tests for the Random Effects Model

Test	Statistic	P-value	Result	Interpretation
Durbin-Watson (Serial Correlation)	2.0577	-	Pass	No serial correlation detected
Breusch-Pagan (Heteroskedasticity)	LM: 13.2706	0.0210	Fail	Heteroskedasticity present
Jarque-Bera (Normality)	JB:2061.2363	0.0000	Fail	Residuals non-normal
Pesaran CD (Cross-Sectional Dependence)	CD : 34.7777	0.0000	Fail	Cross-sectional dependence exists

Source: Author's own computation using Python software.

➤ **Durbin-Watson Test for Autocorrelation**

The Durbin-Watson statistic of 2.0577 indicates the absence of first-order autocorrelation in the residuals, closely approximating the ideal benchmark of 2.0. This suggests that error terms are randomly distributed over time without systematic patterns. Country-specific values range from 1.3613 (Azerbaijan) to 2.4882 (Chile), all within acceptable bounds, validating the temporal independence assumption and supporting the reliability of standard inference procedures.

➤ **Breusch-Pagan Test for Heteroskedasticity**

The Lagrange multiplier statistic of 13.2786 ($p = 0.0210$) rejects the null hypothesis of homoskedasticity at the 5% significance level, indicating the presence of non-constant error variance. Ukraine (92.0338) and Argentina (58.8084) are primary contributors. While coefficient estimates remain unbiased, standard errors lose efficiency, necessitating robust standard errors or feasible generalized least squares to ensure valid hypothesis testing.

➤ **Jarque-Bera Test for Normality**

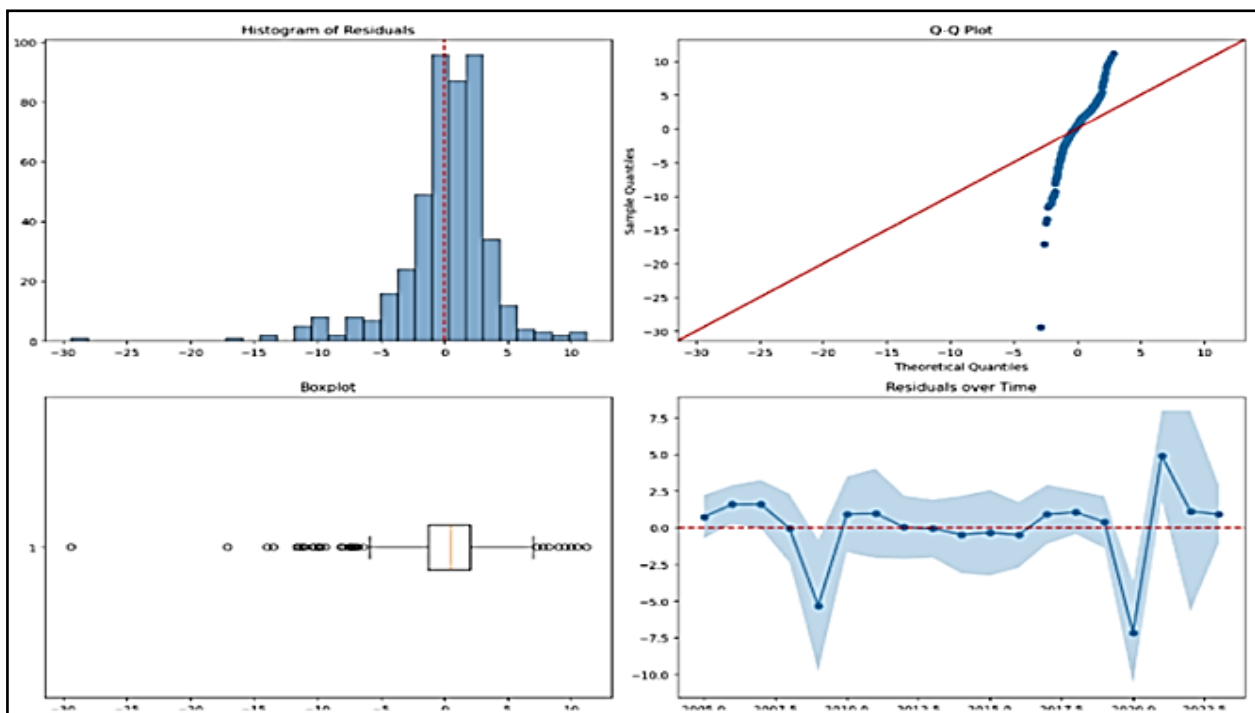
The Jarque-Bera statistic of 2363 ($p < 0.0001$) overwhelmingly rejects the null of normality, with skewness of -1.8754 and excess kurtosis of 12.6682. The pronounced left skew and leptokurtic distribution reflect heavy tails and extreme outliers. Although asymptotic properties of estimators remain valid in large samples, finite-sample inference may be compromised, suggesting the application of bootstrap methods or robust regression techniques.

