



ARTICLE



<https://doi.org/10.1057/s41599-025-05571-8>

OPEN

Financial technology and banking performance in developing countries: evidence from an advanced quantile regression approach

Muhammad Irtaz Ul Hassan^{1,2}, Mengyun WU^{2,3}, Jie Lu^{4✉}, Jan Muhammad Sohu⁵, Shoaib Ali⁶, Hafiz Naveed Anjum² & Muhammad Bilal²

FinTech has emerged as a transformative force in the global banking industry, especially in developing economies where digital solutions are rapidly redefining financial access, efficiency, and competition. Despite its growing relevance, empirical research remains limited regarding the heterogeneous effects of FinTech on banking performance and the role of institutional quality in shaping these outcomes. This study investigates the impact of FinTech adoption on bank performance in 33 developing Asian countries from 2010 to 2022 while assessing the moderating effect of economic governance. Using the Method of Moments Quantile Regression and Bootstrapped Quantile Regression, the analysis captures distributional dynamics and robustly estimates relationships across different levels of bank performance. Findings reveal a consistently positive and statistically significant impact of FinTech on bank performance, particularly in lower-performing banks, suggesting that FinTech fosters financial inclusion and competitiveness. Economic governance is also shown to exert a direct and positive influence, especially in institutional environments where regulatory stability and accountability enhance operational outcomes. Furthermore, the interaction between FinTech and governance is significant, indicating that stronger institutional frameworks amplify the beneficial effects of FinTech. These results are stable across various quantiles and robust to alternative specifications. The study offers critical insights for policymakers and financial regulators, emphasizing the need for synchronized development of digital financial infrastructure and governance frameworks to maximize performance gains in the banking sector. In light of the COVID-19 pandemic's role in accelerating digital adoption, the findings underscore the importance of institutional resilience in mitigating associated risks. This research contributes to the ongoing discourse on digital finance and economic development by integrating technological innovation and institutional quality into a unified empirical framework, offering actionable recommendations for sustainable banking reforms in developing regions.

¹Quanzhou University of Information Engineering, Quanzhou, FUJIAN, China. ²School of Finance and Economics, Jiangsu University, Zhenjiang, China.

³School of Accounting, Shanghai Lixin University of Accounting and Finance, China, Shanghai, China. ⁴School of Business Administration, Shanghai Lixin University of Accounting and Finance, China, Shanghai, China. ⁵Department of Business Administration, Sukkur IBA University, Sukkur, Pakistan. ⁶School of Business Administration, Zhejiang Gongshang University, Zhenjiang, China. ✉email: 20230017@lixin.edu.cn

Introduction

In recent years, the financial technology (FinTech) sector has reshaped the global banking industry, transforming how financial services are delivered and consumed. FinTech includes a diverse set of innovations, such as automated teller machines (ATMs), mobile banking, and digital payment platforms, all of which have significantly improved convenience, operational efficiency, and financial accessibility (Belanche et al. 2019). As fintech evolves, its influence on bank performance becomes a critical area of study, warranting comprehensive exploration and analysis (Pandey et al. 2024). The integration of FinTech into financial services has also led to the emergence of novel products and services, leading to innovative products and services created by well-established pecuniary organizations and technological innovators (Lagna and Ravishankar 2022).

FinTech has notably influenced financial inclusion and user engagement (Omarini 2024). This transformation is particularly evident in the proliferation of ATMs, which offer 24/7 access to banking services, and the increasing use of mobile phones for financial transactions, enhancing accessibility and user engagement (Jourdan et al. 2023). The widespread adoption of fintech is also reflected in the growing number of adults with access to bank accounts, signifying a shift towards financial inclusion and modernization (Thottoli 2024). According to the World Bank's Global Findex Database, the percentage of adults with a bank account worldwide increased from 51% in 2011 to 71% in 2021, highlighting the significant impact of fintech on financial inclusion (World bank (2021)). In addition, the impact of FinTech on the efficiency of banking operations is influenced by different business factors, highlighting the growing importance of technology in strengthening banking systems (Kayed et al. 2025).

FinTech is having a significant impact on the banking industry, affecting profitability to some extent, although not necessarily in a significant way (Keliuotyte-Staniulienė and Smolskyte 2019). The impact of this phenomenon extends to various aspects of the banking industry, including consumers, businesses, financial institutions, regulatory frameworks, and societal dynamics (Elia et al., 2023). In addition, incorporating FinTech into financial services is expected to enhance bank profitability through collaborative strategies (Kurniawati 2023).

The COVID-19 pandemic has accelerated digital transformation in the banking sector, particularly in developing countries, compelling an agile transition towards digital technologies to meet changing societal demands and sustain future viability (Olena et al. 2021). This shift has catalyzed the growth of FinTech, electronic banking, and financial ecosystems to cater (Aniqoh et al. 2022; Elsaid 2023; Rahman and Islam 2021) to the heightened demand for digital services in light of social distancing, concurrently boosting competitiveness within the FinTech domain. Although the pandemic initially slowed FinTech investment, the demand for digital financial services has markedly increased, propelling investment, operational efficiency, and customer satisfaction throughout the industry (Khatun et al. 2021; Rahman and Islam 2021). In locales such as Bangladesh, digital banking usage has significantly risen, underscoring the critical importance of digital conduits in finance and the rapid embrace of mobile banking to expand access to the financially underserved (Banna and Alam 2021; Pellegrino and Abe 2022).

FinTech has also played an essential role in helping the banking sector as well as small and medium-sized enterprises (SMEs) recover post-pandemic, suggesting a broader implication for digital financial inclusion in the sector's resilience and recuperation (Pellegrino and Abe 2022). Moreover, prior research highlights the positive effects of FinTech on banking operations. These researches demonstrate a noticeable improvement in operational effectiveness thanks to technological advancements

(Maryunita and Nugroho 2022). Conversely, the disruption occasioned by FinTech also carries negative connotations for the banking industry. Specific investigations indicate a potential deleterious effect of FinTech firms on banking profit margins (Verma and Chakarwarty 2024). This revolutionary wave is associated with diminished market share and revenue for banks, impacting their operational performance (Yin et al. 2022). Furthermore, the sustainability of the banking sector faces jeopardy due to the burgeoning presence of FinTech as a formidable contender (Yan and Jia 2022).

EG significantly influences institutional performance, innovation, and financial regulation, where the quality of governance augments the impact of human capital on economic growth, especially in nations with medium governance quality (Chen and Xing 2025). It similarly affects the outcomes of private economic endeavours (Wibowo et al. 2021) and significantly impacts the dynamics among Sukuk issuance, Value-Added Tax (VAT) implementation, terrorism, economic policy uncertainty, and economic complexity (Chan et al. 2021; Ogbuabor et al. 2023; Yuliani et al. 2022). The quality of governance emerges as a crucial determinant of economic growth, underscoring its essential role in achieving optimal economic outcomes (Qazi 2025). It also moderates the effects of political risk and governmental expenditure efficacy on sectoral and economic growth, respectively, and influences the correlation between IT innovation and organizational performance through entrepreneurial innovation and the business landscape (Chan et al. 2017; Chege et al. 2020; Erickson 2021; Molonko and Ampah 2017).

Existing literature delineates a lacuna in understanding the modulation by economic governance of the relationship between FinTech and bank performance, especially across the heterogeneous Asian continent, characterized by diverse stages of governance quality and FinTech adoption. This study aims to investigate the impact of FinTech on bank performance and assess how economic governance may influence or moderate this relationship. Specifically, we explore whether stronger governance frameworks amplify the benefits of FinTech while mitigating associated risks. This study also contributes to the broader literature by addressing a critical gap: the lack of multi-country empirical studies on FinTech–bank performance linkages within the context of economic governance in Asia. The research questions guiding this investigation are:

Q1: How does fintech positively impact bank performance?

Q2: How does economic governance positively impact bank performance?

Q3: How does economic governance moderate the relationship between fintech and bank performance?

By addressing these questions, this research offers practical insights for policymakers, regulators, and financial institutions. Encompassing a wide geographical area and spanning the years 2010–2022, this study makes a substantive contribution to scholarly discussions, laying the groundwork for future research, policy formulation, and strategic adaptations in the banking sector to technological progress. Figure 1 depicts an uninterrupted rise in FinTech adoption in the Developing countries' banking industry over time. From 2014 onwards, economic governance has shown a diverse trajectory but has consistently risen. On the other hand, banks have been declining in performance over time, indicative of a downward drift in the banking sector of developing countries.

Using a rigorous empirical framework, we analyze data from BankFocus, the International Monetary Fund (IMF), World Development Indicators (WDI), and the Global

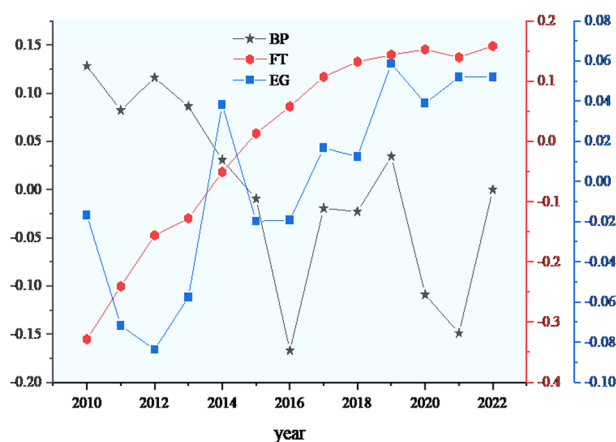


Fig. 1 Statistical trend of BP, FT, & EG.

Financial Development Database (GFDD). These sources provide insights into bank performance, FinTech adoption rates, and governance metrics. The Method of Moments Quantile Regression (MMQREG) is applied to investigate FinTech's varied effects across different levels of bank performance under diverse governance conditions. Bootstrap Quantile Regression (BSQREG) further corroborates these results, bolstering the reliability of the estimates. Spanning 2010–2022, the research captures significant shifts in FinTech and governance, facilitating a comprehensive analysis of the research objectives. This study significantly contributes to the growing knowledge of fintech and bank performance. Elucidating the complex interplay between fintech, economic governance, and bank performance provides a robust framework for understanding the dynamics of financial innovation in the modern banking landscape. The insights from this research are poised to inform future scholarly endeavours, guiding the development of more nuanced and contextually relevant theories and models. Additionally, the practical implications of this study can help shape effective policies and strategies for leveraging fintech to enhance bank performance in diverse economic contexts.

The rest of the research is arranged as follows: Section “Review of Literature” interprets the historical literature. Section “Research Methods” explains the data source and methodology. Section 4 demonstrates the models’ estimations. The last section expresses the study’s conclusion, policy recommendations, and limitations.

