

ICT, HIGH-TECH EXPORTS, AND INSTITUTIONS AS DRIVERS OF BANK EXPANSION GROWTH IN A DUAL BANKING SYSTEM

Sulaeman Sulaeman¹, Arizal Tom Liwafa² and Bayu Arie Fianto^{1*}

¹Department of Islamic Economics, Faculty of Economics and Business, Universitas Airlangga, Indonesia; ²Postgraduate School, Universitas Airlangga, Indonesia

ABSTRACT

This study examines how information and communication technology (ICT) adoption, high-tech exports (HTE), and institutional quality (IQ) influence bank-level expansion growth (BEG) in 218 Islamic and conventional banks operating in 12 countries from 2010 to 2023. Using bank-level panel data analysis, the results reveal that ICT adoption is the most powerful driver of bank expansion growth, reinforcing digital transformation as a universal catalyst for efficiency, competitiveness, and outreach. While HTE alone has a limited and statistically insignificant effect, its interaction with ICT generates a significant synergistic impact, indicating that national innovation capacity amplifies the growth benefits of digitalization. Institutional quality exhibits a positive but indirect role, functioning primarily as an enabling condition that supports bank expansion—particularly for Islamic banks—through stronger governance and regulatory credibility. Comparative findings show that Islamic banks rely more on institutional integrity and technological complementarity, whereas conventional banks depend more on operational efficiency and digital maturity. Robustness checks using dynamic panel estimators confirm the consistency of these relationships. Policy implications highlight the importance of strengthening digital infrastructure, promoting high-tech innovation, and improving institutional governance to foster sustainable and inclusive bank expansion within a dual banking framework.

Keywords: Bank expansion growth, ICT adoption, High-tech exports, Institutional quality, Dual banking system.

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* **CONTACT** Bayu Arie Fianto: bayu.fianto@feb.unair.ac.id; Faculty of Economics and Business, Universitas Airlangga, Dharmawangsa Campus, Airlangga Street No. 4-6, Surabaya 60286, East Java, Indonesia.

I. INTRODUCTION

Global Islamic finance has experienced remarkable growth in recent years. According to the *Islamic Finance Development Report* (LSEG, 2023), total Islamic finance assets are projected to reach USD 6.67 trillion by 2027, with Islamic banking contributing more than 70% of the total—surpassing Sukuk (19%), Islamic funds (5%), and Takaful (2%). Islamic banking assets alone amounted to USD 3.2 trillion in 2022 and are expected to rise to USD 4.6 trillion by 2025 (Puri-Mirza, 2024). Despite this impressive trajectory, the pace and sustainability of bank expansion vary considerably not only across countries, but also across individual banks operating within the same national and regulatory environments. This disparity raises a key question: *what drives bank-level expansion growth within dual banking systems where Islamic and conventional banks coexist and compete?*

Understanding these drivers is vital for ensuring both the growth of banking and the stability of the wider financial ecosystem. In dual banking systems, Islamic and conventional banks operate under the same macroeconomic and institutional environments but face distinct strategic and regulatory challenges. Conventional banks benefit from mature digital infrastructures and established market networks, while Islamic banks must balance innovation and *Shari'ah*-compliance. These differences suggest that expansion dynamics are likely to materialize at the bank level, reflecting heterogeneity in technological adoption, strategic capabilities, and institutional responsiveness. Within this landscape, three interrelated factors—information and communication technology (ICT) adoption, high-technology exports (HTE), and institutional quality (IQ)—emerge as critical determinants of banking expansion and resilience.

ICT adoption reshapes financial intermediation by improving efficiency, transparency, and inclusion (Chong, 2021; Kochanova et al., 2020; Su et al., 2020). Digital transformation allows banks to optimize operations, reduce costs, and reach underserved populations (Tlemsani et al., 2025). Similarly, high-technology exports (HTE) capture a nation's innovation intensity and technological capability, which can generate positive spillovers into the financial sector through fintech development, product innovation, and improved risk management (Kowalewski et al., 2022; Wang et al., 2021). At the bank level, these spillovers are expected to materialize unevenly, depending on banks' internal digital readiness and absorptive capacity. Moreover, these benefits are conditional on the strength of institutional quality (IQ)—including governance effectiveness, legal enforcement, and regulatory integrity (Robinson & Acemoglu, 2012). Effective institutions foster investor confidence, protect intellectual property, and provide a stable environment for both Islamic and conventional financial operations (Moe, 2005).

The interaction among these factors is complex. While technology and innovation are recognized as engines of growth, their outcomes depend on institutional contexts. In countries with strong governance, digitalization and high-tech capabilities often amplify banking efficiency and inclusiveness. Conversely, in weak institutional environments, rapid digital expansion may generate new vulnerabilities—cybersecurity risks, unequal technological access, and regulatory loopholes—that are especially challenging for Islamic banks in their commitment to ethical and *Shari'ah*-compliant practices. These dynamics suggest that technology may operate simultaneously as a driver and a constraint on bank-level expansion within dual banking systems.

Empirical findings on these relationships remain inconclusive. Several studies show that ICT and innovation enhance banking performance and financial stability (Agyapong et al., 2025; Ahinful et al., 2024; Daud et al., 2022). Others argue that excessive or misaligned technological adoption yields limited benefits or even adverse effects in weak institutional environments (Canh et al., 2021; Jeris et al., 2024). Moreover, technological advancement in the broader economy does not always translate into proportional financial sector growth, particularly when measured at the individual bank level, suggesting that institutional strength and digital readiness jointly determine how technology impacts banking expansion. These inconsistencies highlight the need to explore whether ICT, HTE, and IQ operate as complementary or substitutive forces in shaping financial development.

