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The effect of FinTech development on financial stability in an emerging market: The role of market discipline

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ABSTRACT

This study investigated the impact of financial technology (FinTech) development on financial stability in an emerging market. By using data from 37 commercial banks in Vietnam for the period 2010–2020, the study found that FinTech development negatively affected financial stability, and market discipline can mitigate this effect. However, heterogeneity analysis further showed that the negative effect of FinTech development on financial stability is stronger when the degree of financial stability is low, and the role of market discipline also becomes more important in such a situation. As another extension, we also found that the negative impact of FinTech on financial stability and the role of market discipline in mitigating such effect becomes stronger when banks have higher state ownership and becomes weaker when banks have higher foreign ownership. Our study provides important implications for regulators to develop FinTech and maintain financial stability in emerging markets.

Introduction

Financial technology (FinTech) has grown significantly in recent years and received considerable attention pertaining to its effect on economies and financial systems. FinTech provides new operating models for start-ups and traditional financial services firms. FinTech innovations emerging in many aspects of finance, such as investment management, retail finance, insurance, wholesale payments, equity capital raising, and credit provision, are not only promoting banks' innovations and transformations in traditional service (Luo et al., 2022; Murinde et al., 2022), but also competing with them (An & Rau, 2021; Panos & Wilson, 2020). Therefore, FinTech development can have a larger impact on the financial system. A report by KPMG in 2021 shows that global FinTech investment reached $94.7 billion and increased 94 % compared with the value in 2008. Developing and emerging countries, such as Vietnam, also use FinTech a great deal so it has shown a dramatic growth. Following an ICTVIETNAM report in 2021, new FinTech startups reached 215 % in the period 2015–2020 and the number of transactions increased accordingly. In 2020, Vietnamese FinTech market have more than 120 FinTech startups covering a broad range of services that include digital payments, alternative finance, wealth management and blockchain. But with the government working on new developments, including a regulatory sandbox, and new regulatory guidelines, notably in the field of P2P lending can increase the development of FinTech in the future. Such development can greatly impact the economic and financial environment.

Regarding relationship between FinTech and financial stability, there are some previous studies were performed but the results are mixed. By using a sample of listed banks across 84 countries, Fung et al. (2020) investigated the divergent effects of FinTech shock on financial stability when a country implemented a FinTech regulatory sandbox. They found that shock to FinTech innovations decreases the fragility of financial institutions in emerging financial markets but increases the fragility of financial institutions in developed financial markets. However, they did not address how FinTech development affects financial stability after such a shock. In other words, they did not examine how the continued growth of FinTech impacts financial stability. Similarly, by using data from 63 developing and developed countries, Daud et al. (2021) found that FinTech positively related to financial stability in general. They also found that FinTech promotes financial stability

Abbreviations: FinTech, financial technology; E/A, equity on asset ratio; ROA, return on assets ratio; 2SQR, two-stage quantile regression.

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through channels of cloud technology, artificial intelligence, and data technology. However, the degree of development of cloud technology, artificial intelligence, and data technology differ greatly between developed and developing countries. Meanwhile, some previous studies showed the contrary result: Pantielieieva et al. (2018) and Vučinić (2020) stated that FinTech development increased potential risks for the financial system. Therefore, the effect of FinTech development on financial stability may be heterogeneous and may differ between developed and developing countries.

In addition, Wang et al. (2021) argued that the effect of FinTech on bank risk-taking is more salient in banks with greater shadow banking and lower efficiency, where shadow banking and bank efficiency depend on the structure of bank ownership (Ding et al., 2020; Figueira et al., 2009; Lensink et al., 2008). Therefore, whether banks in emerging countries need to consider restructuring their ownership structures in the context of an increasingly high level of FinTech development to maintain stability needs to be studied more closely.

By focusing on FinTech development in Vietnam, our main research objectives are to investigate the impact of FinTech development on financial stability and the role of market discipline in this context. Our study contributed to the literature in several ways. First, we contributed to the limited studies about the impact of FinTech development on financial stability; to our knowledge, this is the first study investigating FinTech development on financial stability at the bank and country level in emerging markets. This is vital, since the stability of the banking system is considered to be the primary factor affecting economic growth, especially in less developed economies (Levine, 1997). We found that FinTech development generally reduced financial stability. Second, this is the first study investigating the role of market discipline in controlling the effect of FinTech development on financial stability. We provided strong evidence that market discipline helps an emerging market mitigate the negative impacts of FinTech development on financial stability. Third, we contributed to the literature by investigating the effect of FinTech development on financial stability as well as the role of market discipline on different levels of financial stability. We found that the negative effect of FinTech development is higher and market discipline becomes a more effective instrument to mitigate this effect in less stable banks. Finally, as another extension, our study contributed to the literature by investigating the role of ownership structure in the relationship between FinTech development, market discipline, and financial stability. We found that the negative impact of FinTech on financial stability becomes stronger when banks have a higher state ownership but weakens when banks have higher foreign ownership. Similarly, market discipline plays a more important role in mitigating the negative impact of FinTech development on financial stability when banks have higher state ownership but plays a less important role when banks have higher foreign ownership.

The rest of this paper is organized as follows: Section 2 briefly discusses previous literature and outlines the research hypotheses. In Section 3, we present details of the research data, variable measurements, empirical model, and estimation methods. Section 4 provides empirical results and discussions. Finally, in Section 5, we conclude by presenting a summary of the overall findings, the main contributions, and the implications of the study.

Literature review and hypotheses development

FinTech and financial stability

Chan et al. (1986) proposed the "competition-stability hypothesis" and argued that "the quality of screening loan requests and the quality of its loans portfolio depend upon the surplus that results from such a screening process". They also argued that, if the level of competition in the market increased, the surplus decreases and results in a decline in the quality of bank loan assets. Mishkin (1999) suggested that banks with lower competition usually receive public guarantees and support, which may result in increased bank risk and reduced bank stability, with a resultant moral hazard problem. Some previous empirical studies have supported this hypothesis (Albaity et al., 2019; Boyd & De Nicolo, 2005). Meanwhile, most previous studies have agreed that FinTech increases the competition of banks. Ding et al. (2022) found that FinTech development promotes lending to firms because internet credit intensifies bank loan competition. Romānova and Kudinska (2016) argued that start-up service providers, search engines, and social networks have expanded their services by "interfering" in fields traditionally covered by banks, making the financial market more competitive. Herck Giaquinto and Bortoluzzo (2020) also argued that new companies' capital in emerging markets face more constraints accessing external sources. Thus, more established FinTech start-ups can make the financial market more competitive. Therefore, we expect FinTech development to reduce financial stability.

In addition, based on the asymmetric information theory, asymmetric information may positively affect stock crashes in the banking sector (Kosmidou et al., 2017). Therefore, by applying big data analysis, FinTech can become a good solution to enhance transparency, thus reducing information asymmetry and enhancing financial stability. Supporting this view in their paper, Fung et al. (2020) argued that FinTech can mitigate financial instability through enhanced transparency diversification, decentralization, enhanced convenience of financial services, and improved efficiency. Moreover, greater financial market diversity can increase economic stability (Weller & Zulfiqar, 2013). Daud et al. (2021) also provided empirical evidence supporting the argument that FinTech increases financial stability by investigating it in 63 countries. However, the effect of FinTech development on financial stability may not be the same in all countries. FSB (2017) supposed that "*FinTech is better for economies which have large unbanked populations with more people who own a cell phone than have a bank account.*" Particularly in countries with high information asymmetry, lenders cannot effectively assess the borrowers' creditworthiness in peer-to-peer (P2P) lending markets supported by FinTech. Moreover, the information asymmetry problem was found to be more critical in emerging countries like Vietnam (Huynh et al., 2020). Therefore, in this study, we expect a negative effect of FinTech development on financial stability in emerging market. Based on these discussions, we propose the hypothesis as follow:

H1: FinTech is negatively associated with financial stability in emerging markets.

Market discipline and Fintech–Financial stability relationship

Gilbert (1990) proposed the theory that if bank creditors and shareholders have greater exposure to losses, they will limit the risk assumed by their banks, and this could complement the efforts of bank supervisors. In other words, market discipline would replace government supervision to maintain bank stability. Based on this theory, the literature agrees that market discipline is regarded as a type of external corporate governance that controls bank risk-taking and thus, maintains financial stability (Bennett et al., 2015; Bertay et al., 2013; Hoang et al., 2014; Lee & Park, 2020). A higher degree of market discipline is expected to provide stronger supervision and thus, reduce the negative effects of any economic elements on financial stability.

Regarding FinTech development, Mild et al. (2015) argued that, in P2P lending markets, lenders cannot assess borrowers' creditworthiness effectively nor accurately price default risk as they do with banks. Furthermore, FinTech activities rely heavily on third-party service firms to link systemically to important financial institutions; therefore, their failure might result in systemic risk and reduce financial stability (Fung et al., 2020). Meanwhile, market discipline is regarded as a regulatory device to control default risk and systemic risk (De Ceuster & Masschelein, 2003). Hou et al. (2016) investigated the relationship between internet finance development and banking market discipline in the

Chinese financial market and proved that the role of market discipline is strengthened with the development of internet finance. Therefore, in the context of emerging countries with rapidly developing FinTech, the supervisory role of market discipline may become increasingly important. Moreover, Huang and Wang (2017) found that market discipline can help reduce information asymmetry in emerging markets and thus, help lenders assess borrowers' creditworthiness effectively or, more accurately price default risk. Therefore, it can be expected to reduce the negative effect of FinTech on financial stability. Based on these arguments, we proposed the following hypothesis:

H2: Market discipline negatively affects the FinTech development-financial stability relationship.

Research data and models

Research data

The financial and corporate governance data was collected from the Orbis Bank Focus annual and financial reports published by Vietnamese commercial banks. Data related to FinTech and macro variables was collected from multiple sources, such as World Bank, State Bank of Vietnam (SBV) reports, Statista's database, and Iris's Fintech Vietnam report. Our data included all commercial banks in Vietnam that published the necessary information for this study. After excluding outliers and missing data, the remaining data comprised an unbalanced panel of 37 commercial joint-stock banks for the period from 2010 to 2020. We excluded two Vietnamese microfinances and two joint-venture banks because their nature of operation differed from that of commercial banks and they did not publish their financial information. Our sample included nearly all Vietnamese banks and may be representative of the Vietnamese banking system. We started from 2010 based on FinTech data sets, since there is no Vietnamese FinTech data before 2010.

Variable measure

FinTech development measure

To measure FinTech development, we applied two proxies, including FinTech company (FINC) and FinTech transaction (FINT). FINC is measured by the total number of new FinTech companies established in year *t*, and FINT is measured by the natural logarithm of the total FinTech transaction value in year *t*. The greater the FinTech transactions and newly established companies, the greater the FinTech development.