Review of Literature

The impact of fintech on bank performance. FinTech has gained growing attention in financial research due to its transformative role in banking and financial services. While its exact origins in the financial lexicon remain unclear, it has been applied in various contexts. Scholars have defined FinTech by examining its core functions. According to Hu et al. (2025), FinTech comprises businesses that enhance the efficiency of financial products. FinTech is a recently emerged segment within the banking and financial sector that utilizes technology to enable a wide range of financial endeavours, including trade, corporate operations, and retail consumer services (Micu and Micu 2016). The integration of technology into banking operations has led financial institutions to adopt FinTech into their strategic frameworks. This shift has fostered the advancement of technologies such as blockchain and artificial intelligence (AI), transforming how financial services are delivered.

Acar & Çıtak, (2019) examine the Turkish financial structure. They describe the progression of recommending the amalgamation of new financial Digitization for Turkish financial institutions. Before implementing technological-financial services, their task included investigating the need to familiarize FinTech with the internal structure of banks. Rapid developments in technological means have induced a shift away from personal connections and toward reliance on data. Arnoud Boot et al. (2020) assessed the implications of technological advances and digital venues on financial conciliation. Also, the proliferation of innovative mediums of expression might compromise the traditional banking system. Furthermore, as a result of these recent adaptations, we are confronted with new hazards, including but not limited to data loss, technological advancements, and alterations in development, which pose challenges in management and Control.

As FinTech adoption increases, developing reliable indicators to measure its integration into banking becomes essential. Web crawlers and word analysis of frequency underpin the FinTech index bank (Cheng and Qu 2020). Liu et al. (2020) delineate the several stages implicated in developing the FinTech index for Chinese banks. More precisely, they use search engines like Baidu to systematically analyze text and determine the frequency of terms related to FinTech. In addition, Deng et al. (2021) derived the FinTech indexes using the government’s digital financial index. The research data used in this study was acquired from the Peking University Digital Finance Research Center. The evaluation of the degree of FinTech development was carried out via a keyword search methodology, as described in the study by (Wang et al. 2021). Based on the theoretical insights and empirical findings discussed above, we propose the following hypothesis:

H1: FT has a positive effect on BP in emerging economies.

Economic governance and bank performance. Economic governance is a key institutional factor influencing banking system performance. It affects regulatory quality, investor confidence, and overall economic stability, all of which are critical to bank profitability and resilience (Haile, Mulugeta (2025)). Numerous studies have emphasized that good governance enhances financial performance by reducing systemic risk and strengthening operational efficiency (Bakar 2020).

For instance, Athari et al. (2023) examined how country-level governance affects the sustainability of the banking sector in vulnerable environments across emerging economies. They found that stronger governance, especially in areas like government effectiveness, political stability, and regulatory quality, helps banks perform better over the long term and reduces their exposure to risks. These results highlight that good governance is important not just for everyday operations but also for keeping the banking sector stable during economic crises or external shocks.

Lestari and Rahmanto, (2021) employed the Worldwide Governance Indicators to quantify governance quality across countries. Their analysis reveals that stronger governance correlates with improved financial sector performance, including higher bank profitability and lower risk levels. The methodology employed in their study, which includes extensive data collection and rigorous statistical analysis, lends credibility to their findings. However, the broad scope of their study necessitates more focused research on specific regions, such as Asia, to understand the nuanced effects of governance on bank performance in different contexts (Fu and Mishra 2022).

In Asia, governance quality varies significantly, influencing bank outcomes across the region. A study by the Asian Development Bank (2021) highlights that countries with robust

Table 1 FinTech and bank performance literature summary.			
Authors	Period	Approach to analyze	Findings
Cheng and Qu (2020)	2008–2017	Analysis by regression	(–) Credit risk
Phan et al. (2020)	1998–2017	Analysis by regression	(–) Bank performance
Katsiampa et al. (2022)	2013–2019	Analysis by regression	(–) Bank performance
Zhao et al. (2022)	2003–2018	Dynamic GMM estimator (Two-step system),	(+) Bank CAR
Wang et al. (2021)	2008–2017	Analysis by regression	(–) EPS & Asset quality
Keliuotytė-Staniulėnienė & Smolskytė (2019)	2010–2017	Panel data fixed effects regression	(+) Total productivity
Nguyen et al. (2022)	2013–2018	Analysis by regression	(–) ROE
Chen et al. (2019)	2003–2017	Machine learning regression analysis	(+) ROE & RAROA
Lee et al. (2021)	2003–2017	Dynamic panel GMM	(+) Financial sector
Tang (2019)	2009–2012	Analysis by regression	(+) Cost efficiency
Li et al. (2022)	2003–2019	FinTech textual analysis, regression analysis	P2P systems complement and replace banks.
			(–) Bank performance

governance frameworks, such as Singapore and Hong Kong, exhibit higher levels of financial sector development and stability. These findings are supported by empirical evidence showing that effective governance mechanisms, including robust regulatory frameworks and transparent financial practices, contribute to improved bank performance. However, these findings are echoed by Bashayreh Ala’and Wadi (2021), who also notes considerable variation within the region, highlighting the need for country-specific studies to understand governance heterogeneity. Drawing on the preceding literature, we formulate the following hypothesis:

H2: EG exerts a positive influence on BP.

Interplay between fintech, economic governance and bank performance. The interaction between FinTech and economic governance presents a complex yet critical determinant of bank performance. While fintech innovations can enhance efficiency and broaden financial inclusion, their impact is mediated by the quality of economic governance (Phan et al. 2020). Strong governance frameworks can facilitate the seamless integration of digital technologies into the financial system, amplifying its positive effects on bank performance.

A study by Pavlov et al. (2022) explores this interaction, focusing on the Chinese banking sector, showing that the benefits of FinTech adoption are more pronounced in regions with stronger governance institutions. Their findings are based on an analysis of governance quality and FinTech uptake, which supports the view that economic governance moderates FinTech’s effects. However, due to the study’s national focus, broader comparative analyses are needed across different Asian economies.

Conversely, studies such as those by Bin-Nashwan (2022) suggest that poor governance can exacerbate the risks associated with fintech adoption. Their research indicates that fintech can increase financial instability and operational risks for banks in countries with weak regulatory frameworks. This underscores the importance of effective governance in mitigating the potential downsides of fintech and ensuring its positive impact on bank performance. Following the discussion above, we advance the third hypothesis as follows:

H3: EG moderates the relationship between FT and BP, such that the positive effect of FT on BP is enhanced under stronger governance frameworks.

Moreover, several research gaps remain Despite the extensive literature on fintech, economic governance, and bank

performance. First, there is a need for more region-specific studies that capture the unique dynamics of fintech adoption and governance in the Asian context. While global and country-specific studies provide valuable insights, Asia’s diverse economic and regulatory landscapes necessitate a more granular analysis. Second, existing studies often examine fintech and economic governance in isolation, overlooking their potential interactions. This study aims to bridge this gap by exploring how economic governance moderates the impact of fintech on bank performance, providing a more holistic understanding of these interdependencies. Third, the literature lacks a critical synthesis of the methodologies and findings of existing studies. This study aims to provide a more nuanced understanding of the fintech-bank performance relationship and its governance context by critically evaluating prior research’s provenance, methodology, objectivity, persuasiveness, and value. The preceding scholarly works are briefly outlined in Table 1. The academic paper emphasizes the duration of the research, the methodologies used, the researchers involved, and the outcomes obtained.

After evaluating the prior research by (Bellardini et al. 2022), Zhao et al. (2022), Nguyen et al. (2022), and Lee et al. (2021), we found an absence of investigation into how FinTech and economic governance affect the banking sector performance of Developing economies, including underdeveloped nations. Few empirical studies analyze FinTech adoption holistically Bellardini et al. (2022) and Arnoud Boot et al. (2020). The role of economic governance and bank performance are interconnected. While individual aspects of these factors have been explored in isolation, there is a gap in the literature that integrates these elements into a cohesive framework, especially within the unique context of Developing countries. Furthermore, the existing body of literature (Antwi-Wiafe et al. 2023; X. Chen et al. 2021) often lacks a regional-specific approach, particularly concerning Developing countries.

Given the significant diversity among Developing economies, the implications of FinTech on economic governance can vary considerably across nations. This gap in region-specific empirical research limits our understanding of how these factors interact within the Asian context. Another literature gap this study aims to address is the need for a more in-depth examination of banking performance, especially in underdeveloped nations (Bashayreh Ala’and Wadi 2021; Phan et al. 2020). The banking sector plays a pivotal role in these economies, and knowing whether FinTech and economic governance affect bank performance is vital for economic development and stability. Furthermore, our objective is to tackle the use of sophisticated statistical

approaches. Numerous studies on FinTech use traditional statistical methods (Cheng and Qu 2020; Katsiampa et al. 2022; Nguyen 2022), which may not fully reflect the complexities of the examined relationships.

The research aims to use advanced approaches such as MMQR and BSQR to provide a more detailed and thorough analysis. Furthermore, the research often overlooks the consequences of the connections between FinTech, economic governance, and bank performance. Policymakers and industry stakeholders seek insights into how these factors inform policy formulation. The finding aspires to conduit this slit by examining the practical implications and offering guidance on policy decisions within the financial sector. In conclusion, due to the lack of literature on the topic, the research further narrows its attention to Developing economies in their developmental stages. The Developing countries were selected because they share comparable economic structures, trade profiles, and development and technological innovation projections.

Using the MMQR & BSQR method, this study analyzed data from 2010 to 2022 to determine how advances in technology and economic governance would affect the Bank's intensity. Including economic governance as a moderating variable adds a layer of complexity, raising questions about how regulatory frameworks can potentially shape the outcomes of this relationship. This research holds particular relevance as Developing countries chart their course in the COVID-19 post-era, where the interplay of technology, governance, and performance has far-reaching consequences for their financial landscapes.

Research Methods

Data. The epistemology that underpins this present research study is positivism, which posts an objective, measurable, and verifiable understanding of reality to account for the phenomenon under study. This theoretical framework facilitates the application of quantitative procedures to develop correlations between factors so that formulated findings can be accurate and applicable to other circumstances. It is similar to the epistemology view that knowledge is obtained from research findings and evidence.

The study, therefore, adopted a correlational research design using Panel Data Analysis as the primary analytical tool. This plan allows the analysis of how FT correlates with EG and BP in several countries over a given period. In light of this, the correlational design is appropriate in establishing the existence degree and direction of the relationships between the study variables, thus warranting comprehensive and methodical responses to the research questions.

This study employs a country-level panel dataset comprising 33 developing Asian countries over the period 2010–2022. BP is constructed using principal component analysis (PCA) on aggregated financial ratios such as Return on Equity, Net Interest Margin, Tobin Q, and liquidity ratio, derived from BankFocus. Given that the FinTech and economic governance indicators are constructed from country-level data, the bank performance metrics were also used at the national level. This approach ensures consistency in the unit of analysis and avoids the need for multilevel modelling. Given the aggregation of all key metrics at the country level and limited variation in the number of banks per country, multilevel modelling was deemed unnecessary and potentially over-specified.