Motivated by these gaps, this study investigates how ICT adoption, high-tech exports, and institutional quality collectively influence bank-level expansion growth (BEG) under dual banking systems. While previous works, such as Cham (2018) and Imam & Kpodar (2013, 2016), examine Islamic banking expansion, they predominantly rely on country-level indicators and do not explicitly account for heterogeneity across banks, nor do they integrate technological and institutional dimensions within a unified analytical framework. This study advances the literature by developing and empirically testing an integrated model that links digital innovation, technological capability, and institutional governance as joint determinants of sustainable and inclusive bank-level growth.

Using panel data from twelve Muslim-majority countries between 2010 and 2023, the study employs fixed-effects and System GMM estimations to examine both direct and interaction effects of ICT adoption, HTE, and IQ on bank expansion. Theoretically, this research contributes to the integration of Innovation Diffusion Theory, the Resource-Based View (RBV), and Institutional Theory, proposing that banking expansion in dual systems emerges from the interplay between digital capabilities, innovation synergies, and institutional integrity at the bank level. Practically, the findings are expected to guide policymakers and financial regulators in designing strategies that enhance digital infrastructure, stimulate high-tech innovation, and strengthen governance frameworks to promote inclusive and resilient banking growth—especially within Islamic finance ecosystems.

II. LITERATURE REVIEW

2.1. Theoretical Foundation

This study examines how the adoption of information and communication technology (ICT), high-tech exports (HTE), and institutional quality (IQ) drive bank-level expansion growth (BEG) in a dual banking system encompassing Islamic and conventional banks from 2010 to 2023. Three main complementary theories, namely Innovation Diffusion Theory (IDT), Resource-Based View (RBV), and Institutional Theory (IT), explain how technological progress, innovation capacity, and governance quality collectively shape heterogeneous expansion outcomes across individual banks operating within the same national context. According to IDT (see Rogers, 2003), CT diffusion depends on relative advantage, compatibility, and institutional readiness. In the banking context, ICT adoption increases efficiency, inclusiveness, and market penetration. At the

bank level, diffusion outcomes vary depending on managerial capability, digital infrastructure, and organizational readiness. In a dual system, Islamic banks face distinct diffusion challenges related to Sharia compliance and trust, making digital adoption not only a technological shift but also an institutional adaptation. The differences in digital transformation between Islamic and conventional banks thus reflect varying levels of bank-specific technological capability and institutional alignment.

According to the RBV (see Barney, 1986), ICT and HTE are strategic resources that together generate sustainable competitive advantage. ICT enhances service delivery and financial innovation, while HTE reflects national technological capacity and the innovation ecosystem. However, national innovation capacity does not automatically translate into bank expansion; its effect depends on banks' absorptive capacity to internalize and deploy external technological resources. The interaction of the two creates knowledge spillovers that strengthen banks' innovation and expansion potential. For Islamic banks, aligning ICT with ethical and Sharia-based principles enhances differentiation and customer trust. Finally, the Institutional Theory (see Meyer & Row (1977) states that institutional quality—through effective governance, regulatory stability, and the rule of law—provides a conducive environment for technological innovation and financial development. While institutional quality is commonly measured at the country level, its influence materializes through bank-level behavior, compliance capacity, and strategic responses to regulation. In a dual banking system, strong institutions ensure fair competition and determine how Islamic and conventional banks leverage digitalization for sustainable growth. Thus, collectively, these perspectives form an integrated framework: ICT represents bank-level technological innovation, HTE captures macro-level innovation capacity, and IQ defines the institutional conditions under which bank-level expansion occurs.

2.2. Relevant Empirical Review and Hypotheses Development

Technological innovation is a key factor in the transformation of the banking sector, particularly in developing countries. Various studies confirm that digitalization, high-tech capabilities, and institutional quality shape banking performance, efficiency, and stability. However, much of the existing empirical literature relies on country-level indicators of banking development, while fewer studies examine how these factors translate into heterogeneous expansion outcomes across individual banks. Nevertheless, the literature shows that bank growth and expansion are influenced by institutional, social, and technological contexts.

Several studies support this argument. Lone & Ahmad (2017) show that Islamic banks maintain the stability of customer investment values, while Lone & Rehman (2017) find that high service quality strengthens the image and expands the customer base of Islamic banks. Rashid & Jabeen (2016) emphasize the importance of operational efficiency and market concentration in driving expansion, while Ramlan & Adnan (2016) find that Islamic banks in Malaysia are more profitable and have higher financing ratios than conventional banks. Chowdhury et al. (2017) highlight the role of internal efficiency and macroeconomic stability in the profitability of Islamic banks in the GCC. Globally, Imam & Kpodar (2013)

demonstrate that the expansion of Islamic banking is influenced by per capita income levels, the proportion of the Muslim population, and economic integration, emphasizing that social and institutional factors remain crucial elements in the growth of the dual banking industry. These studies, however, primarily assess expansion at the aggregate or country level, leaving bank-level dynamics relatively underexplored.

In the technological context, Wang et al. (2021) find that bank financing and institutional quality drive technological innovation in BRICS countries, which boosts GDP growth and high-tech exports (HTE). Similarly, Kowalewski et al. (2022) highlight the role of digitalization and national culture in accelerating the development of fintech and big-tech lending. Empirical evidence suggests that HTE reflects a country's innovation capacity and technological capabilities, which can be transmitted to the financial sector through product innovation, digital infrastructure, and risk management systems. Wang et al. (2021) also, assert that HTE positively contributes to innovation through spillover mechanisms and the diffusion of foreign technology, which strengthens domestic innovation capabilities and boosts productivity.

