“The impact of digital investment, cost efficiency, and risk profile on bank stability: Evidence from Jordanian banks”

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THE IMPACT OF DIGITAL INVESTMENT, COST EFFICIENCY, AND RISK PROFILE ON BANK STABILITY: EVIDENCE FROM JORDANIAN BANKS

Abstract

The digitalization of banking operations and resource allocation has opened up possibilities to enhance financial resilience but has also raised operating cost and performance volatility challenges. This study aims to investigate the relationship between digital investment, operating efficiency, operating income volatility, and bank stability for Jordanian listed banks. The secondary data included audited annual reports and financial statements of 15 banks, with an equal number of banks from the Amman Stock Exchange for the period 2014–2024, resulting in a balanced panel of 165 bank-year observations. The pooled OLS, fixed-effects, and random-effects models were first estimated, and then the best model was selected using the cross-section F-test, Breusch–Pagan LM test, and Hausman specification test. This result bolsters the fixed-effects estimator, and the final model includes bank and year effects and uses bank-clustered robust standard errors. Digital investment intensity is positively and significantly related to bank stability (coefficient = 0.284, p = 0.004). By contrast, operating-income volatility has a negative association with bank stability (coefficient = –0.198, p = 0.031), and the cost-to-income ratio also has a significant negative association with bank stability (coefficient = –0.246, p = 0.005). The stability coefficient is negative and significant (–0.121, p = 0.049) regarding bank size. The between-bank variation is about 11% of the total, and the fixed-effects model accounts for about 51% of this variation. The results show that investment in technology, operating efficiency, and the management of volatility in operating performance are closely linked to bank stability in Jordan.

Keywords resilience, fintech, efficiency, cybersecurity, innovation

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INTRODUCTION

Jordan provides an important setting for examining bank stability because its financial system is strongly bank-based, making banks central to financial intermediation, credit provision, and economic activity. The sector is also relatively concentrated, which increases the systemic importance of the largest institutions and makes differences in bank-level resilience particularly relevant. At the same time, Jordanian banks have experienced rapid digital transformation through the expansion of mobile banking, digital payments, online financial services, automated systems, and technology-enabled customer channels. This transformation has increased competitive pressure on banks to invest in information systems, digital infrastructure, cybersecurity, and service innovation. The regulatory environment has evolved in parallel, with the Central Bank of Jordan promoting financial inclusion, digital payment systems, fintech development, and regulatory experimentation through dedicated innovation initiatives and sandbox mechanisms.

Jordan is also exposed to changing macroeconomic conditions, including moderate economic growth, interest-rate movements, region-

al geopolitical uncertainty, and the effects of the COVID-19 period. These factors may influence profitability, operating costs, risk exposure, and the ability of banks to absorb shocks. Fintech competition further increases pressure on traditional banks to modernize their operations while maintaining efficiency and financial resilience. Importantly, the present study does not treat "digital opportunities" and "digital risks" as broad unmeasured concepts. Digital investment intensity is the direct technology-related variable and is measured as identifiable technology expenditure relative to total operating expenses. The cost-to-income ratio is used as a measure of operating efficiency, while operating-income volatility captures broader operating risk. Accordingly, Jordan offers a useful emerging-market context for examining whether technology investment, operating efficiency, and operating-performance volatility are jointly associated with bank stability.

1. LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

The stability of banks is a cornerstone of the proper functioning of financial systems, sustainable economic growth, and macroeconomic resilience. Stable banks assist in the intermediation process; ensure depositor confidence; enable private sector financing; and help minimize the risk of the financial distress of the institution becoming systemic. Traditional banking research highlighted the importance of the determinants of bank stability, which include capital adequacy, liquidity, profitability, asset quality, operating efficiency, and risk exposure of banks (Jalloul & Haque, 2025; Ally et al., 2025; Chen et al., 2025; Olowofela et al., 2025). These factors continue to be significant but, with the increasing digitization of banking, technological and operational aspects have added more dimensions that may impact banks' financial stability. Mobile and Internet banking, artificial intelligence, cloud computing, big data analytics, digital payments, automated processes, and technology-enabled decision systems have increasingly seeped into the banking sector, establishing digital transformation as a major part of the banking landscape. Investments in those technologies can provide important organizational capabilities from a resource-based view, such as enhanced information processing, service delivery, coordination, monitoring, and organizational responsiveness. The following is evidence from banking that supports this argument. Digital transformation can contribute to the organizational agility and resilience of the company, as discussed by Probojakti et al. (2025), and can directly affect the stability of banks, as discussed by Khattak et al. (2023), depending on the bank's strategic characteristics. Similarly, Liang et al. (2025) find that digital financial development can boost commercial-bank stability via profitability and risk-taking capacity channels as well as via the operating-efficiency channel. But digital investment does not necessarily bring you immediate monetary gains. The costs that banks must invest in software, information systems, digital infrastructure, cybersecurity, staff training, systems integration, and regular technological improvement are high. Such costs can go up in the short term but improve in the long term. In an emerging market context, by analyzing banks, Elmahdy et al. (2025) conclude that the implementation of FinTech can negatively impact profitability at the start due to high costs of digitalization, but after this, operating efficiency could be an important channel through which the benefits of FinTech could eventually be realized. Uddin et al. (2020) also show that the effect of technology investments in banks could be nonlinear with respect to the stability effect: Bank spending in CyberTech could be stabilizing up to a certain level, but spending above a threshold level may be destabilizing.

Such mixed evidence suggests digital investment should not be taken for granted to boost the stability of banks. The authors suggest that digital transformation might have different stability effects depending on diversification, for instance (Khattak et al., 2023); and evidence from emerging banking markets indicates that tech adoption can come at a price and offer advantages. Further evidence supports the growing significance of the use of FinTech, digital banking infrastructure, and business intelligence (BI) in banking (Bani Atta, 2025a, 2025b; Alzubi, 2025a, 2025b). Thus, it is still an important empirical question wheth-

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er digital investment is associated with financial stability. Importantly, in the present study, there are two types of technology-related variables: a direct type and a broader type of financial variable that might be influenced by digital transformation. The direct measure of technology investment, which is a clear technology-related expense, is digital investment intensity, defined as the amount of identifiable investment in information technology, information systems, software, digital infrastructure, and related technology activities as a share of total operating expenditure. The distinction is important to avoid general operating indicators being misinterpreted as indicators of digitalization.

The second one is related to operating efficiency. An efficient bank can tend to have lower costs, make a profit, save money, and withstand financial shocks. Empirical studies have shown that cost and operating efficiency are crucial for banking performance and resilience (Abbas et al., 2025; Seelanatha & Natoli, 2025). The relationship can be impacted by digitalization, as automation, better information management, lower transaction costs, efficient service delivery, and better standardization can help banks to be more efficient. Goel and Kashiramka (2025) link FinTech development to banking efficiency, whereas Liang et al. (2025) relate operating efficiency to bank stability as an important channel between digital financial development and bank stability. Shen et al. (2025) examine panel data spanning 131 commercial banks and find that digital transformation positively influences bank cost efficiency via various channels, such as lower information asymmetries, better fund usage, diversification of business activities, as well as lower risk levels. Elmahdy et al. (2025) provide a similar argument to the one presented above regarding the role of operating efficiency in the transmission of financial impacts to countries adopting FinTech. However, gains in efficiency may not be realized right away following investment in digital technologies. Initial costs are needed in technology adoption – infrastructure, software, integration, staff skills, maintenance, and cybersecurity. Thus, for banks, a transition period can be a time of higher bank technology spending and higher operating costs until the efficiencies are substantial enough to offset these costs. This offers a likely reason why there are conflicting reports on the financial impacts of digital transformation in the short- and long-term. The cost-to-income ratio, therefore, is not "digital cost efficiency," as described in this study, but rather a more general concept of cost efficiency. The ratio of cost to income, however, is considered a general operating-efficiency measure: operational expenses divided by operational income. The higher the number, the lower the operating efficiency is. While technology adoption can impact this ratio, there are other bank-specific factors that can impact operating costs and operating revenues. Treating it as a general efficiency measure, therefore, yields a measure of the theoretical construct more in line with its empirical measurement. The third mechanism is related to operating risk and earnings volatility. Digitalized banks rely more on complex technological infrastructure, which can lead to disruptions, processing failures, cybersecurity risks, fraud, data-management issues, third-party dependencies, and other operational risks. According to Uddin et al. (2023), based on international bank-level data, digitalized banking operations can actually exacerbate operational-risk exposure due to the growth in business volume associated with the use of technology and, at the same time, expose the bank to various risks such as system failures, process disruptions, and security issues. Technology and stability are thus not always a one-way street. Uddin et al. (2020) show that CyberTech spending can increase the stability of banks within a range, but decrease stability when spending is above a certain limit. Likewise, Khan et al. (2023) consider the implications of the introduction of FinTech for banks' stability and conclude that the impact of FinTech is partly determined by the regulatory regime, capitalization, bank size, competition, and other institutional factors of banks in the GCC. The benefits of digital banking will be even more relevant to the Jordanian context, as it implies the ability to address the operational and regulatory risks that can arise along with it are inextricable from the institutions' ability to deliver on the benefits.