Similarly, FT adoption is measured using country-level indicators, such as ATMs per 100,000 adults, financial institution account ownership (age 15+), and outstanding loans from commercial banks, sourced from IMF's FAS and GFDD. The EG variable is also constructed at the country level using PCA on

three World Bank governance indicators: Political Stability, Government Effectiveness, and Voice & Accountability. Since both independent (FT, EG) and dependent (BP) variables operate at the country level, no multilevel modelling was required. The final panel includes country-year observations, with control variables aligned accordingly. Figure 2 presents the geographic distribution of the countries included in the study.

Econometric specification. To further assess the potential impact of economic governance and innovation in technology on Bank performance, we build on the prior argument and the work performed by various scholars to create the multivariate framework (Fig. 3) below:

$$BP_{it} = f(FT_{it}, EG_{it}, OE_{it}, CAD_{it}, GDP_{it}, ING_{it}) \quad (1)$$

Where in Eq. (1): the t and i (2010–2022) and (Developing economies). BP denotes bank performance and the explained variable in the study, FT denotes FinTech and the explanatory variable, EG denotes economic governance and the moderating variable, and Control represents all the control variables, including Return on Assets, Z-score, economic growth, and inflation. Integrating the interaction term into Eq. (1)

$$BP_{it} = f(FT_{it}, EG_{it}, FT_{it} * EG_{it}, OE_{it}, CAD_{it}, GDP_{it}, ING_{it}) \quad (2)$$

In Eq. (2), $FT*EG$ is the notation for the interacting term between FinTech and economic governance.

$$BP_{it} = \theta_0 + \theta_1 FT_{it} + \theta_2 EG_{it} + \theta_3 FT_{it} * EG_{it} + \theta_4 OE_{it} + \theta_5 CAD_{it} + \theta_6 GDP_{it} + \theta_7 ING_{it} + \epsilon_{it} \quad (3)$$

Where in Eq. (3): ϵ is the model's error term. Specifics, such as the unit of measurement and the data sources, are listed in Table 2. Natural logarithm forms for all parameters are used. Expected values for the variables under consideration are as follows: FT is hypothesized to have positive interconnection BP , as defined by ($\theta_1 = \theta_1 BP_{it}/FT_{it} > 0$). Furthermore, we anticipate a positive relationship between EG and BP , as shown by ($\theta_2 = \theta_2 BP_{it}/EG_{it} > 0$). It is expected that the interacting term $FT*EG$ will have a positive relationship with EG and that the relationship between FT and BP will be positive ($\theta_3 = \theta_3 \frac{BP_{it}}{FT_{it} * EG_{it}} > 0$), and that the relationship between the various BP_{it} . Control variables would be mixed (plus and minus).

Methods of Econometrics

Cross-sectional dependence test. The methods proposed by Pesaran (2004) and Hashem Pesaran and Yamagata (2008) evaluate the possibility of cross-sectional dependence and the homogeneity or heterogeneity of the slope coefficients. The inherent ambiguity in slope coefficients and the difficulty of using a cross-sectional study approach might lead to misleading and inconsistent results (Tufail et al. 2023; L. Wang et al. 2020). So, the heterogeneity of the slope coefficient was examined using the methodology suggested by (Hashem Pesaran and Yamagata 2008). Also, to check for cross-section dependence, we used the test that (Hashem Pesaran and Yamagata 2008) and (Pesaran and Yamagata 2021) created. After that, we looked at the features of stationarity. As seen in Eq. (4), the Pesaran cross-section (CD) test's fundamental Equation is:

$$CSD = \sqrt{\frac{2T}{N(N-1)N}} \left(\sum_{i=1}^{N-1} \sum_{k=i+1}^N \widehat{Corr}_{i,t} \right) \quad (4)$$

Unit root test. In previous decades, the prevalent technique for evaluating the dependability of a single time series included the use of typical unit root tests. The process of assessing the presence



Fig. 2 Geographical locations of study.

of a unit root in a panel framework is a comparatively recent technique encompassing intricate asymptotic characteristics, which are highly dependent on the anticipated structure of the analyzed data. Multiple tests have been conducted to assess the conformity of our outcomes with other theories and standards. Levin et al. (2002) suggest using panel unit root testing as a feasible alternative to doing single unit root tests on each explanatory sample. There is a prevailing notion that this test demonstrates higher reliability. The alternative hypothesis states that all-time series must have a unit root, whereas the null hypothesis states that no such root exists. The entire set remains in its original state, with no alterations made. The under examination reveals a configuration similar to a panel-based structure, which is then analyzed using the Augmented Dickey-Fuller (ADF) method. From a mathematical perspective, the Eq. (5) is in disarray.

$$\Delta y_{it} = \sigma_i y_{i,t-1} + \sum_{l=1}^{p_i} \phi_{il} y_{i,t-l} + a_{mi} d_{mi} + \varepsilon_{it}, m = 1, 2, 3 \quad (5)$$

According to Im et al. (2003), the LLC test must exhibit individual homogeneity. This study proposes the inclusion of a heterogeneous coefficient on the lagged dependent variable, $y_{i,t-1}$, and presents a testing methodology that involves aggregating unit root test statistics. The Equation provides the computed model (1). The null hypothesis posits that each series inside the panel has a unit root, denoted as $H_0: \rho_i = \rho = 0$. The alternative hypothesis proposes that particular series have unit roots while others are stationary. Specifically, the alternative hypothesis states that $H_1: \rho_i \neq 0$ for $i = 1, 2, \dots, N$ and $\rho_i = 0$ for $i = N + 1, \dots, N$. The IPS t statistic is

computed as the mean of N separate ADF statistics, provided in the following Eq. (6).

$$\bar{t} = \frac{1}{N} \sum_{i=1}^N t_{\delta i} \quad (6)$$

In addition to the more standard LLC and IPS testing, we performed numerous more complex panel root checks. These new tests were intended to address many issues with previous tests. Each sample's ADF Fisher chi2 test, Pesaran IPS test and PP Fisher chi2 test outperformed the LLC and IPS tests in Monte Carlo simulations for identifying the panel's unit root.

Cointegration test. We employ the Westerlund (2007) cointegration test to investigate the persistence of correlations across time. The Westerlund error correction-based study uses two groups of mean data types and two-panel statistics data types. G_t , G_a , and P_t , P_a are the statistics groups used to represent panel data. A panel study corroborates evidence opposing cointegration and the absence of groups. The cross-section does seem cointegrated if one believes the group statistic employed for the decision. This formula may compute various helpful group mean and panel group statistics.

$$G_a = \frac{1}{N} \sum_{i=1}^N \frac{a_i}{SE(a_i)} \quad (7)$$

$$G_t = \frac{1}{N} \sum_{i=1}^N \frac{Ta_i}{a_i(1)} \quad (8)$$

$$P_t = \frac{a}{SE(a)} \quad (9)$$

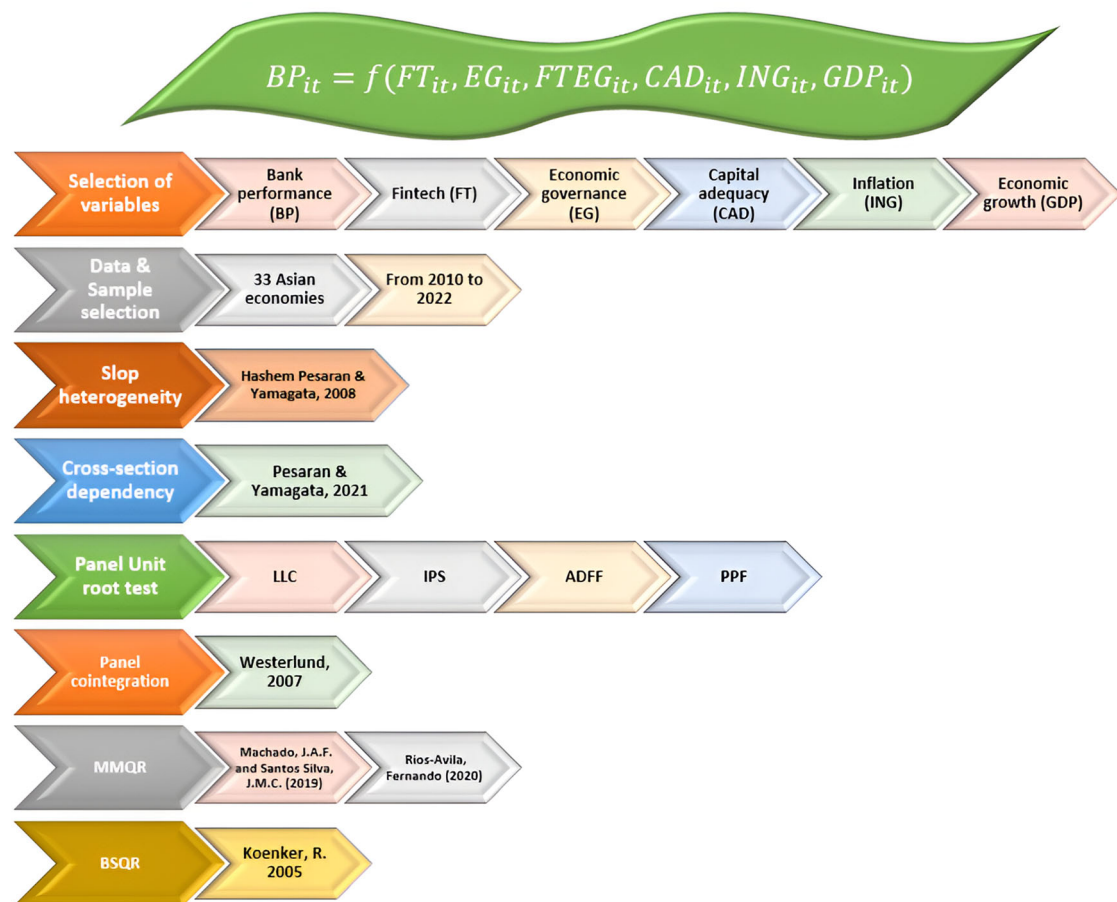


Fig. 3 Study analysis chart.

Table 2 Variable and source of data.

Variables	Description	Source
Dependent		
Bank Performance (BP)	A composite index was generated using Principal Component Analysis (PCA) of five financial ratios: Return on Equity (ROE), Net Profit Margin, Liquidity Ratio, Tobin's Q, and Net Interest Margin. These indicators collectively reflect a bank's profitability and performance.	BankFocus (BvD)
Independent		
FinTech (FT)	A composite index created via PCA based on the following indicators: Number of ATMs per 100,000 adults, Financial institution account ownership (% of population aged 15 +), and Outstanding loans from commercial banks (% of GDP). These indicators capture the level of FinTech adoption and financial access.	IMF-FAS, Global Findex, GFDD (World Bank)
Moderating		
Economic Governance (EG)	An index constructed using PCA from three governance dimensions: Political Stability and Absence of Violence/Terrorism, Government Effectiveness, and Voice and Accountability. These reflect the quality of institutional governance in each country.	World Bank, (WGI)
Control		
Economic Growth (GDP)	GDP per capita (%), a standard measure of economic growth	World Bank, (WDI)
Inflation (ING)	Population total was initially listed but replaced with Inflation rate (%) as a more relevant macroeconomic control.	
Industry-specific Control Variable		
Capital adequacy ratio (CAD)	CAD is a measurement of a bank's available capital expressed as a percentage of a bank's risk-weighted assets (Tier 1 Capital + Tier 2 Capital) / Risk-Weighted Assets	BankFocus (BvD)

$$P_a = T_a \quad (10)$$

In Eqs. (7) to (10), the group T-statistics are G_a , and G_t & T-statistics for the panel are P_t and P_a .

