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The inverted-u-shaped impact of fintech development on bank risk: A study of liability structure and economic uncertainty

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ABSTRACT

In the evolving landscape of financial digitization, the implications of fintech development on commercial bank risk are increasingly vital. This research rigorously examines the depth and breadth of fintech's influence, particularly emphasizing the interplay between liability structures and periods of economic flux. A methodical econometric analysis was undertaken, analyzing panel data from 2011 to 2021, spanning 281 commercial banks. This research encompasses 15 national banks, 266 regional banks, 52 listed entities, and 229 unlisted institutions. Analysis leveraged the capabilities of Stata 17.0 software. The findings depart from a linear interpretation. Instead, fintech's impact on bank risk follows an inverted "U-shaped" trajectory—initially escalating risk, then mitigating it. The liability structure emerges as a consequential intermediary in this dynamic. Moreover, the influence of fintech varies depending on the bank type and equity composition. In times of economic volatility, this relationship is further accentuated. These insights hold paramount significance for commercial banks amid the current digital revolution. They provide a roadmap for judiciously balancing risk in a time when fintech innovations are dominating, ensuring resilience and adaptability in an unpredictable financial domain.

Contribution/Originality: This research illuminates fintech's nuanced impact on commercial bank risk, uncovering heterogeneity across various bank types and equity structures, and providing key insights for refining risk management strategies amid banking digital transformation.

1. INTRODUCTION

The rapid advancement of fintech is significantly shaping the future of the commercial banking sector. As technology continues to evolve and financial innovation thrives, fintech has become a pivotal force driving the transformation and upgrading of the banking sector. In recent years, there have been numerous innovations in the fintech industry, including mobile payments, block chain technology, and robo-advisors, as well as payment, wealth management, insurance, investment, credit investigation, and lending (Chen, Yang, & Ma, 2022). Commercial banks not only face competitive pressures brought about by fintech but can also leverage their capabilities to transform traditional business models and enhance service efficiency and innovation capacity (Berg, Burg, & Gombović, 2020).

As a result of the emergence of fintech, commercial banks are exposed to various risks and challenges. These risks directly impact the banks' profitability and stability and could trigger systemic risks. Internationally, the banking collapses at Silver Gate Bank, Signature Bank, and Silicon Valley Bank within the United States and the bankruptcy of Baoshang Bank in China underscore the importance of banking risk and the urgency of risk management. Credit risk, one of the core risks for commercial banks, has become a crucial factor in inciting systemic risk. Studies indicate that the rapid development of fintech may exacerbate competition for funding sources and intensify credit risk in banks (Qiu, Huang, & Ji, 2018). Concurrently, applying fintech could alter the liability structure, increase interest payment costs, and elevate the banks' risk exposure (Guo & Shen, 2019). Moreover, larger-scale Internet lending platforms with anomalous interest rates may cause spillover effects on the systemic risks of commercial banks (Li & Shen, 2019).

Despite these, researchers have proposed that fintech has a mitigating effect on the risks faced by commercial banks. Innovations in fintech, such as blockchain technology, the Internet of Things, and robo-advisors, not only generate innovative value for commercial banks but also aid in improving credit quality and reducing credit risk (Chen, Wu, & Yang, 2019). Furthermore, fintech has the potential to reduce commercial banks' management costs, compensate for the narrowing of the interest spread, and enhance the banks' operational performance (Gu & Yang, 2018). From a Bank lending perspective, fintech empowers traditional financial institutions to decrease information asymmetry between themselves and enterprises (Demertzis, Merler, & Wolff, 2018) fintech can supplement traditional credit systems, improving loan quality multi-dimensionally and lowering the risk burden on banks (Berg et al., 2020). The best market structure for the banking industry also found that fintech encourages banks to lend money to small and micro-businesses. This means that fintech is a useful way to reduce credit inequality and make digital banking available to more people (Sheng & Fan, 2020).

The impact of fintech on banks has both positive and negative aspects, and the relationship between the two determines whether fintech increases or decreases the risk of commercial banks. This is a question on which existing literature has not yet reached a consistent conclusion. Given the differing viewpoints and conclusions on fintech's impact on banks, this research aims to delve deeper into how fintech influences bank risk. More specifically, this research will examine the effects of fintech development on commercial bank risk and whether the said impact varies across different types of banks and equity structures. Through a profound analysis of these issues, we seek to provide valuable decision-making references for financial institutions and regulatory bodies, propelling the balanced development of risk control amidst the digital transformation of commercial banks.