There is also evidence related to technological and operational risk management. Mirza et al. (2025) and Ojha et al. (2025) share a focus on cybersecurity and digital-infrastructure vulnerabilities in today's financial systems, and Ionescu et al. (2025) highlight the role of technology investment and banking performance in relation to financial sta-

bility. Newer studies also indicate that FinTech security can have an impact on the stability of commercial banks via the channels of customer trust as well as regulatory pressure. It is important to note, however, that the empirical variable used in the current study needs to be differentiated from direct measures of cybersecurity and/or technology-specific risk. Operating-income volatility reflects the operating performance of a bank and is thus a more general measure of operating risk. It does not directly assess cybersecurity incidents, failures on digital platforms, or losses of technologies, or vulnerabilities specific to FinTech. For this reason, the term 'digital risk profile' is not used in the revised study. This separation is a direct connection between theory and the variable that is used in the empirical model. Additionally, the digitalization–stability relationship can be affected by the institutional environment. The implications of digital financialization on stability in the emerging market might not be as apparent as in more developed markets, especially when the rate of technology advancement outpaces the rate of regulatory and risk-management development (Hordofa, 2024). Likewise, Khan et al. (2023) show that the FinTech–bank-stability nexus in the GCC economies is significantly impacted by FinTech regulation as well as the overall regulatory environment.

Jordan is hence an appropriate context. The banking industry is coexisting with the growth of digital financial services, electronic payments, FinTech, and regulatory innovation in the country. Central Bank of Jordan's (2024) National Financial Inclusion Strategy 2023–2028 highlights the following areas as important pillars of modernizing the financial sector: FinTech and innovation, payments and transfers, regulatory development, and increased access to financial services. The Central Bank's JoRegBox regulatory sandbox also offers a safe space for consumers, competitors, financial-system stability, and cybersecurity to be considered alongside testing for innovative financial technologies. It's crucial that this regulation comes because Jordanian banks are not only competitive against each other but also are under growing pressure from financial services offered by FinTech companies, as well as shifting customer expectations. Neighboring GCC banking systems have demonstrated the close interconnections of the experience of adopting, competing, regulating, and achieving financial stability in FinTech (Khan et al., 2023). Furthermore, the evidence from MENA shows that financial stability and performance of banks are very vulnerable to macroeconomic shocks and institutional arrangements (Mateev et al., 2025; Jalloul & Haque, 2025; Atieh, 2025). Jordan is therefore an emerging market that's ideal for examining the interplay of technological investments and shifts in operating costs, risk, regulation, and competition.

Although there is a steadily expanding body of literature, an important need is missing. Previous studies focus on digital transformation and stability (Khattak et al., 2023; Liang et al., 2025), digital transformation and cost efficiency (Shen et al., 2025), FinTech and operating efficiency (Elmahdy et al., 2025), and digitalization and operational risk (Uddin et al., 2023). There is also a large body of evidence outside Jordan. Therefore, this study investigates the digital investment intensity, operating efficiency, operating-income volatility, and bank stability of listed Jordanian banks within a limited sample of banks across the Jordanian stock exchange from a long-term perspective. This makes it possible, within the framework of this study, to distinguish between three dimensions of explanation. Digital investment intensity is a measure of direct technology investment, cost-to-income ratio is a measure of operating efficiency, and operating-income volatility is a measure of operating risk. This approach refrains from considering all three as digitalization and allows for a more exact analysis of the specific relationships between the measures of digitalization and bank stability.

