

RETHINKING ICT AND FINANCIAL DEVELOPMENT: DOES DIGITALIZATION DIRECTLY HINDER ECONOMIC GROWTH?*

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This study examines the relationship between information and communication technology adoption, financial development, and economic growth, emphasizing the moderating role of credit availability. Using panel data for 180 countries from 2000 to 2022, comprising 2,590 observations from the World Bank, the study applies System GMM estimation to address potential endogeneity. The results show significant negative associations between information and communication technology adoption, credit expansion, and GDP growth. The interaction between technology adoption and credit availability is also negative, indicating that greater digitalization combined with financial deepening does not necessarily correspond to stronger economic growth. These findings are consistent with the Too Much Finance Hypothesis and suggest that rapid credit expansion and digital financial development may coincide with financial distortions. The study highlights the importance of financial governance, regulatory oversight, and institutional quality in supporting sustainable economic development.

Keywords: ICT Adoption; Financial Development; Economic Growth; Credit Expansion; Banking Efficiency

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1. INTRODUCTION

In recent years, the rapid expansion of information and communication technology

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(ICT) has fundamentally transformed the banking and financial sectors, reshaping the way financial services are delivered, accessed, and utilized. Digital banking, mobile financial services, and fintech innovations have significantly enhanced financial accessibility and operational efficiency, allowing banks to streamline transactions and reduce costs. At the same time, financial development, characterized by increased access to credit and financial development, has been widely regarded as a key driver of economic growth. However, despite the theoretical expectation that ICT adoption should enhance financial efficiency and economic performance, empirical evidence remains inconclusive and highly context dependent. In some cases, ICT-driven financial expansion has failed to yield expected economic benefits, and in others, it has contributed to financial instability by enabling excessive credit growth and speculative lending practices. This inconsistency raises an important research problem: does ICT adoption, in combination with financial development, necessarily contribute to economic growth, or could it also generate unintended negative consequences?

The current research landscape on ICT and financial development presents mixed findings, with studies highlighting both positive and negative effects. Traditional economic theories, such as endogenous growth theory (Romer, 1990) and financial development theory (Levine, 1997), suggest that financial deepening and technological progress should drive long-term economic growth. Empirical research has supported this view, showing that ICT enhances financial inclusion and improves banking efficiency (Beck et al., 2007; Pradhan et al., 2015). However, other studies have found that excessive credit growth can lead to financial instability, reducing the efficiency of capital allocation and ultimately hindering economic growth (Arcand et al., 2015; Cecchetti and Kharroubi, 2012). Moreover, the impact of ICT on economic performance may depend on institutional quality, regulatory frameworks, and the level of economic development, leading to variations across different economies. These contradictions highlight the need for a more comprehensive examination of how ICT and financial development interact to influence economic outcomes.

Given these gaps in literature, this study aims to analyze the impact of ICT adoption on economic growth, with a particular focus on its interaction with credit availability. Specifically, the study seeks to (i) examine whether ICT adoption enhances or hinders GDP growth, (ii) assess the role of credit expansion in influencing economic performance, and (iii) investigate whether ICT moderates the relationship between financial development and economic growth. By employing System GMM estimation, this research ensures that endogeneity concerns are addressed, providing robust insights into the ICT-finance-growth nexus.

The significance of this study lies in its potential to contribute to both academic research and policymaking. From an academic perspective, the study offers a comprehensive empirical analysis of the role of ICT in financial development and economic growth, helping to clarify the conditions under which ICT enhances or limits economic progress. It also expands existing research by considering interaction effects between ICT and credit availability, an area that remains underexplored in financial

development literature. From a policy standpoint, the findings can help governments, central banks, and financial institutions design strategies to leverage ICT for economic development while minimizing risks associated with excessive financial deepening. By identifying the conditions under which ICT adoption is most beneficial, the study provides valuable insights for ensuring that digital financial transformations contribute to sustainable and inclusive economic growth. This study has a structure of 5 parts as follows: (i) introduction, (ii), literature review, (iii) methodology, (iv) results & discussion, and (v) conclusion & recommendation.

2. LITERATURE REVIEW

2.1. Background Theories

The Resource-Based View posits that firms gain a sustainable competitive advantage by leveraging unique and valuable resources (Barney, 2000). Information and communication technology is considered a strategic resource that enables banks to improve operational efficiency, reduce redundancies, and deliver superior customer services. This perspective is supported by empirical evidence from Berger (2003), who demonstrated that technological advancements significantly enhance economic growth through the optimization of cost structures and the provision of innovative financial services. Similarly, Tallon et al. (2000) emphasized that investments in information technology contribute to organizational agility and efficiency, which are crucial for the dynamic financial sector.