The liability structure was used as an intermediary variable in this study. The impact of financial technology on bank risks is substantial, owing to its prominent channel.

In banking operations, the liability structure primarily reflects the proportion of interbank business and payable bonds in the total interest-bearing liabilities. Hence, with reduced deposits to meet daily funding requirements, banks inevitably expand their interbank borrowing business, thereby changing their liability structure. Furthermore, innovative financial products introduced by banks during the digital transformation provide investors with more investment channels besides deposits. These new investment channels offer higher returns, causing investors to reduce deposit investments and limit the banks' source of funds. This loss of savings deposits makes banks more dependent on interbank borrowing, increasing the risk of cross-infection between institutions. The liability structure significantly influences commercial banks' stable operation and sustainable development. Simultaneously, changes in the liability structure can affect bank risks through channels like changes in financing sources, financing risks, and liquidity (Liu & Jiang, 2021). For instance, the transmission mechanism of interbank business and bank risks suggests that risks can be spread through balance sheets (Allen, 2001). Therefore, financial technology has the potential to indirectly affect

risk by affecting banks' liability structures, for example, by reducing deposit liability and increasing wholesale financing.

As the global economy becomes increasingly uncertain, macroeconomic stability becomes scarce. Economic policy uncertainty directly influences the decision-making behavior of all financial entities and transmits uncertainty to banks through other financial entities. Thus, commercial banks demonstrate a stronger sensitivity to economic policy uncertainty (Tian & Li, 2020). Does economic policy uncertainty have a significant regulatory effect on bank risks? This section introduces the economic policy uncertainty index and empirically analyses its regulatory function.

In summary, the objective of this research is to uncover the influence of fintech on bank risk and encourage the sustainable development of the financial sector. We intend to provide theoretical and empirical evidence for decision-makers and practitioners in the financial industry by conducting in-depth research into the relationship between fintech and bank risk, thereby contributing to the financial system's stability and sustainability.

2. LITERATURE REVIEW

2.1. Fintech and Commercial Bank Risk

The impact of fintech on bank risk is a topic of considerable interest. Early studies proposed various viewpoints and conclusions. Yudaruddin et al. (2023), based on a sample of 141 Indonesian banks from 2004-2018, discovered that a rise in the quantity of fintech enterprises could reduce banking risk and increase capital ratios, thereby enhancing bank stability. Li, Teng, and Ye (2022), using data from 37 listed Chinese commercial banks, posited that fintech could effectively reduce banking risk. Additionally, Liu and Dai (2022) found that fintech has fostered the growth of banks' loan business and escalated their risk. These studies provide some evidence of fintech's impact on bank risk.

According to some studies, the development of fintech may negatively affect banks' credit risk. Banking risk has continuity, and leverage rate regulation can mitigate it (Ma & Fan, 2019). Commercial banks can reduce their economic capital risk by developing fintech (Yao & Song, 2021). There is a positive effect of fintech on operational efficiency, and banks' risk control capabilities have a mediated effect (Du & Liu, 2022). These studies further endorse the complex influence of fintech on commercial bank risk.

In light of the analysis above, this research proposes that market competition, risk contagion, and regulatory delays significantly increase banks' credit risk during the early stages of fintech. In the later stage, fintech aids commercial banks in optimizing risk management processes, enhancing risk control capabilities, and reducing risk. Moreover, combining fintech and government regulation can effectively supervise banks' risk behavior.

Therefore, to better understand the impact of fintech on bank risk, this research proposes Hypothesis H1:

H_1: Fintech imposes a "U-shaped" effect on commercial bank risk, initially escalating and subsequently decreasing.

2.2. Fintech, Liability Structure, and Bank Risk

Financial technology directly affects commercial banks' liabilities and net interest margins, which in turn affects their risks. Even though financial technology represents a technological innovation and does not directly permeate bank risks, its influence on the bank's liability structure is apparent. The proliferation of fintech indirectly augments banks' liability costs, leading to significant changes in the banks' liability structure (Yan, 2022). This, in turn, compels banks to rely more on interbank liabilities and other wholesale financing channels to supplement funds, thereby escalating the risk profile of banks. In particular, banks are relying more and more on interbank liabilities to get money. This is a way of giving loans that involves many channels and has problems with uneven information and management issues after the loan is given, which raises bank risk.