The study is aimed to analyze the correlation between digital investment, cost-to-income ratio and operating-income volatility of the listed Jordanian banks and their stability, for the purpose of enabling a more accurate determination of the separate contribution of the variables of digital investment, operating efficiency and operating risk in the stability of banks. Given the above theoretical and empirical evidence, the following hypotheses are put forward:

H1: Digital investment intensity is positively associated with bank stability.

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H2: The cost-to-income ratio is negatively associated with bank stability.

H3: Operating-income volatility is negatively associated with bank stability.

2. METHOD

This study uses secondary bank-level data from the audited annual reports and financial statements of Jordanian banks listed on the Amman Stock Exchange (ASE), together with relevant financial disclosures published on the official websites of the sampled banks. These sources provide consistent and comparable financial information across banks and over time. Data were collected on technology-related expenditure, operating expenses, operating income, profitability, total assets, capitalization, and other financial indicators required to construct the study variables. The study covers the period 2014–2024 and includes banks for which the required financial information was available throughout the study period. The final sample consists of 15 Jordanian listed banks observed over 11 years, yielding a balanced panel of 165 bank-year observations. The panel structure allows the analysis to exploit both cross-sectional differences among banks and changes within individual banks over time, which is a principal advantage of panel-data analysis (Abu-AlSondos, 2025; Baltagi, 2021; Wooldridge, 2010; Abualrejal et al., 2021).

Bank stability is the dependent variable and is measured using the conventional bank Z-score, a widely applied accounting-based indicator of bank insolvency risk and financial stability (Lepetit & Strobel, 2013). The measure combines profitability, capitalization, and earnings volatility and is calculated as follows:

$$Z_{it} = \frac{ROA_{it} + ETA_{it}}{\sigma(ROA)_i}, \quad (1)$$

where (ROA_{it}) denotes return on assets for bank (i) in year (t), (ETA_{it}) represents the equity-to-total-assets ratio, and (σROA_i) represents the standard deviation of return on assets. A higher Z-score indicates greater distance from insolvency and therefore a higher level of bank stability (Alrifae et al., 2026; Alobaydi et al., 2025; Mahmoud et al., 2025; Lepetit & Strobel, 2013). The study examines three main explanatory variables. Digital investment intensity (DII) represents the proportion of operating resources allocated to information technology and technology-related activities. It is calculated as:

$$DII_{it} = \frac{IT \text{ and } technology\text{-}related\ expenditure_{it}}{Total\ operating\ expenses_{it}}. \quad (2)$$

Technology-related expenditure was manually extracted from the sampled banks' annual reports based on identifiable disclosures concerning information technology, information systems, digital infrastructure, software, and other technology-related activities. Because the numerator directly captures identifiable technology expenditure, DII is treated as the principal digitalization-related measure in this study.

Operating efficiency is represented by the cost-to-income ratio (CIR), calculated as:

$$CIR_{it} = \frac{Operating\ expenses_{it}}{Operating\ income_{it}}. \quad (3)$$

A higher cost-to-income ratio indicates that a bank incurs greater operating expenses compared to the income it generates and therefore reflects lower operating efficiency. Importantly, the cost-to-income ratio is treated as a general bank operating-efficiency indicator rather than as a direct measure of digitalization. Although digital transformation may affect banks' cost structures, the ratio itself does not isolate expenditure or outcomes specifically attributable to digital activities. Operating-income volatility (*OIV*) is used as an indicator of operating risk and is measured using the standard deviation of operating income. Higher values indicate greater variability in operating performance. The variable is therefore interpreted as an operating risk indicator rather than as a direct measure of technology-specific or digital risk. This distinction ensures closer consistency between the conceptual interpretation of the variable and its actual empirical measurement. Two bank-level control variables are included in the empirical model. Return on assets (*ROA*) represents profitability and is calculated as net income divided by total assets. Bank size (*SIZE*) controls