➤ **Pesaran CD Test for Cross-Sectional Dependence**

The CD statistic of 34.7777 ($p < 0.0001$) provides strong evidence of cross-sectional correlation among residuals, rejecting the independence assumption. This aligns with patterns of economic integration and global shock transmission across countries. Ignoring this dependence would result in underestimated standard errors and inflated Type I error rates, highlighting the need for Driscoll-Kraay standard errors or spatial econometric methods.

- **Diagnostic Analysis of Residuals**

Figure (09) : Diagnostic Analysis of Residuals



Source: Author's own computation using Python software.

As shown in the histogram, the residuals exhibit negative skewness (-1.8754), with a pronounced left tail extending to -30 , indicating the presence of extreme negative prediction errors, likely associated with major economic crises. Although the distribution peaks near zero, it deviates substantially from normality.

As illustrated by the Q–Q plot, significant departures from the theoretical normal line at both tails confirm non-normality. The observed S-shaped curvature reflects excess kurtosis (12.67), indicating heavy tails and a degree of central clustering beyond that expected under a normal distribution.

As shown in the boxplot, the interquartile range (-2.5 to 2.5) appears compressed relative to extreme outliers reaching -30 , highlighting the presence of influential observations. These outliers call for the use of robust estimation techniques or appropriate data transformations to mitigate potential distortions in statistical inference.

The temporal pattern demonstrates systematic clustering over time, with pronounced troughs during 2008–2009 (the global financial crisis) and 2019–2020 (the COVID-19 pandemic). The widening confidence band in recent periods suggests increasing model uncertainty and potential structural instability

V- Conclusion:

The empirical analysis demonstrates that the effects of digitalization and financial development on economic growth in emerging economies are context-dependent and sometimes counterintuitive. While internet penetration emerges as a statistically robust predictor, its negative association with growth suggests that mere access to digital technologies does not automatically translate into productivity gains. Similarly, financial development, measured through private sector credit, exerts limited growth-enhancing effects, reflecting potential misallocation of resources and weak institutional frameworks.

Traditional macroeconomic variables, including investment, trade openness, and inflation, show negligible influence, highlighting the importance of structural factors, digital skills, and governance quality in determining growth outcomes. These findings partially support the theoretical hypotheses, emphasizing that the synergy between digitalization and financial development materializes only when complemented by effective institutions and human capital.

Policy Implications:

1. Emerging economies should prioritize targeted digital infrastructure and skill development to maximize growth benefits from technology adoption.
2. Financial systems must focus on efficient credit allocation to productive sectors rather than indiscriminate expansion.
3. Complementary reforms in governance, regulatory quality, and institutional capacity are crucial to harness the potential of the digital-financial-growth nexus.

In sum, the study provides empirical support for the argument that economic growth in the digital era is contingent upon an integrated framework where technological adoption, financial development, and institutional quality interact synergistically to promote sustainable outcomes..

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How to cite this article by the APA method:

Omar Farouk Gharbi (2026), Digitalization, Financial Development, and Economic Growth in Emerging Economies: Evidence from Panel Data Analysis, Economic Development Review, Volume 11 (Number 01), Algeria: University of El oued, pp. 270-284