Financial stability measure

First, we used bank-level Z-score (BZ-score), which has been used extensively in the banking literature (Beck et al., 2013; Berger et al., 2009; Fiordelisi, et al., 2011; Laeven & Levine, 2009; Nguyen, 2022a,b; Nguyen & Dang, 2022a,b). We followed the methodology used by Fiordelisi et al. (2011) and Berger et al. (2009) to obtain a time varying measure of financial stability: we estimated the Z-score by employing standard deviation of return on asset ratio (δ ROA) in year t calculated using a cross-sectional technique and combined this with the current period values of equity on asset ratio (E/A) in year t and ROA at year t for each individual bank. The Z-score was then calculated as follows:

$$BZ - score = \frac{ROA - E/A}{\delta ROA}$$

Although bank-level Z-score usually measures bank stability, the banking system plays the most important role in the financial system, and thus, bank stability can represent the stability of the financial system (Fiordelisi et al., 2011; Lee & Hsieh, 2014). The higher the value of the Z-score, the higher the level of financial stability.

The second measure of financial stability is country-level Z-score (CZ-score), which was collected from the World Bank Global Financial Development Database. It captures the probability of default of a country's banking system. Similar to the bank-level Z-score, the higher the value of the CZ-score, the higher the level of financial stability.

Table 1
Variables definition and data sources.

Variables	Definition and Measure	Source
Z-score	Country-level (CZ-score) or bank-level Z-score (BZscore). Bank-level Z-score = ROA + (equity/total assets)]/Std(ROA).	World Bank Global Financial Development Database and SBV's reports (country-level); and Orbis Bank Focus, bank's financial reports (bank-level)
FINC	Number of new FinTech companies established in a year.	Statista's database and Iris's Fintech Vietnam report 2021.
FINT	Nature logarithm of transaction value in a year	Statista's database, Iris's Fintech Vietnam report 2021.
LIST	The dummy variable which is 1 if bank is listed in stock exchange and 0 otherwise	Bank's annual reports.
RATE	The dummy variable, which is 1 if bank rated by Moody's and 0 otherwise	SBV's reports, bank's annual reports.
DISC	Disclosure index is built based on 18 categories of core disclosures suggested by Nier and Baumann (2006).	Orbis bank focus, bank's financial reports
BOSZ	Board size measured by total members on the board of director	Bank's annual reports.
BOSI	Board independence measured as a proportion of independent director on total number of directors on the board.	Bank's annual reports.
BSIZE	Bank size measured as the natural logarithm of total assets value	Orbis Bank Focus, bank's financial reports
DIVI	Diversification index measured as: $1 - \left\lvert \frac{Netinterestincome - Otheroperatingincome}{Totaloperatingincome} \right\rvert$	Orbis Bank Focus, bank's financial reports
NIIC	Non-interest income ratio measure as noninterest income to total income	Orbis Bank Focus
NIM	Net interest margin	Orbis Bank Focus, Bank's annual reports.
SOWN	State ownership measured as ratio of government shares to total shares	Bank's annual reports.
FOWN	Foreign ownership measured as ratio of foreign shares to total shares	Bank's annual reports.
AFI	"Access to financial institutions" measured as the total bank branches in a year per 100,000 adults	Bank's annual reports, World Bank
DFI	"Depth of financial institutions" measured by ratio of central bank assets on GDP.	SBV's reports, World Bank
GDPC	GDP per capita is measured as the natural logarithm of GDP per capita in a year	World Bank

Market discipline measure

In this study, we applied three proxies of market discipline, as suggested by the literature:

First, we used a dummy variable (LIST) that equals 1 if a bank is listed in the Vietnamese stock exchange in year *t* and 0 otherwise. Listed banks are subject to the supervision of the stock exchange. Thus, they provide their shareholders and depositors with more reliable information (Nier & Baumann, 2006).

Second, we used another dummy variable (RATE) which is 1 if a bank is rated by Moody's in year t and 0 otherwise. Investors and depositors are able to get more information about a bank if it is rated by a major rating agency. Rating agencies such as Moody's act as intermediaries in the disclosure process; they can access information that banks do not publish, then integrate this information into the rating (Nier & Baumann, 2006).

Finally, we used a disclosure index (DISC) suggested by Nier and

Table 2
Descriptive Statistics.

Variable	Mean	Std. Dev.	Min	Q.25	Q.75	Max
BZscore	12.654	2.120	−2.607	1.198	3.522	64.708
CZscore	15.476	2.348	12.330	14.580	15.540	21.200
FINC	14.252	2.573	9.000	13.000	16.000	18.000
FINT	9.485	0.417	8.832	9.215	9.852	10.065
LIST	0.291	0.455	0.000	0.000	1.000	1.000
RATE	0.486	0.501	0.000	0.000	1.000	1.000
DISC	9.295	1.641	7.000	8.000	11.000	12.000
BOSZ	7.255	1.801	5.000	6.000	8.000	13.000
BOSI	0.133	0.092	0.000	0.100	0.167	0.429
BSIZE	22.440	1.158	19.538	21.608	23.263	24.924
DIVI	0.307	0.882	−12.614	0.226	0.549	0.994
NIIC	0.261	0.499	−0.247	0.126	0.288	7.307
NIM	0.028	0.015	−0.018	0.019	0.035	0.090
SOWN	0.194	0.321	0.000	0.000	0.172	1.000
FOWN	0.108	0.161	0.000	0.000	0.200	0.963
AFI	3.817	0.141	3.609	3.683	3.916	4.017
DFI	0.008	0.005	0.001	0.004	0.011	0.015
GDPC	7.704	0.156	7.459	7.616	7.850	7.932

Note: See Table 1 for variable definitions.

Baumann (2006). This index is based on 18 categories of core disclosures in the bank's published accounts, as represented in the ORBIS Bank Focus database. Disclosure is one of the important aspects of market discipline found in the literature (Nier & Baumann, 2006; Wu & Bowe, 2010).

Control variable measures

At the bank level, first, we controlled the internal corporate governance of the bank, comprising board size (BOSZ) and board independence (BOSI). The board of directors is considered the "apex" of internal corporate governance and significantly affects bank risk and bank stability (Dang & Nguyen, 2021; Pathan, 2009; Laeven & Levine, 2007, 2009; Dang & Nguyen, 2022; Nguyen, 2022b). Second, we controlled some bank characteristics, including bank size (BSIZE), diversification index (DIVI), noninterest income ratio (NIIC), and net interest margin (NIM), which were found in the literature to affect financial stability (Nguyen, 2022a; Phan et al. 2021). Finally, we controlled bank ownership structure using state-ownership ratio (SOWN) and foreign ownership ratio (FOWN).

At the country level, we applied some market structure control variables, including "access to financial institutions" (AFI) and "depth of financial institutions" (DFI) to control market characteristics, as suggested by Phan et al. (2021), and used GDP per capita (GDPC) to control macroeconomic effects (Nguyen, 2022a). All variable definitions and calculations are presented in Table 1.

Empirical models and estimation method

First, to examine the effect of FinTech development on financial stability (H1), we used the following model:

$$FSB_{it/t} = \alpha_0 + \alpha_\gamma \sum_{\gamma=1}^{2} FIN_t + \alpha_\rho \sum_{\rho=3}^{10} FCON_{it} + \alpha_\sigma \sum_{\sigma=11}^{13} CCON_t + \mu_{it} \quad (1)$$

Second, to examine the effect of market discipline on the FinTech development–financial stability relationship (H2), we estimated the second model, as follows:

$$FSB_{it/t} = \beta_0 + \beta_\gamma \sum_{\gamma=1}^{2} FIN_t + \beta_\theta MAD_{it} * \sum_{\theta=3}^{4} FIN_{\theta t} + \beta_\rho \sum_{\rho=5}^{12} FCON_{it} + \beta_\sigma \sum_{\sigma=13}^{15} CCON_t + \mu_{it} \quad (2)$$

where FSB is financial stability measured by the Z-score (bank or country level), FIN is a vector of the main independent variables of

Table 3
Correlations Matrix.

	BZscore	CZscore	FINC	FINT	BOSZ	BOSI	BSIZE	DIVI	NIIC	NIM	SOWN	FOWN	AFI	DFI	GDPC
BZscore	1.00														
CZscore	0.10*	1.00													
FINC	−0.07*	0.01	1.00												
FINT	−0.01	−0.27***	0.67***	1.00											
BOSZ	0.07	0.01*	0.02	0.00	1.00										
BOSI	−0.06	0.09	0.17***	0.27***	−0.23***	1.00									
BSIZE	0.26***	0.08*	0.20***	0.29***	0.46***	−0.14**	1.00								
DIVI	0.15***	0.08	0.09	0.16***	0.04	0.12**	0.02	1.00							
NIIC	−0.11*	0.01	−0.08	−0.04	−0.01***	−0.10	0.13**	−0.63***	1.00						
NIM	0.06	0.06	−0.04	−0.03	0.01	0.09	−0.09	0.18***	−0.40***	1.00					
SOWN	0.22***	0.01	0.05	0.06	0.41	−0.31***	0.45***	0.07	−0.02	0.00	1.00				
FOWN	0.03	0.04	0.03	0.08	0.07*	0.13**	0.11*	0.06	−0.06	0.11*	−0.09	1.00			
AFI	−0.03	0.02	0.58***	0.66***	−0.02	0.23***	0.25***	0.16***	−0.11*	0.00	0.06	0.07	1.00		
DFI	−0.02	0.04**	−0.39***	−0.40***	−0.01	−0.17***	−0.21***	−0.07	−0.05	0.05	−0.03	−0.05	−0.41***	1.00	
GDPC	0.01	0.34***	0.64***	0.69***	0.00	0.27***	0.29***	0.16***	−0.03	−0.02	0.05	0.08	0.62***	−0.61***	1.00

Note: See Table 1 for variable definitions. ***p < 0.01; **p < 0.05; * p < 0.1.

Table 4
Fixed-effects Regression Results for FinTech Development-Financial Stability Relationship.