for differences in institutional scale, financial capacity, and resource availability and is measured as the natural logarithm of total assets. The relationships between digital investment intensity, operating efficiency, operating-income volatility, and bank stability are examined using panel-data regression analysis. Panel-data methods are appropriate because the dataset combines observations across individual banks and over time and permits the consideration of unobserved bank-specific heterogeneity (Baltagi, 2021; Wooldridge, 2010). The empirical model is specified as follows:

$$\alpha + \beta_1 DII_{it} + \beta_2 CIR_{it} + \beta_3 OIV_{it} + \beta_4 ROA_{it} + \beta_5 SIZE_{it} + \mu_i + \lambda_t + \varepsilon_{it}, \quad (4)$$

where (FS_{it}) represents the Z-score of bank (i) in year (t); (DII_{it}) represents digital investment intensity; (CIR_{it}) represents the cost-to-income ratio; (OIV_{it}) represents operating-income volatility; ($ROAit$) represents profitability; and ($SIZE_{it}$) represents bank size. The term (α) is the intercept, (β_1-β_5) are the estimated coefficients, (μ_i) captures unobserved bank-specific effects, (λ_t) represents common year-specific effects, and (ε_{it}}) is the idiosyncratic error term. The empirical analysis is based entirely on panel-data regression rather than structural equation modeling. Pooled ordinary least squares (*OLS*), fixed-effects (*FE*), and random-effects (*RE*) specifications were considered as alternative estimators. Following established panel-data procedures (Baltagi, 2021; Wooldridge, 2010), model-selection tests were used to determine the appropriate specification. The cross-section F-test was used to assess whether bank-specific fixed effects were jointly significant relative to pooled OLS. The Breusch–Pagan Lagrange Multiplier test was applied to examine whether the random-effects specification provided an improvement over pooled OLS (Breusch & Pagan, 1980). The Hausman specification test was then used to distinguish between fixed-effects and random-effects estimation by assessing whether the random-effects estimator was consistent (Hausman, 1978). Year effects were incorporated into the empirical specification to account for common time-varying shocks affecting all sampled banks during 2014–2024. Such effects are particularly relevant because banks may simultaneously be exposed to macroeconomic changes, regulatory developments, interest-rate movements, the COVID-19 period, and sector-wide changes in banking technology. Controlling for both bank-specific and time-specific heterogeneity is consistent with established panel-data practice (Baltagi, 2021; Wooldridge, 2010).

The adequacy of the panel specification was further evaluated using relevant diagnostic procedures for multicollinearity, heteroskedasticity, within-bank serial correlation, and cross-sectional dependence. Where the error structure indicated departures from conventional assumptions, robust inference was used to reduce the sensitivity of statistical conclusions to heteroskedasticity and within-panel correlation (Baltagi, 2021; Wooldridge, 2010). The regression results are reported using estimated coefficients, standard errors, test statistics, 95% confidence intervals, p-values, the number of observations, the number of banks, and the appropriate goodness-of-fit statistic. Probability values below 0.001 are reported as ($p < 0.001$), rather than as ($p = 0.000$). Because the study relies on observational bank-level financial data rather than an experimental or quasi-experimental identification strategy, the estimated coefficients are interpreted as statistical associations rather than causal effects. Accordingly, the empirical findings are described using expressions such as "positively associated with" and "negatively associated with," rather than causal terms such as "causes," "increases," or "reduces." Furthermore, all study variables were constructed from audited financial statements, annual reports, and official financial disclosures rather than respondent-based questionnaires. Therefore, questionnaire-related common-method bias is not a central methodological concern in the present research.

3. RESULTS

Table 1 presents descriptive statistics for the study variables observed in 15 Jordanian listed banks over the observation period of 2014–2024, resulting in 165 bank-year observations.

The mean and standard deviation of digital investment intensity for Jordanian banks are 0.142 and 0.061, respectively, showing variability in the amount of operating expenditure that banks invest in technology-related activities. The cost-to-

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Table 1. Descriptive statistics

Variable	Mean	Std. Dev.	Skewness	Kurtosis
Digital investment intensity	0.142	0.061	0.38	2.91
Cost-to-income ratio	0.587	0.114	0.21	2.47
Operating-income volatility	0.093	0.042	0.66	3.08
Bank stability (Z-score)	12.84	4.36	0.19	2.62
Bank size	9.38	0.44	0.52	3.11

income ratio is 0.587, indicating that there are variations in operating efficiency between banks. The mean of operating-income volatility is 0.093, and bank stability (as measured by the Z-score) has a mean of 12.84 and a standard deviation of 4.36. Pooled OLS, fixed-effects, and random-effects specifications were assessed and compared using the relevant panel-model selection tests before the final regression model was estimated. Table 2 gives the results.

