Fintech adoption, the regulatory environment and bank stability: An empirical investigation from GCC economies

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ABSTRACT

The study analyzes the impact of fintech adoption on the banking sector's stability in GCC countries from 2010 to 2022. The study also considers the role of fintech regulations in this framework. We construct an index of fintech adoption by banks by considering several factors such as banks' digital presence, mobile banking capabilities, support for open APIs, fintech partnerships, digital payment solutions, automation and artificial intelligence integration, innovation initiatives, user experience focus and embracing new technologies. The regulatory environment is measured through the existence or introduction of fintech-related regulations such as the regulatory sandbox. The findings imply that fintech adoption has reduced banks' stability in GCC. The fintech-stability relationship varies over various bank-specific and country-specific variables. For instance, large and well-capitalized banks are less likely to experience adverse effects of fintech adoption. Moreover, the negative impact of fintech on financial stability is lower for Islamic, foreign and government banks. In addition, banks operating in well-developed and more competitive banking sectors experience lower financial instability when adopting fintech innovation. We confirm these findings with an alternative indicator of fintech adoption. The study also discusses essential policy implications for the sample countries.

1. Introduction

We explore the effect of financial technology (fintech) adoption on banks' financial stability in Gulf Cooperation Council (GCC) countries. In this context, we also analyze the role of the regulatory sandbox in bank stability and its association with fintech adoption. Fintech has become the talk of the town for its unparalleled growth in the last half of the decade.[1] Fintech encompasses a broad range of digital solutions, including mobile banking, online payments, peer-to-peer lending, robo-advisory services, blockchain-based transactions, and artificial intelligence-powered customer interfaces. Fintech is improving efficiency, accessibility, and convenience in financial services. In addition, it aims to challenge traditional banking models and disrupt the financial industry through innovation (Aduba Jr, Asgari, & Izawa, 2023; Carbó-Valverde, Cuadros-Solas, & Rodríguez-Fernández, 2021, pp. 161–194; Claessens, Frost, Turner, & Zhu, 2018; Cumming, Farag, Johan, & McGowan, 2022; Elsinger et al., 2018; Merton & Thakor, 2019;

Molnár, 2018; Murinde, Rizopoulos, & Zachariadis, 2022; Navaretti, Calzolari, & Pozzolo, 2017; Philippon, 2016; Romānova & Kudinska, 2016; Thakor, 2020; Vives, 2017; Vučinić, 2020).

Banks' fintech adoption offers numerous opportunities for improved efficiency, cost reduction and an enhanced customer experience. Nonetheless, it introduces new challenges like cybersecurity threats, regulatory compliance, and systemic risks. The dynamic nature of fintech innovations has raised concerns about their potential impact on banking sector stability. Moreover, there are questions about the risks and benefits associated with fintech adoption by traditional banks in the face of increasing competition from fintech startups. The existing research is still in its infancy, and only a handful of studies have attempted to explore the consequences of fintech innovations (by banks) for financial stability. The difficulty quantifying fintech development has been a significant reason for the lack of empirical evidence in this domain. A few studies use text mining techniques, following insights from Askitas and Zimmermann (2009), to calculate the extent of fintech

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innovation and relate it to banks' financial stability.[2] However, the collective finding from such studies is inconclusive. For instance, Cheng and Qu (2020) and Liem, Son, Tin, and Canh (2022) find that fintech innovation reduces credit risk in China.

On the contrary, Wang, Liu, and Luo (2021) noticed a U-shaped relationship between fintech adoption and bank risk-taking. Similarly, for Nguyen and Dang (2022) found the destabilizing effect of fintech on financial stability.[3] In the international context, Daud, Khalid, and Azman-Saini (2022) record a supportive role of fintech for financial stability in 63 countries. In another study, Fung, Lee, Yeh, and Yuen (2020) employ the regulatory sandbox as a proxy of fintech innovation and conclude that it promotes stability (instability) in emerging (developed) markets. In a recent study, Liem et al. (2022) used fintech credit data compiled by Cornelli et al. (2023) to gauge fintech development and find its role positive for financial stability in 73 countries. There are more compelling reasons to employ Cornelli et al. (2023) fintech and big tech credit data.[4] However, its scope is currently limited to 73 (primarily advanced) nations with a limited time dimension.[5]

Theoretically, there are several ways in which fintech adoption can influence banks' stability. First, fintech adoption involves the integration of new and often complex technologies into banking operations. Implementing unfamiliar technology can introduce risks, such as system failures, cyberattacks, and data breaches, which may undermine a bank's financial stability if not managed effectively. Second, fintech can enhance operational efficiency through automation and digitization, potentially reducing costs and improving profitability. However, rapid technological changes can lead to implementation challenges and banks that fail to adapt may experience decreased efficiency and profitability, affecting their stability. Third, fintech firms often compete with traditional banks by offering innovative financial services. Increased competition can lead to lower profit margins and market share for banks, impacting their financial stability. On the contrary, banks that successfully integrate fintech solutions may gain a competitive edge. Fourth, banks may use fintech for credit assessment and lending. While fintech can improve credit risk assessment through advanced algorithms and data analytics, it can also lead to increased risk if not properly calibrated, potentially resulting in higher non-performing loans (NPLs) and reduced financial stability. Fifth, fintech adoption may require banks to comply with new regulatory requirements related to technology and data security. Non-compliance can lead to regulatory penalties, affecting a bank's financial stability.

However, banks that proactively address regulatory concerns related to fintech may enhance their stability. Sixth, fintech-driven changes in customer behavior and expectations can affect banks' business models. Banks that fail to adapt to changing customer preferences may lose their market share, impacting their stability. In contrast, those aligning their services with evolving customer demands may remain stable or prosper. Seventh, fintech can influence banks' liquidity management through real-time payment systems and digital wallets. While this can enhance liquidity efficiency, it may also introduce liquidity risks if not adequately managed, potentially affecting financial stability. Finally, the interconnectedness of financial institutions in the fintech ecosystem can introduce systemic risks. A failure or disruption in one fintech entity could have cascading effects on the financial system, impacting the stability of banks and other financial institutions.

The history of fintech innovation in the GCC has not been very different from the rest of the emerging markets as they (GCC countries)

strive to achieve their developmental goals.[6] In the wake of diversifying their economies and reducing oil dependence, the GCC countries are encouraging a favorable environment for fintech adoption that will ultimately stimulate economic growth and enhance financial inclusion. Since fintech has the potential to disrupt the financial sector, its consequences for financial stability have become a significant concern for regulators and policymakers. The governments in the GCC countries have introduced regulatory sandboxes to facilitate fintech experimentation in a controlled environment to address these concerns and strike a balance between innovation and stability. A regulatory sandbox provides a platform for fintech firms to test their innovative solutions under regulatory authorities' supervision and guidance, allowing for identifying and mitigating potential risks before broader implementation. Establishing regulatory sandboxes reflects the GCC countries' commitment to encouraging fintech innovation while safeguarding financial stability. However, the research in this domain is non-existent in the context of the GCC.[7]

In this study, we first construct an index of fintech adoption for banks in GCC countries from 2010 to 2022. We utilize the index to investigate the impact of fintech adoption on banks' financial stability. We also analyze the role of the regulatory sandbox in banks' financial stability and its link with fintech adoption. In addition, we perform a heterogeneity analysis to test the variability of the fintech-stability relationship across various micro and macroeconomic factors. The estimation results imply that fintech adoption decreases banks' financial stability. Furthermore, introducing the regulatory sandbox supports fintech in weakening banks' financial stability. The heterogeneity analysis shows that large and well-capitalized banks are less affected by fintech adoption in terms of financial stability. Furthermore, the adverse effects of fintech on financial stability are lower for Islamic, foreign and government banks. Moreover, specific market characteristics, such as higher bank competition and financial development, mitigate the negative impact of fintech adoption on banks' financial stability. We find similar results with an alternative indicator of fintech adoption.

This study makes significant contributions to fintech and banking sector stability literature. First, it provides a more direct measurement of the extent of fintech adoption by constructing an index. The construction of an index sets up a benchmark for future studies. It allows comparisons across economies, assisting as an in-depth comprehension of the dynamics of fintech adoption and its repercussions. Second, the study explains a previously unexplored area in the GCC context by investigating the impact of fintech adoption on banks' financial stability. It also offers valuable insights into fintech's potential consequences for the banking sector. Third, the findings of this study fill a critical research gap and inform policymakers, regulators, and financial institutions in decision-making by providing empirical evidence on the link between fintech adoption and banks' financial stability in GCC countries. In addition, banks and other financial institutions operating in GCC countries can also benefit from the empirical analysis by adapting their strategies and mitigating potential risks induced by fintech adoption. Fourth, by investigating the role of the regulatory sandbox in banks' financial stability, the study also offers valuable guidance for regulators in designing appropriate frameworks to support fintech innovation and maintain banking sector stability in the GCC region. Finally, the policy implications derived from this study can be used to promote a conducive regulatory environment and facilitate the integration of fintech innovation within the GCC banking sector, eventually supporting financial stability in the region.

The sequence of the rest of the paper is as follows. In Section 2, we

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[2] These measures may or may not offer a robust estimation of the level of fintech innovation, but they have opened a door for discussion and improvement.

[3] In a country-focused study, Safiullah and Paramati (2022) discovered that fintech firms have enhanced banks' financial stability in Malaysia.

[4] See also Gomber, Koch, and Siering (2017) and Pierri and Timmer (2020).

[5] The dataset does not include data on GCC countries.

[6] For instance, Vision 2030 (Bahrain, Saudi Arabia, and Qatar), Vision 2035 (Kuwait), and Vision 2040 (Oman).

[7] There are a few papers that explore various aspects of fintech in a single country or the GCC region. See Khan and Abdulrahman Saad (2022) and Khan and Alhadi (2022).

examine the fintech and regulatory environment in GCC; in Section 3, we present methodology, data and variables; in Section 4, we discuss estimated results; and in Section 5, we conclude with implications and limitations.

2. Overview of fintech in GCC

GCC is an economic and political alliance of the six Arab nations: Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates (UAE). The regional economies possess rich resources of crude oil. Three nations in the GCC, i.e., Saudi Arabia, UAE, and Kuwait, are members of the "Organizations of Petroleum Exporting Countries" (OPEC). The region's GDP growth rate for 2022 is at 6.9%, where Saudi Arabia has the highest of 8.3%, followed by UAE and Qatar with a GDP growth of 5.9% and 4.8% respectively (World Bank, 2021). All GCC countries have formulated diversification plans under the name Vision 2030 (Bahrain, Saudi Arabia and Qatar), Vision 2035 (Kuwait) and Vision 2040 (Oman). The objective is to achieve sustainable growth by decreasing their dependence on oil revenue. Several economists refer to this diversification as an industrial revolution in the region. However, the change is primarily dependent on the digital process. The GCC is considered a high-income region with well-developed technological infrastructure and adoption. The GCC countries are deemed well-developed for digital adoption. In addition, the regional economies have easy access to the Internet and mobile subscriptions (WDI, 2021). Figs. 1 and 2 show the percentage of the population using the internet and subscriptions to mobile services.

Fintech adoption in the context of the banking sector is even more critical as it plays a crucial role in developing all other sectors of an economy.[8] The world is adopting various regulatory approaches – a regulatory sandbox – to support fintech innovation by providing a controlled environment to overcome financial and technological challenges. In the spirit of embracing the digital revolution, the GCC economies also introduced regulatory sandboxes.[9] The experiment period permitted under the regulatory sandbox varies from six months to one year. These regulatory sandboxes are instituted and monitored by the respective countries' securities/capital market authorities or central banks.

Additionally, under the innovation hub, most countries have started open banking. Open banking is sharing customers' data/information among financial services' providers to deliver various financial services.[10] In this regard, all the countries in the GCC region have permitted open banking to operate. Despite having the appropriate infrastructure to be the front runners in the digital economy, the GCC economies also face challenges, such as relevant knowledge and skills required for further progress in innovation. For instance, the adoption and exploration of digital technologies of the GCC among global peers are only average in the "World Competitiveness Center (WCC)" rankings.[11] Concerning the "Global Innovation Index" (GII), the contribution of the GCC is competitive. Furthermore, the position of the GCC economies is encouraging in the global innovation ranking by the "World Intellectual Property Organization" (WIPO)[12]. See Table 1A for GCC ranking in the WCC and the WIPO.

3. Methodology

3.1. Data

All banking institutions in the GCC countries – Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates – constitute the study's sample. We obtained each country's active banks' list from their central banks. Data on bank-level variables were collected from 2010 to 2020 from consolidated financial statements provided by BankFocus. We compiled missing years' data (2021, 2022) from financial statements from banks' sources. Our choice of the study period, i.e., 2010–2022, is based on two reasons. First, the fintech innovation made inroads into the region during this time or gathered pace after 2010. Second, the concerns for financial stability became more prominent in the aftermath of the Global Financial Crisis of 2008 and 2009. We compiled missing years' data from financial statements from banks' sources.

We began with all the banks in the GCC countries. However, we had to exclude several banks for one of the following reasons. First, banks for which we could not find fintech-related data were dropped from the sample. Second, those banks that did not have data around the induction year of the regulatory sandbox were excluded. The final sample consists of 184 banks (80% of the total banks in the GCC) and 1748 bank-year observations. See Table A2 for sample distribution and other related information. We collect data on macroeconomic variables from various sources such as "Global Financial Development Database" (GFDD), "World Development Indicators" (WDI), "World Governance Indicators" (WGI), and "Doing Business Indicators" (WGI). See Table A4 for definitions and sources of variables.

3.2. Variables

3.2.1. Fintech adoption

The quantification of fintech adoption is challenging. Fintech encompasses many technologies and business models, so defining fintech is complicated. In addition, the diverse and evolving nature of fintech innovations makes it difficult to create a standardized measure. Moreover, a precise assessment of fintech is constrained because data availability and quality are inconsistent across different regions and countries. Since fintech adoption often involves blending old and new methods, it becomes challenging to distinguish between traditional financial services and fintech-enabled services. Moreover, the varying pace of fintech adoption across various sectors and institutions makes it difficult to compare progress. Furthermore, rapidly changing behaviors and preferences can confine the estimation of the usage of fintech services and the extent of consumer adoption. Despite these limitations, we strived to define fintech in the context of the banking sector and construct a bank-year indicator of fintech adoption for the GCC countries.