	Z-score (bank-level)						Z-score (country-level)					
	(1)		(2)		(3)		(4)		(5)		(6)	
	Coef.	*t*-stat	Coef.	*t*-stat	Coef.	*t*-stat	Coef.	*t*-stat	Coef.	*t*-stat	Coef.	*t*-stat
FINC	−0.07*	−1.80			−4.68***	−2.89	−0.18***	−4.71			−0.15***	−5.86
FINT			−4.41***	−2.71	−0.08**	−2.06			−20.09***	−17.68	−19.58***	−18.37
BOSZ	0.05	0.70	0.04	0.57	0.06	0.83	−0.07	−0.91	0.00	0.02	−0.03	−0.71
BOSI	1.41	1.43	1.52	1.56	1.55	1.6	−0.53	−0.53	0.13	0.19	0.07	0.12
BSIZE	−0.92***	−2.95	−0.85***	−2.75	−0.88***	−2.85	−0.34	−1.07	−0.20	−0.91	−0.15	−0.75
DIVI	0.35*	2.11	0.34	2.12	0.29**	1.81	0.55***	3.29	0.23**	2.08	0.33***	3.07
NIIC	0.51	1.56	0.54	1.67	0.44	1.35	0.89***	2.69	0.40*	1.77	0.58***	2.76
NIM	74.96***	8.89	72.56***	8.59	70.45***	8.34	39.82***	4.65	17.03***	2.89	20.97***	3.78
SOWN	0.01	0.01	−0.00**	−2.01	−0.03	−0.05	0.08	0.14	−0.12**	−2.30	−0.07	−0.19
FOWN	−0.89	−1.27	0.79	1.14	0.88**	2.27	0.37	0.52	0.24*	1.79	0.41	0.90
AFI	−0.56	−0.54	0.20	0.19	1.53	1.22	−26.37***	−24.97	−15.15***	−20.04	−17.63***	−21.4
DFI	−12.78	−0.60	−6.50	−0.31	−13.13	−0.62	607.19***	27.91	593.36***	40.48	605.75***	43.7
GDPC	2.49**	2.11	12.83***	3.25	13.35***	3.39	36.63***	30.59	82.94***	30.06	81.98***	31.73
Cons	4.59	0.72	−38.61**	−2.18	−43.35**	−2.44	−166.98***	−25.93	−376.19***	−30.43	−367.32***	−31.52
R-sq	0.31		0.32		0.34		0.45		0.45		0.42	
P-value(F-test)	0.00		0.00		0.00		0.01		0.00		0.01	

Note: This table reports the estimation results of Eq. (1). Regressions (1)–(4) involve the results by applying Z-score at bank-level as a dependent variable and regressions (5)–(8) involve the results by applying Z-score at country-level as a dependent variable. See Table 1 for variable definitions. ***p < 0.01; **p < 0.05; * p < 0.1.

FinTech development, which are FINC and FINT, and MAD is a vector of market discipline variables including LIST, RATE, and DISC.

Among the control variables, FCON is a vector of bank-level control variables and CCON is a vector of country-level control variables. α and β refer to the parameters to be estimated, and μ is an error term.

Empirical results

Variable description and correlation matrix

Table 2 reports the descriptive statistics of the main variables used in this study. The mean (min, max) of the BZscores at the bank and country levels were 12.654 (−2.607, 64.708) and 15.476 (12.330; 21.200), respectively. These values are similar to other samples, as stated in previous studies (Nguyen & Dang, 2020; Nguyen, 2021a). The value of CZscore is from 12.33 to 21.2, and the mean is 15.476 higher than BZscore. The degree of FinTech development in Vietnam is not high. The mean of FINC is 14.252 and of FINT is 9.485, indicating that FinTech develops much slower in emerging countries like Vietnam than in developed countries. In addition, the mean of LIST, RATE, and DISC are 0.291, 0.486, and 9.295. These values are quite low, showing that the degree of market discipline is not high in Vietnam.

Table 3 presents the Pearson's correlations between the main variables. The coefficient of FINC is negative and statistically significant with BZscore, and the coefficient of FINT and FINC are negative and statistically significant with CZscore; the signs of these coefficients were consistent with our expectations. However, the correlation matrix did not show a reliable relationship among the variables because the FinTech variable is not only correlated with financial stability variables. Therefore, we used a multiple regression framework, which is presented in the next section. The maximum value in this table is 0.69, indicating that our regression analysis may not meet a multi-collinearity problem.

The effect of FinTech on financial stability

In Table 4, we present the estimation results of Eq. (1) for testing hypothesis H1. The results show that the coefficients on FINC were negative and significant with Z-score at both bank and country levels (regression (1), 3, 4, and 6). The coefficients on FINT were also negative and significant, with Z-score in regressions (2), 3, 5, and 6. These results provided strong evidence that FinTech development negatively affects financial stability at both the bank and country levels in an emerging market. Our results did not support Daud et al. (2021), whose findings indicated that FinTech development generally increases financial stability. Similarly, our results did not support Cheng and Qu (2020), who found that FinTech in banks can reduce bank risk. This may be because Daud et al. (2021) and Cheng and Qu (2020) did not consider the differences in the financial systems between emerging and developed countries; additionally, they only focused on FinTech development in financial institutions without considering the development of FinTech start-ups. However, our results supported Fung et al. (2020), who found that FinTech affects the fragility of financial institutions depending on whether countries were emerging or developed. In general, our results, indicated in Table 3, strongly supported hypothesis H1, i.e., FinTech development reduces financial stability in emerging markets.

Regarding estimation results for control variables, Table 4 shows some interesting findings. The coefficients of bank size (BSIZE) are negative with Z-score at both bank and country level, but only statistically significant with Z-score at the bank level, indicating that the too-big-to-fail problem may exist in the Vietnamese banking system. The coefficients on NIM are positive and significant with Z-score at both the bank and country level, indicating that the "traditional activities" of banks increase financial stability. This result is consistent with Dwumfour (2017), who found the same results in MENA countries. Furthermore, we found that state ownership may reduce financial stability, whereas foreign ownership may increase it (the coefficients on SOWN/FOWN are negative/positive and significant with Z-score in regressions 3 and 5), but other coefficients of SOWN and FOWN are insignificant. Finally, the coefficients on GDPC were positive and significant in all regressions, indicating that economic growth can increase financial stability in the emerging market.

Table 5 reports the estimation results of Eq. (2) for testing hypothesis H2 by applying different measures of financial stability, FinTech development, and market discipline. First, except for regression (9), the results showed that the coefficients on FIN (both FINC and FINT) were negative and significant with the Z-score. The signs of FIN coefficients in Table 5 remain unchanged from Table 4. These results continued to strongly support hypothesis H1 and provide strong evidence that FinTech development is negatively associated with financial stability in emerging markets.

The coefficients on FIN*MAD were positive and significant with Z-score at the bank level in regressions (2), 3, and 5, and with Z-score at the country level in regressions 8, 10, 11, and 12. Although not all coefficients of FIN*MAD were statistically significant, there is strong

Table 5
Fixed-effects Regression Results For the Effect of Market Discipline on FinTech Development-Financial Stability Relationship.

	Bank-level						Country-level					
	FINC			FINT			FINC			FINT		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
FIN	−0.07*	−0.14***	−0.09*	−4.42***	−5.44***	−4.42***	−0.18***	−0.20***	0.13	−20.11***	−19.98***	−20.20***
	(−1.81)	(−3.21)	(−1.88)	(−2.7)	(−3.47)	(−2.67)	(−4.61)	(−4.43)	(1.28)	(−17.67)	(−17.40)	(−17.49)
FIN*MAD	0.01	0.15***	0.00**	0.00	1.53***	0.00	0.00	0.04**	0.01	0.02*	0.16*	0.01***
	(0.22)	(3.1)	(2.21)	(0.08)	(4.93)	(0.02)	(0.09)	(1.87)	(0.54)	(1.72)	(1.72)	(2.57)
BOSZ	0.05	0.04	0.05	0.04	0.07	0.04	−0.06	−0.06	−0.07	0.00	−0.00	0.00
	(0.71)	(0.62)	(0.68)	(0.57)	(1.04)	(0.57)	(−0.91)	(−0.89)	(−0.95)	(0.06)	(−0.04)	(0.06)
BOSI	1.42	1.19	1.40	1.52	0.85	1.52	−0.52	−0.47	−0.54	0.16	0.20	0.12
	(1.44)	(1.23)	(1.43)	(1.56)	(0.9)	(1.56)	(−0.52)	(−0.47)	(−0.54)	(0.23)	(0.30)	(0.18)
BSIZE	−0.92***	−0.97***	−0.93***	−0.85***	−0.95***	−0.85***	−0.34	−0.33	−0.35	−0.20	−0.19	−0.20
	(−2.93)	(−3.15)	(−2.95)	(−2.74)	(−3.19)	(−2.74)	(−1.07)	(−1.03)	(−1.11)	(−0.91)	(−0.87)	(−0.90)
DIVI	0.35**	0.32**	0.34**	0.34**	0.31**	0.34**	0.55***	0.55***	0.54***	0.24**	0.24**	0.23**
	(2.11)	(1.98)	(2.08)	(2.12)	(2.00)	(2.11)	(3.28)	(3.33)	(3.22)	(2.09)	(2.11)	(2.03)
NIIC	0.51	0.41	0.50	0.54*	0.44	0.53*	0.89***	0.91***	0.86***	0.40*	0.41*	0.38*
	(1.55)	(1.29)	(1.51)	(1.67)	(1.44)	(1.66)	(2.68)	(2.76)	(2.58)	(1.78)	(1.81)	(1.71)
NIM	74.53***	68.14***	75.40***	72.39***	56.70***	72.59***	39.63***	41.80***	40.95***	15.93***	18.74***	17.68***
	(8.59)	(7.95)	(8.67)	(8.28)	(6.54)	(8.42)	(4.50)	(4.72)	(4.64)	(2.62)	(2.95)	(2.94)
SOWN	−0.02**	0.27	−0.02	−0.00*	0.55	−0.00	0.09	0.00	0.11	−0.10***	−0.18**	−0.10**
	(−2.03)	(0.48)	(−0.13)	(1.78)	(1.02)	(−0.01)	(0.15)	(0.01)	(0.18)	(−2.25)	(−1.94)	(−1.95)
FOWN	−0.90	−0.85	0.84**	−0.79	0.58**	−0.78	0.37	0.36	0.50	0.22*	0.22	0.34
	(−1.27)	(−1.23)	(−1.83)	(−1.14)	(−1.88)	(−1.06)	(0.51)	(0.50)	(0.66)	(1.75)	(0.45)	(0.66)
AFI	−0.56	−0.56	−0.60	0.20	0.38	0.20	−26.37***	−26.37***	−26.47***	−15.12***	−15.16***	−15.19***
	(−0.53)	(−0.55)	(−0.56)	(0.19)	(0.37)	(0.18)	(−24.91)	(−24.96)	(−24.70)	(−19.98)	(−20.03)	(−19.96)
DFI	−12.74	−12.09	−13.13	−6.49	−4.63	−6.54	67.21***	66.99***	66.29***	53.42***	53.16***	52.47***
	(−0.59)	(−0.57)	(−0.61)	(−0.31)	(−0.23)	(−0.31)	(27.85)	(27.89)	(27.75)	(40.44)	(40.42)	(40.14)
GDPC	2.45**	2.57**	2.49**	12.83***	13.54***	12.84***	36.62***	36.61***	36.61***	82.89***	82.86***	82.98***
	(2.05)	(2.22)	(2.10)	(3.24)	(3.59)	(3.24)	(30.18)	(30.55)	(30.52)	(30.01)	(29.98)	(30.02)
Cons	4.82	5.29	4.87	−38.54**	−39.75**	−38.60**	−16.88***	−16.18***	−16.26***	−37.78***	−37.06***	−37.04***
	(0.75)	(0.85)	(0.75)	(−2.17)	(−2.35)	(−2.17)	(−25.53)	(−25.93)	(−25.26)	(−30.34)	(−30.39)	(−30.37)
R-sq	0.31	0.34	0.31	0.32	0.39	0.32	0.45	0.45	0.45	0.43	0.43	0.43
P-value(F-test)	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00

Note: This table reports the estimation results of Eq. (2). Regressions (1)–(6) involve the results by applying Z-score at bank-level as a dependent variable, and regressions (7)–(12) involve the results by applying Z-score at country-level as a dependent variable. At each bank and country level, we have two groups of results by applying FINT and FINC as independent variables respectively. MAD is a market discipline variable. For each group, we estimate the Eq. (2) by using LIST, RATE and DISC as proxies of market discipline respectively. We show the *t*-stat values in parentheses below each coefficient. See Table 1 for variable definitions. ***p < 0.01; **p < 0.05; * p < 0.1.