The cross-section F-test is significant ($F = 8.46$, $p < 0.001$), which confirms that there are significant bank-specific effects and justifies the use of the fixed-effects rather than pooled OLS specification. In the same way, the Breusch–Pagan LM test is significant ($\chi^2 = 42.31$, $p < 0.001$), which validates the necessity to consider the panel structure. The Hausman specification test is also statistically significant ($\chi^2(4) = 12.87$, $p = 0.012$), suggesting that the fixed-effects estimator should be preferred to the random-effects estimator. The fixed-effects model is the key specification used, therefore. The diagnostic tests suggest heteroskedasticity, within-bank serial correlation, and cross-sectional dependence. Thus, robust standard errors clustered at the bank level are reported for the final estimates. Year effects are also added to the model to capture common shocks that occurred to all banks during 2014-2024. Table 3 shows the outcome of the last fixed-effects regression.

Model statistics: Observations = 165, banks = 15, bank fixed effects = Yes, year fixed effects = Yes, bank-clustered robust standard errors = Yes, within R2 = 0.51, overall model $p < 0.001$.

The digital investment intensity is positively and statistically significantly associated with bank stability (coefficient = 0.284, robust SE = 0.081, t = 3.51, p = 0.004, 95% CI [0.110, 0.458]). This finding suggests that, after controlling for bank-specific and year-specific effects, the higher the share of the bank's operating resources used to identify technology-related expenditure, the higher the level of financial stability. H1 is therefore supported. The cost-to-income ratio is negatively and statistically significantly associated with bank stability (coefficient = –0.246, robust SE = 0.073, t = –3.37, p = 0.005, 95% CI [–0.403, –0.089]). The higher the ratio is, the less efficient their operations are, and the ratio indicates that banks with a higher ratio

Table 2. Panel-model selection and diagnostic tests

Test	Statistic	p-value	Decision
Cross-section F-test	F = 8.46	< 0.001	Fixed effects preferred to pooled OLS
Breusch–Pagan LM test	$\chi^2 = 42.31$	< 0.001	Panel model preferred to pooled OLS
Hausman specification test	$\chi^2(4) = 12.87$	0.012	Fixed effects preferred to random effects
Wooldridge serial-correlation test	F = 9.62	0.008	Serial correlation detected
Modified Wald heteroskedasticity test	$\chi^2 = 76.84$	< 0.001	Heteroskedasticity detected
Pesaran CD test	CD = 2.71	0.007	Cross-sectional dependence detected
Mean VIF	2.18	–	No serious multicollinearity

Table 3. Fixed-effects regression results for bank stability

Variable	Coefficient	Robust SE	t-value	p-value	95% Confidence Interval
Digital investment intensity	0.284	0.081	3.51	0.004	[0.110, 0.458]
Cost-to-income ratio	–0.246	0.073	–3.37	0.005	[–0.403, –0.089]
Operating-income volatility	–0.198	0.082	–2.41	0.031	[–0.374, –0.022]
Bank size	–0.121	0.056	–2.16	0.049	[–0.241, –0.001]

Table 4. Hypotheses testing results

Hypothesis	Relationship	Coefficient	p-value	Decision
H1	Digital investment intensity is positively associated with bank stability	0.284	0.004	Supported
H2	Cost-to-income ratio is negatively associated with bank stability	–0.246	0.005	Supported
H3	Operating-income volatility is negatively associated with bank stability	–0.198	0.031	Supported

of operating costs to operating income are less stable. Thus, the presence of H2 is supported.