We followed a procedure, "the word frequency statistics from text mining", employed by Hou, Gao, and Wang (2016) and Cheng and Qu (2020) to construct a fintech adoption index.

Firstly, we followed an extensive literature – Philippon (2016), Romānova and Kudinska (2016), Navaretti et al. (2017), Vives (2017) Arner, Zetzsche, Buckley, and Barberis (2017), Molnár (2018), Claessens et al. (2018), Tang (2019), Merton and Thakor (2019), (2020), Carbó-Valverde et al. (2021, pp. 161–194), and Murinde et al. (2022) – to define fintech in the context of the banking industry. Consequently, we identified at least nine attributes of fintech adoption – banks' digital presence, mobile banking capabilities, support for open APIs, fintech partnerships, digital payment solutions, automation and artificial intelligence integration, innovation initiatives, user experience focus and embracing new technologies – that are more aligned with operations of banking institutions. See Table 1 for an explanation of each attribute.

We chose these attributes for the following reasons. First, a robust digital presence is crucial in today's banking landscape. It represents a

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[8] See Khan, Bashir, and Islam (2021).
[9] https://www.worldbank.org/en/topic/fintech/brief/key-data-from-regulatory-sandboxes-across-the-globe.
[10] https://www.bis.org/bcbs/publ/d486.pdf.
[11] https://www.imd.org/centers/wcc/world-competitiveness-center/rankings/world-digital-competitiveness-ranking/.
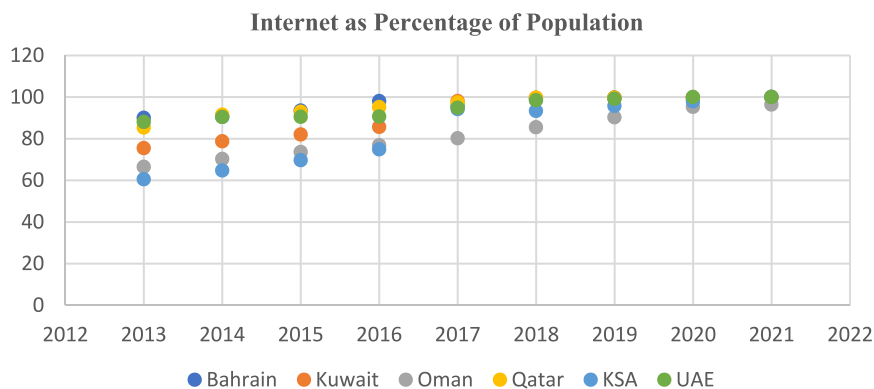[12] https://www.wipo.int/global_innovation_index/en/2022/.

Internet as Percentage of Population

Fig. 1. Access to the internet.

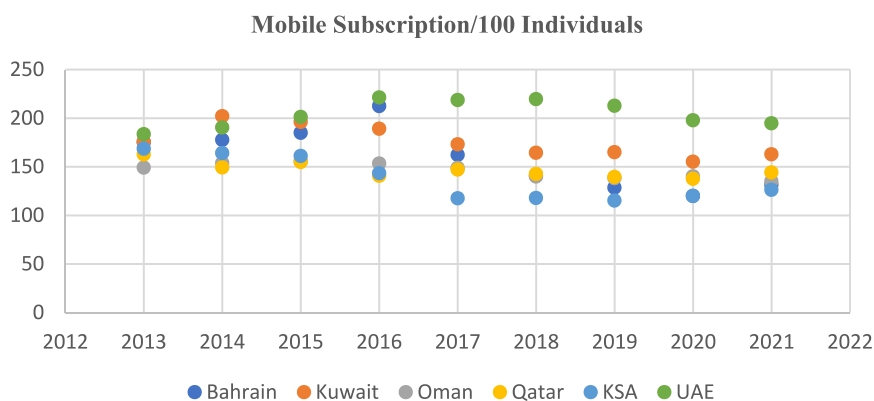**Mobile Subscription/100 Individuals**

Fig. 2. Mobile subscription.

bank's commitment to providing online services, including account management, customer support and access to financial products. A robust digital presence is often the first indicator of a bank's readiness to embrace fintech innovations. Second, mobile banking has become the primary channel for many customers. The ubiquity of smartphones and their convenience makes mobile banking capabilities essential. A bank's ability to offer a seamless and secure mobile banking experience indicates its adaptability to modern fintech trends. Third, open APIs enable interoperability and collaboration with fintech firms. Banks that support open APIs are more likely to engage in partnerships with fintech companies, allowing for the development of innovative financial products and services. Fourth, collaborations between traditional banks and fintech startups are increasingly common. These partnerships enable banks to leverage fintech expertise and technology to enhance their offerings, improve customer experiences, and stay competitive in a rapidly evolving industry. Fifth, the growth of digital payments, including mobile wallets, contactless payments, and peer-to-peer transfers, is a significant fintech trend. Banks that offer diverse and user-friendly digital payment solutions are better positioned to cater to changing consumer preferences. Sixth, automation and AI technologies can streamline processes, enhance security, and provide personalized financial services. Banks that integrate automation and AI demonstrate their commitment to efficiency, safety, and innovation. Seventh, banks prioritizing innovation often establish dedicated teams or labs to explore emerging technologies and fintech trends. Their commitment to innovation strongly indicates their readiness to adapt to the changing financial landscape. Eighth, user experience is a critical factor in retaining and attracting customers. Banks that prioritize user-centric

design in their digital interfaces and services are more likely to excel in a competitive market where customer expectations are constantly rising. Finally, staying up to date with emerging technologies like blockchain, biometrics and quantum computing is essential. Banks that actively explore and adopt new technologies can gain a competitive edge and offer novel services to customers.

In the second step, we used the Google search engine and began our search for newsletters with the bank name, year and keywords.[13] We computed the number of newsletters and the frequency of keywords for each bank and year. In the third step, we applied factor analysis for factor extraction on each fintech attribute.[14] In the final step, we verified that the bank initiated a service corresponding to a particular fintech attribute. For instance, using the text mining technique, we analyzed each bank's website to see if the bank offered a specific service in a particular year. We created a variable (weight) that took the value of 1/9 for each service introduced in a year. The final index was the weighted average of scores obtained in the third step. Table A3 demonstrates the calculation process for a random bank. Our index is different from the one developed by Hou et al. (2016) and Cheng and Qu (2020) in two

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[13] Cheng and Qu (2020) argue that the amount of FinTech news has a positive association with fintech development. Therefore, in a world where the network is the main means of information transmission, the more network news containing keywords, the more bank FinTech will develop.

[14] Values on preliminary tests for factor analysis such – Kaiser-Meyer-Olkin (KMO) Test and Bartlett's Test of Sphericity – have required values implying that the keywords have shared attributes.

Table 1
Attributes of fintech adoption.

	Factors Related to Banking Fintech	Explanation
1	Digital Presence	Banks that have adopted fintech will typically have a solid digital presence. They will have user-friendly websites and mobile apps that allow customers to access banking services and perform transactions online. We look for features like online account opening, digital payments and real-time account information.
2	Mobile Banking Capabilities	Fintech-oriented banks will offer robust mobile banking services. This includes mobile check deposits, fund transfers, bill payments and personalized notifications. Additionally, they may integrate emerging technologies such as biometric authentication (e.g., fingerprint or facial recognition) for enhanced security.
3	Support for Open APIs	Banks that embrace fintech provide open Application Programming Interfaces (APIs) that allow third-party developers to build applications and services on top of their banking infrastructure. These APIs enable integration with external fintech platforms, facilitating innovative services and enhancing the overall customer experience.
4	Fintech Partnerships	Fintech-focused banks frequently establish partnerships with fintech startups or collaborate with established fintech companies. These partnerships allow banks to leverage the expertise and technology of fintech firms to enhance their product offerings and improve operational efficiency.
5	Digital Payment Solutions	Banks that offer a variety of digital payment options beyond traditional methods. This includes support for mobile wallets, peer-to-peer payments, contactless payments (e.g., NFC technology), and integration with digital payment platforms like PayPal or Apple Pay.
6	Automation and Artificial Intelligence Integration	Fintech-oriented banks often leverage automation and artificial intelligence (AI) technologies to streamline processes and enhance customer service. They may use AI chatbots for customer support, employ machine learning algorithms for fraud detection, or utilize data analytics to offer personalized financial recommendations.
7	Innovation Initiatives	Banks actively engaged with fintech will have a culture of innovation and continuous improvement. They may have dedicated innovation labs or programs, participate in fintech conferences, or invest in research and development to explore emerging technologies and trends within the financial industry.
8	User Experience Focus	Fintech-oriented banks prioritize delivering an exceptional user experience. They invest in user-centric design to make banking services intuitive, efficient and personalized. We specifically look for features like simplified onboarding processes, personalized financial insights and easy-to-use interfaces.
9	Embracing New Technologies	Banks that have adopted fintech often embrace emerging technologies like blockchain, cryptocurrency, robo-advisory, or digital lending platforms. They may offer services related to these technologies or explore their potential for improving existing banking processes.

Table Description.

aspects. First, we adopted a more specific approach to define fintech and identify its attributes which were more aligned with banking institutions' operations.

Hou et al. (2016) and Cheng and Qu (2020) on the other hand, adopted a more generic approach and identified primary fintech attributes. Second, we further verified if the bank initiated a service

corresponding to a particular fintech attribute. Fig. 1 compares the aggregate fintech adoption index among GCC countries. We elaborated more on the comparisons in Section 4.1. Although we argued that our index is a more direct assessment of fintech adoption, we also constructed an alternative fintech indicator similar to the one developed by Hou et al. (2016) and Cheng and Qu (2020) and used it for robustness analysis in Section 4.4. Interestingly, the correlation between the two alternative indices is very high, i.e., 0.72. The high correlation is a sort of validation test for both these measures. The ranking of countries – concerning the degree of fintech adoption – is almost identical with the two indices, as can be seen in Figs. 3 and 4.

3.2.2. Regulatory environment

Governments across the globe are trying to strike a balance between consumer protection and fintech innovation. A regulatory sandbox is a generic form of fintech regulation that offers financial institutions a supportive environment to explore and integrate fintech innovations into their operations. It advances collaboration between banks and startups, addresses regulatory challenges, and promotes responsible fintech adoption while ensuring consumer protection. As discussed in Section 1, the regulatory sandbox can affect banks' financial stability negatively or positively. Following Fung et al. (2020), we captured the effect of regulatory sandbox through a binary variable as follows:

$$R\_S\_Box_j = \begin{cases} 1, \text{If country j has implemented regulatory sandbox} \\ 0, \text{Otherwise} \end{cases}$$

The variable [$R\_S\_Box_j$] equals 1 in the year the regulatory sandbox was introduced as well as the years following it. We collect relevant information from the World Bank's Global Fintech-Enabling Regulations Database[15] and the central bank in each country.

3.2.3. Bank stability

We follow earlier literature – Fung et al. (2020), Cheng and Qu (2020), Vučinić (2020), Liem et al. (2022), Li, He, Tian, Sun, and Ning (2022), and Daud et al. (2022) – and use two bank-level variables to assess bank stability, i.e., z-score and nonperforming loan (NPL) ratio. A bank's z-score is calculated as follows:

$$Z\_Score_{it} = \frac{ROA_{it} + CAR_{it}}{SD(ROA)_{it}}$$

ROA_{it} is the return on assets, CAR_{it} is capital to asset ratio, $SD(ROA)_{it}$ is a 5-year rolling standard deviation of ROA for bank i in year t. The z-score assesses a bank's "distance to default". In other words, it measures how many standard deviations a bank can lose before it runs out of capital. The higher (lower) the z-score, the higher (lower) the bank's stability. We use log values of the z-score to address the normality issues. The other variable – NPL – is the ratio of a bank's nonperforming loans to total loans.

$$NPL_{it} = \frac{\text{Nonperfroming Loans}_{it}}{\text{Total Loans}_{it}}$$

The term non-performing loan refers to a bank loan that has been delayed or will not likely be repaid in full by the borrower. The higher (lower) the NPL ratio the higher (lower) the bank's instability.

3.2.4. Control variables

Several studies have indicated that various bank-specific and country-specific factors contribute to bank stability. See for example, Koetter and Poghosyan (2010), Köhler (2015), Adusei (2015), Jin, Kanagaretnam, Lobo, and Mathieu (2017), Goetz (2018), Vo, Nguyen, and Van (2021), Tran, Nguyen, and Nguyen (2022), and Ahmad, Ahmad, and Shaharuddin (2022), among others. We followed the bank

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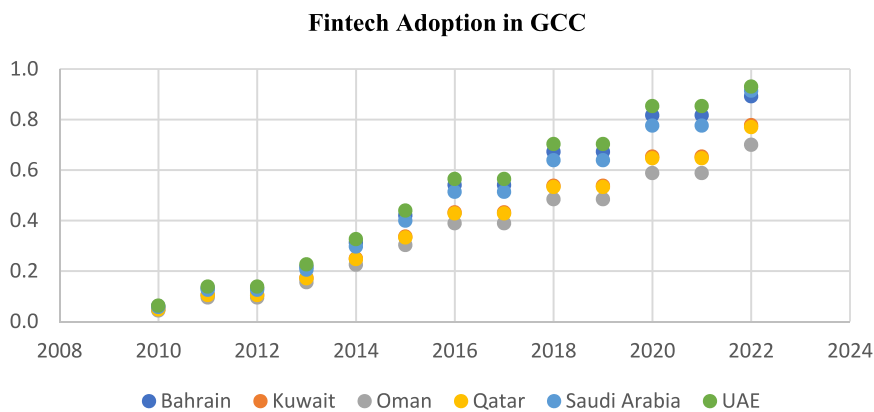[15] Global Fintech-enabling regulations database (worldbank.org).

Fintech Adoption in GCC

Fig. 3. A comparison of fintech adoption in GCC.