Thus, HTE serves not only as a trade indicator but also as a proxy for technological capability and global economic integration. From a bank-level perspective, HTE functions as a contextual enabler whose impact on expansion depends on banks' ability to absorb and utilize external technological spillovers. In the banking context, high-tech exports (HTE) act as a macro enabler that strengthens the positive impact of ICT adoption on banking expansion. When digital infrastructure is established, high-tech intensity accelerates the diffusion of financial innovations such as fintech, digital payments, and online Islamic banking services. The interaction between ICT and HTE creates a strategic synergy that drives technology adoption, market expansion, and financial inclusion—key factors for the growth of both conventional and Islamic banking. Consistent with the findings of Agyapong et al. (2025) and Khan et al. (2024), innovation supported by a strong institutional framework has been shown to accelerate financial market expansion. Therefore, this study proposes the following hypotheses:

H1: ICT adoption positively impacts bank-level expansion growth in a dual banking system.

H2: High-tech exports (HTE) positively impact bank-level expansion growth in a dual banking system.

H3: The interaction between ICT and HTE positively impacts bank-level expansion growth in a dual banking system.

Institutional quality (IQ) plays a pivotal role in shaping financial development and banking expansion. Setianto et al. (2025) demonstrate that financial inclusion enhances bank stability only when institutional quality surpasses a certain threshold, highlighting the governance–stability nexus. Similarly, Canh et al (2021) show that robust institutional frameworks mitigate banking and credit risks, particularly in highly concentrated financial systems. Ali et al. (2019) further reveal that lower levels of corruption strengthen bank stability, while Moudud-Ul-Huq & Akter (2024) find that IQ reduces banks' risk-taking behavior under policy uncertainty. Although Imam & Kpodar (2013) report that IQ has an insignificant influence on Islamic bank expansion during 1992–2006, more

recent evidence indicates that improvements in governance, regulatory quality, and political stability significantly enhance Islamic banks' operational efficiency, market access, and investor confidence. Marquis & Huang (2009) emphasize that the impact of institutional quality is contingent on the broader environmental and structural context in which financial institutions operate. These findings suggest that while IQ is measured at the macro level, its effects are ultimately realized through bank-level governance, compliance, and strategic decision-making. Accordingly, in a dual banking system such as that of many Muslim-majority countries, stronger institutional settings are expected to foster more sustainable Islamic banking expansion. Based on these arguments, this study proposes the following hypotheses:

H4: Institutional quality (IQ) positively impacts bank-level expansion growth in a dual banking system.

III. METHODOLOGY

3.1. Sample and Data

The relationship between information and communication technology (ICT) adoption, high-tech exports (HTE), institutional quality (IQ), and Islamic banking expansion is examined using bank-level panel data covering 218 Islamic and conventional banks over the period 2010–2023 across twelve countries, yielding 3,052 bank-year observations. The countries included in the sample are Bahrain, Bangladesh, Egypt, Indonesia, Jordan, Kuwait, Malaysia, Pakistan, Oman, Qatar, Saudi Arabia, and the United Arab Emirates. The dependent variable, *Islamic banking expansion*, is constructed at the bank level and measured as the ratio of total assets of bank i to the gross domestic product (GDP) of the country in which the bank operates. GDP is employed as a scaling factor to capture the extent to which an individual bank expands relative to the size of its host economy, thereby allowing for meaningful comparisons across countries with different economic scales.

The twelve countries are selected based on two main considerations: (i) a high proportion of Islamic banking assets, and (ii) a predominantly Muslim population, which together reflect the characteristics of a dual banking system in which Islamic and conventional banks coexist. Although 57 member countries of the Organization of Islamic Cooperation (OIC) have Muslim-majority populations and developing Islamic banking sectors, data limitations necessitate restricting the sample to twelve countries. These countries exhibit substantial heterogeneity in terms of banking size and growth dynamics. For example, Saudi Arabia holds the largest Islamic banking assets (USD 200,477 million), while Oman recorded the highest asset growth rate at 28%, illustrating diverse economic and institutional environments within the Islamic world (OIC Statistics Database, 2025). This heterogeneity further motivates the adoption of a bank-level approach, which enables the analysis to capture cross-bank variation within the same country—an aspect that cannot be observed using country-level aggregates commonly employed in the existing literature.

All bank-level financial data are obtained from the Bloomberg database, while country-level macroeconomic and institutional variables are sourced from the

World Development Indicators (WDI, 2025) and the World Governance Indicators (WGI, 2025).

3.2. Variables

Dependent Variable: Bank expansion growth (BEG) is measured at the *bank level* as the ratio of total assets of bank *i* to the gross domestic product (GDP) of the country in which the bank operates. This measure captures the extent of individual bank expansion relative to the size of the host economy, while controlling for differences in economic scale across countries. GDP is employed as a country-level scaling factor to normalize bank size and facilitate cross-country comparability. This indicator reflects the ability of banks to mobilize financial resources relative to overall economic activity, thereby serving as a reliable proxy for banking system depth and outreach. Similar asset-to-GDP measures have been adopted in previous studies, such as Avdukic & Asutay (2025) and Gheeraert & Weill (2015), which link banking assets to macroeconomic performance as an indicator of financial development. Likewise, Naceur et al. (2015) employ bank asset size to examine the relationship between Islamic banking and financial inclusion, underscoring the relevance of asset-based measures for assessing bank expansion and market penetration. While prior studies predominantly adopt a country-level perspective, the bank-level specification in this study allows for capturing heterogeneity across banks within the same country.