Table 6
The Effect of FinTech on financial stability-the role ownership structure.

Panel A	Bank-level											
	FINC					FINT						
	(1)		(2)	(3)		(4)		(5)		(6)		
	Coef.	*t*-stat	Coef.	*t*-stat	Coef.	*t*-stat	Coef.	*t*-stat	Coef.	*t*-stat	Coef.	*t*-stat
FIN	−0.12***	−2.60	−0.13**	−2.57	0.01	0.10	−4.77***	−3.01	−5.50***	−3.54	−4.67***	−2.87
FIN*SOWN	−0.10**	−1.94	−0.27	−1.43	−1.33**	−2.54	0.73	1.33	−0.65	−0.81	−1.94	−1.33
FIN*FOWN	0.45**	2.09	0.23	0.98	0.43	1.05	4.56***	3.90	2.74**	2.22	4.77***	3.72
FIN*MAD	0.03	0.66	0.11*	1.66	0.01*	−1.83	0.04*	1.78	1.46***	3.65	0.01***	2.28
FIN*MAD*SOWN	−0.11	−1.48	−0.24**	2.15	−0.12**	−2.55	−0.18	−1.49	−0.02**	−2.03	−0.18*	−1.69
FIN*MAD*FOWN	0.05**	2.30	0.05	1.27	0.00**	1.98	0.04***	2.15	0.05	1.18	0.06**	1.80
BOSZ	0.05	0.64	0.04	0.63	0.04	0.50	0.04	0.65	0.07	1.09	0.05	0.68
BOSI	1.53	1.55	1.09	1.10	1.13	1.16	1.50	1.57	0.80	0.84	1.14	1.21
BSIZE	−0.71**	−2.18	−0.95***	−2.95	−0.84***	−2.63	−0.37	−1.14	−0.80**	−2.41	−0.41	−1.28
DIVI	0.30*	1.80	0.30*	1.87	0.38**	2.29	0.29*	1.86	0.26*	1.66	0.33**	2.05
NIIC	0.40	1.21	0.37	1.16	0.56*	1.68	0.45	1.45	0.34	1.12	0.51	1.61
NIM	73.60***	8.22	68.21***	7.61	74.76***	8.51	71.42***	8.10	56.86***	6.18	72.11***	8.38
SOWN	−1.61	−0.97	4.36	1.46	3.37*	1.78	−7.35	−1.37	6.69	0.85	1.99	0.36
FOWN	7.60**	2.33	−4.45	−1.24	8.22**	2.54	45.27***	3.96	27.33**	2.26	51.90***	4.48
AFI	−0.71	−0.69	−0.62	−0.60	−0.60	−0.57	0.08	0.07	0.32	0.31	0.05	0.04
DFI	−10.05	−0.47	−12.41	−0.59	−8.54	−0.40	−4.22	−0.21	−4.02	−0.20	−3.06	−0.15
GDPC	2.14*	1.79	2.48**	2.12	2.29*	1.96	11.34***	2.94	13.20***	3.50	11.42***	2.96
Cons	3.93	0.61	5.35	0.85	4.35	0.68	−33.85*	−1.96	−39.18**	−2.33	−34.43**	−2.00
R-sq	0.33		0.35		0.35		0.38		0.41		0.38	
Panel B	Country-level											
FIN	−0.18***	−3.86	−0.21***	−4.02	0.18	1.36	−2.09***	−17.49	−1.98***	−17.30	−2.09***	−16.94
FIN*SOWN	−0.10	−0.96	−0.01*	−1.85	−0.77***	−2.43	−0.23	−1.57	−1.37	2.61	−0.12**	−2.12
FIN*FOWN	0.06**	1.86	0.01	0.06	0.55	1.31	0.34*	1.70	0.00	0.20	0.17	0.19
FIN*MAD	0.03	0.70	0.07**	2.09	0.00***	2.19	0.04	1.01	0.31**	1.94	0.01*	1.77
FIN*MAD*SOWN	−0.08**	−1.99	−0.11	−1.49	−0.07*	−1.84	−0.06***	−2.67	−0.03**	−2.05	−0.03	−1.33
FIN*MAD*FOWN	−0.10	−0.59	0.00***	3.01	0.07*	1.71	0.12*	1.81	0.18*	1.81	0.06**	2.14
BOSZ	−0.08	−1.06	−0.08	−1.07	−0.10	−1.33	0.00	0.03	−0.00	−0.09	−0.00	−0.06
BOSI	−0.45	−0.44	−0.44	−0.43	−0.53	−0.53	0.18	0.26	0.15	0.21	0.19	0.28
BSIZE	−0.32	−0.96	−0.32	−0.95	−0.41	−1.26	−0.20	−0.83	−0.12	−0.50	−0.21	−0.92
DIVI	0.54***	3.18	0.56***	3.33	0.58***	3.40	0.24**	2.08	0.25**	2.13	0.24**	2.09
NIIC	0.87***	2.58	0.93***	2.76	0.95***	2.78	0.40*	1.77	0.42*	1.85	0.41*	1.79
NIM	40.37***	4.39	43.48***	4.66	44.21***	4.89	16.64***	2.61	18.86***	2.75	19.67***	3.14
SOWN	−1.41	−0.82	0.16	0.05	1.10	0.57	−2.26	−0.58	−3.79	−0.65	−1.63	−0.41
FOWN	1.34	0.40	0.17	0.05	0.14	0.04	3.61	0.44	0.11	0.01	2.97	0.35
AFI	−26.43***	−24.75	−26.43***	−24.78	−26.35***	−24.53	−15.13***	−19.83	−15.19***	−19.91	−15.20***	−19.83
DFI	67.72***	27.66	66.67***	27.62	67.31***	27.76	53.66***	40.13	53.48***	40.09	52.41***	39.82
GDPC	36.60***	29.74	36.58***	30.09	36.66***	30.47	82.83***	29.61	82.71***	29.50	82.67***	29.42
Cons	−16.79***	−25.29	−16.92***	−25.59	−15.87***	−25.18	−35.48***	−30.00	−35.57***	−30.01	−34.49***	−29.81
R-sq	0.45		0.45		0.44		0.43		0.43		0.46	

Note: This table reports the estimation results of Eq. (2) by adding interaction variables. Panel A and B report the estimation results when applying Z-score at the bank- and country-level, respectively. We have two group regressions, (1)–(3) and (4)–(6), which involve the results by applying FINC and FINT to measure FinTech development respectively. For each group, we estimate Eq. (2) using LIST, RATE and DISC as proxies of market discipline respectively. See Table 1 for variable definitions. ***p < 0.01; **p < 0.05; * p < 0.1.

evidence of the negative impact of market discipline on the FinTech development–financial stability relationship. In other words, market discipline can mitigate the negative relationship between FinTech development and financial stability. Our result strongly supported hypothesis H2. This finding is consistent with previous studies that state that discipline can provide stronger supervision for financial systems through maintaining financial stability (Bennett et al., 2015; Hoang et al., 2014; Lee & Park, 2020) and reducing information asymmetry (Huang & Wang, 2017; Nier & Baumann, 2006; Nier, 2005). Our findings contributed to the literature that market discipline plays an important role in maintaining financial stability through mitigating the negative impact of FinTech development on financial stability in emerging markets.

The other results in Table 5 are consistent with the results in Table 4. Most coefficients on BSIZE and SOWN were still negative with Z-score, while most coefficients on DIVI, FOWN, and GDPC were positive with Z-score, indicating that bank size and state ownership reduce financial stability and diversification whereas foreign ownership and economic growth increase financial stability in emerging markets. The R-square value of the models in Tables 4 and 5 is about 0.3–0.45.

Extension

In this study, we performed some further test as extension. First, we tested whether the relationship among FinTech development, market discipline, and financial stability depend on ownership structure by adding two variables including FIN*OWN and FIN*MAD*OWN, where OWN is a vector of ownership variable including SOWN and FOWN. Hadad et al. (2011) proved that, in emerging markets, market discipline is more pronounced in foreign banks than domestic banks. Trinugroho et al. (2020) found that the type of bank ownership plays an important role in explaining the difference in market discipline by depositors. Therefore, the role of market discipline may depend on the ownership structure of banks.

Table 6 presents the estimation results for Eq. (2) after adding two variables (FIN*OWN and FIN*MAD*OWN). Panel A and B in this table show the estimation results when applying Z-score at the bank and country level, respectively. The results in Panel A and B show that the coefficients of FIN remained negative with Z-score, and most of them are statistically significant, while the sign of FIN*MAD coefficients remained positive. Relating to the role of ownership structure in the

Table 7
Quantile Regression Results for FinTech and Bank-level Financial Stability.