Fintech Adoption in GCC (Alternative Indicator)
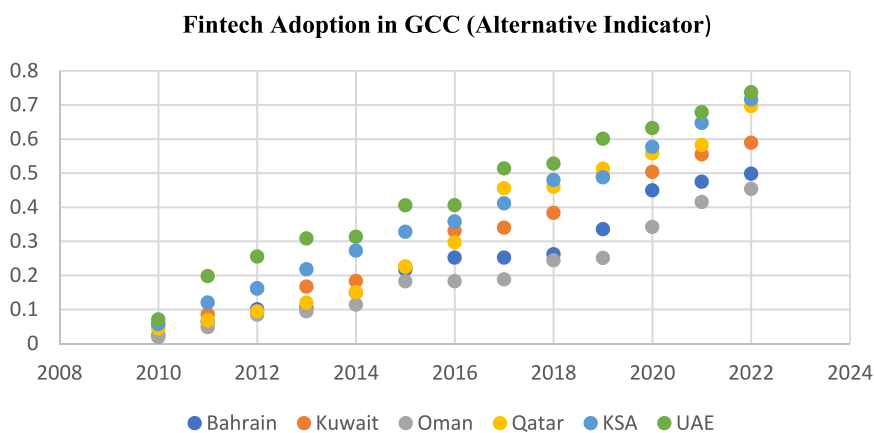
Fig. 4. A comparison of fintech adoption in GCC (alternate measure).

stability literature and considered a large set of micro and macroeconomic variables in our analysis. For instance, large and well-capitalized banks have more resources and expertise to manage and mitigate risks associated with fintech adoption effectively. Similarly, their substantial capital reserves provide a cushion against potential losses or disruptions caused by new technologies. Therefore, we included size (total assets) and capitalization (equity to total assets) to capture bank size and capitalization.

In addition, liquidity and off-balance sheet activities contribute to bank stability (Haq, Tripe, & Seth, 2022; Papanikolaou & Wolff, 2014; Qi, 1994; Wagner, 2007). For example, lacking liquidity can lead to insolvency, erode market confidence, and trigger bank runs. It can result in an interbank market reluctance to lend, force asset sales at distressed prices, regulatory intervention and the maturity mismatch between assets and liabilities. Similarly, off-balance sheet activities, such as derivatives trading and securitization, involve commitments and potential liabilities that are not recorded on the bank's balance sheet but can have significant financial consequences. If these activities lead to unexpected losses or obligations, they can erode a bank's capital, affecting its solvency and overall stability.

Additionally, off-balance sheet activities may involve complex financial instruments sensitive to market volatility, posing risks that can quickly materialize and threaten a bank's stability. In line with these arguments, we incorporated liquidity (loan-to-deposit ratio) and off-balance activities (off-balance sheet items) in the estimation model. Moreover, we also distinguished among various bank classifications,

such as Islamic versus conventional banking, foreign versus domestic banking, and government versus private banking.

The existing literature on bank stability shows that several macroeconomic factors relate to banks' stability. For instance, bank competition (concentration) increases (decreases) bank stability. Similarly, financial sector development (represented by bank and stock market development) improves banks' stability. Furthermore, the overall macroeconomic environment (economic growth and inflations) and other factors such as institutional development, depth of credit information and property rights are essential for the banking sector's functioning and stability. We also controlled the aspects mentioned above while analyzing the effect of fintech adoption on bank stability. See Table A4 for a description and sources of variables.

3.3. Empirical model

A few studies that have explored the effect of fintech on bank stability include Fung et al. (2020), Cheng and Qu (2020), Liem et al. (2022), Li et al. (2022), and Daud et al. (2022). We followed this literature and adopted the following empirical model to identify the role of fintech adoption on banking stability.

$$B\_STA_{ijt} = \omega_0 + \omega_1 FT\_ADP_{ijt-1} + \omega_2 FT\_ADP_{ijt} + \sum_{p=1}^{m} \theta_k X_{ijt} + \sum_{q=1}^{n} \theta_q Z_{jt}$$

$$+ E_{ijt} \tag{1}$$

B_STA_{ijt} denotes one of the two measures of bank stability – banks' Z-score and non-performing loan ratio. FT_ADP_{ijt} represents the index of fintech adoption discussed in Section 3.1.1. X_{ijt} and Z_{jt} symbolize collections of bank-level and country-level variables, respectively. E_{ijt} is the model's error terms. The subscripts i, j, and t identify the bank, country and year. The coefficient on FT_ADP (ω_1) is of particular interest to this study. The prior expectations about ω_1 are unclear as fintech adoption may decrease or increase banking sector stability. In the next step, we use the following equation to explore the role of fintech-related regulation, i.e., the regulatory sandbox, in bank stability and its relationship with fintech adoption.

$$B\_STA_{ijt} = \omega_0 + + \omega_1 FT\_ADP_{ijt-1} + \omega_2 FT\_ADP_{ijt} + \omega_2 R\_S\_BOX_{jt}$$
$$+ \omega_3 \left[FT\_ADP_{ijt} * R\_S\_BOX_{jt} \right] + \sum_{p=1}^{m} \theta_k X_{ijt} + \sum_{q=1}^{n} \theta_q Z_{jt} + \mu_t$$
$$(2)$$

R_S_BOX is a binary variable that equals 1 for the year the regulatory sandbox was introduced and all years following it. The interaction term, i.e., $FT\_ADP_{ijt} * R\_S\_BOX_{jt}$, captures the interactive role of the regulatory sandbox in fintech's relationship with bank stability. The rest of the specification is identical to that of equation (1).

In the estimation of equations (1) and (2), we were also concerned about the endogeneity, i.e., causality running from banks' stability to their adoption of fintech. For instance, stable banks tend to adopt fintech more cautiously, considering factors such as risk tolerance, capital availability, regulatory compliance, customer trust, integration challenges and competitive pressure. However, they may also leverage their stability to form partnerships with fintech companies or gradually integrate fintech into their operations, prioritizing the preservation of their reputation and customer base over rapid technological innovation (Cheng & Qu, 2020; Li et al., 2022). To deal with endogeneity concerns, we employed two-stage least squares (2SLS) and the two-step dynamic panel system GMM.[16] Banks' adoption of fintech relies on advanced digital technology, including mobile devices, secure networks, data storage, and processing capabilities, to deliver financial services and products more efficiently and conveniently. Therefore, we used the number of smartphones per capita (obtained from WDI) as an instrument in 2SLS estimation. In addition, we follow Li et al. (2022) and employ the first lag of the fintech index to instrument fintech adoption in the current period. Before proceeding with the estimation of 2SLS, we assessed the reliability of the instrumental variables. The results of the weak instrument test revealed notably high F-statistics, providing strong evidence that the instruments used in the model are valid (not weak).[17]

4. Estimation results and discussion

4.1. Summary statistics and correlations

The descriptive analysis of the main variables is presented in Table 2. The average z-score for banks is 9.112, with a median of 10.934. The standard deviation of 3.721 indicates that the values are relatively dispersed around the mean. The z-scores range from a minimum of 1.577 to a maximum of 19.129. The mean non-performing loans ratio is 0.018, with a median of 0.022. The standard deviation of 0.105 indicates relatively high variability in the data. The ratio ranges from a minimum of 0.019 to a maximum of 0.183. The mean fintech adoption rate (FTA-1) is 0.434, with a median of 0.534. The standard deviation of 0.259 suggests moderate variability in the adoption rates. The values range from a minimum of 0.038 to a maximum of 0.950. The mean fintech

adoption rate (FTA-2) is 0.315, while the median is slightly lower at 0.284. The standard deviation of 0.196 indicates relatively high variability in the adoption rates. The values range from a minimum of 0.185 to a maximum of 0.737. In terms of mean values on FTA-1 (FTA-2), the UAE is on top with an average score of 0.510 (0.434), followed by Saudi Arabia with an average score of 0.478 (0.371). Bahrain, Kuwait, Qatar, and Oman stand in 3rd, 4th, 5th' and 6th position with mean scores of 0.461 (0.245), 0.388 (0.313), 0.374 (0.327) and 0.349 (0.201), respectively (see Table A5 in Appendix for country-wise summary statistics).

Table 3 shows correlation coefficients among important variables. The z-score (NPL ratio) is negatively (positively) associated with both indicators of fintech adoption. The insight is that fintech adoption may decrease bank stability in the long run. Several bank-specific attributes such as bank size, capitalization and income diversification are positively (negatively) related to banks' z-score (NPL ratio). Similarly, some macroeconomic factors, i.e., the banking sector development, economic growth, institutional development, depth of credit information and property rights, have positive associations with bank stability.

On the other hand, a few bank-level, and country-level variables, i.e., loan-to-deposit ratio, off-balance sheet activities, bank concentration and inflation, are negatively related to bank stability. The two indicators of fintech adoption are highly correlated (0.72), suggesting that they refer to a common aspect of banking. The fintech indicators have reasonably high correlations with other explanatory variables, indicating the significance of these variables in studying fintech and its relationship with banking institutions. However, the correlations among explanatory variables are not too high to cause multicollinearity in the estimation process.

4.2. Fintech adoption and bank stability

The implications of fintech adoption are analyzed in this section. The estimated coefficients from Equation (1) are reported in Table 4. The structure of the table is as follows. The response variables are the Banks' Z-Score (Panel A) and the NPL Ratio (Panel B). We estimated results using OLS (columns 1 and 5), Fixed Effects (columns 2 and 6), 2SLS (columns 3 and 7), and two-step dynamic panel system GMM (columns 4 and 8). Following earlier literature, i.e., Farag and Mallin (2017) and Farag and Mallin (2018), we also controlled for lagged dependent variables in GMM regression.

In all specifications, fintech adoption is statistically significant. The coefficients in panel A are negative and positive in panel B. Since lower values of the z-score imply more financial fragility, a negative coefficient on fintech adoption indicates that fintech may decrease banks' financial stability. On the contrary, lower values of NPL suggest a higher level of financial stability. In this regard, a positive coefficient on fintech adoption indicates a discouraging effect of fintech on banks' financial stability. The findings are consistent across alternative estimation methods. The magnitude of coefficients highlights the economic significance of the relationship. For instance, the regression coefficients on fintech adoption are -0.1995 and 0.1811 for Bank Z-score and NPL ratio, respectively, implying that a one-unit increase in fintech adoption is associated with a decrease of 0.1995 in Bank Z-score and an increase of 0.1811 in the NPL ratio. Our findings generally contrast those of earlier studies that found a positive role of fintech on banks' financial stability in single or multiple-country settings. For instance, Fung et al. (2020), Daud et al. (2022), and Liem et al. (2022) analyzed the fintech-stability nexus in multi-country environments and found that fintech promotes financial stability.[18] Similarly, Cheng and Qu (2020),

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[16] We also used Pooled OLS and Fixed Effects to test the consistency of estimates.

[17] F-statistics for the first stage regression, in case of 2SLS estimation, are reported in the relevant columns.

[18] Fung et al. (2020) found a positive role of fintech in relation to financial stability for emerging economies. However, their findings for developed countries are aligned with ours. In addition, Wang et al. (2021) found a negative role of fintech on banks' risk-taking in China.

Table 2
Summary statistics - aggregate.

VARIABLES	OBS	MEAN	MED	STD	MIN	MAX	Expected Relationship with Response DV	
							Z Score	NPL
Banks' Z-Score	1748	9.112	10.934	3.721	1.577	19.129	–	–
Non-Performing Loans (NPL) Ratio	1748	0.018	0.022	0.105	0.019	0.183	–	–
Fintech Adoption 1 (FTA-1)	1748	0.434	0.534	0.259	0.038	0.950	Positive/Negative	Positive/Negative
Fintech Adoption 2 (FTA-2)	1748	0.316	0.285	0.197	0.019	0.737	Positive/Negative	Positive/Negative
Bank Size (US Dollar Billions)	1748	95.5	80.7	0.531	30.85	308.9	Positive	Negative
Bank Capitalization	1748	0.534	0.572	0.204	0.177	0.852	Positive	Negative
Loan to Deposit Ratio	1748	0.211	0.255	0.091	0.114	0.378	Negative	Positive
Income Diversification	1748	0.264	0.322	0.115	0.053	0.479	Positive	Negative
Off-Balance Sheet Activities	1748	0.297	0.358	0.128	0.059	0.532	Negative	Positive
Degree of Banking Concentration	78	0.785	0.776	0.102	0.638	0.968	Negative	Positive
Banking Sector Development	78	0.733	0.757	0.167	0.520	1.000	Positive	Negative
Stock Market Development	78	1.141	0.845	0.674	0.420	2.370	Positive	Negative
Economic Growth	78	0.116	0.168	0.067	−0.059	0.270	Positive	Negative
Inflation	78	0.051	0.049	0.027	0.032	0.064	Negative	Positive
Institutional Development	78	2.000	1.800	1.500	1.000	2.500	Positive	Negative
Depth of Credit Information	78	6.000	6.000	1.000	5.000	8.000	Positive	Negative
Legal Rights	78	7.000	8.000	2.000	5.000	1.000	Positive	Negative

Table Description: The table shows summary statistics for the main variables of the study. OBS = Observations, MED = Median, STD = Standard Deviation, MIN = Minimum, MAX = Maximum, DV = Dependent Variable.

Li et al. (2022), and Safiullah and Paramati (2022) discovered that fintech improves bank stability in China and Malaysia, respectively.

We took advantage of the rich theoretical literature on fintech – Philippon (2016), Romānova and Kudinska (2016), Navaretti et al. (2017), Vives (2017) Arner et al. (2017), Molnár (2018), Claessens et al. (2018), Merton and Thakor (2019), (2020), Carbó-Valverde et al. (2021, pp. 161–194) and Murinde et al. (2022) – to explain the negative relationship between fintech adoption and banks' financial stability. First, fintech adoption disrupts traditional banking practices and introduces new operational challenges. Integrating fintech solutions may require significant changes in banks' infrastructure, processes, and their workforce. If not managed properly, these disruptions may lead to operational inefficiencies, increased risks, and decreased z-scores. Second, the adoption of fintech may unconsciously impact credit risk management. The increased accessibility and ease of loan processing facilitated by fintech can lead to higher loan volumes.

However, this may also result in a relaxation of credit standards or inadequate due diligence, potentially leading to a higher NPL ratio. The rise in nonperforming loans negatively impacts banks' financial health and contributes to the observed decrease in z-scores. Third, the evolving nature of fintech often outpaces existing regulations. Banks adopting fintech solutions may face challenges in navigating the regulatory landscape, ensuring compliance, and managing associated risks. Failure to meet regulatory requirements can result in penalties, reputational damage, and increased credit risk exposure. Fourth, fintech adoption introduces new risks related to data security and privacy. The collection, storage, and utilization of customer data in fintech processes require robust security measures. Data breaches or privacy violations can erode customer trust, lead to reputational damage, and increase the likelihood of loan defaults, contributing to higher NPL ratios and lower z-scores.