Operating-income volatility also has a negative and statistically significant association with bank stability (coefficient = –0.198, robust SE = 0.082, t = –2.41, p = 0.031, 95% CI [–0.374, –0.022]). This suggests that more financial instability is correlated with increased banks' operating variability. H3 is thus affirmed. The coefficient of bank size has a negative and statistically significant value (coefficient = –0.121, robust SE = 0.056, t = –2.16, p = 0.049). This finding suggests that the trend of increase in bank size is associated with a decrease in bank stability in the estimated specification. Overall, the fixed-effects model accounts for about 51% of the within-bank variation in stability (within R^2 = 0.51). The bank-specific and year-specific dummy variables help to control for time-invariant differences between banks and common shocks in the Jordanian banking sector over the study period.

All three hypotheses are supported by the results. Bank stability is correlated positively with digital investment intensity, while the cost-to-income ratio and operating-income volatility are correlated negatively with bank stability. The study is an observational panel study, and therefore these relationships are seen as statistical associations and not as cause and effect.

4. DISCUSSION

The results show that there is a pattern of differences in the relationships between technology-related investment, operating efficiency, operating-income volatility, and bank stability in Jordan. There is a positive and significant relationship between digital investment intensity and bank stability. The positive link between the ratio of identifiable technology expenditure to operating expenditures and financial stability is suggestive of financial stability being stronger for those banks that dedicate more of their operating resources to such identifiable technology expenditure. This finding supports past studies that focused on the role of digital transformation, technological capability and banking technology investment on organizational resilience and bank stability respectively (Khattak et al., 2023; Mirza et al., 2025; Probojakti et al., 2025). This also aligns with Liang et al. (2025), who show that digital financial development had a positive relationship with commercial bank stability. This discovery corroborates the theory that spending on technology can be used to enhance a bank's information processing, operational coordination, monitoring, service delivery, and decision-making. The result is not necessarily a sign of increased stability, however, due to digital investment. The study is an observational panel study, and hence only shows statistical, but not causal, associations. The uniqueness of this study is in analyzing an expenditure-based indicator of digital investment intensity in the banking sector in Jordan given that there is a scarcity of bank-level longitudinal data available for this investment.

The cost-to-income ratio (CII) is negatively and significantly related to the stability of banks. The results suggested that the higher the cost-to-income ratio, the lower the operating efficiency, suggesting that banks with a higher cost-to-income ratio are less stable. This finding aligns with the wider literature, which has highlighted the significance of cost and operating efficiency in assessing the performance and resilience of banks (Abbas et al., 2025; Seelanatha & Natoli, 2025). It also aligns with evidence that digital transformation and FinTech applications can have an impact on bank efficiency; however, the benefits of applying FinTech will depend on implementation costs, organizational readiness, and the capacity of banks to turn the investments in technology into efficiency gains (Elmahdy et al., 2025; Goel & Kashiramka, 2025;

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Shen et al., 2025). Importantly, the cost-to-income ratio should not be considered as a direct measure of digitalization. The present findings are thus not evidence that the "digital costs" affect bank stability. Instead, they demonstrate that those firms with less-than-superior operating efficiency have a negative relationship with stability. Digital initiatives can affect the operating cost-to-income ratio, but there are also several non-digital components to the operating cost-to-income ratio. This separation adds to the conceptual understanding of those results and prevents general operating inefficiencies from being put solely on digital transformation. Bank stability is also negatively and significantly correlated with operating-income volatility. This indicates that the greater the operating performance, the lower the financial stability will be. The outcome is in line with the findings of the papers that highlight that operational uncertainty, vulnerabilities at the technology level, and variations in banking activities can negatively impact financial resilience (Uddin et al., 2020; Uddin et al., 2023). Similarly, Khan et al. (2023) find that factors such as the regulatory environment, banks' characteristics, and the institutional environment also influence the relationship between the adoption of FinTech and bank stability.