Furthermore, assets linked to banks' interbank liabilities are often associated with specific "channel type" accounting investment projects, which tend to have a high level of risk, further increasing banks' credit risk.

A different perspective examines how fintech advancements impact commercial banks' credit risk, especially considering liability costs and structural factors (Fu, Pei, & Sun, 2023). It is observed that fintech indirectly augments banks' liability expenses, leading to a heightened dependence on interbank liabilities as a countermeasure. Lin and Xuezhi (2021) came up with a new liability structure based on Basel III and the Total Loss-Absorbing Capacity (TLAC) Term Sheet. This structure focused on layered contingent capital and the possible effects of fintech on banking vulnerabilities. Leanza, Sbuelz, and Tarelli (2021) also found that a well-grounded bail-in resolution approach can stop people from taking on too much debt and delay possible defaults, highlighting its crucial role in managing financial risk. Xiaoping, Hongji, and Yingfan (2021) looked at how fintech tools affect bank credit outreach through a methodological lens. They gave important information about how the banking landscape changes as fintech grows. The changing liability framework indirectly influences commercial banks' risk exposure, suggesting that their liability construct plays a pivotal role in determining the repercussions of fintech innovations.

In summary, current research demonstrates that the evolution of fintech affects commercial banks' liability structures, subsequently influencing their risk profiles. Some studies suggest that the advent of fintech leads commercial banks to rely more on interbank liabilities and other financing channels, thereby escalating risk. Moreover, changes in commercial banks' Liability Structure transmit the impact of fintech on risk through a mediating effect. Drawing from these recent studies, this research proposes Hypothesis H2.

H_2: The impact of fintech on the risk of commercial banks is mediated by banks' liability structures.

2.3. Development of fintech and Analysis of Commercial Bank Heterogeneity

The type of commercial bank influences the impact of fintech on bank risk. Commercial banks can be divided into national and regional banks (Yin, Wu, & Lin, 2014). National banks encompass state-owned and joint-stock banks, while regional banks comprise city and rural commercial banks. Deng, Lv, Liu, and Zhao (2021) found that the development of fintech has significantly reduced bank risk-taking levels. Their heterogeneity analysis shows that the reduction effect of fintech on bank risk-taking is more pronounced in banks in the eastern and western regions of China, the large banks, and the urban commercial banks. Beltratti and Stulz (2012) posit that systemically important banks, like national banks, face stricter regulatory capital standards. Thus, their risk behavior tends to be more cautious, with risk absorption effects dominating. Conversely, Wang and Dai (2011) suggest that regional banks are more susceptible to financial fragility and squeeze-out effects because their operations are limited to specific areas.

Additionally, banks' equity structures influence fintech's impact on risk. With the expansion of economic uncertainty in China accompanied by sustained high growth, commercial banks must periodically finance to supplement capital to satisfy the regulatory standards for capital sufficiency. Simultaneously, commercial banks will encounter more stringent regulatory demands and operate within a market-oriented framework after undergoing shareholding reform and becoming publicly listed entities. Listed banks will experience enhancements in their development strategy, business philosophy, and incentive constraints, emphasizing quality, efficiency, stability, and sustainable development (Pan, 2013). Unlike non-listed banks, listed banks have more vigor, are more receptive to new business philosophies and technical forms, and can better utilize fintech to improve financial services and mitigate risk.

In conclusion, different types of commercial banks demonstrate disparities in fintech development and bank risk levels. Due to their scale, resource advantages, and ability to cooperate with fintech companies, national banks have stronger resilience to fintech shocks. They are better suited to internal fintech research and development. Conversely, listed banks have advantages in capital and cost, business philosophy

improvement, and market trust, thereby utilizing fintech better to reduce bank risk. Hence, fintech's impact on risk within various segments of the banking industry may exhibit variability.

Based on the analysis above, the following research hypotheses are proposed:

H_3: The influence of fintech development on bank risk varies among distinct categories of commercial banks.