Main independent variables: The main independent variables in this study include ICT adoption, High-Tech Exports (HTE), and Institutional Quality (IQ), all of which are measured at the *country level* and matched to individual banks based on their country of operation and year. The first independent variable, ICT adoption, represents a country's level of technology diffusion and digital capacity. Following Hasan et al. (2025) and Mahran (2023), the ICT index is constructed using Principal Component Analysis (PCA) based on four indicators: mobile telephone subscriptions (MPS), fixed broadband subscriptions (FBS), fixed telephone subscriptions (FTS), and secure internet servers (SIS). Table 1 reports the PCA results, indicating a KMO value of 0.812, which suggests excellent sampling adequacy. Two principal components with eigenvalues above one explain 92.85% of the total variance, confirming strong intercorrelations and structural consistency among the digital indicators.

The second independent variable, HTE, captures a country's technological advancement and innovation capacity and is measured as the share of high-technology exports in total manufacturing exports, normalized by GDP at the country level. Previous studies, including Canh et al. (2021) and Jeris et al. (2024), emphasize its positive role in financial and banking development. The third independent variable, IQ, measures institutional and governance quality at the country level. It is constructed using PCA based on six governance indicators: control of corruption (CC), government effectiveness (GE), political stability (PS), regulatory quality (RQ), rule of law (RL), and voice and accountability (VA). Table 1 presents the PCA results, with a KMO value of 0.794 and two components explaining 73.8% of the total variance, indicating a reliable and valid construct for measuring institutional strength and governance quality.

Table 1.
Eigenvalue and KMO Results

Component	Eigenvalue	Difference	Proportion	Cumulative	KMO
ICT Adoption					0.812
FBS	2.607	1.501	0.652	0.652	
FTS	1.107	0.887	0.277	0.929	
MPS	0.219	0.153	0.055	0.983	
SIS	0.067	0.000	0.017	1.000	
Institutional Quality (IQ)					0.794
CC	2.599	0.769	0.433	0.433	
GE	1.830	0.878	0.305	0.738	
PS	0.952	0.514	0.159	0.897	
RQ	0.438	0.283	0.073	0.970	
RL	0.155	0.127	0.026	0.995	
VA	0.028	0.000	0.005	1.000	

Source(s): Data processing by the authors (2025)

Control variables: Several control variables are included to account for bank-specific and macroeconomic characteristics. Bank-specific variables—Return on Assets (ROA) and Return on Equity (ROE)—are measured at the *bank level* and capture profitability and managerial efficiency. These variables are obtained from the Bloomberg database. Macroeconomic control variables include GDP per capita (GDPC), real interest rate (RIR), and inflation rate (INF), all measured at the country level and matched to banks accordingly. These controls follow Kowalewski et al. (2022) and Khan et al. (2024), who argue that both profitability and macroeconomic stability play significant roles in shaping bank expansion and competitiveness. All variables, except those expressed in percentages, are transformed into natural logarithms prior to estimation, as summarized in Table 2

Table 2.
Variables and Data Sources

Variables	Definition	Exp.Sign	Sources
Dependent variables (Bank-level)			
BEG	Bank expansion growth measured as total assets of bank i to the GDP of the sample country (%).	n/a	Bloomberg databases
Main independent variables (Country-level)			
ICT	The ICT adoption index is constructed via PCA from MPS, FBS, FTS, and SIS indicators.	(+)	WDI
HTE	High-technology exports as R&D-intensive manufactured products normalized by GDP (%).	(+)	WDI
IQ	Institutional Quality Index (IQI) is constructed via PCA using six governance indicators (CC, GE, PS, RQ, RL, VA).	(+)	WGI

Table 2.
Variables and Data Sources (Continued)

Variables	Definition	Exp.Sign	Sources
Bank-specific variables (Bank-level)			
ROA	Return on assets, measuring profitability and efficiency in asset utilization (%).	(+)	Bloomberg databases
ROE	Return on equity, measuring profitability relative to shareholders' equity (%).	(+)	Bloomberg databases
Macroeconomic variables (Country-level)			
GDPC	Nominal GDP divided by population (GDP per capita).	(+)	WDI
RIR	Nominal interest rate adjusted for inflation (%).	(+/-)	WDI
INF	Annual change in consumer price index (%).	(+)	WDI

Source: Authors' compilation (2025)

3.4. Models and Estimation

This study formulates the relationship between information and communication technology (ICT) adoption, high-technology exports (HTE), their interaction (ICT×HTE), institutional quality (IQ), and bank expansion growth (BEG) using a bank-level panel data framework, as suggested by Gujarati & Porter (2009). The empirical specification explicitly distinguishes between bank-level and country-level variables. The baseline model is expressed as follows:

$$BEG_{i,t} = \beta_0 + \beta_1 ICT_{i,t} + \beta_2 HTE_{j,t} + \beta_3 (ICT \times HTE)_{j,t} + \beta_4 IQ_{j,t} + \beta_5 BS_{i,t} + \beta_6 MC_{j,t} + \varepsilon_{i,t} \tag{1}$$

Where $BEG_{i,t}$ denotes bank expansion growth of bank i operating in country j at time t . $ICT_{j,t}$, $HTE_{j,t}$, their interaction term, and $IQ_{j,t}$ are country-level explanatory variables measured for country j and matched to individual banks operating in the same country and year. $BS_{i,t}$ represents bank-specific control variables, while $MC_{j,t}$ denotes macroeconomic control variables at the country level. Here, i indexes banks, j indexes countries, and t denotes the period from 2010 to 2023. The error term $\varepsilon_{i,t}$ captures idiosyncratic shocks.