The Transaction Cost Theory highlights the role of information and communication technology in reducing transaction costs, which are inherent in traditional banking operations. Coase (1998) and Williamson (1979) argue that the adoption of technology minimizes information asymmetry, automates routine tasks, and streamlines operations. For instance, digital payment systems and automated teller machines reduce the costs associated with manual processing and increase transaction speed. Studies by Berger and Mester (1997) confirm this argument, showing that economics that adopt advanced digital tools experience significant cost reductions and operational efficiency improvements. These efficiency gains align with the broader goals of economic development by making financial services more accessible and cost-effective.

The Technology Acceptance Model provides a behavioral framework for understanding the adoption of information and communication technology. Davis (1989) suggested that the perceived usefulness and ease of use of technology are critical factors influencing its acceptance. Venkatesh et al. (2003) extended this model, introducing additional constructions such as social influence and facilitating conditions, which are particularly relevant in the macroeconomic context. For example, the widespread

adoption of mobile applications on financial services demonstrates how ease of use and perceived benefits drive user engagement, ultimately enhancing the efficiency of financial institutions. Empirical studies, such as those by Lee et al. (2003), further validate this perspective by showing that customer adoption of digital tools significantly improves financial markets performance metrics.

The Diffusion of Innovations Theory, proposed by Rogers (1962), complements these perspectives by explaining how technological advancements spread across industries and influence systemic efficiency. This theory suggests that early adopters of innovative technologies, such as leading banks, play a crucial role in setting industry standards, thereby accelerating the diffusion of information and communication technology. Siddik and Kabiraj (2020) highlighted that digital innovation in financial facilitates not only operational improvements but also financial inclusion, which is a key driver of financial development. Similarly, Demirgüç-Kunt et al. (1998) found that technological advancements in banking systems lead to more efficient credit allocation and increased economic participation.

2.2. Empirical Studies

The relationship between ICT and bank efficiency has been widely explored in financial and economic literature. Several studies confirm that ICT adoption enhances banking efficiency by reducing transaction costs, improving service delivery, and streamlining operations (Berger, 2003; Tan and Floros, 2018). Empirical evidence suggests that banks utilizing digital financial services, mobile banking, and online payment systems tend to have lower cost-to-income ratios and improved return on assets (Awo and Akotey, 2019; Zheng et al., 2023). Studies on emerging markets also find that technological innovations significantly increase financial inclusion, enabling banks to expand their customer base while maintaining operational efficiency (Beck et al., 2007; Sassi and Goaied, 2013). Moreover, cross-country analyses indicate that ICT-driven banking reforms improve efficiency in both developed and developing economies (Pradhan et al., 2015).

The impact of ICT adoption on financial development has also been widely investigated. ICT is considered a critical driver of financial deepening, credit accessibility, and capital market efficiency (Demirgüç-Kunt et al., 1998). Several studies argue that the digitization of financial services leads to higher levels of financial intermediation, which translates into increased access to credit for households and businesses (Levine, 1997; Zins and Weill, 2016). However, some studies point out potential risks, including market concentration, cybersecurity threats, and financial exclusion for unbanked populations (Gomber et al., 2017; Lang and Welzel, 1996). In emerging economies, the effectiveness of ICT in driving financial development often depends on regulatory quality, financial literacy, and institutional strength (Asongu and Nwachukwu, 2019; Pradhan et al., 2015).

While ICT improves bank efficiency, its interaction with domestic credit to the

private sector remains a subject of debate. Some studies find a positive and reinforcing effect, where ICT enables banks to efficiently allocate credit, reducing non-performing loans and boosting profitability (Beck and Levine, 2004; Saqib, 2015). Others suggest a nonlinear relationship, where excessive credit growth, especially when fueled by technology, may lead to financial instability and banking crises (Arcand et al., 2015; Sahay et al., 2015). Empirical findings also show that the effectiveness of credit allocation depends on institutional factors, such as central bank regulations and banking supervision (Cecchetti and Kharroubi, 2012; Halkos and Trigoni, 2010). In developed markets, ICT adoption facilitates complex financial instruments that enhance risk management (Tantri, 2021), while in developing economies, excessive reliance on digital credit may lead to over-indebtedness and predatory lending (Jagtiani and Lemieux, 2017; Mhlanga, 2024).

The role of ICT in moderating the relationship between bank efficiency and financial development is another crucial area of research. Studies indicate that technology adoption enhances the impact of bank efficiency on financial sector growth by reducing transaction costs and information asymmetry (Laeven et al., 2015; Luintel et al., 2008). Additionally, financial innovations such as blockchain, artificial intelligence, and fintech have accelerated financial development by enhancing transparency and improving capital flows (Frost, 2020; Hasan et al., 2024; Tantri, 2021). However, empirical research highlights that the benefits of ICT are not evenly distributed, with developing economies facing barriers such as poor infrastructure, lack of regulatory oversight, and cybersecurity risks (Pradhan et al., 2015; Vasishta and Singla, 2024). Furthermore, cross-country studies suggest that while ICT moderates banking efficiency positively in high-income economies, its effect in low-income countries is highly dependent on regulatory enforcement and financial education (Jahn and Kick, 2012; Xu et al., 2019).