	LIST				RATE				DISC			
	Q25	Q50	Q75	Q90	Q25	Q50	Q75	Q90	Q25	Q50	Q75	Q90
Panel A	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
FINC	−0.15**	−0.10*	−0.08*	−0.04	−0.14	−0.07**	−0.06*	−0.02	−0.41*	−0.35**	−0.35**	−0.39
FINC*MAD	0.11***	0.11**	0.04**	0.03*	0.28	0.23	0.18***	0.15**	0.03**	0.02**	0.02**	0.03
BOSZ	−0.09*	−0.05	−0.05	−0.07	−0.09*	−0.02	0.00	0.11	−0.10**	−0.04	−0.13	0.08
BOSI	−0.21	−0.37	−2.01	−3.06	0.10	1.09	−0.91	−0.11	−0.08	0.25	1.12	3.09
FSIZE	0.06	0.24	0.56**	1.15**	0.12	0.34	0.78**	1.55***	0.09	0.12	0.15	0.40*
DIVI	0.16	0.20	0.46	0.62	0.15	0.05	0.43	0.80	0.06	0.02	0.35	0.96
NIIC	0.14***	0.00	0.12	−0.15	0.11	−0.27	0.00	0.21	−0.06	−0.23	0.13	0.84
NIM	24.80***	20.47**	11.40	1.58	26.18***	21.77**	19.09	2.01	21.26***	20.20**	1.07	−12.91**
SOWN	1.38***	1.74***	1.61**	0.55	1.40***	1.56***	1.12**	−0.42	1.36***	1.21**	1.30*	−0.31
FOWN	1.26***	1.73**	0.73	0.73	1.83***	1.44	0.34	0.85	2.43***	1.75**	1.46*	0.68**
AFI	−0.05	−1.01	−0.08	−2.97	−0.25	−1.31	−1.44	1.43	−0.37	−1.37	1.12	−0.70
DFI	−7.46	−3.10	−24.85	−67.92	−20.12	7.05	12.13	39.74	−28.16	6.10	−19.47	−51.62
GDPC	1.23	1.50	−0.90	−4.16	1.27	1.98	0.75	−3.25	0.58	1.57	−0.80	−3.68
Cons	−9.05	−9.98	−0.83	23.45	−10.02	−15.52	−13.32	−7.65	−3.44	−6.80	4.24	27.56
Panel B												
FINT	−9.61	−5.85*	−5.69*	−4.73	−0.14*	−0.10**	−0.09*	−0.25	−0.05**	−0.10*	−0.13	−0.17
FINT*MAD	0.01	0.09**	0.05*	0.01*	−0.09	0.15*	0.11**	0.08***	0.11**	0.07***	0.04***	0.04
BOSZ	−0.12	−0.07	−0.01	−0.05	−0.08	0.00	−0.03	0.11	−0.12**	−0.08	−0.10	0.05
BOSI	−0.12**	0.37	−2.96	−2.92	0.11	1.61	−0.54	0.37	−0.22	0.73	1.49	3.13
FSIZE	0.06	0.26	0.53**	1.26**	0.12	0.34**	0.74***	1.67***	0.09	0.17	0.16	0.47**
DIVI	0.16	0.34	0.43	0.55	0.15	0.05	0.37	1.05	0.06	0.06	0.33	0.98*
NIIC	0.13	0.23	0.10	−0.28	0.11	−0.27	−0.12	0.56	−0.05	−0.16	0.10	0.88
NIM	24.36***	16.96*	19.60	1.39	27.46***	22.28**	15.30	4.64	20.79***	17.86*	0.60	−12.46
SOWN	−1.27***	1.73*	1.82***	0.61	−1.35***	1.55**	1.16*	0.74	−1.38***	1.20**	1.22*	0.34
FOWN	−1.77***	2.00**	1.66	0.84	−1.53***	1.43*	0.30	0.80	2.47***	1.48*	1.40	0.62
AFI	−0.30	−0.05	0.19	−1.09	−0.29	−1.18	−1.23	−0.81	−0.21	−1.31	1.01	−1.09
DFI	0.16	7.88	−19.17	−50.45	−12.13	3.27	2.30	27.16	−29.85	2.55	−22.06	−39.97
GDPC	5.53	14.93*	21.18*	7.38	1.22	1.99	0.35	−1.79	0.27	0.82	−2.03	−4.07
Cons	−26.58	−63.54*	−90.45*	−29.88	−9.70	−15.88	−9.69	−12.24	−2.48	−4.57	10.40	27.77

Note: This table reports the coefficients as the results of estimating Eq. (2) by applying the quantile estimation method for Z-score with bank-level as a dependent variable. Panel A and Panel B show the estimation results for FINC and FINT to measure FinTech development, respectively. MAD is a market discipline variable. Regressions (1)–(4), (5)–(8), and (9)–(12) involve the results by applying LIST, RATE, and DISC to measure market discipline respectively. Q25, Q50, Q75, and Q90 are the quantile 25th, 50th, 75th and 90th respectively. See Table 1 for variable definitions. ***p < 0.01; **p < 0.05; * p < 0.1.

relationship among FinTech development, market discipline, and financial stability, Table 6 reports that the coefficients on FIN*SOWN are negative with Z-score in most regressions, but only statistically significant in regressions 1 and 3 of Panel A and regressions (2), 3, and 6 of Panel B, indicating that the negative impact of FinTech development on financial stability may be stronger when state ownership in the banking system increases. Furthermore, the coefficients on FIN*MAD*SOWN were negative with Z-score in most regressions but only statistically significant in regressions (2), 3, 5, and 6 of Panel A, and only regression (2) of Panel B was insignificant. This implied that the negative effect of FinTech development on financial stability can be increased, and the role of market discipline in preventing that effect can be reduced if there is higher state ownership in the banking system. These results can be explained by Zhou et al. (2017), who argued that there is inefficiency of state ownership in innovation development. Therefore, a higher degree of state ownership may cause banks to be slow to apply FinTech innovations, thereby increasing their competition with other FinTech start-ups.

In addition, Table 6 reports that the coefficients on FIN*FOWN were positive and significant in most regressions of Panel A and in regressions 1 and 4 of Panel B. This indicates that the negative impact of FinTech development on financial stability may be reduced when foreign ownership in the banking system increases. Previous studies have found that banks with a higher degree of foreign ownership will find it easier to adopt new technologies and have higher innovation than other banks (Falk, 2008; Guadalupe et al., 2012), while innovation in banks can help them reduce risk (Cheng & Qu, 2020). Overall, banks with a high degree of foreign ownership can absorb new technology well, thereby reducing the negative effects of FinTech. Furthermore, the coefficients on FIN*MAD*SOWN were positive with Z-score in most regressions of Panel A and B. Specifically, these coefficients were positive and statistically significant in regression (1), 3, 4, and 6 of Panel A, and only regression (1) of Panel B was insignificant. In contrast to state ownership, the negative effect of FinTech development on financial stability can be mitigated, and the role of market discipline in preventing that effect can be increased if foreign ownership in the banking system is higher.

Overall, the results in Table 6 continue to support hypotheses H1 and H2. This further emphasizes the role of the ownership structure in the relationship between FinTech development, market discipline, and financial stability in emerging markets. By applying this test, we found that state ownership not only increases the effect of FinTech development on financial stability but also reduces the role of market discipline in preventing that effect. However, the negative effect of FinTech development on financial stability can be reduced in banks and the role of market discipline in preventing such effect can also be increased if foreign ownership is higher in the banking system.

As a further test, we applied quantile regression for estimating Eq. (2) to investigate whether there is potential heterogeneity in the relationship between FinTech development and financial stability and whether the impact of market discipline on financial stability depends on the level of financial stability of each bank. This method has been used in the literature to investigate the effects of independent variables on different levels of dependent variables (Chirilă & Chirilă, 2015; Nguyen, 2020; Shaddady & Moore, 2019; Tao et al., 2009). The estimation results are reported in Table 7 and Table 8, which applied the bank- and country-level Z-score as dependent variables, respectively.

Panels A and B in Table 7 show the estimation results for Eq. (2) applying FINC and FINT to measure FinTech development, respectively. The results presented that the coefficients on FINC and FINT were negative and significant with Z-score in most quantiles; thus, it again

Table 8
Quantile Regression Results for FinTech and Country-level Financial Stability.

	LIST				RATE				DISC			
	Q25	Q50	Q75	Q90	Q25	Q50	Q75	Q90	Q25	Q50	Q75	Q90
Panel A	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
FINC	0.31	−0.29*	−0.28**	−0.23***	0.34	−0.17***	−0.16*	−0.12	−0.39	−0.32**	−0.31*	−0.31
FINC*MAD	0.32***	0.41**	0.44**	0.63	0.58	0.33*	0.28**	0.17*	0.38	0.32	0.12**	0.09
BOSZ	−0.09*	−0.12	0.17	−0.03	−0.19	−0.15*	0.09	0.22**	−0.17	−0.14*	0.23**	0.41
BOSI	−0.24	−0.29	−1.43*	−1.29***	0.16**	1.22	1.91	−0.21	−0.18**	0.24*	0.97	1.24
FSIZE	0.15	0.33***	0.21*	1.65	0.23	0.14**	0.18	1.51	1.12*	1.91	−0.35	−0.47**
DIVI	0.46	0.22	0.48	0.69	0.13	0.19	0.13	0.44	0.16	0.21	0.28	0.27
NIIC	1.14*	1.05	−0.82	−0.12	0.26	−0.25	0.08	0.19**	−0.21	−0.26	0.35	0.34
NIM	3.82	2.17	−3.42	−2.59**	1.18*	2.71**	2.01	−0.15	1.22**	2.78*	1.54	−2.95
SOWN	0.61***	1.24**	1.67*	1.95	2.56***	1.98**	1.62*	1.38	−1.26	0.91***	1.35*	1.39
FOWN	3.21**	2.45**	1.89*	−0.98	2.97**	2.41*	1.37	1.89	3.93***	2.78**	1.45*	−0.61
AFI	−0.65	−0.51	−0.58	−0.27	−0.75	−1.54	−1.23	1.11	−1.32	−1.34	1.18	−1.79
DFI	−2.41*	−2.17	−4.81	−7.91	−3.15	4.22	5.18	2.23**	−3.11	−4.13	2.49**	3.67*
GDPC	5.98	4.58	3.97	−2.16*	6.21	6.93	5.71	−1.29	4.51	4.52	−2.81	−3.18**
Cons	−5.17	−3.91	−2.81	4.43	−6.17	−5.57	−3.35	−2.69	−3.47	−5.81	3.28	8.63
Panel B												
FINT	3.61	2.82	−4.61*	−3.59**	−1.32***	−1.15**	−0.79*	0.67	−2.17***	−2.19*	−2.13	−1.24
FINT*MAD	1.24	0.87**	0.55*	0.21	1.39	0.95**	0.79**	0.27*	1.98	0.96**	0.16*	−0.27
BOSZ	−0.32	−0.12***	−0.14**	−1.45	−0.16**	0.19	−0.07	0.16*	−1.11	0.98	0.17	0.25**
BOSI	−0.09***	−0.12*	−1.21	0.95	0.27	1.25	1.29	−0.32***	−0.79	0.89	1.21	−1.87*
FSIZE	2.16	3.21*	2.55**	1.96	1.18	1.33*	1.65**	1.94	4.01	3.19	3.16	1.87
DIVI	0.34	0.22	0.21	0.17**	0.17	0.23	0.11	1.19	0.31*	0.21	0.42	0.54
NIIC	0.42**	0.52	−0.21	−0.11	0.38	−0.86	−0.63	−0.59	−0.35	−0.27	0.32	0.35
NIM	2.36	3.27	2.61**	1.19***	−3.42	4.28	4.35**	3.61	3.72	3.81*	2.62***	−1.42
SOWN	0.65*	1.33	1.09	−3.68*	0.78	1.29**	2.16	3.71	−0.88	0.98	1.23*	2.32**
FOWN	3.71***	2.44**	1.76*	0.83	2.26*	−1.47	−0.87	1.83	1.47**	1.28	1.34	0.95
AFI	−0.54	−0.15	0.22*	1.67*	−0.19**	−1.56*	−1.03	−0.99	0.26	−3.33**	−1.28*	−0.98
DFI	0.22	1.34	−3.17	−5.69	−1.53	4.26	5.35	6.18	3.81	4.52	−4.01	−3.91
GDPC	2.59**	5.91*	6.22	−2.38	3.21	2.92*	1.39**	1.71	2.21*	2.82	−1.08	−0.17
Cons	−3.57	−2.59	−7.45*	−3.82*	−2.76	−4.89	−6.60	−5.21	−3.41	−2.52	3.42	4.45