$H_{3.1}$: The impact of fintech on bank risk exhibits differences across various types of banks (national and regional).

$H_{3.2}$: The impact of fintech on bank risk varies between listed and non-listed banks.

2.4. Impact of Economic Uncertainty

Economic policy uncertainty plays a moderating role in the relationship between fintech and bank risk. When EPU is elevated, the influence of fintech on banks' risk-taking propensities can be amplified (Bordo, Duca, & Koch, 2016). On the other hand, Moudud-Ul-Huq and Akter (2022) show that there is a strong negative correlation between EPU and the growth of bank loans. This means that higher levels of EPU might lessen the effect of fintech on bank risk by limiting the growth of loans in policy environments where uncertainty exists.

In a nutshell, the uncertainty surrounding economic policy has a significant impact on reducing the risk that banks face as a result of fintech. On the one hand, economic policy uncertainty motivates banks to seek more risk management and return optimization tools. Fintech can help banks improve risk management and operational efficiency and expand their customer base. Conversely, economic policy uncertainty may amplify the inherent risks associated with fintech, compelling banks to oversee and mitigate such hazards adeptly. As a result, economic policy uncertainty moderates the impact of fintech on bank risk, and both its positive and negative effects must be carefully considered to ensure banks' stability and sustainable development.

Hence, Hypothesis H4 is proposed:

H_4: Economic uncertainty moderates the impact of fintech on commercial bank risk.

2.5. Theory Support

The influence of fintech on bank risks can be elucidated from several theoretical perspectives. First, the theory of information asymmetry suggests that fintech, or systemic risk information, can help mitigate information asymmetry problems, thereby lessening the bank's credit risk (Lapavitsas & Santos, 2008; Liu, 2016; Stiglitz & Weiss, 1981; Wu, 2015). In addition, the theory of inclusive finance demonstrates that fintech can facilitate the accessibility and convenience of banking services, benefiting a broader range of individuals and businesses and diversifying bank risks (Beck, Demirguc-Kunt, & Martinez Peria, 2007). Lastly, the efficiency theory elucidates how fintech can lower bank risks by enhancing operational efficiency and reducing operational costs (Berger & Humphrey, 1997). However, it is noteworthy to consider Schumpeter and Backhaus (1934) concept of "disruptive innovation" from the financial innovation theory, wherein when the usage of a particular technology reaches a tipping point, it may cease to bring additional benefits and could instead diminish them. This concept is significant in fintech, which exhibits disruptive and revolutionary characteristics, encapsulating this concept of disruptive innovation. If innovation breaches the established framework, potential pitfalls may arise in the innovative business processes, possibly inciting instability within the financial sector. These kinds of financial innovations make it harder to figure out where risks come from, make it more likely that they will spread, and make it harder to hide risks. This makes the financial system more volatile and increases the chance of systemic risks, which directly threaten financial stability (Xu, 2018). These theories collectively provide a comprehensive, multi-dimensional understanding of how fintech impacts bank risks.

3. MATERIALS AND METHODS

3.1. Data Sources and Variable Definition

Based on the classification of the CSMAR database, there are currently 375 commercial banks in China. Due to the elimination of specific annual data that was unattainable and data missing essential variables, this research compiles a panel of data for 281 Chinese commercial banks from 2011 to 2021. The research includes data from 15 national banks, 266 regional banks, 52 listed banks, and 229 unlisted banks.

Data sources include the CSMAR database for bank financial data and commercial bank types; the Wind database for bank listing times; the stats.gov.cn database for macro-level variables; and the Economic Policy Uncertainty website http://www.policyuncertainty.com for data on economic policy uncertainty. Stata 17.0 is employed for the econometric analysis.

Differentiating Our Empirical Model from Prior Research:

While various studies have addressed the impact of fintech development on bank risk, our empirical model introduces innovative features and refinements:

Dependent Variable: Unlike other studies that use a single risk indicator, we use the loan-to-asset ratio (LAR) as a primary risk indicator, further enhancing the comprehensiveness of our results with the non-performing loan rate (NPL) in a robustness test.