Overall, empirical research confirms that ICT is a key enabler of banking efficiency and financial development, but its effects depend on institutional factors, credit allocation mechanisms, and regulatory environments. The mixed findings in the literature suggest the need for further empirical testing across different financial systems and economic contexts (Gomber et al., 2017; Pradhan et al., 2015; Sahay et al., 2015). Future research should also explore the long-term effects of ICT-driven banking models, the role of central bank digital currencies, and the implications of decentralized finance on traditional banking efficiency (Mhlanga, 2024; Zheng et al., 2023). These considerations are essential for policymakers aiming to leverage ICT to enhance financial stability and economic development while mitigating associated risks (Zheng et al., 2023).

3. METHODOLOGY

3.1. Data

This study utilizes a panel dataset covering 180 countries from 2000 to 2022, collected from the World Development Indicators (WDI) database of the World Bank. The dataset includes key macroeconomic, financial, and ICT-related indicators to examine the impact of ICT adoption, financial development, and their interaction on economic growth. Given the variability in data availability across countries and years, only observations with complete data for the selected variables were included, resulting in a final sample of 2,590 observations. To ensure data reliability and mitigate the influence of extreme values, a data trimming process was applied. Specifically, the top and bottom 3% of the distribution for each continuous variable were removed, reducing the impact of outliers that could distort the regression results. Additionally, missing and incomplete data points were excluded, ensuring that the final dataset consists of high-quality, consistent information across the study period.

3.2. Models

To empirically assess the impact of ICT adoption, financial development, and their interaction on economic growth, this study adopts a dynamic panel data approach using the System Generalized Method of Moments (System GMM) estimator. The baseline econometric model is specified as follows:

$$gdp_growth_{i,t} = \beta_1 gdp_growth_{i,t-1} + \beta_2 ICT_{i,t} + \beta_3 Credit_{i,t} + \beta_4 (ICT * Credit)_{i,t} + \beta_5 Control_{i,t} + \varepsilon_{i,t}$$

In the model, GDP growth represents the economic growth rate of country i in year t , while its lagged value captures persistence in economic performance. ICT adoption is represented alternatively by internet usage, mobile cellular subscriptions, and ICT exports. Financial development is measured by credit to the private sector and credit to the private sector provided by banks. The interaction between ICT adoption and credit availability captures whether the relationship between ICT and economic growth varies with the level of financial development. The model further controls for foreign direct investment, inflation, gross capital formation, and trade openness. Country-specific unobserved effects and the idiosyncratic error component are incorporated into the dynamic panel specification.

System GMM is employed to mitigate potential endogeneity arising from the inclusion of the lagged dependent variable, unobserved country-specific heterogeneity, and possible simultaneity between economic growth, ICT adoption, and financial development. The estimator combines equations in first differences with equations in

levels and uses appropriate lagged values of the variables as internal instruments. The interpretation of the estimates is therefore conditional on the identifying assumptions of the System GMM framework, particularly the validity of the selected instruments and the absence of second-order serial correlation in the differenced disturbances. Instrument validity is assessed using the Hansen test of overidentifying restrictions, while the Arellano–Bond AR(1) and AR(2) tests are used to evaluate serial correlation. Accordingly, the estimated coefficients are interpreted as conditional dynamic relationships rather than as definitive causal effects.

Table 1. Variables Measurement

Factor	Symbol	Measurement
Economic growth	gdp_growth	GDP Growth (%)
ICT adoption	internet	Individuals using the Internet (% of population)
	mobile	Mobile cellular subscriptions (per 100 people)
	ict_export	ICT goods exports (% of total goods exports)
Credit Availability	cps	Credit to the Private Sector (% of GDP)
	cpsb	Credit to the Private Sector by Banks (% of GDP)
Foreign direct investment	fdi	Foreign Direct Investment (% of GDP)
Inflation	inf	Inflation, consumer prices (annual %)
Gross capital formation	gcf	Gross Capital Formation (% of GDP)
Trade openness	trade	Trade Openness

Source: World Development Indicators (World Bank)

Table 1 outlines the definitions and measurements of the variables used in the study. The dependent variable, economic growth, is captured by GDP growth (%), representing the annual percentage increase in a country's economic output. ICT adoption is assessed through three indicators: internet usage (% of population), mobile cellular subscriptions (per 100 people), and ICT goods exports (% of total goods exports), which collectively reflect the extent of digital connectivity and the role of technology in trade. Financial development is measured using credit to the private sector (CPS) and credit provided by banks (CPSB), both expressed as a percentage of GDP, indicating the availability of financial resources to private entities. In addition, the model includes several control variables: foreign direct investment (FDI), inflation (INF), gross capital formation (GCF), and trade openness, which help account for other macroeconomic and structural factors that influence growth. These variable definitions ensure a comprehensive framework to evaluate the impact of ICT and financial development on economic performance.