Fifth, the level of technological infrastructure and connectivity across GCC countries varies. Inadequate technological infrastructure and limited connectivity can hinder fintech solutions' seamless integration and performance. Systematic operational issues arising from technical limitations can impact banks' efficiency, credit risk management and overall financial health, reflected in lower z-scores and higher NPL ratios. Sixth, the GCC economies are susceptible to fluctuations in oil prices and economic volatility. The concentration of banks' loan portfolios in specific sectors, such as real estate or energy, can amplify credit risk during economic downturns. Fintech adoption may not adequately address sectoral risks, resulting in increased loan defaults and NPL ratios, thereby impacting banks' z-scores. Seventh, fintech adoption may face challenges in customer acceptance and adoption in

the GCC region. For instance, cultural preferences, trust issues and conservative attitudes towards financial transactions can hinder the widespread adoption of fintech services.

Similarly, low customer uptake can limit the benefits and effectiveness of fintech solutions, impacting banks' financial health and is reflected in lower z-scores. Finally, fintech solutions often rely on credit scoring models driven by algorithms and machine learning. However, these models can introduce biases, leading to inaccurate credit assessments and potentially higher default rates. Inadequate consideration of local GCC-specific factors or preferences within the data used for training algorithms can contribute to higher NPL ratios and lower z-scores.

There are several important insights regarding coefficients on control variables. First, banks with specific traits such as being large size, high capitalization and income diversification enjoy more financial stability than their counterparts. Second, a high loan-to-deposit ratio and off-balance sheet activities are related to lower financial stability. Third, Islamic, government-owned, foreign banks are more financially stable than conventional, private, domestic banks. Fourth, banks faced more financial fragility during COVID-19. Fifth, in line with the "concentration-fragility hypothesis" we notice that a higher bank concentration impairs bank stability [see (Berger, Klapper, & Turk-Ariss, 2017, pp. 185–204) for an extensive review of the topic]. Sixth, banks operating in the well-developed financial sector are financially more stable. Seventh, a macroeconomic system with high economic growth and low inflation improves banks' financial stability. Finally, economies with high institutional development, more credit information availability and effective legal rights promote banks' financial stability.

4.3. Role of regulatory environment

The fintech-related regulations are relevant for banks' financial stability in several ways. For instance, the regulatory environment strives to ensure effective risk management, promotes consumer protection, addresses cybersecurity and data protection, facilitates innovation through regulatory sandboxes, establishes interoperability standards, enforces capital and prudential requirements, and provides regulatory guidance. In this study, we follow Fung et al. (2020) and consider the regulatory sandbox a representative regulatory environment surrounding the fintech adoption. We analyze the collaborative function of the regulatory sandbox in fintech adoption and its link with banks' financial stability using Equation (2). The induction of the regulatory sandbox is captured through a binary variable that equals 1 for

Table 3
Coefficients of correlation.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1 Banks' Z-Score	1.000																
2 Non-Performing Loans (NPL) Ratio	-0.295	1.000															
3 Fintech Adoption 1 (FTA-1)	-0.250	0.167	1.000														
4 Fintech Adoption 2 (FTA-2)	-0.275	0.138	0.720	1.000													
5 Bank Size	0.320	-0.229	0.303	0.256	1.000												
6 Bank Capitalization	0.099	-0.170	0.270	0.187	0.333	1.000											
7 Loan to Deposit Ratio	-0.261	0.190	-0.310	-0.187	0.274	0.298	1.000										
8 Income Diversification	0.205	-0.268	0.229	0.234	0.203	0.340	0.278	1.000									
9 Off-Balance Sheet Activities	-0.273	0.192	0.198	0.163	0.245	0.277	0.232	0.244	1.000								
10 Degree of Banking Concentration	-0.217	0.091	0.232	0.144	0.257	0.148	0.289	0.194	0.171	1.000							
11 Banking Sector Development	0.318	-0.330	0.130	0.361	0.273	0.152	0.219	0.024	-0.202	-0.192	1.000						
12 Stock Market Development	0.323	-0.187	0.201	0.395	0.208	0.293	0.335	0.266	-0.194	-0.224	0.224	1.000					
13 Economic Growth	0.193	-0.248	0.288	0.196	0.299	0.208	0.297	0.109	-0.304	-0.136	0.285	0.280	1.000				
14 Inflation	-0.364	0.402	-0.268	-0.209	-0.215	-0.189	-0.175	0.260	0.218	0.255	-0.224	-0.156	-0.244	1.000			
15 Institutional Development	0.301	-0.252	0.124	0.242	0.272	0.240	0.206	0.223	0.298	0.246	0.244	0.251	0.259	0.354	1.000		
16 Depth of Credit Information	0.116	-0.328	0.317	0.239	0.172	0.277	0.265	0.201	0.316	0.253	0.143	0.199	0.390	0.249	0.275	1.000	
17 Legal Rights	0.152	-0.229	0.350	0.175	0.408	0.158	0.176	0.202	0.254	0.206	0.159	0.375	0.339	0.175	0.063	0.073	1.000

Table Description: The table displays coefficients of correlation among important variables of the study.

the year the sandbox was introduced and all the years following it. The estimated coefficients are reported in Table 5. The response variables are z-score (panel A) and NPL ratio (Panel B). The fintech adoption is significant in all regressions, as earlier. The coefficients on the regulatory sandbox are significantly negative (positive) for the z-score (NPL ratio). The results imply that banks' financial stability has decreased in the years following the induction of the regulatory sandbox. The interaction term also shows a similar behavior, i.e., significantly negative (positive) for z-score (NPL ratio). The findings indicate that the induction of a regulatory sandbox has added to the discouraging role of fintech adoption in banks' financial stability. The result contrasts with Fung et al. (2020), who find a promising role of a regulatory sandbox in promoting banks' stability.

There could be several reasons for GCC banks to experience a lower z-score and a higher NPL ratio after the induction of the regulatory sandbox. First, the regulatory sandbox offers a relaxed environment for experimentation and innovation. This lenient regulatory supervision allows fintech firms to engage in riskier activities without sufficient safeguards. Banks collaborating with or competing against these fintech firms within the sandbox may adopt riskier strategies to remain competitive. The increased risk-taking can lead to higher default rates, nonperforming loans, and a decrease in banks' z-scores, ultimately impacting their financial stability. Second, fintech innovations introduced through regulatory sandboxes can disrupt traditional banking models and intensify competition. Banks may face challenges in adapting to the rapid pace of technological advancements and the emergence of agile fintech competitors. This disruption and increased competition can erode banks' market share, profitability and asset quality, contributing to decreased z-scores and increased nonperforming loans.

Third, while designed to foster innovation, regulatory sandboxes can introduce regulatory uncertainty. The flexible and evolving nature of sandboxes may create a regulatory environment where banks and fintech firms exploit loopholes or engage in regulatory arbitrage. Banks may attempt to take advantage of the sandbox's leniency to engage in riskier activities or circumvent specific regulatory requirements, thereby increasing risk exposure and undermining financial stability. Fourth, participating in a regulatory sandbox requires banks to allocate resources to understand and implement new technologies and processes. Adopting fintech innovations may involve significant upfront costs, including infrastructure upgrades, staff training and technology investments. These operational challenges and costs can strain banks' financial resources and impact their financial stability, mainly if the expected benefits from the sandbox participation do not materialize. Finally, introducing a regulatory sandbox may raise concerns among consumers regarding the reliability and stability of financial services. For instance, consumers may perceive sandbox participants as experimental or less secure than traditional banks. This perception can lead to a loss of consumer trust and a potential decrease in deposits and customer loyalty. A decline in consumer confidence can adversely affect banks' financial stability, reflected in lower z-scores and a higher nonperforming loan ratio.

4.4. Micro and macroeconomic heterogeneity

In Section 4.2, we found that fintech adoption undermines banks' financial stability. However, such a relationship may not be homogenous across various bank-specific and country-specific factors. Insights from extensive banking literature also reveal that the effect of factors contributing to financial stability varies across bank-level and economic characteristics [see Berger et al. (2017, pp. 185–204)]. Therefore, following earlier studies in this domain – Fung et al. (2020), Cheng and Qu (2020), and Li et al. (2022) – we tested the heterogeneity of the relationship across several bank-specific and country-specific traits. More specifically, we introduced interactions of the fintech index with bank size, bank capitalization, bank type, ownership structure, banking sector development and bank concentration in the estimation model.

Table 4
Fintech adoption and bank stability.

Response Variable: Banks' Z-Score (Panel A) and NPL Ratio (Panel B)

Variables	Panel A: Banks' Z-Score				Panel B: NPL Ratio			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent Variable (T-1)	–	–	–	0.1680**	–	–	–	0.1127**
	–	–	–	(0.0752)	–	–	–	(0.0504)
Fintech Adoption	−0.1789***	−0.1742***	−0.1941***	−0.1895***	0.1797***	0.1957***	0.1791***	0.1811***
	(0.0336)	(0.0316)	(0.0401)	(0.0424)	(0.0340)	(0.0408)	(0.0337)	(0.0516)
Bank Size	0.0652**	0.1110**	0.0461**	0.0636**	−0.1208**	−0.1108**	−0.0471**	−0.0416**
	(0.0292)	(0.0497)	(0.0206)	(0.0285)	(0.0541)	(0.0496)	(0.0211)	(0.0186)
Bank Capitalization	0.1344**	0.0635**	0.1849**	0.1089**	−0.0710**	−0.1220**	−0.1272**	−0.0624**
	(0.0602)	(0.0284)	(0.0827)	(0.0487)	(0.0318)	(0.0546)	(0.0569)	(0.0279)
Loan to Deposit Ratio	−0.0714**	−0.1918**	−0.0429**	−0.1233**	0.0238**	0.0844**	0.1593**	0.1916**
	(0.0320)	(0.0859)	(0.0192)	(0.0552)	(0.0107)	(0.0378)	(0.0713)	(0.0858)
Income Diversification	0.0488**	0.0407**	0.1715**	0.1575**	−0.1549**	−0.0427**	−0.0674**	−0.0632**
	(0.0218)	(0.0182)	(0.0767)	(0.0705)	(0.0693)	(0.0191)	(0.0302)	(0.0283)
Off-Balance Sheet Activities	−0.1507**	−0.1195**	−0.0311**	−0.0304**	0.1395**	0.1369**	0.1241**	0.1729**
	(0.0674)	(0.0535)	(0.0139)	(0.0136)	(0.0624)	(0.0613)	(0.0556)	(0.0774)
Islamic versus Conventional (Dummy)	0.1626**	0.0824**	0.1844**	0.1737**	−0.0885**	−0.0438**	−0.0606**	−0.1122**
	(0.0728)	(0.0369)	(0.0825)	(0.0777)	(0.0396)	(0.0196)	(0.0271)	(0.0502)
Foreign (Dummy)	0.1920**	0.0850**	0.1430**	0.1426**	−0.1897**	−0.0778**	−0.0906**	−0.0967**
	(0.0859)	(0.0380)	(0.0640)	(0.0638)	(0.0849)	(0.0348)	(0.0406)	(0.0433)
Government (Dummy)	0.0642**	0.1398**	0.0824**	0.1037**	−0.0345**	−0.0684**	−0.0709**	−0.1292**
	(0.0287)	(0.0625)	(0.0369)	(0.0464)	(0.0154)	(0.0306)	(0.0317)	(0.0578)
COVID-19 (Dummy)	−0.0541**	−0.0496**	−0.0583**	−0.0278**	0.1457**	0.0874**	0.1363**	0.1202**
	(0.0242)	(0.0222)	(0.0261)	(0.0124)	(0.0652)	(0.0391)	(0.0610)	(0.0538)
Degree of Banking Concentration	−0.1364**	−0.1420**	−0.0796**	−0.1307**	0.1376**	0.0503**	0.0692**	0.0224**
	(0.0610)	(0.0635)	(0.0356)	(0.0582)	(0.0616)	(0.0225)	(0.0310)	(0.0100)
Banking Sector Development	0.1665**	0.0732**	0.0560**	0.1894**	−0.0933**	−0.1051**	−0.0441**	−0.0976**
	(0.0745)	(0.0327)	(0.0251)	(0.0848)	(0.0418)	(0.0470)	(0.0197)	(0.0437)
Stock Market Development	0.1651**	0.1250**	0.0223**	0.1335**	−0.1909**	−0.1861**	−0.1545**	−0.1588**
	(0.0739)	(0.0559)	(0.0100)	(0.0597)	(0.0854)	(0.0833)	(0.0691)	(0.0711)
Economic Growth	0.1931**	0.1627**	0.0448**	0.0433**	−0.0940**	−0.1404**	−0.0352**	−0.0291**
	(0.0864)	(0.0728)	(0.0200)	(0.0194)	(0.0421)	(0.0629)	(0.0158)	(0.0130)
Inflation	−0.1650**	−0.0971**	−0.0874**	−0.0572**	0.0962**	0.0540**	0.0773**	0.1589**
	(0.0739)	(0.0434)	(0.0391)	(0.0256)	(0.0430)	(0.0242)	(0.0346)	(0.0711)
Institutional Development	0.0914**	0.0568**	0.1851**	0.1808**	−0.0905**	−0.0549**	−0.1296**	−0.1767**
	(0.0409)	(0.0254)	(0.0828)	(0.0809)	(0.0405)	(0.0246)	(0.0580)	(0.0791)
Depth of Credit Information	0.1606**	0.0793**	0.1756**	0.1280**	−0.0524**	−0.1177**	−0.0654**	−0.1174**
	(0.0719)	(0.0355)	(0.0786)	(0.0573)	(0.0234)	(0.0527)	(0.0293)	(0.0525)
Legal Rights	0.1162**	0.1931**	0.1013**	0.1748**	−0.1225**	−0.1930**	−0.0646**	−0.0567**
	(0.0520)	(0.0864)	(0.0453)	(0.0782)	(0.0548)	(0.0864)	(0.0289)	(0.0254)
Constant	0.1405**	0.0921**	0.0246**	0.1897**	0.1505**	0.0990**	0.1918**	0.1113**
	(0.0629)	(0.0412)	(0.0110)	(0.0849)	(0.0674)	(0.0443)	(0.0858)	(0.0498)
Country Dummy	YES	YES	YES	YES	YES	YES	YES	YES
Time Dummy	YES	YES	YES	YES	YES	YES	YES	YES
F-Statistics (First Stage Regression)	–	–	17.693	–	–	–	18.577	–
AB (1)	–	–	–	0.0319	–	–	–	0.0378
AB (2)	–	–	–	0.2048	–	–	–	0.1864
Sargan/Hansen	–	–	–	0.2799	–	–	–	0.2598
No. of Instruments	–	–	–	147	–	–	–	147
No. of Groups	184	184	184	184	184	184	184	184
No. of Observations	1748	1748	1748	1748	1748	1748	1748	1748

Table Description: The effects of fintech adoption on bank stability (the estimated coefficients from equation (1)) are reported in this table. The response variables are the Banks' Z-Score (Panel A) and the NPL Ratio (Panel B). We estimated results using OLS (columns 1 and 5), Fixed Effects (columns 2 and 6), 2SLS (columns 3 and 7), and two-step dynamic panel system GMM (columns 4 and 8). The primary predicting variable (fintech adoption) is an index implying the extent of banks' embracement of fintech innovations. High (low) values of the index imply more (less) fintech adoption. The post-estimation tests – AB (1), AB (2), and Sargan/Hansen – indicate that the estimation model is appropriate. Corrected standard errors are reported in parentheses. The significance of relationships is indicated by single asterisks (10%), double asterisks (5%), and triple asterisks (1%).