To address econometric challenges commonly associated with bank-level panel data—such as unobserved heterogeneity across banks, simultaneity bias, and potential endogeneity (Godos-Díez et al., 2018; Hayakawa, 2007; Roodman, 2009)—this study employs the System Generalized Method of Moments (System GMM) estimator developed by Blundell & Bond (1998). This estimator is particularly suitable for the present framework, as banks constitute the primary unit of observation, while country-level variables capture the macroeconomic and institutional environment in which banks operate. Moreover, System GMM effectively controls for endogeneity by using internal instruments derived from lagged values of the regressors.

Accordingly, the dynamic specification is expressed as:

$$BEG_{i,t} = \beta_0 + \alpha BEG_{i,t-1} + \beta_1 ICT_{j,t} + \beta_2 HTE_{j,t} + \beta_3 (ICT \times HTE)_{j,t} + \beta_4 IQ_{j,t} + \beta_5 BS_{it} + \beta_6 MC_{j,t} + \varepsilon_{i,t} \quad (2)$$

Here, $BEG_{i,t-1}$ denotes the one-period lag of bank expansion growth, capturing persistence in bank expansion behavior over time at the individual bank level. The parameters β_0 , α , and β_n represent the coefficients to be estimated.

Furthermore, to mitigate potential multicollinearity arising from the interaction term between ICT adoption and high-technology exports, the study applies a demeaning transformation at the country level, following Balli & Sørensen (2013). This procedure centers the constituent variables prior to constructing the interaction term, thereby reducing correlation between the main effects and their interaction and improving the stability and interpretability of the estimated coefficients.

IV. RESULTS AND ANALYSIS

This section presents the main findings addressing the research questions and four hypotheses concerning the effects of ICT adoption, high-technology exports (HTE), and institutional quality (IQ) on bank expansion growth within a dual banking system.

4.1. Descriptive Statistics

Table 3 presents descriptive statistics for both *bank-level* and *country-level* variables used in this study, including the mean, standard deviation (SD), minimum, and maximum values. The dataset consists of 3,052 bank-year observations, ensuring consistent coverage across banks, countries, and years. The mean value of bank expansion growth (BEG) is 10.52, with a relatively large SD of 25.23, indicating substantial variation in expansion across individual banks. ICT adoption (ICT), measured at the country level and matched to banks, has a mean value normalized around 0.00 and an SD of 0.96, reflecting disparities in digital infrastructure across countries. High-technology exports (HTE) record a mean of 1.82 with an SD of 6.12, showing heterogeneous national innovation capacity. Institutional quality (IQ) has an average score of 43.38 with an SD of 16.11, indicating cross-country differences in governance quality. Regarding bank-specific variables, the average return on assets (ROA) and return on equity (ROE) are 0.96 and 8.81, respectively, suggesting variation in profitability across banks. Macroeconomic variables, including inflation (INF), real interest rate (RIR), and GDP per capita (GDPC), exhibit substantial cross-country heterogeneity, reflecting diverse economic environments in which banks operate.

Table 3.
Descriptive Statistics

Variable	Mean	Std. Dev.	Min	Max	Obs.
[1] BEG	10.522	25.225	0.002	267.912	3052
[2] ICT	0.000	0.964	-2.020	2.140	3052
[3] HTE	1.824	6.121	0.000	33.568	3052
[4] IQ	43.377	16.111	18.727	71.513	3052
[5] ROA	0.963	2.422	-52.707	28.457	3052
[6] ROE	8.805	16.642	-209.142	146.992	3052
[7] INF	4.493	4.551	-2.540	33.885	3052
[8] RIR	3.128	6.746	-19.873	40.860	3052
[9] GDPC	8.903	1.375	6.630	11.590	3052

Source(s): Data processing by the authors (2025)

4.2. Correlation Matrics

To check for multicollinearity, a Pearson’s pairwise correlation test is conducted (Appendix A1). The results show that the correlation coefficients among independent variables are generally weak to moderate, with all values below 0.50, indicating no serious correlation issues (Gujarati, 2003; Gujarati & Porter (2009). This suggests that no pair of variables is highly correlated enough to cause estimation bias or model instability. In addition, all Variance Inflation Factor (VIF) values are below the critical threshold of 10, confirming the absence of multicollinearity and supporting the robustness and reliability of the regression estimations.

4.3. Panel Estimation Results

Table 4 presents *bank-level* panel regression results for 218 banks operating in twelve countries under dual banking systems during the period 2010–2023. The model incorporates year and country fixed effects, with robust standard errors clustered at the country level to account for within-country correlation among banks, ensuring consistent and reliable estimates. All explanatory variables at the country level (ICT, HTE, IQ, and macroeconomic controls) are matched to individual banks by country and year. The estimation results provide strong empirical support for the study’s theoretical propositions and hypotheses.

First, ICT (technology adoption) exhibits a positive and highly significant effect on bank expansion growth (BEG), confirming Hypothesis 1 (H1). This result aligns with the Diffusion of Innovation Theory, which states that technology adoption depends on an organization’s perceived relative advantage and institutional readiness. In the banking context, digital transformation—through mobile banking, online financial platforms, and fintech integration—improves operational efficiency, reduces transaction costs, and expands customer access, thereby accelerating expansion at the individual bank level. This finding reinforces previous empirical evidence (Agyapong et al., 2025; Gyau et al., 2024) showing that ICT adoption drives competitiveness, service innovation, and profitability. In a dual banking system, this digitalization process also facilitates Sharia-

compliant financial innovation, linking technological efficiency with the ethical and institutional values underlying Islamic finance.