Benchmark Estimations (MMQR). Due to the deficiencies of traditional methods of assessing distributional and heterogeneity effects, panel quantile regression analysis across quantiles is increasingly being employed (Sarkodie and Strezov 2019). Panel

Table 3 Descriptive statistics.

Variable	BP	FT	EG	CAD	ING	GDP	FTEG
Mean	3.035	−3.505	−8.165	2.681	17.000	8.745	1.272
Median	0.046	0.162	0.247	2.830	17.000	8.482	0.568
Maximum	3.450	2.223	2.118	4.134	33.000	11.493	12.242
Minimum	−8.471	−3.879	−6.349	0.385	1.000	6.286	−1.502
Std. Dev.	1.117	1.317	1.402	0.698	9.533	1.294	2.179
Skewness	−1.534	−0.517	−1.706	−0.697	−6.275	0.220	2.559
Kurtosis	11.537	2.375	7.781	3.377	1.798	2.054	10.744
Jarque-Bera	1470.899	26.125	616.632	37.256	25.835	19.461	1540.140

Source: The authors' estimations.

quantile regression was developed in 1978 by Koenker & Bassett, (1978) to assess the conditional means of several dependent variables in light of explanatory variables employing quantile regressions. The quantile regression estimate method is less affected by outliers since it determines the conditional standard of the independent parameters. This approach is suggested when two variable-dependent methods are unstructured (Aziz et al. 2020). Moment's quantile regression (MMQR) using a fixed effects approach was employed by (Machado and Santos Silva 2019). Unobserved panel diversity cannot be handled by quantile regression, only outliers.

Unlike previous solutions, the method described here reflects the predetermined heterogeneous covariance implications of bank performance variables by allowing the particular influence to affect the complete distribution (Canay 2011; Koenker 2004). In the case of cloistered effects and endogenous explanatory variables, the method employed is the most suited. Quantile regression generates realistic non-crossing valuing quotations. Since it generates non-crossing price quotations, MMQR is straightforward. Using the Equation below, we can estimate the conditional quantiles for the location-scale alternative $Qy(|X)$

$$Y_{it} = \hat{a}_i + \ddot{X}_{it}\beta + (\delta_i + \dot{Z}_{it}\gamma)\mathcal{U}_{it} \quad (11)$$

Equation (11) requires examining the probability, $P = (a, \hat{\beta}, \hat{\delta}, \hat{\gamma})$, and parameters. Z indicates the k -vector of known elements of X , whereas the individual i -fixed effects are $(a_i, \delta_i), i = 1, \dots, n$.

Results & Discussion

Empirical estimations. The estimates obtained using the econometric methodologies discussed in this section are offered here, along with a comprehensive breakdown and argument of the resultant statistics. Descriptive statistics offer comprehensive insights into the variables studied, and the results are reported in Table 3. BP shows a notable disparity between its mean of 3.035 and its standard deviation (SD) of 1.117. Notably, Iraq has the minimum BP value at −8.471, indicating its banks are among the least stable in the dataset. The other countries with the lowest BP values are the Syrian Arab Republic (SAR), Georgia, and Japan, which reflect higher financial risk for them. The maximum BP value, 3.450, was attributed to Kazakhstan in 2010, along with other top emitting nations, including Kyrgyzstan, Tajikistan, and Azerbaijan.

The FT mean is −3.505, with an SD of 1.317 values. Notable countries like Tajikistan, Pakistan, Cambodia, Nepal, and Iraq reflect lower values. Tajikistan reported a minimum value of −3.879 in 2011, indicating varied levels of FT. On the other hand, the United Arab Emirates (UAE), Japan, Thailand, and Kuwait consistently exhibit higher FT values, often surpassing 2. However, UAE achieved a maximum of 2.223 in 2017, highlighting commendable achievements and indicating strong digital financial service adoption.

Table 4 Slope coefficients are homogenous.

$\tilde{\Delta}$	$\tilde{\Delta}^{Adjusted}$
2.964	5.343

Source: The authors' estimations.

Table 5 Cross-Section Dependence Test.

Variables	CD	CDw	CDw++
BP	18.470 ^a	5.250 ^a	766.580 ^a
FT	37.730 ^a	11.040 ^a	1090.410 ^b
EG	1.960 ^a	3.560 ^a	818.440 ^a
CAD	−0.270 ^c	−1.430 ^a	655.480 ^a
GDP	22.940 ^a	7.690 ^a	558.770 ^b
ING	23.740 ^a	4.760 ^a	841.860 ^b

Source: The authors' estimations. The coefficient is significant at 1%^a, 5%^b and 10%^c.

The mean EG during the sample period is −8.165, with an SD of 1.402. Across most Asian economies, mixed-trend EG values are prevalent, with Japan, Singapore, Cyprus, and Malaysia reporting high values. Syrian Arab Republic records a minimum EG value of −6.349 in 2022. In contrast, Japan consistently demonstrates high EG values, reaching a maximum of 2.117 in 2015. The mean of OE is 0.172, with an SD of 0.791. The mean of CAD is 32.681, with an SD of 0.698. The mean of ING is 17.000, with an SD of 9.533, and the mean of GDP is 8.745, with an SD of 1.294.

The study evaluates the asymmetry of the numbers, specifically focusing on the non-normal distribution of the variables as indicated by their skewness and kurtosis values. In this examination, it is crucial to prioritize verifying the normal distribution of the statistics. Therefore, a normality test is employed (Jarque and Bera 1987). Consequently, it is experimental that all variables exhibit anticipated nonlinear patterns and refute the null hypothesis.

This study further employs two conventional methods to detect the presence of panel data issues, namely the tests for heterogeneity of slope coefficients and cross-sectional dependence. According to Tables 4 and 5, these assessments led to the following conclusions. The arithmetic significance of both the delta and the corrected delta was determined at the 1% level after examining the diversity in slope coefficients. Based on the findings of Hashem Pesaran & Yamagata, (2008), which rejected the null hypothesis of equal slope coefficients, it was determined that slopes exhibited non-uniformity across the distribution.

This observation affirms the distinctiveness of these economies in terms of their economic status, national political systems, power dynamics, monetary aspects, and other relevant factors.

Table 6 Panel unit root analysis.

Variables	LLC	IPS	ADFF	PPF
BP	−8.925 ^a	−3.723 ^a	108.328 ^a	138.182 ^a
FT	−11.626 ^a	−6.659 ^b	177.401 ^a	168.810 ^a
EG	−11.560 ^a	−7.782 ^a	176.542 ^b	378.831 ^a
CAD	−7.030 ^a	−3.340 ^a	102.470 ^a	139.134 ^a
GDP	−5.980 ^a	−5.181 ^b	131.606 ^b	173.451 ^b
ING	−5.904 ^a	−4.247 ^a	128.508 ^a	141.994 ^a

Source: The authors' estimations. The coefficient is significant at 1%^a and 5%^b.

Table 7 Cointegration analysis.

Statistic	Gt	Ga	Pt	Pa
Values	−6.139 ^a	−0.731	−9.740 ^a	−0.998
P-Values	0.000	1.000	0.000	1.000

Source: The authors' estimations. The coefficient is significant at 1%^a.

On the other side of the picture, CD evaluation results indicate that nearly all components have significant impacts. Hence, it may be deduced that the Developing economies exhibit characteristics of cross-sectional reliance. The CD test yielded noteworthy findings, particularly indicating the potential for interdependence among economies; any change in one economy could affect how healthy measures are done in other countries.

Table 6 presents the panel unit root test results using four approaches: Levin, Lin & Chu (LLC), Im, Pesaran & Shin (IPS), ADF-Fisher Chi-square (ADFF), and PP-Fisher Chi-square (PPF). These tests assess the stationarity of all variables employed in the analysis. The results indicate that all variables are stationary at level form across most testing methods at the 1% or 5% significance level. Specifically, BP, FT, CAD, GDP, and ING reject the null hypothesis of a unit root under all four test criteria, confirming their stationarity. However, EG displays mixed results. While the ADFF and PPF tests suggest significance at the 1% level, the LLC and IPS tests do not consistently reject the unit root hypothesis at conventional significance levels.

These mixed results for EG suggest that it may not be stationary in level form across all test methods. However, when first differenced, the variable achieves stationarity at the 1% significance level across all test types, indicating that it is integrated of order one, I(1). This finding implies that all variables included in the model are suitable for further panel data analysis, such as co-integration testing or dynamic panel estimation, as the majority demonstrate stationarity or become stationary after first differencing.

According to Table 7, the cointegration study yielded the following results. Consider a test statistic that is statistically significant at a 1% level for a cointegrated variable. In that case, it may be inferred that the variable is cointegrated. In the Asian setting, there are enduring associations among many financial indicators, namely BP, FT, EG, CAD, GPD, and ING. The confirmation of long-run cointegrating correlations is achieved using the suitable panel regression approach to predict long-run coefficients.

Empirical analysis outcomes. The results from the MMQR are presented in Table 8, providing detailed estimates across location, scale, and quantile-specific effects. The findings show that FT has a positive and statistically significant impact on BP across all

quantiles, though the magnitude of this effect decreases at higher quantiles. Specifically, FT's effect ranges from 0.135 ($z = 2.09$, $p < 0.05$) at the 10th quantile to 0.055 ($z = 1.08$, $p < 0.10$) at the 90th quantile. This pattern indicates that FT contributes more substantially to BP improvements in lower-performing banks compared to higher-performing ones.

This phenomenon may arise because FT provides financial goods and services to individuals and small firms without access to such resources. While the credit risk profiles of these new participants remain a concern, the results indicate that FT's net impact is beneficial, potentially driving inclusivity without the destabilizing effects previously theorized. However, challenges persist, as regulatory and supervisory bodies in developing countries might face difficulties consistently keeping up with the rapid evolution of financial technologies. Ensuring that newly introduced participants in the financial system adhere to prudential norms and consumer protection requirements continues to pose significant challenges, particularly at higher quantiles where the impact of FT diminishes.