Table 6 reports the estimated coefficients. The fintech index enters all regressions significantly with a negative (positive) sign for z-score (NPL ratio) as in Section 4.2. Coefficients on all interaction terms are statistically significant with a sign opposite to that on the fintech index.

The results provide many vital insights. First, the adverse effects of fintech adoption on financial stability are lower for large and well-capitalized banks. These banks have more resources and expertise to manage and mitigate risks associated with fintech adoption effectively. Similarly, their substantial capital reserves provide a cushion against potential losses or disruptions caused by new technologies. Thirdly, their diverse business lines and broad customer base help spread the risks associated with fintech adoption. In addition, their market power

and established customer relationships allow them to compete with fintech startups more effectively. Moreover, their financial resources enable them to invest in research and development, technological infrastructure and talent acquisition.

Second, compared to their counterparts, the financial stability of Islamic, foreign and government banks is less affected by fintech adoption. Islamic banks operate under a different financial framework emphasizing risk-sharing and asset-backed transactions, which may provide inherent stability when dealing with technological disruptions. Foreign banks often have access to global expertise, advanced technologies, and diversified markets, which can enhance their ability to adapt to fintech innovations. Government banks, backed by the state, may

Table 5
Fintech adoption, regulatory environment and bank stability.

Response Variable: Banks' Z-Score (Panel A) and NPL Ratio (Panel B)

Variables	Panel A: Banks' Z-Score				Panel B: NPL Ratio			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent Variable (T-1)	–	–	–	0.1247**	–	–	–	0.1210**
	–	–	–	(0.0558)	–	–	–	(0.0541)
Fintech Adoption	−0.1631***	−0.2140***	−0.1921***	−0.1540***	0.1694**	0.1859**	0.1801***	0.1651***
	(0.0098)	(0.0486)	(0.0393)	(0.0230)	(0.0296)	(0.0451)	(0.0341)	(0.0278)
Regulatory Environment (Sandbox)	−0.1122**	−0.1303**	−0.0538**	−0.1292**	0.0638**	0.0595**	0.0691**	0.0527**
	(0.0478)	(0.0556)	(0.0229)	(0.0551)	(0.0272)	(0.0254)	(0.0295)	(0.0224)
Fintech Adoption X Regulatory Environment	−0.0875**	−0.0598**	−0.0653**	−0.0381**	0.0623**	0.0833**	0.0964**	0.0765**
	(0.0377)	(0.0255)	(0.0278)	(0.0179)	(0.0266)	(0.0355)	(0.0411)	(0.0326)
Bank Size	0.1234**	0.0705**	0.1185**	0.1039**	−0.1611**	−0.1641**	−0.1063**	−0.1525**
	(0.0552)	(0.0315)	(0.0530)	(0.0452)	(0.0721)	(0.0734)	(0.0476)	(0.0682)
Bank Capitalization	0.1839**	0.1092**	0.0824**	0.0861**	−0.1597**	−0.1594**	−0.1679**	−0.0437**
	(0.0823)	(0.0489)	(0.0369)	(0.0385)	(0.0714)	(0.0713)	(0.0752)	(0.0196)
Loan to Deposit Ratio	−0.0355**	−0.0450**	−0.0566**	−0.1262**	0.0510**	0.1308**	0.1313**	0.1543**
	(0.0159)	(0.0201)	(0.0510)	(0.0565)	(0.0228)	(0.0585)	(0.0588)	(0.0691)
Income Diversification	0.1033**	0.0365**	0.1757**	0.0480**	−0.1422**	−0.0441**	−0.1068**	−0.0512**
	(0.0462)	(0.0163)	(0.0786)	(0.0215)	(0.0636)	(0.0197)	(0.0478)	(0.0229)
Off-Balance Sheet Activities	−0.0606**	−0.1023**	−0.1802**	−0.1480**	0.0700**	0.0231**	0.0687**	0.1924**
	(0.0271)	(0.0458)	(0.0806)	(0.0662)	(0.0313)	(0.0104)	(0.0307)	(0.0861)
Islamic versus Conventional (Dummy)	0.1294**	0.0565**	0.1256**	0.1315**	−0.0743**	−0.0484**	−0.0769**	−0.1203**
	(0.0579)	(0.0253)	(0.0562)	(0.0588)	(0.0333)	(0.0217)	(0.0344)	(0.0539)
Foreign (Dummy)	0.1838**	0.1435**	0.1547**	0.1502**	−0.0652**	−0.0284**	−0.0297**	−0.0667**
	(0.0822)	(0.0642)	(0.0693)	(0.0672)	(0.0292)	(0.0127)	(0.0133)	(0.0299)
Government (Dummy)	0.0484**	0.0687**	0.1632**	0.0328**	−0.1461**	−0.1106**	−0.0844**	−0.0359**
	(0.0217)	(0.0308)	(0.0730)	(0.0147)	(0.0654)	(0.0495)	(0.0377)	(0.0161)
COVID-19 (Dummy)	−0.1090**	−0.1201**	−0.1258**	−0.0934**	0.0974**	0.0733**	0.1149**	0.1438**
	(0.0488)	(0.0538)	(0.0563)	(0.0418)	(0.0436)	(0.0328)	(0.0514)	(0.0644)
Degree of Banking Concentration	−0.0816**	−0.0647**	−0.1546**	−0.0759**	0.1849**	0.1034**	0.0633**	0.1636**
	(0.0365)	(0.0289)	(0.0692)	(0.0339)	(0.0827)	(0.0463)	(0.0283)	(0.0732)
Banking Sector Development	0.1468**	0.0720**	0.0278**	0.1141**	−0.1492**	−0.0913**	−0.0897**	−0.1926**
	(0.0657)	(0.0322)	(0.0124)	(0.0510)	(0.0668)	(0.0403)	(0.0401)	(0.0862)
Stock Market Development	0.0574**	0.0268**	0.1163**	0.1704**	−0.1605**	−0.1577**	−0.1704**	−0.1083**
	(0.0257)	(0.0120)	(0.0520)	(0.0763)	(0.0718)	(0.0706)	(0.0762)	(0.0484)
Economic Growth	0.0858**	0.1792**	0.0552**	0.0823**	−0.0250**	−0.1493**	−0.0682**	−0.1603**
	(0.0384)	(0.0802)	(0.0247)	(0.0368)	(0.0112)	(0.0668)	(0.0305)	(0.0717)
Inflation	−0.0477**	−0.0720**	−0.1399**	−0.1103**	0.0623**	0.1302**	0.1475**	0.0849**
	(0.0213)	(0.0322)	(0.0626)	(0.0449)	(0.0279)	(0.0583)	(0.0660)	(0.0380)
Institutional Development	0.1879**	0.1026**	0.1186**	0.1869**	−0.1149**	−0.0973**	−0.1475**	−0.1740**
	(0.0841)	(0.0459)	(0.0531)	(0.0837)	(0.0514)	(0.0436)	(0.0660)	(0.0779)
Depth of Credit Information	0.0595**	0.1402**	0.1748**	0.1630**	−0.1922**	−0.0677**	−0.1276**	−0.0432**
	(0.0266)	(0.0627)	(0.0782)	(0.0730)	(0.0860)	(0.0303)	(0.0571)	(0.0193)
Legal Rights	0.1528**	0.1320**	0.1079**	0.1877**	−0.1148**	−0.0637**	−0.0971**	−0.1455**
	(0.0684)	(0.0591)	(0.0483)	(0.0840)	(0.0514)	(0.0285)	(0.0435)	(0.0651)
Constant	0.0297**	0.1275**	0.1703**	0.0883**	0.0664**	0.1358**	0.1730**	0.1441**
	(0.0133)	(0.0571)	(0.0762)	(0.0395)	(0.0297)	(0.0608)	(0.0774)	(0.0645)
Country Dummy	YES	YES	YES	YES	YES	YES	YES	YES
Time Dummy	YES	YES	YES	YES	YES	YES	YES	YES
F-Statistics (First Stage Regression)	–	–	21.505	–	–	–	22.581	–
AB1	–	–	–	0.0260	–	–	–	0.0361
AB2	–	–	–	0.2164	–	–	–	0.2540
Sargan/Hansen	–	–	–	0.2753	–	–	–	0.2146
No. of Instruments	–	–	–	147	–	–	–	147
No. of Groups	184	184	184	184	184	184	184	184
No. of Observations	1748	1748	1748	1748	1748	1748	1748	1748

Table Description: The effects of fintech adoption on bank stability (the estimated coefficients from equation (1)) are reported in this table. The response variables are the Banks' Z-Score (Panel A) and the NPL Ratio (Panel B). We estimated results using OLS (columns 1 and 5), Fixed Effects (columns 2 and 6), 2SLS (columns 3 and 7), and two-step dynamic panel system GMM (columns 4 and 8). The primary predicting variable (fintech adoption) is an index implying the extent of banks' embracement of fintech innovations. High (low) values of the index imply more (less) fintech adoption. The post-estimation tests – AB (1), AB (2), and Sargan/Hansen – indicate that the estimation model is appropriate. Corrected standard errors are reported in parentheses. The significance of relationships is indicated by single asterisks (10%), double asterisks (5%), and triple asterisks (1%).

have greater resilience due to their access to financial support and potential regulatory advantages. In addition, these types of banks may have stricter regulatory frameworks and risk management practices, ensuring a more cautious approach to fintech adoption. Furthermore, their focus on specific customer segments or industries can provide a niche advantage in navigating fintech challenges. Moreover, the brand reputation and trust associated with these banks may offer a certain level of stability and customer loyalty.

Finally, well-developed, and more competitive banking sectors can moderate the adverse effects of fintech innovation on financial stability. A well-developed banking sector typically exhibits higher financial sophistication, including robust risk management frameworks and regulatory oversight. This enables banks to assess better and mitigate risks associated with fintech innovation. A competitive banking sector encourages banks to continuously improve their services and operational efficiency, which can drive them to adopt fintech innovations strategically and responsibly. Moreover, increased competition prompts banks to invest in technological advancements, allowing them to better adapt

Table 6
Fintech adoption, bank stability and bank-level heterogeneity.