Second, the interaction between ICT and high-technology exports (ICT $\times$ HTE) is positive and statistically significant, validating Hypothesis 3 (H3) and supporting the Resource-Based View. This indicates that bank-level expansion benefits from complementarities between digital infrastructure and national innovation capacity. In other words, economies that combine advanced ICT adoption with innovation-intensive export structures create an enabling environment that strengthens banks' growth potential. This interaction effect reflects the notion of resource complementarity, where digital readiness enhances the productive spillovers from innovation-oriented sectors. This finding is consistent with Khan et al. (2024) and Wang et al. (2021), which show that ICT diffusion and technology intensity jointly stimulate fintech ecosystems and digital financial development.

Third, high-technology exports (HTE) on their own exhibit a negative but statistically insignificant effect on BEG, providing only partial support for Hypothesis 2 (H2). This suggests that technological progress in the export sector does not automatically translate into bank expansion unless it is accompanied by sufficient digital absorptive capacity within the banking system. This pattern reflects the indirect nature of innovation spillovers, whereby technological development influences bank growth primarily through its interaction with ICT adoption and institutional conditions, rather than through an independent channel.

Fourth, institutional quality (IQ) shows a positive but statistically insignificant relationship with bank expansion growth. While not a direct determinant, this finding is consistent with the Institutional Theory, which emphasizes that governance quality, regulatory effectiveness, and institutional credibility shape trust and legitimacy in the financial system. A strong institutional framework enhances regulatory predictability and investment security, thereby serving as an enabling condition that strengthens the effectiveness of technology- and innovation-driven bank expansion within a stable and transparent governance environment.

Regarding the control variables, bank profitability (ROE) exerts a positive and statistically significant effect on BEG, confirming that more profitable banks possess stronger internal capacity for expansion. Inflation (INF) negatively affects bank expansion, reflecting the adverse impact of macroeconomic instability on credit growth and financial intermediation. The real interest rate (RIR) contributes positively to BEG, indicating that monetary stability supports lending activity, while GDP per capita (GDPC) is negatively associated with BEG, suggesting that bank expansion is more pronounced in developing economies where financial inclusion potential remains high.

In summary, the results confirm that bank-level expansion in dual banking systems is primarily driven by digital transformation and technological complementarities, while institutional quality plays a facilitating role by providing a stable governance environment. The integration of Diffusion of Innovation Theory, the Resource-Based View, and Institutional Theory highlights that bank growth emerges from the interaction between technological capability, innovation capacity, and institutional strength within an adaptive financial ecosystem.

Table 4.
Panel Data Estimation Results (Full Sample)

Variables	Dependent variable: BEG
ICT	1.198*** (0.377)
HTE	-0.079 (0.149)
ICTxHTE	0.301*** (0.102)
IQ	0.020 (0.071)
ROA	-0.057 (0.037)
ROE	0.014** (0.005)
INF	-0.098*** (0.025)
RIR	0.021** (0.008)
GDPC	-5.743*** (1.481)
Constant	61.166*** (15.41)
Year FE	Yes
Country FE	Yes
Bank Clustered	Yes
SE Clustered at country level	Yes
F-Statistics	5.41***
Adjusted R ² (within)	0.063
Observation	3,052
Number of Banks	218

Note(s): Robust standard errors are in parentheses; * p < 1%, ** p < 5%, *** p < 1%; All models are estimated at the bank level, with country-level explanatory variables matched to banks by country and year.

Source(s): Data processing by the authors (2025)

4.4. Comparative Analysis Results (Islamic vs Conventional Banks)

To enrich the empirical analysis, this study conducts a bank-level comparative analysis of the determinants of bank expansion growth (BEG) between Islamic and conventional banks operating within a dual banking system, as reported in Table 5. The estimations are performed on bank-level subsamples, with country-level explanatory variables (ICT, HTE, IQ, and macroeconomic controls) matched to individual banks by country and year. The results reveal distinct patterns in how technological, institutional, and macroeconomic factors shape expansion dynamics across banking models.

The findings confirm that ICT adoption at the country level exerts a strong and statistically significant positive effect on bank-level BEG for both Islamic and conventional banks, highlighting digitalization as a universal catalyst for banking expansion. Conventional banks exhibit a relatively larger coefficient, suggesting

that they benefit more rapidly from ICT adoption due to their established digital infrastructure and broader technological ecosystems. However, Islamic banks also experience significant gains, indicating that digital transformation—through fintech integration, online banking services, and Sharia-compliant digital platforms—has become essential to their competitiveness and market outreach.

Table 5.
Comparative Analysis Results (Islamic vs Conventional Banks)

Variables	Dependent variable: BEG	
	Islamic Banks	Conventional Banks
ICT	0.923*** (0.215)	1.467*** (0.149)
the	0.315 (0.248)	−0.281** (0.128)
ICT×HTE	0.519* (0.292)	0.248* (0.149)
IQ	0.296*** (0.076)	−0.115*** (0.041)
ROA	−0.023 (0.068)	−0.188* (0.110)
ROE	0.021* (0.013)	0.016 (0.011)
INF	−0.162** (0.063)	−0.079** (0.034)
RIR	0.010 (0.027)	0.030 (0.019)
GDPC	−5.765*** (1.052)	−6.105*** (0.606)
Constant	56.064*** (10.020)	66.017*** (5.492)
Year FE	Yes	Yes
Country FE	Yes	Yes
Bank Clustered	Yes	Yes
SE Clustered at country level	Yes	Yes
F-Statistics	8.65***	18.17***
Adjusted R ² (within)	0.076	0.081
Observation	1036	2016
Number of Banks	74	144

Note(s): Robust standard errors are in parentheses; * $p < 1\%$, ** $p < 5\%$, *** $p < 1\%$; All estimations are conducted at the bank level, with country-level explanatory variables matched to banks by country and year.