4. RESULTS AND DISCUSSION

4.1. Descriptive Analysis

Table 2 presents the descriptive statistics of the key variables used in the study, highlighting notable trends and variations. The GDP growth rate has a mean of 2.16%, but with a high standard deviation of 4.45%, indicating significant economic fluctuations across countries. The extreme minimum (-55.23%) and maximum (33.77%) values suggest that some economies experience severe contractions, while others achieve rapid growth. The log of GDP ($\ln_gdp$) shows a relatively stable distribution, with values ranging from 19.56 to 30.89, reflecting differences in economic size among the sampled countries. Regarding ICT indicators, mobile penetration averages 90.46 subscriptions per 100 people, but with a wide range (0.02 to 420.85), implying disparities in mobile access across economies. Similarly, internet penetration varies substantially, with a mean of 42.85%, but some countries having near-total access (100%) while others remain in early adoption stages (0.04%).

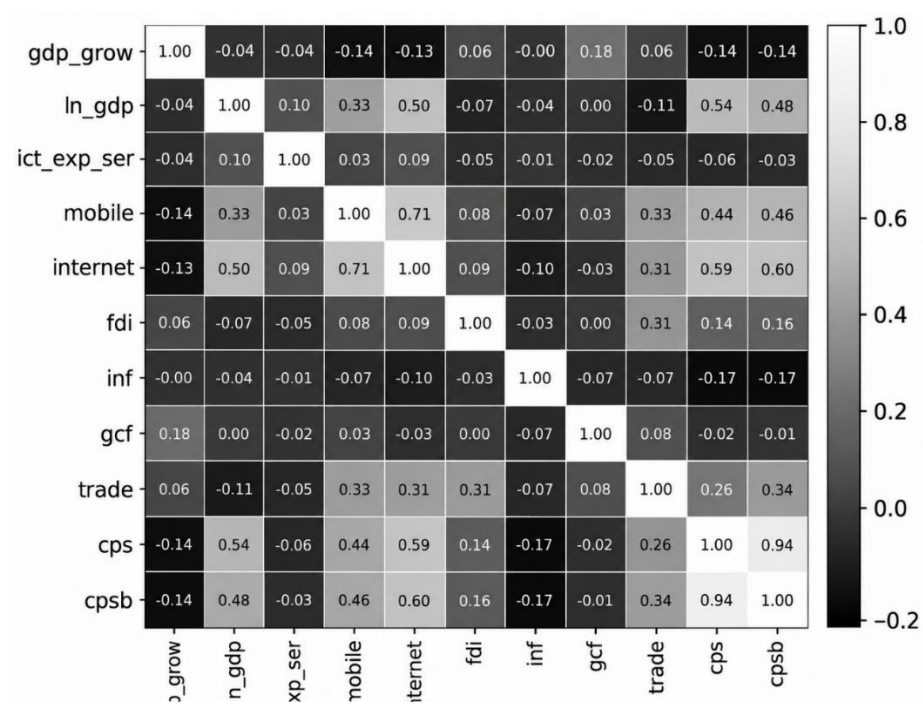
Table 2. Descriptive Analysis

Dependent Variable: gdp_growth								
Variable	N	Mean	SD	Min	25th percentile	Median	75th percentile	Max
gdp_grow	2,590	2.16	4.45	-55.23	0.38	2.21	4.33	33.77
$\ln_gdp$	2,590	24.84	2.12	19.56	23.29	24.7	26.38	30.89
ict_exp_ser	2,590	8.36	9.02	0	2.9	5.64	9.96	61.45
mobile	2,590	90.46	48.97	0.02	55.05	98.89	123.18	420.85
internet	2,590	42.85	31.63	0.04	10.87	40.8	72.2	100
fdi	2,590	6.47	24.38	-101.83	1.36	2.87	5.49	452.22
inf	2,590	5.93	16.68	-25.96	1.58	3.54	7.13	604.95
gcf	2,590	24.12	7.08	3.34	19.67	23.07	26.95	76.78
trade	2,590	89.29	57.16	15.28	54.83	76.08	105.73	442.62
cps	2,590	58.7	46.5	0	23.75	45.62	82.79	286.56
cpsb	2,590	54.72	42.51	0	22.75	44.72	73.49	286.56

Source: Author's calculations based on World Development Indicators (World Bank).

Investment and trade-related variables also exhibit noteworthy characteristics. Foreign direct investment (FDI) shows significant variation (mean = 6.47% of GDP, std = 24.38%), with values as low as -101.83%, indicating capital outflows in some economies, while others attract substantial inflows (max = 452.22%). Inflation (INF) is highly volatile, with an average of 5.93% but an extreme maximum of 604.95%, suggesting cases of hyperinflation. The gross capital formation (GCF), a measure of investment, averages 24.12% of GDP, while trade openness (TRADE) varies widely,

with some economies engaging heavily in global trade (max = 442.62%) and others maintaining more restricted trade environments. Regarding financial development, credit to the private sector (CPS) averages 58.7% of GDP, while credit by banks (CPSB) is slightly lower at 54.72%, demonstrating the critical role of financial institutions in providing funding for economic activities. These statistics highlight the diversity in macroeconomic conditions, financial development, and ICT adoption across countries, which could have significant implications for economic performance.