Response Variables: Banks' Z-Score (1, 3, 5, 7, 9, 11) and NPL Ratio (2, 4, 6, 8, 10, 12)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Dependent Variable (T-1)	0.1735**	0.1820***	0.1557***	0.1906**	0.1427***	0.1760**	0.1309**	0.1447***	0.1622***	0.1953***	0.1456**	0.1515**	0.1740***	0.1754***
	(0.0776)	(0.0367)	(0.0249)	(0.0853)	(0.0191)	(0.0788)	(0.0586)	(0.0200)	(0.0278)	(0.0427)	(0.0652)	(0.0678)	(0.0331)	(0.0338)
Fintech Adoption	−0.0454**	0.1161**	−0.0478**	0.0570**	−0.0837**	0.0309**	−0.0699**	0.0859**	−0.1054**	0.0742**	−0.0807**	0.0723**	−0.1088**	0.0583**
	(0.0194)	(0.0495)	(0.0204)	(0.0243)	(0.0357)	(0.0132)	(0.0324)	(0.0366)	(0.0428)	(0.0317)	(0.0344)	(0.0308)	(0.0464)	(0.0249)
Bank Size X Fintech Adoption	0.0907***	−0.0768**												
	(0.0213)	(0.0362)												
Bank Capitalization X Fintech Adoption			0.0311**	−0.0566**										
			(0.0146)	(0.0253)										
Islamic Bank (Dummy) X Fintech Adoption					0.0290**	−0.0324**								
					(0.0140)	(0.0135)								
Foreign Bank (Dummy) X Fintech Adoption							0.0374**	−0.0217**						
							(0.0173)	(0.0103)						
Government Bank (Dummy) X Fintech Adoption									0.0340**	−0.0123**				
									(0.0142)	(0.0055)				
Bank Concentration X Fintech Adoption											−0.0393**	0.0389**		
											(0.0194)	(0.0183)		
Bank Sector Development X Fintech Adoption													0.0631**	−0.0532**
													(0.0269)	(0.0259)
Bank Size	0.1017**	−0.1421**	0.0522**	−0.0755**	0.1821**	−0.1265**	0.0260**	−0.0396**	0.1067**	−0.1084**	0.1710**	−0.1921**	0.0603**	−0.1089**
	(0.0455)	(0.0636)	(0.0233)	(0.0338)	(0.0815)	(0.0566)	(0.0116)	(0.0177)	(0.0478)	(0.0485)	(0.0765)	(0.0860)	(0.0270)	(0.0487)
Bank Capitalization	0.0532**	−0.1645**	0.1386**	−0.1394**	0.0662**	−0.0359**	0.0461**	−0.1551**	0.1367**	−0.1453**	0.1493**	−0.1258**	0.1861**	−0.0312**
	(0.0238)	(0.0736)	(0.0620)	(0.0624)	(0.0296)	(0.0161)	(0.0206)	(0.0694)	(0.0612)	(0.0650)	(0.0668)	(0.0501)	(0.0833)	(0.0140)
Loan to Deposit Ratio	−0.1217**	0.0779**	−0.0553**	0.1092**	−0.1196**	0.1392**	−0.0939**	0.0553**	−0.1179**	0.1778**	−0.0330**	0.0562**	−0.1712**	0.1022**
	(0.0503)	(0.0349)	(0.0248)	(0.0489)	(0.0535)	(0.0623)	(0.0420)	(0.0247)	(0.0528)	(0.0796)	(0.0148)	(0.0251)	(0.0766)	(0.0457)
Income Diversification	0.1818**	−0.0713**	0.1241**	−0.1810**	0.1181**	−0.1771**	0.0627**	−0.1414**	0.0745**	−0.1655**	0.0415**	−0.0252**	0.0678**	−0.1606**
	(0.0814)	(0.0319)	(0.0555)	(0.0810)	(0.0529)	(0.0793)	(0.0281)	(0.0633)	(0.0333)	(0.0741)	(0.0186)	(0.0113)	(0.0303)	(0.0719)
Off-Balance Sheet Activities	−0.1770**	0.0461**	−0.0334**	0.1303**	−0.1827**	0.1546**	−0.1160**	0.0487**	−0.0910**	0.1634**	−0.0340**	0.0569**	−0.1191**	0.1718**
	(0.0792)	(0.0206)	(0.0149)	(0.0583)	(0.0817)	(0.0692)	(0.0519)	(0.0218)	(0.0407)	(0.0731)	(0.0152)	(0.0254)	(0.0533)	(0.0769)
Islamic versus Conventional (Dummy)	0.0328**	−0.1839**	0.1339**	−0.1370**	0.1642**	−0.0919**	0.1203**	−0.1156**	0.0597**	−0.0446**	0.0313**	−0.0915**	0.1497**	−0.0541**
	(0.0147)	(0.0823)	(0.0599)	(0.0613)	(0.0735)	(0.0411)	(0.0538)	(0.0517)	(0.0267)	(0.0200)	(0.0140)	(0.0409)	(0.0671)	(0.0242)
Foreign (Dummy)	0.0265**	−0.0902**	0.0377**	−0.1637**	0.1875**	−0.0225**	0.1147**	−0.0275**	0.1181**	−0.1572**	0.0991**	−0.1609**	0.1621**	−0.1896**
	(0.0119)	(0.0404)	(0.0169)	(0.0733)	(0.0839)	(0.0100)	(0.0513)	(0.0123)	(0.0528)	(0.0703)	(0.0444)	(0.0720)	(0.0725)	(0.0849)
Government (Dummy)	0.0752**	−0.0698**	0.1184**	−0.0321**	0.1722**	−0.0774**	0.1830**	−0.1088**	0.1120**	−0.1636**	0.1654**	−0.1526**	0.1075**	−0.1765**
	(0.0337)	(0.0313)	(0.0530)	(0.0144)	(0.0771)	(0.0347)	(0.0819)	(0.0487)	(0.0501)	(0.0732)	(0.0740)	(0.0683)	(0.0481)	(0.0790)
COVID-19 (Dummy)	−0.1464**	0.0625**	−0.0876**	−0.0858**	0.0968**	−0.1424**	0.1146**	−0.1641**	0.1405**	−0.1130**	0.0935**	−0.0285**	0.1507**	−0.0366**
	(0.0655)	(0.0280)	(0.0392)	(0.0384)	(0.0433)	(0.0637)	(0.0513)	(0.0734)	(0.0629)	(0.0506)	(0.0418)	(0.0127)	(0.0675)	(0.0164)
Degree of Banking Concentration	−0.1521**	0.1503**	−0.1131**	0.1875**	−0.1593**	0.1349**	−0.0929**	0.0863**	−0.1546**	0.1115**	−0.0408**	0.0630**	−0.0864**	0.0929**
	(0.0680)	(0.0673)	(0.0506)	(0.0839)	(0.0713)	(0.0604)	(0.0416)	(0.0386)	(0.0692)	(0.0499)	(0.0183)	(0.0282)	(0.0387)	(0.0416)
Banking Sector Development	0.1164**	−0.1611**	0.0547**	−0.1089**	0.0451**	−0.1862**	0.1490**	−0.1028**	0.0939**	−0.1402**	0.1207**	−0.0637**	0.0787**	−0.0743**
	(0.0521)	(0.0721)	(0.0245)	(0.0487)	(0.0202)	(0.0833)	(0.0667)	(0.0460)	(0.0420)	(0.0628)	(0.0540)	(0.0285)	(0.0352)	(0.0332)
Stock Market Development	0.0883**	−0.0270**	0.1410**	−0.1474**	0.0476**	−0.1121**	0.1782**	−0.1566**	0.0605**	−0.0551**	0.1925**	−0.1310**	0.0768**	−0.1467**
	(0.0395)	(0.0121)	(0.0631)	(0.0660)	(0.0213)	(0.0502)	(0.0798)	(0.0701)	(0.0271)	(0.0246)	(0.0861)	(0.0497)	(0.0344)	(0.0656)
Economic Growth	0.0628**	−0.1068**	0.1561**	−0.1663**	0.1670**	−0.1734**	0.1850**	−0.0749**	0.0415**	−0.1721**	0.1187**	−0.1763**	0.1642**	−0.0949**
	(0.0281)	(0.0478)	(0.0698)	(0.0744)	(0.0747)	(0.0776)	(0.0828)	(0.0335)	(0.0186)	(0.0770)	(0.0531)	(0.0789)	(0.0735)	(0.0425)
Inflation	−0.0712**	0.0973**	−0.1818**	0.1553**	−0.1411**	0.1714**	−0.0270**	0.0608**	−0.1342**	0.0335**	−0.1920**	0.1580**	−0.0621**	0.1828**
	(0.0319)	(0.0435)	(0.0695)	(0.0695)	(0.0632)	(0.0767)	(0.0121)	(0.0272)	(0.0601)	(0.0150)	(0.0603)	(0.0707)	(0.0278)	(0.0818)
Institutional Development	0.0836**	−0.0622**	0.1347**	−0.1714**	0.0699**	−0.0526**	0.1329**	−0.1150**	0.0421**	−0.0608**	0.1284**	−0.0464**	0.1015**	−0.0564**
	(0.0374)	(0.0278)	(0.0603)	(0.0767)	(0.0313)	(0.0235)	(0.0595)	(0.0514)	(0.0189)	(0.0272)	(0.0575)	(0.0208)	(0.0454)	(0.0252)
Depth of Credit Information	0.0255**	−0.0914**	0.1776**	−0.1883**	0.1422**	−0.0775**	0.0530**	−0.1412**	0.1526**	0.0593**	0.0518**	−0.0328**	0.1692**	−0.1813**
	(0.0114)	(0.0409)	(0.0795)	(0.0842)	(0.0637)	(0.0347)	(0.0237)	(0.0632)	(0.0683)	(0.0265)	(0.0232)	(0.0147)	(0.0757)	(0.0811)
Legal Rights	0.1892**	−0.1411**	0.1936**	−0.1682**	0.1211**	−0.0369**	0.1334**	−0.0834**	0.0704**	−0.0860**	0.1815**	−0.1729**	0.1214**	−0.1560**
	(0.0847)	(0.0631)	(0.0866)	(0.0753)	(0.0542)	(0.0165)	(0.0597)	(0.0373)	(0.0315)	(0.0385)	(0.0812)	(0.0774)	(0.0543)	(0.0698)

Table 6 (*continued*)

Response Variables: Banks' Z-Score (1, 3, 5, 7, 9, 11) and NPL Ratio (2, 4, 6, 8, 10, 12)														
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Constant	0.1241**	0.1680**	0.1127**	0.1445**	0.1500**	0.0737**	0.0800**	0.1839**	0.1232**	0.1055**	0.0528**	0.1133**	0.1072**	0.1793**
	(0.0555)	(0.0752)	(0.0504)	(0.0647)	(0.0671)	(0.0330)	(0.0358)	(0.0823)	(0.0551)	(0.0472)	(0.0236)	(0.0507)	(0.0480)	(0.0803)
Country Dummy	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Time Dummy	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
AB1	0.0362	0.0240	0.0388	0.0374	0.0366	0.0252	0.0348	0.0313	0.0245	0.0249	0.0351	0.0289	0.0373	0.0481
AB2	0.2084	0.1589	0.2876	0.2532	0.2866	0.2753	0.1615	0.1845	0.1962	0.1922	0.1831	0.1392	0.1796	0.2316
Sargan/Hansen	0.1930	0.1657	0.2690	0.1657	0.2599	0.1425	0.2298	0.1511	0.1333	0.1410	0.1662	0.1324	0.1708	0.2203
No. of Instruments	143	143	143	143	143	143	143	143	143	143	143	143	143	143
No. of Groups	184	184	184	184	184	184	184	184	184	184	184	184	184	184
No. of Observations	1748	1748	1748	1748	1748	1748	1748	1748	1748	1748	1748	1748	1748	1748

Table Description: The table shows the results of variations in bank stability and its relationship with fintech adoption across various bank-specific and market-specific characteristics such as bank size, capitalization, banking models (Islamic versus traditional banking), ownership structure (foreign, government, and private), banking market structure and banking sector development. The response variables are z-score (columns 1, 3, 5, 7, 9, 11) and nonperforming loan ratio (columns 2, 4, 6, 8, 10, 12). The results are estimated with the two-step system GMM. The post-estimation tests – AB (1), AB (2), and Sargan/Hansen – indicate that the estimation model is appropriate. Corrected standard errors are reported in parentheses. The significance of relationships is indicated by a single asterisk (10%), double asterisks (5%), and triple asterisks (1%).

to disruptive changes and stay resilient.

Additionally, well-developed banking sectors tend to have more diversified revenue streams and customer bases, reducing the reliance on a single source of income and mitigating potential disruptions caused by fintech adoption. In addition, well-established institutions foster trust and stability in the financial system, providing a solid foundation for fintech integration. More so, the robust regulatory framework and oversight in well-developed banking sectors ensure that fintech activities are conducted within defined boundaries, reducing the likelihood of destabilizing effects. The existing literature has also found the fintech-stability relationship to vary across bank-specific and market-specific characteristics. For instance, risk reduction through fintech innovation is more evident in larger, state-owned and competitive banks (Li et al., 2022); the diminishing effect of fintech on credit risk is weaker for large, state-owned banks and listed banks (Cheng & Qu, 2020); concentrated banking industry supports fintech in enhancing financial stability (Daud et al., 2022).

4.5. Robustness analysis

As discussed in Section 3.1.1, an accurate and comprehensive measurement of fintech adoption presents significant challenges for several reasons, such as the multifaceted nature of fintech adoption, data limitations and the dynamic landscape of technological advancements. Nonetheless, we constructed a bank-year indicator of fintech adoption for GCC countries. We used it to analyze the role of fintech adoption and the regulatory environment in the banking sector's stability reported in Sections 4.2, 4.3, and 4.4. The difference between our indicator and the ones used by Cheng and Qu (2020) and Daud et al. (2022) is that we identified fintech attributes more related to the banking industry. Moreover, we verified if a service corresponding to a particular fintech attribute is offered or initiated by a bank. This way, we felt that our measure was more reflective of banks' adoption of fintech innovations. In this section, we re-estimated Equations (1) and (2) with an alternative indicator of fintech adoption constructed following a similar procedure as in Cheng and Qu (2020) and Daud et al. (2022). The behavior of both indicators – FTA-1 (new index) and FTA-2 (alternative index) – is remarkably similar. The evolution of fintech across GCC economies with both indicators is generally identical (Figs. 3 and 4). Furthermore, the correlation coefficient is also very high, i.e., 0.72 (Table 3).

Table 7 shows the effect of fintech adoption on bank stability when an alternative index of fintech adoption is employed. The formation of the table is shown in Table 4. All coefficients on the fintech adoption index are significant, with the negative (positive) sign in panel A (panel B). The findings are qualitatively identical to those reported in Table 4. There are some differences in the size of coefficients on fintech adoption in Tables 4 and 7 For instance, the coefficients in Table 4 range between 0.1742 and 0.1957. In contrast, they are considerably smaller in Table 7, ranging from 0.0283 to 0.0690. However, the main finding that fintech adoption weakens banks' financial stability remains relevant. In Table 8, the alternative fintech index is used to analyze the role of the regulatory sandbox in financial stability and its relationship with fintech adoption. The estimated coefficients on fintech adoption and its interaction with the regulatory environment are significantly positive (negative) in panel A (panel B). The findings are equivalent to those discussed in Section 4.3. In summary, we find robust evidence that fintech adoption has induced bank-level financial instability in GCC countries. Furthermore, the induction of the sandbox supplements the negative link between fintech adoption and financial stability.

5. Conclusion and implications

Financial technology (Fintech) is changing the landscape of the financial sector through the application of technology and innovation to deliver financial services. Traditional financial institutions such as banks are among the leading players in the fintech industry. Banks' adoption of

Table 7

Fintech adoption and bank stability (robustness check- alternative fintech adoption indicator).