The study's findings are partially consistent with those of Antwi-Wiafe et al. (2023), who showed that FT positively impacts African banks' short-term and long-term performance. However, the new results suggest that the relationship between FT and BP is context-dependent, with FT providing net positive effects under specific economic conditions. Similarly, Nguyen et al. (2022) noted an adverse association between financial inclusion and performance, which may still apply in specific contexts but is less pronounced in the current study's findings. The positive correlation between FinTech and bank profitability aligns with the view that FinTech credit can diversify financial portfolios, enhancing BP in emerging markets. However, these findings challenge the conclusions drawn by Dasilas and Karanović (2023), Yudaruddin, (2023), and (Kharrat et al. 2023), which suggested a uniformly positive relationship between FT use and improvements in BP.

The interaction term, FTEG, also shows a positive and statistically significant relationship with BP across all quantiles, although its effect is more modest. The coefficient is highest at the median quantile (0.097, $z = 4.07$, $p < 0.01$) and remains significant up to the 90th quantile (0.059, $z = 2.09$, $p < 0.05$). This implies that the effectiveness of FinTech is enhanced in countries with stronger governance structures, as sound regulation and accountability help mitigate risks associated with rapid financial innovation.

EG independently exerts a strong and statistically significant positive effect on BP throughout the distribution. At the 10th quantile, the coefficient is 0.288 ($z = 4.08$, $p < 0.01$), declining to 0.110 ($z = 1.90$, $p < 0.10$) at the 90th quantile. This result suggests that economic governance plays a more influential role in improving the performance of weaker banking systems, where institutional frameworks are essential for reducing systemic risk and ensuring confidence in financial operations.

Our findings align with those of (Ozili 2018), who determined that many factors, such as political stability, government efficacy, investor protection, regulatory quality, unemployment rates, and corruption control, play a crucial role in influencing banking stability in the African context. Study findings suggested that governance structures (GS) and law and order (LAO) have favourable and statistically significant effects on foreign policy (Danlami et al., 2023). Regarding control variables, all three, ING, CAD, and GDP, exhibit statistically significant relationships with BP. ING shows a consistent positive effect across quantiles, with a coefficient of 0.037 ($z = 1.30$, $p < 0.10$) at Q10, increasing to 0.062 ($z = 2.75$, $p < 0.01$) at Q90. This may reflect the pricing power of banks in inflationary contexts, particularly in developing economies.

Table 8 MMQR analysis.

Variables		FT	EG	FTEG	CAD	ING	GDP	_cons
Location		0.099 ^a	0.209 ^a	0.090 ^a	0.214 ^a	0.048 ^a	−0.287 ^a	2.937 ^a
z-stats		2.58	4.86	4.24	5.53	2.83	−9.13	10.18
Scale		0.026	0.058 ^c	0.018 ^b	0.002	0.008	−0.026	0.531 ^b
z-stats		0.88	1.78	1.12	0.08	0.64	−1.1	2.42
Lower Quantile	0.1	0.135 ^b	0.288 ^a	0.115 ^a	0.211 ^a	0.037 ^c	−0.251 ^a	2.217 ^a
	z-stats	2.09	4.08	3.26	3.26	1.30	−4.81	4.67
	0.2	0.124 ^b	0.265 ^a	0.108 ^a	0.212 ^a	0.040 ^c	−0.261 ^a	2.424 ^a
	z-stats	2.26	4.37	3.57	3.82	1.65	−5.82	5.94
	0.3	0.117 ^b	0.247 ^a	0.102 ^a	0.212 ^a	0.043 ^b	−0.269 ^a	2.584 ^a
	z-stats	2.39	4.60	3.82	4.33	1.98	−6.77	7.14
Middle Quantile	0.4	0.109 ^b	0.229 ^a	0.097 ^a	0.213 ^a	0.045 ^b	−0.278 ^a	2.750 ^a
	z-stats	2.51	4.80	4.07	4.91	2.37	−7.89	8.56
	0.5	0.100 ^b	0.210 ^a	0.091 ^a	0.214 ^a	0.048 ^a	−0.286 ^a	2.926 ^a
	z-stats	2.58	4.89	4.25	5.5	2.81	−9.08	10.13
	0.6	0.092 ^b	0.192 ^a	0.085 ^a	0.215 ^a	0.051 ^a	−0.295 ^a	3.093 ^a
	z-stats	2.52	4.74	4.24	5.88	3.15	9.93	11.36
Higher Quantile	0.7	0.083 ^b	0.171 ^a	0.079 ^a	0.215 ^a	0.054 ^a	−0.304 ^a	3.280 ^a
	z-stats	2.27	4.22	3.91	5.90	3.33	−10.23	12.03
	0.8	0.073 ^c	0.149 ^a	0.072 ^a	0.216 ^a	0.057 ^a	−0.314 ^a	3.478 ^a
	z-stats	1.85	3.37	3.28	5.46	3.24	−9.72	11.66
	0.9	0.055 ^c	0.110 ^c	0.059 ^b	0.218 ^a	0.062 ^a	−0.332 ^a	3.841 ^a
	z-stats	1.08	1.90	2.09	4.25	2.75	−7.93	9.88

Source: The authors' estimations. The coefficient is significant at 1%^a, 5%^b and 10%^c.

CAD also has a strong and stable positive impact on BP, ranging from 0.211 ($z = 3.26$, $p < 0.01$) to 0.218 ($z = 4.25$, $p < 0.01$) across all quantiles, indicating that well-capitalized banks are better positioned to absorb risks and maintain performance levels. In contrast, GDP shows a statistically significant negative relationship with BP throughout the distribution. The coefficient declines from -0.251 ($z = -4.81$, $p < 0.01$) at the 10th quantile to -0.332 ($z = -7.93$, $p < 0.01$) at the 90th. This counterintuitive result may be due to the delayed transmission of macroeconomic growth benefits to individual bank performance in developing countries or possibly reflects increased competition and margin pressures during periods of economic expansion.

The empirical evidence from Table 8, along with the corresponding z-statistics and significance levels, confirms that FT, EG, and their interaction play crucial roles in shaping BP in emerging economies. These findings not only reinforce the positive impacts highlighted in earlier studies such as those by Antwi-Wiafe et al. (2023) and Ozili (2018) but also contribute to the ongoing debate regarding the potential risks and limitations associated with financial innovation in developing contexts (Nguyen et al. 2022; Dasilas and Karanović 2023; Yudaruddin 2023; Kharrat et al. 2023). Additionally, the significant effects of control variables like ING, CAD, and GDP provide further insights into how macroeconomic factors interact with technological and institutional variables to influence BP.

Discussion of results. The findings from our empirical analysis offer several important insights into the relationship between FT, EG, and BP in developing countries. The results indicate that FT is positively and significantly associated with BP across all quantiles. This effect is more pronounced at lower quantiles, i.e., the FT coefficient is approximately 13.5% at the 10th quantile, suggesting that financial technology may contribute more substantially to improving performance in relatively weaker banks. At higher quantiles, the impact declines to around 5.5%, indicating a diminishing marginal benefit of FT among higher-performing institutions. This pattern suggests that FT could play

a facilitative role in enhancing financial inclusion by extending services to underserved populations and small enterprises. While some prior studies Antwi-Wiafe et al. (2023) and Nguyen et al. (2022) have reported negative associations between FT and BP, often attributed to credit risks or loan quality concerns, our findings underscore that these outcomes may vary by context. Differences in institutional environments, regulatory standards, and technological maturity likely influence the direction and magnitude of FT's effects. In this regard, our findings are partially consistent with more optimistic perspectives presented by Dasilas & Karanović, (2023), Yudaruddin (2023), and Kharrat et al. (2023).

In parallel, EG is found to have a positive and statistically significant relationship with BP across all quantiles. For instance, a one-percent improvement in EG corresponds to a 28.8% increase in BP at the 10th quantile, with a gradual decline in effect size at higher quantiles. This suggests that robust governance frameworks, encompassing regulatory quality, rule of law, and institutional effectiveness, are especially critical for supporting banking performance in less stable financial environments. These findings are aligned with earlier work by Ozili (2018) and Hassan et al. (2023), who emphasize the importance of governance mechanisms in mitigating the risks associated with financial inefficiencies and corruption. Furthermore, the interaction term between FT and EG (FTEG) shows a modest yet statistically significant positive effect on BP, particularly around the median quantile. A coefficient of 0.097 at the 50th quantile implies that the complementarity between digital innovation and institutional strength can enhance bank performance. This reinforces the argument that FT's benefits are maximized when embedded within a supportive regulatory and governance context.

The control variables also reveal noteworthy associations. ING has a positive effect on BP across quantiles, potentially reflecting banks' ability to maintain pricing power in inflationary environments. CAD also shows a consistent and positive relationship with BP, highlighting the role of capital buffers in enhancing banking resilience. Conversely, GDP is negatively associated with BP at all quantiles, with coefficients ranging from -0.251 to

Table 9 Bootstrap quantile regression.

Variables		FT	EG	FTEG	CAD	ING	GDP	_cons
Lower Quantile	0.1	0.106 ^a	0.227 ^a	0.116 ^a	0.21 ^a	0.036 ^c	−0.247 ^a	2.196 ^a
	z-stats	3.07	6.78	4.72	3.59	1.65	−7.48	7.84
	0.2	0.126 ^a	0.249 ^a	0.109 ^a	0.182 ^a	0.038 ^a	−0.248 ^a	2.236 ^a
	z-stats	5.12	11.50	6.80	4.71	3.06	−11.14	11.98
Middle Quantile	0.3	0.151 ^a	0.231 ^a	0.113 ^a	0.209 ^a	0.048 ^a	−0.222 ^a	2.161 ^a
	z-stats	4.98	7.58	7.02	9.14	3.54	−10.16	12.43
	0.4	0.122 ^a	0.212 ^a	0.101 ^a	0.207 ^a	0.058 ^a	−0.242 ^a	2.388 ^a
	z-stats	3.17	8.46	5.39	6.03	2.44	−7.98	10.43
Higher Quantile	0.5	0.14 ^a	0.202 ^a	0.082 ^a	0.224 ^a	0.076 ^a	−0.224 ^a	2.343 ^a
	z-stats	4.43	7.39	6.68	6.25	5.15	−13.32	14.26
	0.6	0.11 ^a	0.178 ^a	0.071 ^a	0.232 ^a	0.077 ^a	−0.244 ^a	2.624 ^a
	z-stats	3.13	5.26	3.44	9.70	5.21	−7.54	8.67
Higher Quantile	0.7	0.086 ^b	0.200 ^a	0.056 ^a	0.207 ^a	0.081 ^a	−0.293 ^a	3.074 ^a
	z-stats	2.45	3.91	3.15	5.38	2.99	−6.93	9.69
	0.8	0.036	0.114 ^c	0.062 ^a	0.188 ^a	0.035	−0.308 ^a	3.354 ^a
	z-stats	0.68	1.96	3.42	5.13	0.85	−10.47	11.93
Higher Quantile	0.9	0.039	0.13 ^b	0.061 ^b	0.182 ^a	0.037	−0.331 ^a	3.715 ^a
	z-stats	0.87	2.32	2.20	3.98	1.45	−10.19	10.44

Source: The authors' estimations. The coefficient is significant at 1%^a, 5%^b and 10%^c.