Source: Author's calculations based on World Development Indicators (World Bank).

Figure 1. Correlation Matrix of the Main Variables

Figure 1 presents the correlation heatmap, illustrating the relationships among key macroeconomic, financial, and ICT-related variables. The correlation matrix reveals notable patterns, with mobile and internet penetration showing a strong positive correlation (0.71) and both being moderately correlated with credit to the private sector (CPS: 0.44, 0.59) and credit by banks (CPSB: 0.46, 0.60), suggesting that ICT expansion aligns with financial deepening. However, GDP growth (gdp_grow) exhibits weak or negative correlations with most variables, notably mobile (-0.14) and internet (-0.13), implying that higher ICT penetration does not necessarily translate into immediate

economic growth. Additionally, $\ln_gdp$ (log of GDP) is positively correlated with internet (0.50) and credit indicators (CPS: 0.54, CPSB: 0.48), reflecting that larger economies tend to have more developed financial and digital infrastructures. The weak or negative relationships between inflation (inf) and credit indicators (CPS: -0.17, CPSB: -0.17) highlight the potential impact of macroeconomic instability on financial development. Overall, the heatmap suggests that ICT and financial development are interconnected, but their direct effect on economic growth remains ambiguous, warranting further empirical investigation.

4.2. Results

Table 3 presents the System GMM estimates for GDP growth as the dependent variable across six model specifications. $\ln_GDP$ has a positive and statistically significant coefficient across the specifications, with estimates ranging from approximately 0.91 to 1.15. The positive sign indicates that, conditional on the other variables included in the models, countries with higher $\ln_GDP$ tend to exhibit higher subsequent growth. This result should not be interpreted as evidence of beta-convergence because conventional convergence would generally require a negative relationship between initial income and subsequent growth. Instead, the positive coefficient is more consistent with persistence or divergence in economic performance within the sample. The lagged GDP growth variable is also positive and significant in most models, indicating a degree of persistence in economic performance over time. Among the financial indicators, credit to the private sector (CPS) and credit to the private sector by banks (CPSB) both exhibit negative and highly significant coefficients (at the 1% level).

Credit to the private sector and credit provided by banks are negatively and significantly associated with GDP growth across the corresponding specifications. These results are consistent with arguments in the ‘too much finance’ literature that greater financial deepening may not always correspond to stronger growth, particularly when credit allocation is inefficient. However, the estimates do not by themselves establish that the observed credit levels are excessive or identify the specific mechanism underlying the negative relationship. This finding aligns with previous studies indicating that excessive credit, particularly if misallocated, can lead to financial instability and weaker long-term growth.

In terms of ICT-related variables, the results reveal a negative and significant relationship between internet penetration and GDP growth (-0.036 to -0.037, at the 1% level). Internet penetration, mobile subscriptions, and ICT exports generally exhibit negative estimated associations with GDP growth. These results indicate that higher levels of the ICT indicators are not systematically associated with stronger contemporaneous growth in the sample, conditional on the included covariates and System GMM identifying assumptions. They should not be interpreted as evidence that ICT adoption itself causes lower economic growth.

Table 3. System GMM Estimates, Two-step Results with GDP Growth as Dependent Variable

Dependent Variable: gdp_growth Variables	(1)	(2)	(3)	(4)	(5)	(6)
Lag GDP growth	0.1068* [1.80]	0.1109* [1.76]	0.1359** [2.08]	0.1130* [1.90]	0.1184* [1.91]	0.1340** [2.09]
ln_GDP	1.1316*** [4.00]	1.1463*** [2.69]	0.9077** [2.47]	0.9857*** [3.84]	1.0983*** [2.90]	1.0688*** [3.36]
Credit to private sector (CPS)	-0.0328*** [-3.89]	-0.0391*** [-3.06]	-0.0410*** [-3.21]			
Credit to private sector by bank (CPSB)				-0.0307*** [-3.51]	-0.0397*** [-3.12]	-0.0472*** [-3.71]
Internet	-0.0375*** [-4.92]			-0.0362*** [-4.63]		
Mobile		-0.0210*** [-4.78]			-0.0211*** [-5.18]	
ICT export			-0.0368** [-2.07]			-0.0319* [-1.95]
Foreign direct investment	0.0146*** [3.10]	0.0142*** [2.75]	0.0157*** [2.58]	0.0138*** [3.04]	0.0145** [2.61]	0.0151*** [2.77]
Inflation	-0.0124*** [-1.82]	-0.0118*** [-2.66]	-0.0119*** [-2.60]	-0.0108** [-2.52]	-0.0108** [-2.50]	-0.0115** [-2.43]
Gross capital formation	0.0731** [1.98]	0.0874*** [3.03]	0.0704** [2.41]	0.0795** [2.29]	0.0860*** [3.10]	0.0763** [2.40]
Trade openness	0.0187*** [3.53]	0.0193*** [2.83]	0.0140*** [2.85]	0.0186*** [3.62]	0.0208*** [3.40]	0.0171*** [3.05]
Constant	-26.013*** [-4.00]	-26.158*** [-2.66]	-21.003*** [-2.48]	-22.863*** [-3.86]	-25.168*** [-2.86]	-25.330*** [-3.43]
Wald test (chi)	[196.70]	[202.39]	[195.39]	[189.21]	[217.00]	[149.86]
Prob > chi2	0.000	0.000	0.000	0.000	0.000	0.000
AR1 test (chi)	[-3.53]	[-3.58]	[-3.54]	[-3.51]	[-3.62]	[-3.57]
Prob > chi2	0.000	0.000	0.000	0.000	0.000	0.000
AR2 test (chi)	[-0.16]	[0.01]	[0.08]	[-0.08]	[0.07]	[0.02]
Prob > chi2	0.874	0.990	0.940	0.938	0.943	0.986
Hansen test	[136.61]	[133.00]	[126.04]	[136.87]	[134.24]	[129.92]
Prob > chi2	0.129	0.180	0.208	0.126	0.177	0.118
No. instruments	128	128	123	128	129	121
No. groups	144	144	144	144	144	144
No. Observation	2443	2443	2443	2243	2443	2443