Response Variable: Banks' Z-Score (Panel A) and NPL Ratio (Panel B)								
Variables	Panel A: Banks' Z-Score				Panel B: NPL Ratio			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent Variable (T-1)	–	–	–	0.1024**	–	–	–	0.1039**
	–	–	–	(0.0458)	–	–	–	(0.0465)
Fintech Adoption	−0.0631**	−0.0557**	−0.0690**	−0.0398**	0.0283**	0.0457**	0.0567**	0.0514**
	(0.0269)	(0.0067)	(0.0294)	(0.0426)	(0.0124)	(0.0208)	(0.0242)	(0.0347)
Bank Size	0.1181**	0.0516**	0.1189**	0.1224**	−0.0571**	−0.1765**	−0.1378**	−0.1120**
	(0.0529)	(0.0231)	(0.0532)	(0.0548)	(0.0256)	(0.0790)	(0.0617)	(0.0501)
Bank Capitalization	0.0445**	0.0488**	0.0777**	0.0870**	−0.1915**	−0.1364**	−0.0313**	−0.0733**
	(0.0199)	(0.0218)	(0.0348)	(0.0389)	(0.0857)	(0.0610)	(0.0140)	(0.0328)
Loan to Deposit Ratio	−0.0995**	−0.0739**	−0.0426**	−0.0749**	0.0347**	0.0835**	0.1499**	0.1716**
	(0.0445)	(0.0331)	(0.0191)	(0.0335)	(0.0155)	(0.0374)	(0.0671)	(0.0768)
Income Diversification	0.0547**	0.0959**	0.1119**	0.1772**	−0.1668**	−0.0543**	−0.0726**	−0.1418**
	(0.0245)	(0.0429)	(0.0501)	(0.0793)	(0.0746)	(0.0243)	(0.0325)	(0.0634)
Off-Balance Sheet Activities	−0.0856**	−0.1610**	−0.1835**	−0.0240**	0.1862**	0.0984**	0.0876**	0.0955**
	(0.0383)	(0.0721)	(0.0821)	(0.0108)	(0.0833)	(0.0440)	(0.0392)	(0.0427)
Islamic versus Conventional (Dummy)	0.1078**	0.0446**	0.1811**	0.0248**	−0.1002**	−0.1062**	−0.0372**	−0.1767**
	(0.0483)	(0.0200)	(0.0811)	(0.0111)	(0.0448)	(0.0475)	(0.0166)	(0.0791)
Foreign (Dummy)	0.1351**	0.1925**	0.0654**	0.0561**	−0.0224**	−0.1896**	−0.0946**	−0.1867**
	(0.0605)	(0.0861)	(0.0292)	(0.0251)	(0.0100)	(0.0848)	(0.0423)	(0.0836)
Government (Dummy)	0.1189**	0.0791**	0.0547**	0.1779**	−0.1347**	−0.0229**	−0.0791**	−0.0236**
	(0.0532)	(0.0354)	(0.0245)	(0.0796)	(0.0603)	(0.0102)	(0.0354)	(0.0106)
COVID-19 (Dummy)	−0.0723**	−0.1839**	−0.0621**	−0.1660**	0.1661**	0.0493**	0.1538**	0.1703**
	(0.0323)	(0.0823)	(0.0278)	(0.0743)	(0.0743)	(0.0221)	(0.0688)	(0.0762)
Degree of Banking Concentration	−0.1830**	−0.0973**	−0.1917**	−0.0909**	0.0332**	0.1483**	0.0868**	0.1944**
	(0.0819)	(0.0435)	(0.0858)	(0.0403)	(0.0149)	(0.0664)	(0.0388)	(0.0870)
Banking Sector Development	0.1196**	0.0852**	0.0531**	0.1172**	−0.0981**	−0.1258**	−0.1321**	−0.0682**
	(0.0535)	(0.0381)	(0.0237)	(0.0524)	(0.0439)	(0.0563)	(0.0591)	(0.0305)
Stock Market Development	0.0313**	0.1319**	0.0837**	0.1833**	−0.0702**	−0.1424**	−0.0793**	−0.0675**
	(0.0140)	(0.0590)	(0.0374)	(0.0820)	(0.0314)	(0.0637)	(0.0355)	(0.0302)
Economic Growth	0.1829**	0.0663**	0.1793**	0.0803**	−0.1789**	−0.1815**	−0.1116**	−0.1445**
	(0.0818)	(0.0297)	(0.0359)	(0.0359)	(0.0801)	(0.0812)	(0.0500)	(0.0646)
Inflation	−0.0582**	−0.0765**	−0.0378**	−0.1740**	0.0525**	0.1609**	0.0333**	0.1560**
	(0.0260)	(0.0342)	(0.0169)	(0.0779)	(0.0235)	(0.0720)	(0.0149)	(0.0698)
Institutional Development	0.0310**	0.0313**	0.0321**	0.1713**	−0.1592**	−0.1640**	−0.1857**	−0.1178**
	(0.0139)	(0.0140)	(0.0144)	(0.0767)	(0.0712)	(0.0734)	(0.0831)	(0.0527)
Depth of Credit Information	0.0254**	0.1560**	0.0297**	0.0419**	−0.1125**	−0.0671**	−0.1220**	−0.0821**
	(0.0114)	(0.0698)	(0.0133)	(0.0187)	(0.0504)	(0.0300)	(0.0546)	(0.0368)
Legal Rights	0.0335**	0.0328**	0.0622**	0.1077**	−0.1071**	−0.0872**	−0.0886**	−0.1861**
	(0.0150)	(0.0147)	(0.0278)	(0.0482)	(0.0479)	(0.0390)	(0.0397)	(0.0833)
Constant	0.1535**	0.1464**	0.1519**	0.1527**	0.1511**	0.0955**	0.0891**	0.0381**
	(0.0687)	(0.0655)	(0.0680)	(0.0683)	(0.0676)	(0.0427)	(0.0399)	(0.0170)
Country Dummy	YES	YES	YES	YES	YES	YES	YES	YES
Time Dummy	YES	YES	YES	YES	YES	YES	YES	YES
F-Statistics (First Stage Regression)	–	–	19.506	–	–	–	19.048	–
AB (1)	–	–	–	0.0238	–	–	–	0.0376
AB (2)	–	–	–	0.1826	–	–	–	0.1439
Sargan/Hansen	–	–	–	0.1437	–	–	–	0.2785
No. of Instruments	–	–	–	147	–	–	–	147
No. of Groups	184	184	184	184	184	184	184	184
No. of Observations	1748	1748	1748	1748	1748	1748	1748	1748

Table Description: The effects of fintech adoption on bank stability (the estimated coefficients from equation (1)) are reported in this table. The response variables are the Banks' Z-Score (Panel A) and the NPL Ratio (Panel B). We estimated results using OLS (columns 1 and 5), Fixed Effects (columns 2 and 6), 2SLS (columns 3 and 7), and two-step dynamic panel system GMM (columns 4 and 8). The primary predicting variable (fintech adoption) is an index implying the extent of banks' embracement of fintech innovations. High (low) values of the index imply more (less) fintech adoption. The post-estimation tests – AB (1), AB (2), and Sargan/Hansen – indicate that the estimation model is appropriate. Corrected standard errors are reported in parentheses. The significance of relationships is characterized by single asterisks (10%), double asterisks (5%), and triple asterisks (1%).

fintech innovation has important implications for their efficiency, profitability and financial stability. At the same time, governments' regulatory stance is of utmost significance in promoting fintech innovation and ensuring financial stability. The existing research in the fintech domain is scarce probably because measuring fintech adoption is challenging for several reasons, such as the multifaceted nature of fintech adoption, data limitations and the dynamic landscape of technological advancements. In this study, we constructed a fintech adoption index for banks in GCC countries and utilized it to investigate the impact of fintech adoption and the regulatory environment on banks' financial stability.

The findings suggest that fintech adoption has increased banks'

financial instability in GCC economies. Moreover, the induction of a regulatory sandbox adds to the financial instability introduced by fintech adoption. A careful examination of additional variables offers many valuable insights. First, large-sized, and high-capitalized banks with diversified sources of income are financially more stable than their counterparts. Second, banks with a high loan-to-deposit ratio and more off-balance sheet activities experience increased financial instability. Third, conventional, private, and domestic banks are more financially unstable than Islamic, government-owned and foreign banks. Fourth, banks' financial stability in GCC economies was lower during COVID-19. Fifth, the level of bank competition and financial development promote bank stability. Sixth, the macroeconomic environment characterized by

Table 8

Fintech adoption, fintech regulations and bank stability (robustness check- alternative fintech adoption indicator).

Response Variable: Banks' Z-Score (Panel A) and NPL Ratio (Panel B)

Variables	Panel A: Banks' Z-Score				Panel B: NPL Ratio			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent Variable (T-1)	–	–	–	0.1399**	–	–	–	0.1399**
	–	–	–	(0.0626)	–	–	–	(0.0626)
Fintech Adoption	−0.1091**	−0.0557**	−0.0818**	−0.0717**	0.1325**	0.0750**	0.1243**	0.0629**
	(0.0426)	(0.0237)	(0.0349)	(0.0306)	(0.0565)	(0.0320)	(0.0530)	(0.0268)
Regulatory Environment (Sandbox)	−0.1083**	−0.0374**	−0.0270**	−0.0495**	0.0887**	0.0210**	0.0324**	0.1101**
	(0.0462)	(0.0159)	(0.0115)	(0.0211)	(0.0378)	(0.0090)	(0.0138)	(0.0469)
Fintech Adoption X Regulatory Environment	−0.1054**	−0.0703**	−0.1230**	−0.0975***	0.0937**	0.0665**	0.1265**	0.1503**
	(0.0449)	(0.0303)	(0.0524)	(0.0032)	(0.0400)	(0.0283)	(0.0539)	(0.0641)
Bank Size	0.1773**	0.0570**	0.0311**	0.0613**	−0.0414**	−0.1527**	−0.0348**	−0.1255**
	(0.0793)	(0.0255)	(0.0139)	(0.0274)	(0.0185)	(0.0684)	(0.0156)	(0.0562)
Bank Capitalization	0.1530**	0.1130**	0.0850**	0.0929**	−0.1333**	−0.0802**	−0.1927**	−0.1560**
	(0.0685)	(0.0506)	(0.0380)	(0.0416)	(0.0597)	(0.0359)	(0.0862)	(0.0698)
Loan to Deposit Ratio	−0.1388**	−0.1178**	−0.1847**	−0.0851**	0.0520**	0.1498**	0.1920**	0.0423**
	(0.0621)	(0.0527)	(0.0827)	(0.0381)	(0.0233)	(0.0671)	(0.0859)	(0.0189)
Income Diversification	0.0625**	0.1159**	0.1080**	0.1049**	−0.0785**	−0.1359**	−0.1329**	−0.0595**
	(0.0280)	(0.0519)	(0.0483)	(0.0469)	(0.0351)	(0.0608)	(0.0595)	(0.0266)
Off-Balance Sheet Activities	−0.1675**	−0.1361**	−0.0260**	−0.0467**	0.0748**	0.1892**	0.0290**	0.1898**
	(0.0749)	(0.0609)	(0.0116)	(0.0209)	(0.0335)	(0.0847)	(0.0130)	(0.0849)
Islamic versus Conventional (Dummy)	0.1842**	0.1387**	0.1291**	0.1558**	−0.1071**	−0.1794**	−0.0732**	−0.1888**
	(0.0824)	(0.0621)	(0.0578)	(0.0697)	(0.0479)	(0.0803)	(0.0328)	(0.0845)
Foreign (Dummy)	−0.0908**	−0.1464**	−0.1747**	−0.0717**	0.1519**	0.1314**	0.1769**	0.0326**
	(0.0451)	(0.0655)	(0.0782)	(0.0321)	(0.0680)	(0.0588)	(0.0792)	(0.0146)
Government (Dummy)	0.0697**	0.1887**	0.1537**	0.0845**	−0.0333**	−0.0471**	−0.0565**	−0.1783**
	(0.0312)	(0.0844)	(0.0688)	(0.0378)	(0.0149)	(0.0211)	(0.0253)	(0.0798)
COVID-19 (Dummy)	−0.0326**	−0.1273**	−0.0931**	−0.1703**	0.0831**	0.1573**	0.1522**	0.0866**
	(0.0146)	(0.0570)	(0.0417)	(0.0762)	(0.0372)	(0.0704)	(0.0681)	(0.0388)
Degree of Banking Concentration	−0.1574**	−0.0592**	−0.1241**	−0.1594**	0.1769**	0.1371**	0.1542**	0.1085**
	(0.0705)	(0.0265)	(0.0555)	(0.0713)	(0.0792)	(0.0614)	(0.0690)	(0.0486)
Banking Sector Development	0.1903**	0.0581**	0.0934**	0.0447**	−0.1223**	−0.0426**	−0.0861**	−0.1559**
	(0.0852)	(0.0260)	(0.0418)	(0.0200)	(0.0547)	(0.0191)	(0.0386)	(0.0697)
Stock Market Development	0.1187**	0.1448**	0.0386**	0.1817**	−0.0405**	−0.0465**	−0.1368**	−0.1739**
	(0.0531)	(0.0648)	(0.0173)	(0.0813)	(0.0181)	(0.0208)	(0.0612)	(0.0778)
Economic Growth	0.1361**	0.0759**	0.1397**	0.1525**	−0.1549**	−0.1738**	−0.1942**	−0.1832**
	(0.0609)	(0.0340)	(0.0625)	(0.0683)	(0.0693)	(0.0778)	(0.0869)	(0.0820)
Inflation	−0.1022**	−0.0542**	−0.0814**	−0.0240**	0.1625**	0.0822**	0.1228**	0.1646**
	(0.0458)	(0.0242)	(0.0364)	(0.0107)	(0.0727)	(0.0368)	(0.0550)	(0.0737)
Institutional Development	0.1775**	0.1919**	0.0310**	0.1305**	−0.0368**	−0.1673**	−0.1608**	−0.0427**
	(0.0794)	(0.0859)	(0.0139)	(0.0584)	(0.0165)	(0.0749)	(0.0720)	(0.0191)
Depth of Credit Information	0.0230**	0.0632**	0.1387**	0.1275**	−0.1057**	−0.1371**	−0.1789**	−0.1243**
	(0.0103)	(0.0283)	(0.0621)	(0.0571)	(0.0473)	(0.0614)	(0.0801)	(0.0556)
Legal Rights	0.1484**	0.0737**	0.0952**	0.1081**	−0.0893**	−0.0819**	−0.0606**	−0.1903**
	(0.0664)	(0.0330)	(0.0426)	(0.0484)	(0.0392)	(0.0367)	(0.0271)	(0.0852)
Constant	0.1764**	0.0233**	0.0971**	0.1056**	0.1541**	0.1456**	0.1422**	0.1177**
	(0.0790)	(0.0104)	(0.0435)	(0.0473)	(0.0690)	(0.0652)	(0.0636)	(0.0527)
Country Dummy	YES	YES	YES	YES	YES	YES	YES	YES
Time Dummy	YES	YES	YES	YES	YES	YES	YES	YES
F-Statistics (First Stage Regression)	–	–	17.162	–	–	–	18.141	–
AB1	–	–	–	0.0288	–	–	–	0.0352
AB2	–	–	–	0.2319	–	–	–	0.1904
Sargan/Hansen	–	–	–	0.2168	–	–	–	0.2350
No. of Instruments	–	–	–	147	–	–	–	147
No. of Groups	184	184	184	184	184	184	184	184
No. of Observations	1748	1748	1748	1748	1748	1748	1748	1748

Table Description: The effects of fintech adoption on bank stability (the estimated coefficients from equation (1)) are reported in this table. The response variables are the Banks' Z-Score (Panel A) and the NPL Ratio (Panel B). We estimated results using OLS (columns 1 and 5), Fixed Effects (columns 2 and 6), 2SLS (columns 3 and 7), and two-step dynamic panel system GMM (columns 4 and 8). The primary predicting variable (fintech adoption) is an index implying the extent of banks' embracement of fintech innovations. High (low) index values imply more (less) fintech adoption. The post-estimation tests – AB (1), AB (2), and Sargan/Hansen – indicate that the estimation model is appropriate. Corrected standard errors are reported in parentheses. The significance of relationships is indicated by single asterisks (10%), double asterisks (5%), and triple asterisks (1%).

economic growth and price stability enhances banks' financial stability. Finally, institutional development, availability of credit information and an effective legal system all encourage banks' financial stability. An additional analysis of the fintech-stability relationship reveals several facts. For instance, the adverse effects of fintech adoption on financial stability are lower for large and well-capitalized banks. In addition, compared to their counterparts, the financial stability of Islamic, foreign and government banks is less affected by fintech adoption. Furthermore, well-developed, and more competitive banking sectors can moderate the

adverse effects of fintech innovation on financial stability.