Source(s): Data processing by the authors (2025)

The impact of high-technology exports (HTE) differs across banking systems, illustrating how national innovation capacity translates into heterogeneous bank-level outcomes. For Islamic banks, HTE displays a positive but statistically insignificant effect, suggesting that technology intensity enhances the broader digital environment without directly translating into immediate bank expansion.

In contrast, for conventional banks, HTE exhibits a negative and statistically significant relationship with BEG, implying that innovation-driven sectors in more technologically advanced economies may rely more heavily on capital markets and venture financing rather than traditional bank intermediation.

The interaction term between ICT adoption and high-technology exports (ICT $\times$ HTE) is positive and statistically significant for both banking models, confirming a synergistic effect between digital readiness and innovation capacity at the bank level. The magnitude of this effect is relatively stronger for Islamic banks, indicating that technological complementarities play a crucial role in helping them overcome structural constraints and expand market share. This finding underscores that innovation-driven digitalization is particularly transformative for Islamic banks operating in emerging financial markets, where ICT-enabled innovation facilitates financial inclusion and strengthens Sharia-compliant competitiveness in systems traditionally dominated by conventional institutions.

A clear divergence emerges in the role of institutional quality (IQ). For Islamic banks, institutional quality has a positive and highly significant effect on bank expansion growth, highlighting the importance of governance effectiveness, regulatory quality, and institutional credibility in supporting Sharia-compliant financial intermediation. Strong institutions enhance investor confidence, ensure regulatory compliance, and reduce uncertainty within Islamic banking frameworks. In contrast, for conventional banks, institutional quality is negatively and significantly associated with BEG, suggesting that in more mature regulatory environments, stricter prudential oversight may constrain expansion by limiting risk-taking and balance-sheet growth. Overall, these results demonstrate that while ICT adoption acts as a universal driver of bank-level expansion, Islamic banks rely more heavily on institutional strength and technological complementarities, whereas conventional banks depend primarily on operational efficiency and digital maturity within a dual banking system.

4.5. Robustness Check

A robustness analysis is conducted using the System GMM estimator to ensure the reliability and consistency of the baseline results. This dynamic panel estimator is particularly suitable for bank-level panel data with a relatively large cross-section and shorter time dimension, as it effectively addresses key econometric challenges such as unobserved bank-specific heterogeneity, simultaneity bias, dynamic persistence, and potential endogeneity of regressors through the use of internal instruments and lagged variables. The positive and highly significant coefficient of the lagged dependent variable ($BEG_{(t-1)}$) across all specifications confirms the presence of persistence in bank expansion growth, indicating that past expansion patterns significantly influence current performance. This finding reflects path-dependent dynamics in bank growth behavior, which is consistent with the theoretical premise of gradual balance-sheet adjustment in the banking industry.

Table 6.
Dynamic Panel-Data Estimation (Robustness Check)

Variables	Full Sample	Islamic Banks	Conventional Banks
BEG _(t-1)	0.618*** (0.031)	0.326*** (0.055)	0.650*** (0.053)
ICT	0.097* (0.050)	0.131 (0.127)	0.184** (0.094)
THE	-0.029 (0.046)	0.140 (0.122)	0.135 (0.097)
ICT × THE	0.044 (0.206)	2.595*** (0.483)	-0.808 (0.648)
IQ	0.523*** (0.061)	0.965*** (0.125)	0.224* (0.119)
ROA	0.007 (0.026)	0.049 (0.041)	0.000 (0.103)
ROE	0.030*** (0.004)	0.015* (0.008)	0.030 (0.019)
INF	-0.178*** (0.021)	-0.647*** (0.062)	-0.028 (0.040)
RIR	0.034** (0.013)	-0.042** (0.021)	0.110*** (0.035)
GDPC	-5.364*** (0.779)	-11.361*** (1.700)	-1.402 (1.205)
Constant	29.793*** (4.587)	74.829*** (10.877)	5.097 (5.886)
Wald χ^2	22032.17***	9713.96***	491.77***
Country fixed effect	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes
Bank fixed effect	Yes	Yes	Yes
Arellano-Bond test (2)	-0.662	0.320	-1.311
Sargan test	931.52***	274.57***	952.53***
Number of Obs.	2,834	962	1,872
Number of Banks	218	74	144
Number of Instruments	52	52	52

Note(s): Robust standard errors are in parentheses; * $p < 1\%$, ** $p < 5\%$, *** $p < 1\%$; System GMM estimations are conducted at the bank level, with country-level explanatory variables matched by country and year; The Arellano-Bond AR(2) test indicates no second-order serial correlation, supporting model validity.

Source(s): Data processing by the authors (2025)

For the full sample, the robustness results reaffirm that ICT adoption and institutional quality remain statistically significant drivers of bank-level expansion growth, even after controlling for dynamic effects and endogeneity. This consistency strengthens the validity of the baseline fixed-effects results, reinforcing the conclusion that digital transformation and governance quality are fundamental to enhancing bank expansion within dual banking systems. In contrast, high-technology exports (HTE) alone remain statistically insignificant, indicating that technological progress at the national level contributes to banking expansion primarily through interaction effects with ICT adoption or institutional quality, rather than as an independent determinant.