Notes: The standard errors are given in parentheses. One, two, and three stars denote significance at the 10%, 5%, and 1% levels, respectively.

Source: Author's calculations based on World Development Indicators (World Bank).

Among the macroeconomic control variables, foreign direct investment (FDI) consistently shows a positive and significant effect on GDP growth (0.0138 to 0.0157, at the 1% or 5% level), reinforcing the role of FDI in fostering capital accumulation and productivity gains. Meanwhile, inflation has a negative and significant effect at the 1% and 5% levels, supporting the conventional view that macroeconomic instability and rising inflation rates can slow economic growth. Additionally, gross capital formation (GCF) and trade openness are both positive and statistically significant, emphasizing the importance of investment and global trade in economic performance.

The specification diagnostics are broadly consistent with the identifying conditions required for the System GMM estimator. The Arellano–Bond AR(1) test is significant across all specifications, as expected for first-differenced residuals, whereas the AR(2) test is insignificant, providing no evidence of second-order serial correlation. The Hansen test of overidentifying restrictions also fails to reject the null across the specifications, with p-values ranging from 0.118 to 0.208. Together with instrument counts below the number of country groups, these results provide support for, although they do not establish conclusively, the validity of the chosen instrument sets and model specification.

Table 4 presents the System GMM two-step estimates the similar models but incorporating interaction terms between ICT indicators (internet, mobile, ICT exports) and credit availability (CPS and CPSB). The results reveal a strong persistence in economic growth, as the lagged GDP growth variable is positive and significant across most models (0.0839 to 0.1288). $\ln_GDP$ remains positively associated with economic growth across all specifications. As in the baseline models, this positive coefficient does not provide evidence of beta-convergence; rather, it indicates persistence in cross-country growth differences conditional on the variables included in the model. In line with previous findings, credit to the private sector (CPS) and credit by banks (CPSB) exhibit negative and highly significant coefficients, indicating that excessive credit expansion may slow economic growth, likely due to financial inefficiencies or misallocated lending.

The interaction coefficients between ICT indicators and credit availability are predominantly negative and statistically significant. Within the estimated specifications, this indicates that the association between ICT adoption and economic growth becomes less favorable as credit availability increases, and equivalently that the relationship between credit and growth varies with the level of ICT adoption. This pattern is consistent with the possibility that digitalization does not automatically improve the growth contribution of financial deepening. Nevertheless, the interaction coefficients do not directly identify mechanisms such as inefficient credit allocation, over-indebtedness, or financial instability; these mechanisms should therefore be regarded as possible interpretations rather than empirically established channels.

Table 4. System GMM Estimates, Two-step Results with GDP Growth as Dependent Variable, Interaction with Credit Availability