The findings of this study offer important policy implications for regulators and bank authorities in the GCC. Firstly, the regulatory institutions and bank authorities must enhance risk management practices to address the challenges introduced by fintech adoption. Serious consideration must be given to employing robust risk assessment frameworks and developing mechanisms to monitor and alleviate risks linked with new technologies. The related policies must also ensure that banks possess essential capabilities to manage the potential disruptions

triggered by fintech. Secondly, the regulatory authorities must balance advancing fintech innovation and preserving financial stability. They should review and update existing regulations to address the emerging risks associated with fintech and ensure that banks have appropriate compliance mechanisms. Thirdly, the impact of fintech adoption on banks' financial stability must be monitored, and timely action should be taken if necessary. For this purpose, a close collaboration between banks, fintech firms and regulatory authorities is crucial.

Moreover, open dialogue and partnerships must be encouraged to advance responsible innovation while mitigating risks. Additionally, the design and implementation of sandboxes should consider potential adverse effects and strike a balance between innovation and stability. Fourthly, governments must invest in the capacity building of banks and regulatory institutions to understand the dynamics of risks posed by fintech adoption. The objectives of such a program must include enhancing financial literacy, providing training, and creating an environment that promotes innovation, collaboration, and knowledge sharing. Finally, frequent monitoring and evaluation of the impact of fintech adoption on banks' financial stability are crucial. The steps may include continuous analysis of key indicators such as banks' z-scores, nonperforming loan ratios and other relevant metrics. More importantly, the policy responses should be data-driven and adaptive to ensure the effectiveness of measures taken to safeguard financial stability.

The study suffers from a few limitations. For instance, fintech is a relatively new phenomenon, and banks and regulators need more time to understand its dynamics. Moreover, fintech needs time to generate more data and allow researchers to construct reliable measures and observe its impact on various aspects of the banking sector. In this regard, it is essential to consider that the decrease in financial stability indicators in the short term may be a temporary phenomenon. Moreover, introducing a regulatory sandbox may initially disrupt the traditional banking landscape, leading to short-term challenges. However, over time, as the sandbox matures and regulatory frameworks adapt, banks may benefit from the innovation and collaboration facilitated by the sandbox, ultimately improving their financial stability in the long term.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors have used ChatGPT to improve the language and readability of the paper. After using this tool, the authors have reviewed and edited the content as needed and take full responsibility for the publication's content.

Acknowledgement

Appendix

Table A1
Digital Competitiveness and Global Innovation Ranking of GCC Countries

Countries	Score	WIPO GII Ranking*	Regional Innovation Ranking*	Global Digital Competitiveness Ranking (Adoption and Exploration) **
United Arab Emirates	42.5	31	1	13
Saudi Arabia	33.4	51	2	35
Qatar	32.9	52	3	34
Kuwait	29.9	62	4	NA
Bahrain	28	72	5	32
Oman	26.8	79	6	NA

Source: Authors compilation based on *WIPO global innovation index, &**IMD WCC, 2022. NA: not available

Table A2
Sample Distribution

Countries	Total Banks	Sample Banks	Sample Percentage	Observations
Bahrain	86	63	73.26%	600
Kuwait	11	9	81.82%	86
Oman	19	16	84.21%	152
Qatar	18	15	83.33%	143
Saudi Arabia	36	29	80.56%	276
United Arab Emirates	60	52	86.67%	494
Total	**230**	**184**	**80.00%**	**1748**

Table A3
Construction of Fintech Adoption Index for a Random Bank

Service/Year	S1	S2	S3	S4	S5	S6	S7	S8	S9	Weight	Index
2010	YES	NO	NO	NO	NO	NO	NO	NO	NO	1/9	0.05
2011	YES	YES	NO	NO	NO	NO	NO	NO	NO	2/9	0.09
2012	YES	YES	NO	NO	NO	NO	NO	NO	NO	2/9	0.13
2013	YES	YES	YES	NO	NO	NO	NO	NO	NO	3/9	0.18
2014	YES	YES	YES	YES	NO	NO	NO	NO	NO	4/9	0.26
2015	YES	YES	YES	YES	YES	NO	NO	NO	NO	5/9	0.35
2016	YES	YES	YES	YES	YES	YES	NO	NO	NO	6/9	0.41
2017	YES	YES	YES	YES	YES	YES	YES	NO	NO	7/9	0.45

(continued on next page)

Table A3 (*continued*)

Service/Year	S1	S2	S3	S4	S5	S6	S7	S8	S9	Weight	Index
2018	YES	YES	YES	YES	YES	YES	YES	NO	NO	7/9	0.54
2019	YES	YES	YES	YES	YES	YES	YES	NO	NO	7/9	0.61
2020	YES	YES	YES	YES	YES	YES	YES	YES	NO	8/9	0.68
2021	YES	YES	YES	YES	YES	YES	YES	YES	NO	8/9	0.73
2022	YES	YES	YES	YES	YES	YES	YES	YES	YES	9/9	0.81

Table A4
Variables Description and Sources

Variable Name	Variable Description & Sources
Response Variables	
Banks' Z-Score	The z-score assesses a bank's "distance to default". In other words, it measures how many standard deviations a bank can lose before it runs out of capital. The higher (lower) the z-score, the higher (lower) the bank's stability.
Non-Performing Loan Ratio	The ratio of nonperforming loans to total loans. A non-performing loan refers to a bank loan that has been delayed or is not likely to be fully repaid by the borrower. The higher (lower) the NPL ratio, the higher (lower) the bank's instability.
Main Explanatory Variables	
Fintech Adoption 1 (FTA-1)	An index of fintech adoption constructed by authors. Following the burgeoning literature on fintech, we first identified at least nine attributes of fintech adoption – banks' digital presence, mobile banking capabilities, support for open APIs, fintech partnerships, digital payment solutions, automation and artificial intelligence integration, innovation initiatives, user experience focus and embracing new technologies. See Table 1 for an explanation of each attribute.
Fintech Adoption 2 (FTA-2)	An alternative index of fintech adoption constructed following the procedure in Cheng and Qu (2020) and Daud et al. (2022).
Fintech Regulations	A binary variable that equals 1 for the year the regulatory sandbox was introduced and all years following it. Adopted from Fung et al. (2020).
Bank Level Controls	
Bank Size	Bank size is measured through the log of total assets. Source: BankFocus
Bank Capitalization	Bank capitalization is the ratio of a bank's equity to total assets. Source: BankFocus
Loan to Deposit Ratio	It is an inverse indicator of a bank's liquidity measured as the ratio of total loans to deposits. Source: BankFocus
Income Diversity	Income diversity is the ratio of non-interest income to total income. Source: BankFocus
Off-Balance Sheet Activities	Off-balance sheet activities are captured through the ratio of off-balance sheet items to total assets. Source: BankFocus
Merger (Dummy)	A binary variable that equals 1 if banks merged during a year, and 0 otherwise.
Islamic versus Conventional (Dummy)	A binary variable that equals 1 if a bank is categorized as an Islamic bank, and 0 if not.
Foreign (Dummy)	A binary variable that equals 1 if a bank is categorized as a foreign bank, and 0 if not.
Government (Dummy)	A binary variable that equals 1 if a bank is owned by the government, and 0 if not.
Country Level Controls	
Degree of Banking Sector Concentration	The degree of banking sector concentration is measured through the three-bank concentration ratio (CR3) which is the sum of market shares [asset-based] of the top three banks in a particular country in a year. Source: "Global Financial Development Database" (GFDD)
Banking Sector Development	The banking sector development is measured as the ratio of domestic credit to the private sector to the gross domestic product (GDP). Source: "Global Financial Development Database" (GFDD).
Stock Market Development	The stock market development is assessed as the ratio of stock market capitalization to the gross domestic product (GDP). Source: "Global Financial Development Database" (GFDD)
Economic Growth	An indicator of the macroeconomic environment, calculated as the annual growth in real GDP. Source: "Global Financial Development Database" (GFDD)
Inflation	An indicator of a general increase in price levels. It is calculated as the annual percentage changes in the GDP deflator. Source: "Global Financial Development Database" (GFDD)
Institutional Development	The aggregate of six indices represents "voice and accountability", "regulatory quality", "political stability", "rule of law", "control of corruption", and "government effectiveness". The index ranges between −2.5 to 2.5, higher values indicate more developed institutions. Sources: "World Governance Indicators" (WGI).
Depth of Credit Information	An index of credit information availability covering public or private credit bureaus. Source: "Doing Business Indicators" (DBI)
Legal Rights	An index that assesses the extent of protection provided to creditors and debtors by collateral and bankruptcy regulations. The index ranges between 0 and 10. Source: "Doing Business Indicator" (DBI).

Table Description: The table shows description and sources of variables.

Table A5
Country-wise Summary Statistics

VARIABLES	MEAN	MEDIAN	ST. DEV	MIN	MAX
Panel A: Summary Statistics for Bahrain					
Banks' Z-Score	9.780	11.736	3.994	1.693	20.533
Non-Performing Loan (NPL) Ratio	0.019	0.023	0.113	0.021	0.196
Fintech Adoption 1 (FTA-1)	0.461	0.540	0.288	0.060	0.892
Fintech Adoption 2 (FTA-2)	0.245	0.252	0.157	0.023	0.498
Regulatory Environment (Sandbox)	0.175	0.135	0.043	0.000	1.000
Panel B: Summary Statistics for Kuwait					
Banks' Z-Score	10.758	12.910	4.394	1.862	22.586
Non-Performing Loan Ratio	0.021	0.026	0.125	0.023	0.216
Fintech Adoption 1 (FTA-1)	0.388	0.432	0.239	0.048	0.778
Fintech Adoption 2 (FTA-2)	0.313	0.331	0.181	0.056	0.589
Regulatory Environment (Sandbox)	0.193	0.149	0.047	0.000	1.000
Panel C: Summary Statistics for Oman					
Banks' Z-Score	9.575	11.490	3.910	1.657	20.101

Table A5 (*continued*)

VARIABLES	MEAN	MEDIAN	ST. DEV	MIN	MAX
Non-Performing Loan (NPL) Ratio	0.019	0.023	0.111	0.020	0.192
Fintech Adoption 1 (FTA-1)	0.349	0.389	0.215	0.043	0.700
Fintech Adoption 2 (FTA-2)	0.201	0.183	0.137	0.019	0.454
Regulatory Environment (Sandbox)	0.164	0.141	0.044	0.000	1.000
Panel D: Summary Statistics for Qatar					
Banks' Z-Score (Log Values)	8.330	9.996	3.402	1.442	17.488
Non-Performing Loan (NPL) Ratio	0.016	0.020	0.096	0.018	0.167
Fintech Adoption 1 (FTA-1)	0.374	0.428	0.236	0.048	0.770
Fintech Adoption 2 (FTA-2)	32.795	29.692	22.550	4.451	69.641
Regulatory Environment (Sandbox)	0.110	0.085	0.027	0.000	1.000
Panel E: Summary Statistics for Saudi Arabia					
Banks' Z-Score	7.726	9.272	3.155	1.337	16.221
Non-Performing Loan (NPL) Ratio	0.015	0.018	0.089	0.016	0.155
Fintech Adoption 1 (FTA-1)	0.478	0.513	0.282	0.057	0.914
Fintech Adoption 2 (FTA-2)	0.328	0.297	0.226	0.045	0.696
Regulatory Environment (Sandbox)	0.094	0.073	0.023	0.000	1.000
Panel F: Summary Statistics for UAE					
Banks' Z-Score	8.499	10.199	3.471	1.471	17.843
Non-Performing Loans (NPL) Ratio	0.017	0.020	0.098	0.018	0.170
Fintech Adoption 1 (FTA-1)	0.510	0.565	0.301	0.063	0.930
Fintech Adoption 2 (FTA-2)	0.434	0.406	0.201	0.070	0.737
Regulatory Environment (Sandbox)	0.075	0.058	0.018	0.000	1.000
Panel G: Summary Statistics for Entire Sample					
Banks' Z-Score	9.112	10.934	3.721	1.577	19.129
Non-Performing Loans (NPL) Ratio	0.018	0.022	0.105	0.019	0.183
Fintech Adoption 1 (FTA-1)	0.434	0.534	0.259	0.038	0.950
Fintech Adoption 2 (FTA-2)	0.316	0.285	0.197	0.019	0.737
Regulatory Environment (Sandbox)	0.135	0.107	0.034	0.000	1.000

Table Description: The table shows summary statistics for the main variables of the study.

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