Table 10 Comparison of COVID-19.

Variables	Pre-2020 Covid-19		During-2020 Covid-19		Post-2021 Covid-19	
	Coefficients	T-statistics	Coefficients	T-statistics	Coefficients	T-statistics
FT	0.085 ^a	1.820	0.132 ^a	2.210	0.103 ^a	3.300
EG	0.228 ^a	4.734	0.334 ^a	5.640	0.080 ^a	2.780
FTEG	0.088 ^a	3.934	0.109 ^a	4.140	0.116 ^a	8.250
CAD	0.203 ^a	3.640	0.272 ^a	4.480	0.274 ^a	5.540
ING	0.049 ^a	1.877	0.146 ^a	4.060	0.189 ^a	8.810
GDP	−0.301 ^a	−6.807	−0.315 ^a	−6.110	−0.404 ^a	−15.010
R2	0.830		0.849		0.824	
Adj R2	0.826		0.805		0.772	
Obs	329		67		33	

Source: The authors' estimations. The coefficient is significant at 1%^a, 5%^b and 10%^c.

−0.332. This counterintuitive result may reflect macroeconomic pressures or market competition in rapidly growing economies that constrain profitability. The findings suggest that FT may support banking performance, particularly among lower-performing institutions, but its effectiveness depends heavily on the quality of governance. Strong EG not only improves BP directly but also enhances the positive influence of FT. These insights contribute to the broader literature on the interplay between financial technology and economic governance, while also highlighting the importance of macroeconomic stability and sound regulation in shaping financial outcomes.

The robustness of these empirical results is further confirmed through Bootstrap Quantile Regression (BSQR), as illustrated in Table 9. The consistency between the MMQR and BSQR estimates reinforces the reliability of our findings and underscores the critical roles of both FT and EG in shaping bank performance in emerging economies.

Covid-19 (Covid-2020). The global outbreak of COVID-19 has adversely affected global economic conditions. In this study, Table 10 is used to examine the COVID-19 exogenous shock and its effects on the causative relationships between the level of banks' pre-2020 FinTech expenditure and their performance

throughout the progression of the pandemic. The present study reproduces the previously established results reported by (Ali et al. 2023; Phan et al. 2021; Shabir et al. 2022). Thus, the overall dataset, comprising 429 observations from 33 developing Asian countries over the period 2010–2022, was divided into three distinct subsamples. These subsamples represent the pre-COVID period (2010–2019), the COVID shock period (2020–2021), and the post-COVID recovery period (2022 onwards). The differences in subsample sizes arise solely from variations in the number of observations available each year and the total number of years included in each period. In other words, as the dataset is broken down by year, the total observations for each subsample reflect the data reporting practices and availability for that specific time window. The data presented in this study demonstrate a degree of resilience against the bearings of COVID-19. Research has shown that COVID-19 has severely impacted financial services due to the pandemic (Hassan et al. 2025; Phan et al. 2021; Shabir et al. 2022). With the COVID-19 pandemic factored in, the FinTech impact showed a consistent direction, statistical significance, and economic significance.

In both the pre-COVID-19 and during-COVID-19 periods, FinTech has consistently contributed to the positive performance of banks due to its presence. Notably, FinTech's impact on bank performance was most apparent during Covid-19. After COVID-

Table 11 Causality test (Hurlin and Dumitrescu).

Ho	Wald - Stats	Z-Stats	p-values
B P ϕ FT	2.749 ^b	2.152	0.031
FT ϕ BP	4.461 ^a	7.068	0.000
B P ϕ EG	2.092 ^a	4.434	0.000
EG ϕ BP	3.134 ^a	3.258	0.001
B P ϕ FTEG	2.776 ^b	2.229	0.026
FTEG ϕ B P	2.021 ^a	4.149	0.000
B P ϕ CAD	3.509 ^a	10.193	0.000
CAD ϕ B P	2.747 ^b	2.147	0.032
B P ϕ ING	4.068 ^a	5.939	0.000
ING ϕ BP	1.825 ^a	3.351	0.001
B P ϕ GDP	6.312 ^a	12.386	0.000
GDP ϕ B P	1.855 ^a	3.474	0.001

Source: The coefficient is significant at 1%^a and 5%^b.

19, the current landscape has enhanced the benefits of FinTech for banks. Cutting-edge technology is one of the main factors contributing to the ongoing collaboration flanked by banks and FinTech businesses. In the post-pandemic period, it is imperative to bolster digital capabilities, optimize operational processes, and provide customer-centric services (Toumi et al. 2023). Analyzing COVID-19 results with post-adjustment procedures, utilizing panel data set at the country level.

Robustness analysis. To perform a robustness check, A further investigation was conducted using BSQR to assess the relationship between our crucial study variables, including BP, FT, EG, FTEG, CAD, ING, and GDP. We find that estimates of coefficients from all three approaches are consistent. The coefficient estimates in all models exhibit consistent magnitudes, signs, and significance levels. As a result, the results are more robust. FT, FTEG, CAD, and GDP stability variables significantly negatively correlate with BP over the long term. Meanwhile, CAD and ING have a positive effect on BP over time.

Panel causality outcomes. This analysis uses the Dumitrescu & Hurlin (2012) test to look for relationships between bank performance, FinTech, economic governance, and other control factors. As mentioned earlier, the technique has a causal relationship between these factors and practical qualities (this test can resolve the CSD problem). The causality is determined using the heterogeneous test non-causality (alternative hypothesis) and homogeneous non-causality (null hypothesis). Table 11 presents the test results from (Dumitrescu and Hurlin 2012).

The Dumitrescu-Hurlin panel technique was used in the current investigation to determine the causal relationship between each likely determinant. The cause-and-effect relationships between FT_{it} , EG_{it} , $FT_{it} * EG_{it}$, CAD_{it} , GDP_{it} , and ING_{it} are shown in Table 11. Banking performance and FinTech have a bidirectional causal relationship in Developing economies. Dumitrescu-Hurlin panel test results further demonstrated the existence of two-way causation between $BP\phi FT$, $BP\phi EG$, $BP\phi FTEG$, $BP\phi CAD$, $BP\phi ING$, and $BP\phi GDP$, and $BP\phi GDP$. The bidirectional causality between BP and key predictors indicates a feedback loop where FinTech and governance reforms not only influence performance but are also shaped by it. However, GDP shows a consistent inverse causality, possibly reflecting structural lags in economic benefit transmission to bank-level outcomes.

Theoretical implications. This research has significant theoretical and practical implications for the study of FinTech, economic governance, and the performance of banks in developing countries. The prevailing positive assumptions about the impact of financial technology on banking need to be reconsidered in light of new evidence showing a positive correlation between FinTech development and bank performance. Additionally, our research underscores the importance of Asian financial institutions managing their FinTech resources effectively. This study further emphasizes the need to explore the complex relationships between legal frameworks, financial performance, and technological advancements. Gaining a deeper understanding of these connections can significantly enhance current frameworks and theories in finance.

Managerial implications. This study has important implications for financial industry professionals and decision-makers. First, it underscores the need for a balanced and sustainable approach to developing FinTech. Emphasizing responsible digitization and sustainability in FinTech initiatives is crucial for creating a strong and resilient financial landscape. Government oversight should be strengthened to ensure that FinTech initiatives are well-governed. Collaboration between various sectors is essential for establishing regulations that balance innovation with financial performance. Enhancing cybersecurity measures and enforcing strict data privacy regulations are vital for building trust in FinTech services and ensuring the stability of financial systems.

Interdisciplinary and societal implications. While our findings confirm the positive role of FinTech in improving bank performance, they also carry significant societal implications. In developing economies, the expansion of digital financial services is closely linked to broader efforts in reducing income inequality, enhancing financial inclusion, and bridging the urban-rural digital divide. The role of economic governance is particularly relevant in ensuring that FinTech does not exacerbate existing disparities, but rather supports equitable access to financial tools across socioeconomic groups.

Additionally, this study indirectly touches on emerging ethical considerations, including the use of AI and data-driven decision-making in banking systems. As FinTech becomes more integrated with artificial intelligence and algorithmic credit scoring, concerns arise regarding bias, transparency, and accountability in financial services. These questions underscore the need for not only sound governance frameworks but also ethical oversight in digital finance, a topic of growing interest in both economics and the humanities.

Conclusions

This study contributes to the growing literature on the role of financial technology in shaping banking performance within developing economies, particularly in Asia. While existing studies emphasize the efficiency gains and innovation brought by FinTech, there remains a gap in understanding its varied effects across different levels of bank performance and governance contexts. Using panel data from 2010 to 2022 and robust econometric techniques including MMQR and BSQR, we assess how FinTech and economic governance interact to influence banking outcomes.

The results show that financial technology is positively associated with bank performance across all quantiles, with stronger effects observed among lower-performing banks. This suggests that financial technology may offer greater relative benefits to less efficient institutions, possibly through improved access to digital services and cost-effective delivery models. However, these

benefits may be accompanied by operational risks and institutional challenges, particularly in under-regulated environments. Therefore, the impact of financial technology appears to be context-dependent and contingent on complementary institutional factors.

Economic governance is found to have a consistently positive relationship with bank performance across the distribution. Strong governance frameworks, characterized by accountability, regulatory quality, and institutional stability, appear to enhance the resilience and operational capacity of financial institutions. The interaction between financial technology and governance further reinforces these effects, indicating that financial technology adoption yields the best outcomes when embedded within a sound institutional environment. Among the control variables, GDP exhibits a statistically significant negative association with bank performance across quantiles. While this may reflect the pressures of rapid economic expansion on financial institutions, it also underscores the need for banks to strengthen risk management as economies grow. Inflation and capital adequacy, on the other hand, show positive associations with performance, aligning with theoretical expectations.

Limitations and prospects. This study is subject to several limitations that should be acknowledged. First, the exclusive reliance on quantitative panel data restricts the exploration of behavioral and contextual dynamics that are often better captured through qualitative methods. Consequently, deeper socio-institutional mechanisms influencing the relationship between financial technology, economic governance, and bank performance may remain underexplored.

Second, while the sample includes 33 developing Asian economies, the findings may not be generalizable to other regions due to significant variations in institutional quality, regulatory frameworks, and cultural settings. These regional differences limit the external validity of the results, particularly when applied to developed economies or low-income countries with weaker data availability.

Third, the post-2021 segment of the dataset shows a decline in available observations, which may introduce attrition bias. Although the core structure of the panel remains intact, future research should evaluate whether the missing data affects sample representativeness or alters underlying relationships.

Finally, this study does not account for certain emerging determinants of bank performance, such as environmental risks, cross-border trade linkages, or technological absorptive capacity. In addition, non-economic factors like institutional trust, digital literacy, and public attitudes toward financial surveillance were not captured in the model but may significantly shape FinTech adoption and governance effectiveness.