But while volatility in operating income is a broad indicator of operating performance risk – not specifically cybersecurity risk, failure of the digital platform, or losses associated with any technology – it is still a key indicator. This finding should therefore not be viewed as a sign of the impact of digital risk on the stability of banks. Rather, it suggests that banks that have more volatile operating income are less stable. This interpretation is in line with the revised conceptual framework, which separates the direct investment in technology from the general level of operating-risk conditions. The estimated specification has a negative and significant relationship between bank size and bank stability. This means that the size of banks in the sample is not necessarily associated with greater stability in the absence of bank and year effects. This may be because larger institutions are more likely to have complex organizational structures, wider risk profiles, and/or higher levels of organizational complexity. Previous studies also find that the relationship between bank size and its stability is context-specific, not always positive (Del Sarto, 2025; Khan et al., 2023). The association between these two should be interpreted with caution, though, as the coefficient estimated reflects an association within the Jordanian sample. The results overall suggest that bank stability does not equate to an overall concept of "digital transformation." Alternatively, the results show unique relationships along three dimensions. The investment intensity is positively related to stability, while lower operating efficiency and higher operating-income volatility are related to lower stability. This distinction is an important contribution of the study since operating efficiency and operating risk are not direct measures of digitalization. The findings hence indicate that technology investments should be analyzed in the context of the financial and operational environment in which banks are making digital transformation efforts.

CONCLUSION

This study aims to investigate the relationship between digital investment intensity, operating efficiency, operating-income volatility, and bank stability for listed banks in Jordan from 2014 to 2024. The findings indicate that, using panel-data analysis, digital investment intensity is positively and significantly associated with bank stability, whereas the ratio of cost to income and operating income volatility are negatively and significantly associated with bank stability. Additionally, there is a negative association between bank size and specification stability. The results yield several insights of interest. First, technology investment seems to be a significant factor in relation to the financial resilience of the Jordanian banking sector. Stability is higher among banks that devote more resources to specific information-technology and digital-infrastructure activities. The relationship, however, is based on observation rather than on experimentation and should be viewed as an association, not a cause-and-effect relationship. Second, the negative relationship between cost-to-income ratio and bank stability indicates the need for operating efficiency. The results also indicate that the costs of digital per unit of income do not have

any negative effect on stability, as the cost-to-income ratio is a general efficiency indicator in operation. Rather, they suggest that the more expensive the bank is, in terms of its operating expenses compared to its income, the less financially stable it will be. Proper technology investment should, therefore, go hand in hand with judicious handling of costs and organizational mechanisms that can convert technology investment into operational gains. Third, the negative relationship between operating-income volatility and bank stability is of interest, in that it underscores the need for stable operating performance. Volatile operating income does not directly reflect on cybersecurity or technology-specific risk but rather reflects general operating risk. Therefore, technology investments must be balanced with good operational risk management, internal controls, governance, and resilience processes in place at the bank. The study enhances the banking literature by differentiating a direct technology-investment measure from the other measures of operating efficiency and operating risk. This separation offers a better context to discuss the stability of banks in a context of ongoing digital transformation, especially in the case of Jordan as an emerging market. The results have implications for bankers and bank regulators as well. When considering digital investments, bank managers should not only look at technological innovation but also weigh it against its long-term impact on efficiency, resilience, and sustainable financial performance. The impact of technological modernization, operating efficiency, and operational resilience may also be taken into account when evaluating the stability of the banking sector by regulators. Longer time series, cross-country or other samples of emerging markets could be included in further research. Additional research could also use more direct measures of cybersecurity events, risk of digital platforms, exposure to FinTech, or losses due to technology, and could examine dynamic or lagged ties between digital investment and bank stability.

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APPENDIX A

Table A1. Banks listed on the Amman Stock Exchange

No.	Bank Name	Website
1	Jordan Kuwait Bank	https://www.jkb.com
2	Jordan Commercial Bank	https://www.jcbank.com.jo
3	Housing Bank	https://www.hbtf.com
4	Arab Jordan Investment Bank	https://www.ajib.com
5	Bank al Etihad	https://www.bankaletihad.com
6	Arab Banking Corporation	https://www.bank-abc.com
7	Invest Bank	https://www.ibank.jo
8	Capital Bank of Jordan	https://www.capitalbank.jo
9	Cairo Amman Bank	https://www.cab.jo
10	Bank of Jordan	https://bankofjordan.com
11	Ahli Bank	https://ahli.com
12	Arab Bank	https://arabbank.jo
13	Jordan Islamic Bank	https://www.jordanislamicbank.com
14	Safwa Islamic Bank	https://www.safwabank.com
15	Islamic International Arab Bank	https://iiabank.com.jo