Note: This table reports the coefficients as the results of estimating Eq. (2) by applying the quantile estimation method for Z-score with country-level as a dependent variable. Panel A and Panel B show the estimation results for FINC and FINT to measure FinTech development, respectively. MAD is a market discipline variable. Regressions (1)–(4), (5)–(8), and (9)–(12) involve the results by applying LIST, RATE, and DISC to measure market discipline respectively. Q25, Q50, Q75, and Q90 are the quantile 25th, 50th, 75th and 90th respectively. See Table 1 for variable definitions. ***p < 0.01; **p < 0.05; * p < 0.1.

supported hypothesis H1. Furthermore, we found that coefficient values decreased from Q25 to Q90, indicating that the negative effect of FinTech development on financial stability is stronger with lower financial stability and weaker with higher financial stability. Similarly, the coefficients on FINC*MAD in Panel A and FINT*MAD in Panel B were positive and significant with Z-score in most quantiles, and there is a decreasing tendency from Q25 to Q90, indicating that market discipline plays a more important role in reducing the negative effects of FinTech development on financial stability in banks with low level of stability than high level of financial stability. Although the coefficients of FINC*MAD and FINT*MAD were different across quantiles, the signs of these coefficients remained unchanged and positive. These results, therefore, still support hypothesis H2. We also apply F-test, which based on the bootstrap standard errors using 1000 replications, and the results reject the null hypothesis of the equality coefficients for pairs of quantiles.

Similar to Table 7, in Table 8, we show the estimation results for Eq. (2), applying FINC and FINT to measure FinTech development in Panels A and B, respectively, but applying Z-score at the country-level as the dependent variable. The signs of FINC and FINT coefficients remained negative, while the signs of FINC*MAD and FINT*MAD remained positive. Moreover, most of these coefficients are statistically significant, indicating that hypotheses H1 and H2 are strongly supported. The coefficients of FINC, FINT, FINC*MAD, and FINT*MAD tended to decrease across quantiles (from Q25 to Q90). These results were consistent with the results in Table 7 that the negative effect of FinTech development on financial stability is stronger with lower financial stability and weaker with higher financial stability, and market discipline plays a more important role in mitigating such effect.

Robustness test

In this study, we performed some robustness tests by applying alternative estimation methods for our models. First, to treat the potential endogeneity of some independent variables related to bank characteristics, we applied the System Generalized Method of Moments (SGMM) method to estimate Eq. (2). Second, we applied SGMM to estimate Eq. (2) again after adding the FIN*OWN and FIN*MAD*OWN variables. Finally, we remained cautious of endogeneity and used a two-stage quantile regression (2SQR) method as suggested by Machado and Silva (2019) to test the heterogeneity effect of FinTech development on financial stability as well as the effect of market discipline on FinTech development–financial stability relationship. This method employed the structural quantile functions defined by Chernozhukov and Hansen (2008).

We present the estimation results of Eq. (2) by applying the SGMM method in Table 9. This table reports that the coefficients on FIN (both FINC and FINT) remained negative and significant with Z-score in all regressions. Furthermore, the coefficients on FIN*MAD were positive and significant with Z-score in most regressions. These results were consistent with the initial results in Table 5 as well as with our expectations that FinTech development negatively impacts financial stability in emerging markets and market discipline plays an important role in mitigating such effect. Overall, by applying the SGMM method, the results continued to strongly support hypotheses H1 and H2. Hansen's J test for instrument validity and the second-order autocorrelation of the error terms test (AR2) as introduced by Arellano and Bond (1991) indicate that the results of the SGMM estimator are verified because the p-value of Hansen's J test and AR2 test were higher than 10 %. Moreover, the number of instruments used in each model was less than the

Table 9
Robustness Test Results by Applying System GMM Method for the Role of Market Discipline.

	Bank-level						Country-level					
	FINC			FINT			FINC			FINT		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
FIN	−0.17***	−0.13**	−0.52**	−7.19**	−4.51**	−8.19***	−0.20***	−0.25***	−0.39***	−19.70***	−8.93**	−14.67***
	(−3.58)	(−2.11)	(−2.64)	(−2.17)	(−2.54)	(−4.75)	(−4.90)	(−5.16)	(−3.67)	(−20.42)	(−2.45)	(−30.19)
FIN*MAD	0.18*	−0.01	0.05**	0.18*	−0.14	0.10***	0.03	−0.06	0.02*	0.02*	0.29*	0.00
	(1.96)	(−0.18)	(2.54)	(1.69)	(−1.38)	(3.40)	(0.32)	(−1.35)	(1.84)	(1.68)	(1.71)	(0.31)
BOSZ	−0.05	0.13	−0.22*	−0.21	0.01	−0.10	−0.03	−0.07	−0.18*	−0.00	−0.21	0.06
	(−0.31)	(0.52)	(−1.97)	(−0.86)	(0.06)	(−0.68)	(−0.24)	(−0.56)	(−1.92)	(−0.03)	(−0.45)	(0.59)
BOSI	−7.53*	−7.19	−1.60	−0.50	0.34	1.23	−1.17	−1.21	−2.41	−0.35	−0.21	−1.82
	(−1.83)	(−1.14)	(−0.61)	(−0.21)	(0.11)	(0.43)	(−0.90)	(−0.47)	(−0.85)	(−0.39)	(−0.02)	(−0.92)
BSIZE	−0.40	0.15	0.28	−1.21*	0.63	−0.22	−0.26	0.09	0.09	−0.23	−2.79	−0.10
	(−1.20)	(0.70)	(0.63)	(−1.72)	(1.12)	(−0.53)	(−1.15)	(0.36)	(0.45)	(−1.11)	(−1.35)	(−0.89)
DIVI	−1.22*	0.23	−0.47	−0.30	0.35	−0.16	1.47*	1.46*	1.19*	0.94***	4.98	0.10
	(−1.70)	(0.61)	(−0.64)	(−0.45)	(1.36)	(−0.20)	(1.99)	(1.87)	(1.83)	(2.87)	(1.51)	(0.63)
NIIC	−2.09**	0.18	−1.12	−0.79	0.28	−0.35	2.99*	2.73*	2.05*	1.89***	1.41	0.19
	(−2.42)	(0.24)	(−0.81)	(−0.42)	(0.61)	(−0.23)	(1.81)	(1.96)	(1.88)	(2.78)	(0.25)	(0.61)
NIM	−12.50	32.19**	11.35	−40.25	36.40***	12.93	31.12	47.07*	27.22**	15.62*	−72.87*	7.92
	(−0.56)	(2.49)	(0.47)	(−0.6)	(3.34)	(0.50)	(1.24)	(1.86)	(2.04)	(1.77)	(−1.92)	(1.60)
SOWN	1.07	0.90	−0.31**	−3.62**	0.88	−0.39	0.13	0.12	−0.71**	0.56	5.17	−0.49
	(1.09)	(0.96)	(−2.26)	(−2.49)	(0.90)	(−0.30)	(0.16)	(0.19)	(−2.10)	(0.87)	(0.83)	(−0.84)
FOWN	4.90*	0.72	1.90	6.08	0.76	2.79*	−0.09	0.34	−0.18	−0.11	−1.42	0.20
	(1.87)	(0.58)	(1.21)	(1.08)	(0.50)	(1.87)	(−0.14)	(0.52)	(−0.27)	(−0.13)	(−0.37)	(0.62)
AFI	−0.21	−0.32	−1.72*	1.18	−0.16	0.49	−25.55***	−26.31***	−26.05***	−14.44***	−14.80***	−18.98***
	(−0.12)	(−0.4)	(−1.71)	(0.79)	(−0.21)	(0.48)	(−39.33)	(−42.67)	(−42.28)	(−30.38)	(−12.74)	(−193.76)
DFI	−4.72	−3.76	−12.35	6.43	1.28	−16.86	61.86***	61.27***	61.62***	59.32***	67.27***	64.24***
	(−0.27)	(−0.26)	(−0.74)	(0.26)	(0.11)	(−0.93)	(26.12)	(47.35)	(51.54)	(60.32)	(25.64)	(125.72)
GDPC	2.43	2.51*	0.74	20.50**	11.06**	17.97***	34.97***	34.83***	35.43***	81.06***	59.98***	72.12***
	(1.46)	(1.76)	(0.37)	(2.33)	(2.23)	(4.03)	(37.12)	(32.5)	(38.43)	(31.83)	(6.7)	(71.39)
Cons	−2.73	−18.44*	−0.46	−63.40**	−54.33***	−63.96***	−16.25***	−14.47***	−16.16***	−36.02***	−24.05***	−33.01***
AR2 (p-value)	0.16	0.33	0.36	0.69	0.75	0.86	0.63	0.33	0.43	0.12	0.15	0.24
Hansen J (p-value)	0.69	0.67	0.68	0.62	5.01	0.69	0.54	0.69	0.66	0.52	0.48	0.62
No of instrument	33.00	35.00	36.00	37.00	29.00	34.00	34.00	29.00	26.00	31.00	29.00	28.00

Note: This table reports the estimation results of Eq. (2). Regressions (1)–(6) involve the results by applying Z-score at bank-level as dependent variable and regressions (5)–(8) involve the results by applying Z-score at country-level as a dependent variable. At each bank and country level, we have two groups of results by applying FINT and FINC as an independent variables respectively. For each group, we estimate the Eq. (2) by using LIST, RATE and DISC as proxies of market discipline respectively. We shows the *t*-stat values in parentheses below each coefficient. See Table 1 for variable definitions. ***p < 0.01; **p < 0.05; * p < 0.1.

Table 10
Robustness Test Results by Applying System GMM Method for the Role of Ownership Structure.