Dependent Variable: gdp growth						
Variables	(1)	(2)	(3)	(4)	(5)	(6)
Lag GDP growth	0.1107*	0.1167**	0.1038*	0.1222**	0.0839	0.1288**
ln GDP	[1.92] 1.800***	[2.05] 0.8638***	[1.64] 1.2951***	[2.00] .8473**	[1.24] 1.6344***	[2.15] 0.9161***
Credit to private sector (CPS)	[3.96] -0.0298***	[3.78] -0.0298***	[2.93] -0.0439***	[2.32] -0.0345***	[4.23] -0.0421***	[2.93] -0.0391***
Internet	[-3.89]	[-3.89]	[-3.19]	[-2.68]	[-3.45]	[-2.67]
Internet * CPS	-0.0230***	-0.0217***				
Internet * CPSB	[2.93] -0.0117***	[2.85] -0.0116***				
Internet * CPSB	[-2.88]	[-2.84]				
Mobile						
Mobile * CPS			-0.0217***	-0.0184***		
Mobile * CPSB			[-4.96] -0.0406*	[-4.23]		
Mobile * CPSB			[-1.85]			
ICT export						
ICT export * CPS				-0.0837***		
ICT export * CPSB				[-2.73]		
ICT export * CPSB					-0.0362 [-1.64] -0.0502***	-0.0276* [-1.68]
Foreign direct investment						
Foreign direct investment	0.0134***	0.0127***	0.0148***	0.0113**	0.0162***	-0.0133**
Inflation	[3.23] -0.0115***	[3.30] -0.0099***	[2.61] -0.0133***	[2.45] -0.0102**	[3.03] -0.0330	[-2.13] 0.0129** [2.44]
Gross capital formation	[-2.82] 0.0801**	[-2.33] 0.0841***	[-2.64] 0.0862***	[-2.10] 0.0821***	[-1.00] 0.0558	[-0.93] 0.0747**
Trade openness	[2.38] 0.0184***	[2.66] 0.0185***	[2.81] 0.0209***	[2.69] 0.0177***	[1.49] 0.0251***	[2.36] 0.0181***
Constant	[3.59] -22.603***	[3.61] -19.648***	[2.89] -29.255***	[2.61] -18.401**	[3.17] -37.184***	[3.02] -20.536***
Wald test	[-3.91] [215.57]	[-3.70] [219.15]	[-2.92] [184.73]	[-2.24] [197.45]	[-4.34] [135.27]	[-2.92] [206.01]
Prob > chi2	0.000	0.000	0.000	0.000	0.000	0.000
AR1 test (chi)	[-3.57]	[-3.56]	[-3.59]	[-3.57]	[-3.55]	[-3.66]
Prob > chi2	0.000	0.000	0.000	0.000	0.000	0.000
AR2 test (chi)	[-0.01]	[0.06]	[-0.10]	[0.07]	[-0.48]	[0.13]
Prob > chi2	0.995	0.951	0.918	0.944	0.634	0.900
Hansen test	[135.37]	[135.13]	[132.85]	[130.82]	[130.94]	[130.19]
Prob > chi2	0.145	0.148	0.182	0.198	0.095	0.209
No. instruments	129	129	129	128	121	128
No. groups	144	144	144	144	144	144
No. Observation	2443	2443	2443	2443	2443	2443

Notes: The standard errors are given in parentheses. One, two, and three stars denote significance at the 10%, 5%, and 1% levels, respectively.

Source: Author's calculations based on World Development Indicators (World Bank).

Macroeconomic control variables confirm expected relationships, with foreign direct investment (FDI) showing a consistently positive effect on GDP growth (0.0113 to 0.0162, at the 1% or 5% level), highlighting its role in capital accumulation. Inflation is negative and significant in most cases, though its effect weakens in models (5) and (6). Additionally, gross capital formation (GCF) and trade openness remain positive and statistically significant, emphasizing their importance in promoting economic growth. The diagnostic tests are broadly supportive of the System GMM specifications. AR(2) tests fail to reject the null of no second-order serial correlation, while Hansen test p-values range from 0.095 to 0.209. Instrument counts range from 121 to 129 and remain below the 144 country groups. These diagnostics support the identifying assumptions used in interpreting the estimates, although they should not be viewed as definitive proof of instrument validity.

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

This study examines the relationships among ICT adoption, credit availability, and economic growth using a dynamic cross-country panel estimated with System GMM. The results show that the ICT indicators and the two measures of private-sector credit are generally negatively associated with GDP growth within the estimated specifications. The interactions between ICT indicators and credit availability are also predominantly negative, indicating that greater ICT penetration does not necessarily strengthen the association between financial deepening and economic growth. These findings are consistent with the view that the economic benefits associated with digitalization and financial development depend on complementary institutional, regulatory, and macroeconomic conditions.

The main conclusion of this study is that ICT adoption, credit expansion, and their interaction exhibit negative conditional associations with economic growth in the estimated models, suggesting that financial deepening through digitalization does not always translate into economic benefits. This finding aligns with Arcand et al. (2015) and Cecchetti and Kharroubi (2012), who argue that excessive financial expansion can slow economic growth due to inefficiencies in credit allocation. The negative relationship between ICT and GDP growth is also consistent with Vasishta and Singla (2024), who finds that ICT-driven financial inclusion may lead to over-indebtedness and regulatory challenges, particularly in emerging economies. Similarly, Mhlanga (2024) support the notion that digital lending platforms, while expanding financial access, can contribute to unsustainable credit growth and economic instability.

Furthermore, the negative interaction between ICT and credit suggests that the

combined effect of digitalization and financial expansion can amplify financial risks rather than foster economic growth, which contrasts with the expectation that ICT enhances financial efficiency. This result is consistent with Sassi and Goaied (2013) and Jagtiani and Lemieux (2017), who found that ICT-driven banking transformations do not always lead to higher economic performance, particularly when institutional quality is weak. The study's findings also contrast with Levine (1997) and Romer (1990), who emphasize the positive role of financial development and technological progress in economic growth, indicating that these benefits may not be automatic but instead depend on complementary economic and regulatory conditions.