When the sample is disaggregated by banking type, notable structural differences emerge. Islamic banks exhibit stronger sensitivity to the interaction between ICT adoption and high-technology exports, suggesting that their expansion is most effectively driven by synergies between digital capabilities and national innovation capacity. This result implies that Islamic banks benefit disproportionately from environments where digital infrastructure supports the absorption of technological spillovers, enabling them to expand outreach and overcome structural constraints.

Institutional quality continues to play a crucial and statistically significant role for Islamic banks, underscoring their reliance on credible governance frameworks, regulatory clarity, and institutional trust to sustain expansion. These findings suggest that Islamic financial institutions benefit more from environments where digitalization and institutional integrity operate jointly, enhancing operational efficiency and market penetration. In contrast, for conventional banks, expansion is primarily driven by ICT adoption and macroeconomic stability, reflecting their higher technological readiness and deeper integration into capital markets. The interaction between ICT and high-technology exports appears weaker and statistically insignificant, indicating that conventional banks rely more on direct technological efficiencies than on sectoral innovation spillovers. Overall, the robustness checks validate the consistency and credibility of the main findings: technological progress, institutional strength, and innovation complementarity are the primary engines of bank expansion, although their transmission mechanisms differ between Islamic and conventional banking systems.

V. CONCLUSION AND RECOMMENDATIONS

This study examines how information and communication technology (ICT) adoption, high-tech exports (HTE), and institutional quality (IQ) influence bank-level expansion growth (BEG) in Islamic and conventional banks operating under dual banking systems in twelve Muslim-majority countries over the period 2010–2023. Using a bank-level panel data framework, the analysis captures heterogeneity across individual banks while accounting for country-level technological, institutional, and macroeconomic conditions. The results confirm four key findings. *First*, ICT adoption consistently exerts a strong and positive effect on bank expansion growth, underscoring digital transformation as a universal catalyst for financial expansion at the individual bank level. *Second*, HTE exhibits only a limited and indirect effect, implying that technological progress in the export sector does not automatically translate into banking expansion unless it is accompanied by sufficient digital absorptive capacity within the banking system. *Third*, the interaction term between ICT and HTE ($ICT \times HTE$) is positive and statistically significant, indicating that technological resources combined with national innovation capacity generate synergistic effects that strengthen bank expansion and financial deepening. *Fourth*, institutional quality (IQ) displays a positive but statistically insignificant direct relationship with BEG in the full sample, suggesting that governance effectiveness functions primarily as a facilitating and enabling condition, rather than a direct driver, of banking expansion.

The comparative analysis further highlights distinct expansion mechanisms between Islamic and conventional banks. ICT adoption promotes expansion in both banking models, confirming digitalization as a universal driver of growth. However, Islamic banks benefit more strongly from the interaction between ICT adoption and national innovation capacity, indicating that technological complementarities are particularly important for overcoming structural constraints and expanding outreach in Islamic finance. In contrast, conventional banks rely more heavily on direct ICT-driven efficiency gains, reflecting their greater technological maturity and deeper integration into capital markets.

Institutional quality emerges as a key differentiating factor between the two banking systems. Strong governance frameworks and regulatory credibility significantly support Islamic bank expansion by enhancing trust, Shariah compliance, and investor confidence. Conversely, stricter institutional and regulatory oversight appears to moderate expansion in conventional banks, suggesting that mature regulatory environments may constrain aggressive growth strategies. Collectively, these findings indicate that Islamic banks depend more on institutional credibility and technological complementarity, while conventional banks rely more on operational efficiency and digital maturity within a dual banking system.

Robustness checks using the System GMM estimator confirm the consistency and reliability of the main results, demonstrating that the observed relationships remain stable after accounting for dynamic persistence, endogeneity, and unobserved bank-specific heterogeneity. The persistence of bank expansion growth further indicates path-dependent behavior in bank growth dynamics. Overall, the findings strengthen the theoretical integration of Innovation Diffusion Theory, the Resource-Based View, and Institutional Theory, suggesting that bank expansion emerges from the interaction of digital capabilities, innovation synergies, and institutional integrity, rather than from any single factor in isolation.

From a policy perspective, the results suggest several important implications. Policymakers and regulators should prioritize the development of digital infrastructure, promote innovation in high-technology sectors, and strengthen institutional governance to create an enabling environment for bank-level expansion. For Islamic banks, digital transformation aligned with Shariah principles and supported by strong institutional frameworks can accelerate financial inclusion and sustainable growth. Conventional banks, meanwhile, should continue to leverage ICT to enhance operational efficiency and competitiveness in increasingly digitized financial markets. Finally, future research could extend this framework by incorporating variables such as digital literacy, fintech regulation, and Shariah governance quality, which may further illuminate the technological-institutional mechanisms shaping bank expansion within dual banking systems.

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APPENDIX

Appendix A1.
Correlation Matrics

Variables	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	VIF
[1] BEG	1.000									
[2] ICT	0.025	1.000								1.02
[3] HTE	0.211	0.036	1.000							1.32
[4] IQ	0.268	0.064	0.299	1.000						5.21
[5] ROA	0.029	-0.068	0.014	0.038	1.000					1.50
[6] ROE	0.028	-0.047	0.044	-0.086	0.568	1.000				1.53
[7] INF	-0.202	-0.011	-0.145	-0.618	0.042	0.150	1.000			1.71
[8] RIR	-0.010	0.024	-0.032	-0.035	-0.003	-0.014	-0.101	1.000		1.09
[9] GDPC	0.267	0.070	0.061	0.850	0.053	-0.061	-0.558	-0.130	1.000	4.53

Source(s): Data processing by the authors (2025)