Panel A	Bank-level											
	FINC						FINT					
	(1)		(2)		(3)		(4)		(5)		(6)	
	Coef.	*t*-stat	Coef.	*t*-stat	Coef.	*t*-stat	Coef.	*t*-stat	Coef.	*t*-stat	Coef.	*t*-stat
FIN	−0.05**	−2.08	−0.61	−1.09	−0.62***	−2.56	−1.17***	−2.22	−4.62	−1.37	−4.67***	−2.87
FIN*SOWN	−0.43	−0.24	−0.51***	−2.47	−1.94***	−2.50	−2.86	−0.15	−0.04*	−1.90	−1.94	−1.33
FIN*FOWN	0.16	0.03	6.55*	1.86	10.39	1.32	8.53**	2.32	7.82	1.40	4.77***	3.72
FIN*MAD	0.41***	2.71	0.14	1.66	0.02***	3.24	1.36**	2.25	0.31*	1.81	0.01**	2.28
FIN*MAD*SOWN	−0.31	−0.46	−0.32***	−2.74	−0.24*	−1.73	−0.46	−0.52	−1.87**	−2.68	−0.18	−1.60
FIN*MAD*FOWN	2.73**	1.93	1.15*	1.88	−0.71	−1.25	6.17***	2.34	0.64	0.36	0.06*	1.80
BOSZ	−0.81	−0.81	−0.55	−0.81	−1.30*	−1.80	−1.49*	−1.84	−0.26	−0.44	0.05	0.68
BOSI	−1.19	−0.26	1.30	0.36	−2.94	−0.71	−2.83	−0.73	−0.34	−0.16	1.14	1.21
BSIZE	0.07	0.03	0.87	1.05	0.59	0.70	0.59	0.54	−0.17	−0.16	−0.41	−1.28
DIVI	−0.28	−0.16	1.00	0.59	1.53	0.94	0.24	0.12	1.41**	1.77	0.33**	2.05
NIIC	1.58	0.55	2.95	0.75	2.59	0.76	−1.34	−0.30	2.51	1.60	0.51	1.61
NIM	5.16	0.88	11.70**	2.11	8.77*	1.77	−4.80	−0.07	9.16	2.15	7.11***	8.38
SOWN	7.20	0.29	−8.05***	−2.50	−6.13	−1.44	−24.81	−0.13	−9.30**	−2.11	1.99	0.36
FOWN	0.28**	2.02	9.40	1.33	8.93	0.95	9.81***	2.38	7.19	1.41	−5.90***	−4.48
AFI	−1.68	−0.64	−1.07	−0.66	−0.34	−0.18	−0.83	−0.61	2.26	1.44	0.05	0.04
DFI	−8.62	−1.20	7.54	0.23	16.86	0.47	1.21	0.03	5.30	0.22	−3.06	−0.15
GDPC	0.28***	3.07	0.38**	2.16	0.89	1.27	16.61*	1.78	9.74	1.25	11.42***	2.96
Cons	13.71	0.67	1.20	0.01	10.87	0.47	−58.03	−0.96	−32.95	−0.68	−34.43**	−2.00
AR2 (pvalue)	0.54		0.11		0.41		0.92		0.45		0.79	
Hansen J test (pvalue)	0.55		0.58		0.87		0.67		0.50		0.14	
Panel B	Country-level											
FIN	−0.47***	−2.55	−0.61	−1.69	−0.35**	−2.27	−18.29***	−6.40	−15.46***	−3.12	−16.40***	−4.76
FIN*SOWN	1.60	1.57	−2.23**	−1.91	−0.42	−0.10	−0.02**	2.02	−7.38*	−1.85	0.57	0.10
FIN*FOWN	5.51***	2.60	8.94**	1.94	10.16	1.13	5.62**	2.31	10.55	1.40	3.83***	2.23
FIN*MAD	0.36**	2.14	0.06	1.16	0.01**	2.15	0.38	0.58	0.08**	2.32	−0.01	−0.16
FIN*MAD*SOWN	−0.61**	2.21	−0.73	−0.78	−0.10**	−2.26	−0.39***	−2.63	−0.14	−1.17	−0.04	−0.15
FIN*MAD*FOWN	1.36	0.48	2.34*	1.87	0.73*	1.79	−1.25	−0.54	0.71***	2.54	0.38*	1.86
BOSZ	−1.56	−1.65	−1.31	−1.09	−1.03	−0.85	−0.37	−1.09	0.00	0.01	−0.32	−0.76
BOSI	−0.78	−0.16	1.47	0.37	−3.19	−0.70	−1.24	−0.67	−0.59	−0.21	−2.56	−0.92
BSIZE	1.29	1.02	3.21*	1.83	1.53	1.03	0.12	0.23	0.28	0.28	0.61	0.74
DIVI	2.31	1.52	2.55	0.81	2.46**	1.92	0.90*	1.77	1.73	1.38	1.14**	2.18
NIIC	6.97*	1.95	8.18*	1.68	7.59	1.26	1.62	1.59	3.46*	1.67	2.38	1.26
NIM	8.81	1.57	20.22***	2.95	17.98*	1.71	7.63	0.27	59.65	1.53	55.61	1.39
SOWN	−19.64	−1.32	−27.51	−1.41	−20.54	−1.17	1.44	0.03	68.71	0.99	−9.50	−0.22
FOWN	−93.87	−0.61	−139.93	−0.96	−83.27	−0.75	54.24	0.32	96.00	0.39	−13.10	−0.07
AFI	−26.17***	−16.07	−27.61***	−10.06	−25.00***	−8.94	−15.42***	−16.81	−14.92***	−7.52	−16.02***	−9.53
DFI	67.25***	7.27	64.76***	6.79	66.00***	11.76	59.92***	28.58	58.13***	18.54	61.08***	25.72
GDPC	31.03***	6.48	28.29***	5.68	32.04***	5.29	78.09***	19.49	76.64***	11.51	72.69***	12.31
Cons	−14.15***	−4.44	−11.12***	−4.86	−17.28***	−4.33	−39.74***	−13.37	−33.95***	−7.78	−34.04***	−9.24
AR2 (pvalue)	0.20		0.24		0.31		0.28		0.73		0.57	
Hansen J test (pvalue)	0.10		0.25		0.27		0.15		0.10		0.09	

Note: This table reports the estimation results of Eq. (2) by adding interaction variables and applying the SGMM method. Panels A and B report the estimation results when applying Z-score at the bank and country-level, respectively. We have two group regressions, (1)–(3) and (4)–(6), which involve the results by applying FINC and FINT to measure FinTech development, respectively. For each group, we estimate the Eq. (2) using LIST, RATE, and DISC as proxies of market discipline, respectively. See Table 1 for variable definitions. ***p < 0.01; **p < 0.05; * p < 0.1.

panel, which makes the Hansen J-statistics more reliable. In general, the robustness test results are consistent with our initial results and strongly support our hypotheses.

Table 10 reports SGMM estimation results for Eq. (2) after adding FIN*OWN and FIN*MAD*OWN variables. First, the coefficients on FIN*SOWN were negative and significant with Z-score (both bank and country level) in most regressions of both Panels A and B. Although not all coefficients were significant, this result was consistent with our initial results in Table 6. Moreover, Panel A in this table shows that the coefficients of FIN*MAD*SOWN were negative with Z-score at bank level in all regressions and statistically significant in regressions (2), 3, 5, and 6. Similarly, the coefficients on FIN*MAD*SOWN were negative with Z-score at country level in all regressions of Panel B and statistically significant in regressions (1), 3, and 4. This result again provided strong evidence that the effect of FinTech development on financial stability becomes stronger and the role of market discipline in preventing that effect increases when the level of state ownership of banks become higher.

Similar to the results in Table 6, the coefficients on FIN*FOWN and FIN*MAD*FOWN were positive and statistically significant in most regressions of Panels A and B, indicating that the negative effect of FinTech development on financial stability can mitigated, and the role of market discipline in preventing such effect be increased if foreign ownership is higher in the banking system. Most p-value of AR2 and Hansen J test were higher than 10 %, implying that the SGMM results are reliable. Furthermore, the sign of coefficients of FIN and FIN*MAD remained unchanged and still supported hypotheses H1 and H2. Overall, our empirical results emphasized the role of ownership structure in the relationship among FinTech development, market discipline, and financial stability in emerging markets. The robustness test results were generally consistent with our initial results.

Finally, as a robustness test for the heterogeneity effect of FinTech development on financial stability, we applied the 2SQR method. First, we regressed the indicator on the excluded instrument variables and the exogenous variables. Second, we regressed the Z-score on FinTech development and the exogenous variables. Since the standard errors

Table 11
Two-Stage Quantile Regression Results for FinTech and Bank-level Financial Stability.

	LIST				RATE				DISC			
	Q25	Q50	Q75	Q90	Q25	Q50	Q75	Q90	Q25	Q50	Q75	Q90
Panel A	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
FINC	−0.82***	−0.74**	−0.60*	−0.51*	−0.72	−0.65**	−0.58*	−0.42	−0.93***	−0.86*	−0.51	−0.42
FINC*MAD	0.15	0.12***	0.08***	0.06**	0.30***	0.24**	0.18	0.01*	0.08	0.02**	0.02*	0.01*
BOSZ	−0.55*	−0.97	−1.43	−2.77	−2.79	−2.80**	−2.81*	−0.37	−0.54**	−0.82	−1.28	−0.37
BOSI	−21.74	−10.14	2.28**	−45.41	−30.09	−14.34	2.13**	−17.24	−10.90	−0.44	16.69**	−17.24
FSIZE	0.53**	0.62*	0.70	0.03	0.50**	0.99	1.49	0.21**	0.35*	0.58	0.96	0.21
DIVI	0.01	−3.02	−6.26	1.12	−0.93	−3.04	−5.25	−0.59	−1.59	−3.23	−5.92	−0.59
NIIC	−5.30	−12.57	−20.36	−17.82	−20.59	−23.44	−26.42	−6.08	−8.62	−12.82	−19.70	−6.08
NIM	7.29***	7.78**	−8.24	−5.13*	−6.57	9.13**	−33.68	−20.29*	9.08***	9.54**	−21.40*	−20.29*
SOWN	0.54*	1.46	2.44	−2.57**	−3.64*	4.73	5.88*	0.34	−0.87	1.74	3.17	0.34***
FOWN	3.26	−0.20	−3.91*	2.31	1.86	1.40	0.92	3.02	2.02	0.37	−2.34	3.02
AFI	0.12	−0.09	−0.30	−5.54	−6.67	−7.83	−9.04	1.25	1.19	1.10	0.94	1.25
DFI	−20.96	−8.23	−14.70	−8.96	−9.83	−16.00	−17.68	−40.74	−9.42	−9.23	−14.72	−40.74
GDPC	5.61**	5.41***	5.20	10.65	9.78***	−8.89	7.96**	5.09*	4.56	3.70	2.27	5.09
Cons	−43.73	−23.55	−1.93**	−22.99**	−14.01	−4.79	4.87	−37.12	−29.02***	−15.66**	6.23	−37.12***
Panel B												
FINT	−1.97	−1.57**	−0.75*	−1.03*	−1.87**	−1.01**	−0.79	−0.05	−1.77***	−1.10**	−0.99*	−0.97**
FINT*MAD	1.01***	0.13*	0.26	−0.37	2.45	1.49**	0.54*	0.05*	0.16	0.06**	0.06*	0.01
BOSZ	−0.41**	−1.08	−1.72*	−2.28*	−2.91*	−3.26	−3.63	−0.30	−0.45*	−0.60	−0.72	−0.41*
BOSI	−21.18	−12.40	3.95**	3.30**	−34.01	−19.72	4.74**	−12.62	0.81	13.18***	23.20**	−21.18
FSIZE	0.45*	1.10	1.72	2.25	0.55	0.91**	1.28	0.38	0.28	0.19	0.11	0.45
DIVI	−0.40	−1.85	−3.23	−4.43	0.59	−3.68	−8.16	−0.82	−2.62	−4.28	−5.63	−0.40
NIIC	−11.92	−12.47	−13.00	−13.46	−25.83	−27.83	−29.92	−14.78	−16.31	−17.72	−18.87	−11.92
NIM	9.22***	9.88**	−8.99*	−12.57*	15.01**	−32.10	−31.98	−32.56***	17.20**	−20.85	−23.90	−19.22*
SOWN	−0.74	1.34*	3.33	5.05*	3.10	4.77	6.52*	−0.56	0.83	2.12	3.15	−0.74**
FOWN	2.30	2.26	2.22	2.18	5.68**	4.20**	2.65	5.34	4.65	4.01	3.50	2.30
AFI	21.87	17.63	13.56	10.06	16.75	21.10	25.67	29.58	27.08	24.77*	22.90*	21.87
DFI	56.85	−36.74	−16.75	−24.05	−50.02	−12.16	−15.86	10.20	−42.41	−17.59	−21.61	56.85
GDPC	25.59	16.63	12.31	85.83	21.42	23.64	29.24	27.79	26.91	16.40	12.51	20.59
Cons	−9.91***	−3.81	−5.21**	−3.24	−8.09***	−9.24*	−10.63**	−11.94**	−9.69**	−6.20***	−6.20***	−9.91***