Explanatory Variables: The prevalent approach in most studies involves using a singular fintech index. In contrast, our research uniquely incorporates both Fintech1 and Fintech2. The municipal index (Fintech1), encompassing data from the provincial to county level, offers an in-depth perspective, and the index is based on the Peking University Digital Financial Inclusion Index of China (Guo et al., 2020). Our choice of a 10-year span is strategically designed to capture the entire evolution of financial technology. Following Li, Yan, Song, and Yang (2020), the Fintech2 index is the number of results related to Baidu News Advanced Search keywords. Further, our robustness analysis uses the Fintech2 index's logarithmic transformation to measure regional financial technology development.

Mediator and Moderator Variables: By utilizing the asset-liability ratio (ALR) and the logarithmic transformation of the China Economic Policy Uncertainty Index, our study ensures a detailed and precise measure, thereby standing out from simplistic models.

Table 1. List of variables.

Variable type	Variable name	Symbol	Variable definition
Explanatory variables	Fintech	Fintech1	《Peking University digital inclusive finance composite index》(11—21)
		Fintech2	Baidu News advanced search keywords related to fintech, in natural log
Explained variables	Bank risk	Npl	Non-performance loan ratio
		LAR	Total loan to Total assets ratio
Moderator variable	EPU index	lnEPU	log(EPU Index)
Mediating variable	Liability structure	ALR	Asset liability ratio
Control variables	Monetary policy	M2	$(M2_t - M2_{t-1})/M2_{t-1}$
	Economic growth	GDP	$(GDP_t - GDP_{t-1})/GDP_{t-1}$
	Industry competition	HHI	Hirschman-Herfindahl index
	Deposit growth	DG	The percentage change in the total amount of deposits (D). $DG = (D_t - D_{t-1}) / D_{t-1}$
	Loan growth	LG	The rate of change in the total loan portfolio (L). $LG = (L_t - L_{t-1}) / L_{t-1}$
	Size	AS	log (Total assets)

Control Variables: We employ a broad range of control variables, such as the Deposit growth rate (DG), loan growth rate (LG), and asset size (AS), adding depth to our model's robustness. Macro-level variables incorporate China's GDP (Gross Domestic Product) growth rate, logged for normalization (GDP logarithm), representing the monetary value of all finished goods and services produced within a country's borders in a specific period. Also included are the degree of competition in the commercial banking industry (HHI) and the M2 growth rate. Furthermore, our inclusion of bank type and equity structure, specifically for subsample regression, introduces a layer of specificity. Table 1 defines variables.

3.2. Model Design

Our Empirical Equations 1 to 3 further delve into analyzing the "inverted U-shaped" relationship between fintech and commercial bank risk. It is mediated by the liability structure ALR and the modulation by economic uncertainty. Each model has been carefully crafted to serve a distinctive investigative purpose.

Our methodology offers a holistic, detailed, and refined exploration of the complex dynamics between fintech development and bank risk, setting it apart from previous studies.

Equation 1 examines the presence of an "inverted U-shaped" correlation between fintech and commercial bank risk.

$$LARit = \beta 0 + \beta 1\, lnFTi,t + \beta 2\, lnFT,t + \delta Xi,t + \lambda t + \mu i + \varepsilon i,t \quad (1)$$

Equation 2 examines the mediating role of the liability structure ALR in the relationship between the amount of fintech and commercial bank risk.

$$ALRit = \gamma 0 + \gamma 1\, lnFTi,t + \gamma 2\, lnFT,t + \delta Xi,t + \lambda t + \mu i + \varepsilon i,t \quad (2)$$

$$LARit = \pi 0 + \pi 1\, lnFTi,t + \pi 2\, lnFT,t + \pi 3\, ALRit + \delta Xi,t + \lambda t + \mu i + \varepsilon i,t \quad (3)$$

Equation 3: To verify the moderating effect of economic uncertainty in the process of assessing the impact of fintech on bank risk.

$$LARit = \theta 0 + \theta 1\, lnFTi,t + \theta 2\, EPUt + \theta 3\, lnFTi,t \times EPUt + \theta 4\, lnFT,t + \delta Xi,t + \lambda t + \mu i + \varepsilon i,t \quad (4)$$

In Equations 1 2 3 4, the fintech index FTi,t and its square term lnFT,t are used to see if there is an "inverted U-shaped" relationship between bank risk and fintech integration. The benchmark regression results focus on the positive and negative aspects of the square term coefficient of the fintech index. If the coefficient is negative, the hypothesis is verified. The signs and significance of coefficients $\beta 2$, $\gamma 2$, $\theta 4$, $\alpha 2$, $\eta 3$, and $\phi 4$ can be used to verify the existence of this relationship. The LARit variable denotes the level of risk associated with commercial banks, while ALRit reflects the liability structure. EPUt signifies the degree of uncertainty in economic policy, and lnFTi,t×EPUt examines the correlation between economic policy uncertainty and the degree of fintech. Xi,t represents control variables, λt and μi represent time and individual effects, respectively, and $\varepsilon i,t$ represents the residual term.