The study's results also contribute to theoretical discussions on ICT, financial development, and economic growth. Traditional endogenous growth models and financial development theories suggest that technological progress and financial deepening should contribute positively to long-term economic growth (Levine, 1997; Romer, 1990). However, the negative coefficients observed in this study align more closely with the Too Much Finance Hypothesis (Arcand et al., 2015) and the Financial Instability Hypothesis (Minsky, 1992), which argue that excessive financial sector growth can undermine economic stability. Additionally, the results support the Transaction Cost Theory (Williamson, 1979), which posits that while ICT reduces transaction costs, its benefits are contingent on how efficiently digital financial services are utilized. The negative ICT coefficients suggest that technological progress alone is insufficient and requires complementary regulatory and economic structures to generate sustainable growth.

This research provides several key contributions to the literature on ICT, banking efficiency, and financial development. First, it expands the empirical understanding of ICT's role in economic growth by integrating its interaction with credit availability, revealing that ICT adoption, coupled with credit expansion, may lead to financial inefficiencies rather than growth enhancement. Second, it contributes to policy discussions on financial stability, emphasizing that merely increasing financial access through digital banking or credit expansion does not automatically lead to better economic outcomes. Third, by employing System GMM estimation, this study accounts for dynamic persistence and several potential sources of endogeneity, subject to the validity of the internal instruments and the associated specification assumptions. Lastly, the study highlights the importance of institutional quality, regulatory frameworks, and financial governance in ensuring that ICT-driven banking transformations yield positive economic outcomes rather than amplifying financial instability.

5.2. Recommendation

The findings of this study suggest that ICT adoption and financial expansion must be accompanied by strong regulatory frameworks and institutional support to ensure positive economic outcomes. Policymakers should focus on enhancing financial governance to prevent the negative effects of excessive credit growth, particularly in

digital lending and fintech services. Implementing strict credit risk assessments, improving financial literacy, and strengthening banking regulations can help mitigate the risks associated with rapid ICT-driven financial deepening. Given the observed negative interaction between ICT and credit availability, governments and financial institutions should ensure that digital financial services promote responsible lending practices. This includes enhanced oversight of digital credit platforms, improved transparency in financial transactions, and the establishment of consumer protection mechanisms to prevent over-indebtedness. Additionally, financial regulators should consider adopting macroprudential policies that balance credit growth with economic stability, ensuring that financial development does not lead to systemic risks.

Moreover, infrastructure development and institutional capacity-building should be prioritized to maximize the benefits of ICT adoption. Expanding broadband access, cybersecurity measures, and digital payment systems in a well-regulated environment will help create an ecosystem where ICT supports sustainable economic growth. Governments should also collaborate with the private sector to promote inclusive digital financial services, ensuring that technological advancements benefit all segments of the economy rather than contributing to financial inequality. Finally, given the mixed effects of trade openness and foreign direct investment, policymakers should design strategies that leverage digital technologies to enhance global economic integration. Encouraging responsible investment in ICT-driven industries, fostering innovation-friendly policies, and ensuring that digital transformation aligns with economic development goals will help countries harness the full potential of financial and technological advancements while minimizing associated risks.

5.3. Limitations and Further Research

While this study provides valuable insights into the relationship between ICT adoption, financial development, and economic growth, it has several limitations. First, the analysis is constrained by data availability, particularly in measuring the quality and efficiency of ICT-driven financial services across different countries. The study primarily relies on aggregate ICT and credit indicators, which may not fully capture the heterogeneity in digital financial infrastructure, financial inclusion, and institutional quality. Additionally, the System GMM approach mitigates several sources of endogeneity but relies on the validity of its internal instruments and serial-correlation assumptions. Although the reported AR(2) and Hansen tests are broadly supportive of these conditions and the instrument count remains below the number of country groups, the estimates should still be interpreted conditionally rather than as definitive causal effects. Lastly, the study does not account for potential nonlinear relationships or threshold effects, where the impact of ICT and financial development may vary depending on a country's level of economic maturity, regulatory framework, or digital infrastructure quality.

Future research should explore nonlinear and threshold effects to determine whether

there is an optimal level of ICT penetration and financial deepening that maximizes economic growth. Additionally, a more granular approach, incorporating firm-level or industry-specific data, could provide deeper insights into how ICT adoption and financial development affect different sectors of the economy. Further studies should also consider the role of financial regulation, institutional quality, and macroeconomic stability as mediating factors in the ICT-finance-growth nexus. Moreover, analyzing the long-term effects of digital transformation on financial stability, inequality, and labor markets could offer a more comprehensive understanding of the broader economic implications of ICT-driven financial expansion. Lastly, comparative studies between developed and developing economies could help policymakers design targeted strategies that ensure digital financial innovation contribute positively to sustainable economic development.

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