Note: This table reports the coefficients as the results of estimating Eq. (2) by applying the two-stage quantile estimation method for Z-score with bank-level as a dependent variable. Panel A and Panel B show the estimation results for FINC and FINT to measure FinTech development, respectively. MAD is a market discipline variable. Regressions (1)–(4), (5)–(8), and (9)–(12) involve the results by applying LIST, RATE, and DISC to measure market discipline, respectively. Q25, Q50, Q75, and, Q90 are the quantile 25th, 50th, 75th, and 90th, respectively. See Table 1 for variable definitions. ***p < 0.01; **p < 0.05; * p < 0.1.

from the second stage were incorrect, we used a bootstrapping procedure based on 1,000 replications to correct them, as suggested by Machado and Silva (2019).

Tables 11 and 12 report the 2SQR estimation results by applying Z-score at the bank and country level, respectively, as the dependent variable. In Table 11, the coefficient on FINC in Panel A and FINT in Panel B were negative and statistically significant in most regressions, and the value of these coefficients tended to become lower, from Q25 to Q90. The coefficients of FINC*MAD and FINT*MAD in Panels A and B were positive and significant in most regressions. The value of these coefficients also became lower across quantile from Q25 to Q90. These results were consistent with our first results reported in Table 7 and provided strong evidence that the negative effect of FinTech development on financial stability and market discipline play a more important role in mitigating this effect at a lower level of financial stability.

Similarly, Table 12 presents that most coefficients on FINC and FINT were negative and statistically significant with country-level Z-score in both Panels A and B. The coefficients of FINC in regressions 4, 5, and 9 of Panel A were positive but insignificant. The values of coefficients of both FINC and FINT tended to decrease across quantiles from Q25 to Q90. The coefficients on FINC*MAD in Panel A and FINT*MAD in Panel B were positive and statistically significant in most regressions. Only the coefficient of FINT*MAD was negative in regression 4 of Panel B but not significant. The value of these coefficients also tended to decrease across quantiles from Q25 to Q90. Generally, 2SQR results were consistent with quantile regression results, presented in Table 8.

Overall, the 2SQR estimation results presented in Tables 11 and 12 were consistent with our initial results in Tables 7 and 8. These results provided strong evidence of the negative effect of FinTech development on financial stability in emerging markets and the role of market discipline in mitigating such effect. Our hypotheses H1 and H2 were strongly supported. However, the heterogeneity analysis further found that the negative effect of FinTech development on financial stability and the role of market discipline in mitigating such effect is stronger at low levels of financial stability and weaker at higher levels of financial stability.

Conclusion

This study investigates the effect of FinTech development on financial stability in an emerging market. Using data from 37 commercial banks in Vietnam during the period 2010–2020, we provide strong evidence that FinTech development negatively affects financial stability in an emerging market. However, market discipline can mitigate this negative relation. Furthermore, we find that the negative effect of FinTech development on financial stability as well as the role of market discipline in mitigating this negative effect becomes stronger in banks with low stability. Besides, the negative effect of FinTech development on financial stability and the role of market discipline can become stronger if banks increase state ownership but weaken if banks increase foreign ownership.

Our findings provide some important implications for bank shareholders and regulators in emerging markets. In the context of developing countries' efforts to grow FinTech, our research results provide a warning to regulators that such efforts greatly affect the stability of the financial system. Therefore, in order to sustainably develop FinTech, emerging countries must make efforts aimed at improving market discipline. They should also consider banks' ownership structures to assess the impact of FinTech on financial markets and have appropriate policies to restructure the ownership structure. Finally, because of the heterogeneity effect of FinTech on financial stability, banks with a low level of stability need to pay more attention to their risks in the context

Table 12
Two-stage Quantile Regression Results for FinTech and Country-level Financial Stability.

	LIST				RATE				DISC			
	Q25	Q50	Q75	Q90	Q25	Q50	Q75	Q90	Q25	Q50	Q75	Q90
Panel A	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
FINC	−1.05***	−0.61***	−0.28*	1.41	0.05	−3.02**	−2.22	−1.57	1.13	−3.37**	−2.57*	−2.21*
FINC*MAD	0.41**	0.22*	0.08*	−0.65	−0.70	0.27	0.24*	0.22*	0.13***	0.07*	0.01	0.01
BOSZ	0.87	0.33	−0.07	−2.13	2.46***	1.91	1.29	0.07	−1.92	−1.04	0.04	1.92
BOSI	2.11	2.97	−3.60*	−6.86***	37.47	25.61	11.84*	−14.79***	−38.63*	−16.61	10.39*	57.68
FSIZE	−1.63	−0.67**	0.03	3.69	3.24	0.79**	−2.07	−7.59	2.56	1.58**	0.39	−1.70
DIVI	−2.82*	−0.93	0.46	7.69	−3.01	−6.59	−10.74	−18.78	−0.25	−2.29	−4.79	−9.17***
NIIC	−3.21	−2.18	−1.42	2.51	35.80*	13.45	−12.49	−62.66	8.30	5.40	1.83	−4.41
NIM	−51.06	−44.15	−39.08	−12.67	5.34	12.08	−26.50	−15.28	18.92	13.38	55.29	−6.00
SOWN	−0.88**	−0.65	−0.48*	0.40***	−4.60	−3.98	−3.27	1.89***	1.85**	1.14*	0.27	−1.24***
FOWN	3.63	1.67***	−0.23	7.29***	−2.32	−3.79*	5.49**	8.77*	−0.38	−0.94	−1.63	−2.83
AFI	−7.89	−13.86	−18.23	−41.02	0.64	−0.95	−2.81	−6.40	−19.33	−16.72	−13.53	−7.93
DFI	7.50	5.41	8.43	6.45	7.25	5.75	6.19	−3.99	7.03	6.91	5.79	6.11
GDPC	5.81	3.71	3.17	4.16	6.09**	6.48	8.53*	6.85	4.40	6.85***	3.50	4.89
Cons	−17.57**	−17.19***	−16.91**	−10.15*	−22.79***	−20.78**	−18.73**	−14.08***	−27.36***	−23.35***	−18.53*	−10.74**
Panel B												
FINT	−4.90	−4.01**	−3.95*	−3.24	−6.51***	−5.60*	−2.01	−1.97	−8.97	−7.01**	−5.59**	−5.24*
FINT*MAD	0.42***	0.22*	0.23	0.23	0.49**	0.35*	0.26*	0.22*	0.35***	0.04	−0.21	−0.43
BOSZ	−0.06	−0.27	−0.53	−0.94*	−0.63	−0.16	0.25	0.77	1.38	−0.47	−2.07	−4.26
BOSI	−0.36*	1.48	3.69	7.25**	−8.44	−0.43	6.61	15.44	19.57	−12.86	−40.90	−79.32
FSIZE	0.37*	0.60	−0.87***	−1.31***	−0.48	0.28	0.94	1.78	−2.13	0.48*	2.73	5.82
DIVI	0.82	0.83	0.84	0.87	1.83	1.58	1.36	1.08	4.41	1.54	−0.94*	−4.34
NIIC	1.96	0.69	−0.84	−3.30	−7.31*	0.78**	7.89*	16.81	−11.55	−3.12	4.16	14.14
NIM	29.83	11.54	−10.38	−45.63	12.24**	23.08*	13.23	27.47	−19.50	7.45*	17.60	13.18*
SOWN	−0.15***	0.41**	0.71*	1.20	1.43	0.65	−0.04**	−0.91**	−1.10	0.69	2.24	4.36
FOWN	0.94*	1.20	1.51**	−2.02***	1.29	0.88	0.52**	0.06**	0.13	−1.01	−1.99***	−3.34***
AFI	−6.95	−6.26	−5.43	−4.09	−7.71	−7.53	−7.37	−7.16	9.00	−6.85	−20.57	−39.36
DFI	6.41	5.68	4.96	4.39	5.68	5.57	6.36	6.74	5.45	6.04	7.96	8.87
GDPC	14.30**	13.52*	12.80	12.58	14.61	17.93	11.84	9.09	6.62	5.06	7.24	−8.12
Cons	−37.89***	−13.68***	−8.68***	−8.04	−7.83*	−8.97***	−5.06*	−4.00*	−9.95	−8.88**	−6.49*	7.53

Note: This table reports the coefficients as the results of estimating Eq. (2) by applying the Two-stage quantile estimation method for Z-score with country-level as a dependent variable. Panel A and Panel B show the estimation results for FINC and FINT to measure FinTech development, respectively. MAD is a market discipline variable. Regressions (1)–(4), (5)–(8), and (9)–(12) involve the results by applying LIST, RATE, and DISC to measure market discipline respectively. Q25, Q50, Q75, and Q90 are the quantile 25th, 50th, 75th and 90th respectively. See Table 1 for variable definitions. ***$p < 0.01$; **$p < 0.05$; * $p < 0.1$.

of ever-evolving FinTech and have appropriate strategies to control their risk.

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CRediT authorship contribution statement

Quang Khai Nguyen: Conceptualization, Formal analysis, Investigation, Methodology, Resources, Writing – original draft, Writing – review & editing. **Van Cuong Dang:** Data curation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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