Moreover, these limitations suggest several avenues for future research. Mixed-method approaches, including case studies or expert interviews, could complement quantitative findings and provide a more nuanced understanding of institutional behavior. Expanding the geographic scope to include underrepresented regions (e.g., Sub-Saharan Africa, Latin America) would enhance comparative insights. Furthermore, interdisciplinary research that integrates political economy, sociology, and information systems perspectives may offer a richer, socially grounded view of digital financial transformation.

Data availability

The data used in this study are available from the corresponding author upon reasonable request.

Received: 13 January 2025; Accepted: 16 July 2025;

Published online: 02 September 2025

References

- Acar O, Çitak YE (2019) Fintech Integration Process Suggestion for Banks. *Procedia Computer Sci* 158:971–978. <https://doi.org/10.1016/j.procs.2019.09.138>
- Ali K, Hongbing H, Liew CY, Jianguo D (2023) Governance perspective and the effect of economic policy uncertainty on financial stability: evidence from developed and developing economies. *Economic Change Restruct* 56(3):1971–2002. <https://doi.org/10.1007/s10644-023-09497-6>
- Aniqoh NAFA, Nihayah AZ, Amalia F (2022) The Role of Digital Banking Industry Towards Consumer Behavior During The Covid 19. *J Digital Mark Halal Ind* 4(2):75–88. <https://doi.org/10.21580/jdmhi.2022.4.2.13378>
- Antwi-Wiafe K, Asante GN, Takyi PO (2023) Is financial technology a complement or substitute for domestic financial institutions in Ghana? *J Financ Econ Policy*. <https://doi.org/10.1108/JFEP-02-2023-0038>
- Arnoud Boot, BY, Hoffmann, P, Laeven, L, Ratnovski, L, Soledad Martinez Peria, M, Beyer, A, Colliard, J-E, Faltermeier, J, Heider, F, Hertig, G, Mancini-Griffoli, T, Manganelli, S, Martin, A, & Schepens, G (2020). Financial Intermediation and Technology: What's Old, What's New? Authorized for distribution by (20; 161)
- Asian Development Bank (2021) Fintech to Enable Development, Investment, Financial Inclusion, and Sustainability: <https://doi.org/10.22617/TCS210190-2>
- Athari SA, Saliba C, Khalife D, Salameh-Ayanian M (2023) The Role of Country Governance in Achieving the Banking Sector's Sustainability in Vulnerable Environments: New Insight from Emerging Economies. *Sustainability* 15(13):10538. <https://doi.org/10.3390/su151310538>
- Aziz N, Mihadjo LW, Sharif A, Jermisittiparsert K (2020) The role of tourism and renewable energy in testing the environmental Kuznets curve in the BRICS countries: fresh evidence from methods of moments quantile regression. *Environ Sci Pollut Res* 27(31):39427–39441. <https://doi.org/10.1007/s11356-020-10011-y>
- Bakar S (2020) Fintech Investment And Banks Performance In Malaysia, Singapore & Thailand. 610–618. <https://doi.org/10.15405/epsbs.2020.12.05.66>
- Banna H, Alam MR (2021) Does digital financial inclusion matter for bank risk-taking? evidence from the dual-banking system. *J Islamic Monetary Econ Financ* 7(2):401–430. <https://doi.org/10.21098/jimf.v7i2.1320>
- Bashayreh Ala'and Wadi, RMA (2021) The Effect of Fintech on Banks' Performance: Jordan Case. In A. and E. I. Alareeni Bahaeddinand Hamdan (Ed.), *The Importance of New Technologies and Entrepreneurship in Business Development: In The Context of Economic Diversity in Developing Countries* (pp. 812–821). Springer International Publishing
- Belanche D, Casaló LV, Flavián C (2019) Artificial Intelligence in FinTech: understanding robo-advisors adoption among customers. *Ind Manag Data Syst* 119(7):1411–1430. <https://doi.org/10.1108/IMDS-08-2018-0368>
- Bellardini L, Del Gaudio BL, Previtali D, Verdoliva V (2022) How do banks invest in fintechs? Evidence from advanced economies. *J Int Financial Mark, Inst Money* 77:101498. <https://doi.org/10.1016/j.intfin.2021.101498>
- Bin-Nashwan SA (2022) Toward diffusion of e-Zakat initiatives amid the COVID-19 crisis and beyond. *Foresight*, 24(2). <https://doi.org/10.1108/FS-08-2020-0082>
- Canay IA (2011) A simple approach to quantile regression for panel data. *Econ J* 14(3):368–386. <https://doi.org/10.1111/j.1368-423X.2011.00349.x>
- Chan S-G, Ramly Z, Karim MZA (2017) Government Spending Efficiency on Economic Growth: Roles of Value-added Tax. *Glob Economic Rev* 46(2):162–188. <https://doi.org/10.1080/1226508X.2017.1292857>
- Chan S-G, Ramly Z, Zulkhairi M (2021) Value-added tax and economic efficiency: Role of country governance. *Panoeconomicus* 68(3):325–358. <https://doi.org/10.2298/PAN18021020C>
- Chege SM, Wang D, Suntu SL (2020) Impact of information technology innovation on firm performance in Kenya. *Inf Technol Dev* 26(2):316–345. <https://doi.org/10.1080/02681102.2019.1573717>
- Chen X, You X, Chang V (2021) FinTech and commercial banks' performance in China: A leap forward or survival of the fittest? *Technol Forecast Soc Change* 166:120645
- Chen Z, Xing R (2025) Digital economy, green innovation and high-quality economic development. *Int Rev Econ Financ* 99:104029. <https://doi.org/10.1016/j.ieref.2025.104029>
- Cheng M, Qu Y (2020) Does bank FinTech reduce credit risk? Evidence from China. *Pac -Basin Financ J* 63:101398. <https://doi.org/10.1016/j.pacfin.2020.101398>
- Dasilas A, Karanović G (2023) The impact of FinTech firms on bank performance: evidence from the UK. *EuroMed J Business*. <https://doi.org/10.1108/EMJB-04-2023-0099>

- Deng L, Lv Y, Liu Y, Zhao Y (2021) Impact of Fintech on Bank Risk-Taking: Evidence from China. *Risks* 9(5):99. <https://doi.org/10.3390/risks9050099>
- Dumitrescu EI, Hurlin C (2012) Testing for Granger non-causality in heterogeneous panels. *Econ Modelling* 29(4). <https://doi.org/10.1016/j.econmod.2012.02.014>
- Elia G, Stefanelli V, Ferilli GB (2023) Investigating the role of Fintech in the banking industry: what do we know? *Eur J Innov Manag* 26(5):1365–1393. <https://doi.org/10.1108/EJIM-12-2021-0608>
- Elsaid HM (2023) A review of literature directions regarding the impact of fintech firms on the banking industry. *Qualitative Res Financial Mark* 15(5):693–711. <https://doi.org/10.1108/QRFM-10-2020-0197>
- Erickson M (2021) Moderating Effect of Political Instability on ICT and Economic Growth Nexus in Kenya: ARDL Bound - Co-Integration Approach. *J Econ, Financ Manag Stud* 04(10). <https://doi.org/10.47191/jefms/v4-i10-08>
- Fu J, Mishra M (2022) Fintech in the time of COVID–19: Technological adoption during crises. *J Financ Intermediati* 50. <https://doi.org/10.1016/j.jfi.2021.100945>
- Haile MA, MK J, Mulugeta W (2025) Does regulatory convergence shape banking resilience in Africa *Heliyon* 11(1):e41347. <https://doi.org/10.1016/j.heliyon.2024.e41347>
- Hashem Pesaran M, Yamagata T (2008) Testing slope homogeneity in large panels. *J Econometr* 142(1). <https://doi.org/10.1016/j.jeconom.2007.05.010>
- Hassan MIU, Wu M, Awan MB, Anjum HN, Akhtar S (2023) Examining the contribution of fiscal policy on economic growth: Analytical insights from Pakistan. *Int J Emerg Trends Soc Sci* 15(2):24–30. <https://doi.org/10.55217/103.v15i2.693>
- Hassan MIU, Wu M, Rasool Y, Sohu JM, Ali S (2025) The Role of the Blue Economy, Renewable Energy, and Energy Intensity in Mitigating CO₂ Emissions: Evidence from China Using MMQREG Analysis. *Geol J*. <https://doi.org/10.1002/gj.5224>
- Hu H, Jia Z, Yang S (2025) Exploring FinTech, green finance, and ESG performance across corporate life-cycles. *Int Rev Financial Anal* 97:103871. <https://doi.org/10.1016/j.irfa.2024.103871>
- Im KS, Pesaran MH, Shin Y (2003) Testing for unit roots in heterogeneous panels. *J Econ* 115(1):53–74. [https://doi.org/10.1016/S0304-4076\(03\)00092-7](https://doi.org/10.1016/S0304-4076(03)00092-7)
- Jarque CM, Bera AK (1987) A Test for Normality of Observations and Regression Residuals. *Int Stat Rev / Rev Int de Statistique* 55(2):163. <https://doi.org/10.2307/1403192>
- Jourdan Z, Corley JK, Valentine R, Tran AM (2023) Fintech: A content analysis of the finance and information systems literature. *Electron Mark* 33(1):2. <https://doi.org/10.1007/s12525-023-00624-9>
- Katsiampa P, McGuinness PB, Serbera JP, Zhao K (2022) The financial and prudential performance of Chinese banks and Fintech lenders in the era of digitalization. *Rev Quant Financ Account* 58(4). <https://doi.org/10.1007/s11156-021-01033-9>
- Kayed S, Alta'any M, Meqbel R, Khatatbeh IN, Mahafzah A (2025) Bank FinTech and bank performance: evidence from an emerging market. *J Financial Report Account* 23(2):518–535. <https://doi.org/10.1108/JFRA-09-2023-0526>
- Keliuotyte-Staniulienė G, Smolskytė G (2019) Possibilities for Financial Technology Sector Development and its Impact on Banking Sector Profitability in Lithuania. *Econ Cult* 16(1):12–23. <https://doi.org/10.2478/jec-2019-0002>
- Kharrat H, Trichilli Y, Abbes B (2023) Relationship between FinTech index and bank's performance: a comparative study between Islamic and conventional banks in the MENA region. *J Islamic Account Business Res*. <https://doi.org/10.1108/JIABR-03-2022-0081>
- Khatun MN, Mitra S, Sarker MNI (2021) Mobile banking during COVID-19 pandemic in Bangladesh: A novel mechanism to change and accelerate people's financial access. *Green Financ* 3(3):253–267. <https://doi.org/10.3934/GF.2021013>
- Koenker R (2004) Quantile regression for longitudinal data. *J Multivar Anal* 91(1):74–89. <https://doi.org/10.1016/j.jmva.2004.05.006>
- Koenker R, Bassett G (1978) Regression Quantiles. *Econometrica* 46(1):33. <https://doi.org/10.2307/1913643>
- Kurniawati RZA (2023) The Influence of FinTech and Banks Collaboration towards Banks Performance: Indonesian Banks Listed. *J Bus, Manag, Soc Stud* 2(4):166–174. <https://doi.org/10.53748/jbms.v2i4.50>
- Lagna A, Ravishanker MN (2022) Making the world a better place with fintech research. *Inf Syst J* 32(1):61–102. <https://doi.org/10.1111/isj.12333>
- Lee CC, Li X, Yu CH, Zhao J (2021) Does fintech innovation improve bank efficiency? Evidence from China's banking industry. *Int Rev Econ Financ* 74. <https://doi.org/10.1016/j.iref.2021.03.009>
- Lestari D, Rahmanto BT (2021) Fintech and its challenge for banking sector. *Manag J Binaniaga* 6(1):55. <https://doi.org/10.33062/mjb.v6i1.428>
- Levin A, Lin CF, Chu CSJ (2002) Unit root tests in panel data: Asymptotic and finite-sample properties. *J Econometr* 108(1). [https://doi.org/10.1016/S0304-4076\(01\)00098-7](https://doi.org/10.1016/S0304-4076(01)00098-7)
- Liu M, Tripe DWL, Jiang W (2020) Does FinTech Increase or Reduce Commercial Banks' Risk-taking? Evidence from China's Banking Sector
- Machado JAF, Santos Silva JMC (2019) Quantiles via moments. *J Econ* 213(1):145–173. <https://doi.org/10.1016/J.JECONOM.2019.04.009>
- Maryunita L, Nugroho IT (2022) Fintech Innovation and Bank Efficiency in Indonesia. *Khazanah Sos* 4(4):626–635. <https://doi.org/10.15575/ks.v4i4.20239>
- Micu I, Micu A (2016) Financial technology (fintech) and its implementation on the romanian non-banking capital market. *SEA - Practical Application Sci* 11:379–384. <https://econpapers.repec.org/RePEc:cmj:seapasy:2016:i:11:p:379-384>
- Molonko B, Ampah SN (2017) Moderating Effect of Political Risk on the Relationship between Capital Expenditure and Sectoral Economic Growth in Kenya. *Int J Econ Financ* 10(1):129. <https://doi.org/10.5539/ijef.v10n1p129>
- Nguyen DT, Le TD, Ho TH, Ngo T (2022) A cross-country analysis on diversification, Sukuk investment, and the performance of Islamic banking systems under the COVID-19 pandemic. *Heliyon* 8(3):e09106. <https://doi.org/10.1016/j.heliyon.2022.e09106>
- Nguyen L, Tran S, Ho T (2022) Fintech credit, bank regulations and bank performance: a cross-country analysis. *Asia-Pacific J Business Administr* 14(4). <https://doi.org/10.1108/APJBA-05-2021-0196>
- Nguyen TAN (2022) Does Financial Knowledge Matter in Using Fintech Services? Evidence from an Emerging Economy. *Sustainability* 14(9):5083. <https://doi.org/10.3390/su14095083>
- Ogbuabor JE, Emeka ET, Nwosu EO (2023) Effects of terrorism and economic policy uncertainty on economic complexity in Africa: A study of the moderating role of governance institutions. *South Afr J Econ* 91(4):528–557. <https://doi.org/10.1111/saje.12353>
- Olena E, Oksana K, Tetiana G (2021) Banking digitalization during the covid-19 pandemic. *Her Kyiv Natl Univ Trade Econ* 140(6):133–146. [https://doi.org/10.31617/visnik.knute.2021\(140\)11](https://doi.org/10.31617/visnik.knute.2021(140)11)
- Omarini A (2024) Bank and fintech for transformation of financial services: what to keep and what is changing in the industry. *J financial Transform* 58:104–113. <https://iris.unibocconi.it/handle/11565/4061700>
- Ozili PK (2018) Banking stability determinants in Africa. *Int J Manag Financ* 14(4):462–483. <https://doi.org/10.1108/IJMF-01-2018-0007>
- Pandey DK, Hassan MK, Kumari V, Zaied YBen, Rai VK (2024) Mapping the landscape of FinTech in banking and finance: A bibliometric review. *Res Int Bus Financ* 67:102116. <https://doi.org/10.1016/j.ribaf.2023.102116>
- Pavlov O, Yan C, Bakkar Siddik A, Yong L, Dong Q, Zheng G-W, Nafizur Rahman M (2022) A Two-Stage SEM-Artificial Neural Network Approach to Analyze the Impact of FinTech Adoption on the Sustainability Performance of Banking Firms: The Mediating Effect of Green Finance and Innovation. <https://doi.org/10.3390/systems10050148>
- Pellegrino A, Abe M (2022) Digital financing for SMEs' recovery in the post-COVID era: A bibliometric review. *Front Sustain Cities* 4. <https://doi.org/10.3389/frsc.2022.978818>
- Pesaran MH (2004) General diagnostic tests for cross section dependence in panels. University of Cambridge, Faculty of Economics, Cambridge Working Papers in Economics No. 0435. Center for Economic Studies & Ifo Institute for Economic Research CESifo, 1229
- Pesaran MH, Yamagata T (2021) Testing Slope Homogeneity in Large Panels. *SSRN Electronic J*. <https://doi.org/10.2139/ssrn.671050>
- Phan DHB, Iyke BN, Sharma SS, Affandi Y (2021) Economic policy uncertainty and financial stability—Is there a relation? *Economic Model* 94:1018–1029. <https://doi.org/10.1016/j.econmod.2020.02.042>
- Phan DHB, Narayan PK, Rahman RE, Hutabarat AR (2020) Do financial technology firms influence bank performance? *Pac -Basin Financ J* 62:101210. <https://doi.org/10.1016/j.pacfin.2019.101210>
- Qazi A (2025) Fostering economic development and sustainability: insights into the role of regulatory quality and e-commerce legislation in future technologies. *Int J Innov Sci*. <https://doi.org/10.1108/IJIS-04-2024-0091>
- Rahman A, Islam S (2021) Covid-19 brings blessing for digital-banking in world-economy country-wise: an analysis under demand-supply model of market economics. *J Bus Economic Dev* 6(2):65. <https://doi.org/10.11648/jbed.20210602.12>
- Sarkodie SA, Strezov V (2019) Effect of foreign direct investments, economic development and energy consumption on greenhouse gas emissions in developing countries. *Sci Total Environ* 646:862–871. <https://doi.org/10.1016/J.SCITOTENV.2018.07.365>
- Shabir M, Jiang P, Hashmi SH, Bakhsh S (2022) Non-linear nexus between economic policy uncertainty and bank lending. *Int Rev Econ Financ* 79:657–679. <https://doi.org/10.1016/j.iref.2022.02.016>
- Thottoli MM (2024) The tactician role of FinTech in the accounting and auditing field: a bibliometric analysis. *Qualitative Res Financial Mark* 16(2):213–238. <https://doi.org/10.1108/QRFM-11-2021-0196>
- Toumi A, Najaf K, Dhiaf MM, Li NS, Kanagasabapathy S (2023) The role of Fintech firms' sustainability during the COVID-19 period. *Environ Sci Poll Res* 30(20). <https://doi.org/10.1007/s11356-023-26530-3>
- Tufail M, Song L, Ali S, Wahab S, Hassan T (2023) Does more immigration lead to more violent and property crimes? A case study of 30 selected OECD countries. *Economic Res -Ekonomiska Istraživanja* 36(1):1867–1885. <https://doi.org/10.1080/1331677X.2022.2094437>

- Verma D, Chakarwarty Y (2024) Impact of bank competition on financial stability—a study on Indian banks. *Competitiveness Rev: Int Bus J* 34(2):277–304. <https://doi.org/10.1108/CR-07-2022-0102>
- Wang L, Zhang J, Chen W, Fu F, Qian K (2020) Short term crack width prediction of CFRP bars reinforced coral concrete. *Eng Struct* 218:110829. <https://doi.org/10.1016/j.ENGSTRUCT.2020.110829>
- Wang Q, Li L, Hu S (2021) Computer network information security protection faced by digital art museums based on the internet of things. *Wirel Commun Mob Comput* 2021:1–10. <https://doi.org/10.1155/2021/2297733>
- Westerlund J (2007) No Title. *Oxf Bull Econ Stat* 69(6):709–748. <https://doi.org/10.1111/j.1468-0084.2007.00477.x>
- Wibowo M, Kusuma H, Qizam I (2021) The role of institution and macroeconomic policy mix on economic growth in muslim country. *Int J Islamic Econ Financ (Ijief)* 5(1):59–88. <https://doi.org/10.18196/ijief.v5i1.11646>
- World bank (2021).The Global Findex 2021: Interactive Executive Summary Visualization. Global Findex 2021 Report. <https://www.worldbank.org/en/publication/globalfindex/interactive-executive-summary-visualization>
- Yan J, Jia P (2022) The Impact of COVID-19 on Bank Sector Traditional Business Model Sustainability in China: Bank Branch Versus Fintech. *Front Phys* 10. <https://doi.org/10.3389/fphy.2022.820646>
- Yin F, Jiao X, Zhou J, Yin X, Ibeke E, Iwendi MG, Biamba C (2022) Fintech application on banking stability using Big Data of an emerging economy. *J Cloud Comput* 11(1):43. <https://doi.org/10.1186/s13677-022-00320-7>
- Yudaruddin R (2023) Financial technology and performance in Islamic and conventional banks. *J Islamic Account Bus Res* 14(1):100–116. <https://doi.org/10.1108/JIABR-03-2022-0070>
- Yuliani I, Qizam I, Nugroho A, Mu'arrif ZI (2022) The Impact of Sukuk On The Country's Economic Growth with Country Governance as a Moderating Variable. *Al-Uqud : J Islamic Econ* 6(1):135–148. <https://doi.org/10.26740/aluqud.v6n1.p135-148>
- Zhao J, Li X, Yu CH, Chen S, Lee CC (2022) Riding the FinTech innovation wave: FinTech, patents and bank performance. *J Int Money Financ* 122:102552. <https://doi.org/10.1016/j.jimonfin.2021.102552>

Author contributions

MIH: conceptualisation, methodology, software, data curation, formal analysis, visualisation, and writing the original draft. WM: Review and editing, supervision, and conceptualisation. LJ: provided critical input during revisions, especially on methodology and theory, and will manage journal correspondence. JMS: methodology, software, data curation. SA: Review and editing. HNA: Formal analysis. MB: Software and visualisation.

Competing interests

The authors declare no competing interests.

Ethical approval

This article does not contain any studies with human participants performed by any of the authors.

Informed consent

This article does not contain any studies with human participants performed by any of the authors.

Additional information

Correspondence and requests for materials should be addressed to Jie Lu.

Reprints and permission information is available at <http://www.nature.com/reprints>

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.



Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

© The Author(s) 2025