Our methodology differs from prior research in several key aspects:

Firstly, there is distinct focus on inverted U-shaped correlation. Unlike the studies conducted by Cheng and Qu (2020), our Equation 1 explicitly looks at the possibility of an "inverted U-shaped" correlation between fintech and commercial bank risk. Although Cheng and Qu delved into the effects of bank fintech on credit risk, they did not focus on this specific correlation.

Secondly, the use of the mediating role of the liability structure. Wang and Qin (2021) proposed a new type of bank liability structure. However, our Equation 2 directly addresses the mediating role of liability structure in the relationship between fintech and commercial bank risk, which was not the core focus of their research.

Thirdly, the inclusion of the economic uncertainty variable. Our Equation 3 introduces a novel aspect by considering the moderating effect of economic uncertainty on the impact of fintech on bank risk. This is a unique feature not explored in-depth by prior researchers (Leanza et al., 2021).

Finally, a more comprehensive approach to the issues. While Xiaoping et al. (2021) examined how fintech might influence the bank credit structure, our methodology encompasses a broader array of variables and factors, offering a more holistic perspective.

By aligning our research approach with contemporary issues and combining various aspects from previous studies, we believe our methodology has contributed to the literature to further increase understanding of the issues.

4. RESULTS AND DISCUSSION

4.1. Descriptive Statistics

Table 2 displays the descriptive statistics of the sample data. The average value of Fintech1 is 4.285, suggesting that the application level of financial technology in commercial banks is relatively high. The standard deviation of 1.309 indicates a relatively large variation in the Fintech1 data in the sample. This indicates that some commercial banks are far ahead of the average level in terms of financial technology applications, while other banks are relatively lagging.

The average value of LAR (Total loan to Total assets ratio) is 0.584, reflecting the degree of banks' risk exposure. This indicator displays the proportion of the bank's assets that bear risk to its total assets. The standard deviation is 0.112, indicating a specific difference in the risk-weighted asset ratio among different banks in the sample; that is, the risk exposure of different banks varies. This means some banks bear higher risks while others have lower risks.

The average value of ALR (liability structure) is 0.922, indicating that the equity ratio in the liability structure of commercial banks is relatively high. The standard deviation is 0.023, indicating a variation in the liability structure among the sampled banks.

Table 2. Descriptive statistics.

Variable	Obs.	Mean	Std. dev.	Min.	Max.
LAR	1562	0.584	0.112	0.01	1.55
Fintech1	1564	4.285	1.309	0	7.146
lnEPU	1568	5.258	0.527	4.523	5.967
ALR	1562	0.922	0.023	0.58	1.01
M2	1568	10.479	2.121	8.1	13.8
GDP	1568	6.602	1.747	2.3	9.551
HHI	1568	0.088	0.01	.065	0.106
DG	1485	0.138	0.105	-0.96	1.22
LG	1486	0.164	0.112	-0.99	1.42
AS	1563	24.926	1.522	21.12	30.52

Note: LAR = Total loan /Total Asset, Fintech1 = Financial technology index1, lnEPU= log(EPU Index), ALR= Asset liability ratio, $M2=(M2_t - M2_{t-1})/M2_{t-1}$, $GDP=(GDP_t - GDP_{t-1})/GDP_{t-1}$, HHI= Hirschman-Herfindahl index, $DG = (D_t - D_{t-1}) / D_{t-1}$, $LG = (L_t - L_{t-1}) / L_{t-1}$, AS= log (Total assets).

Contextualizing our findings in light of existing literature is crucial before exploring our primary regression results. Recent studies investigating the effect of fintech on bank risk have revealed a wide range of outcomes: Okoli (2020) discerned a U-shaped relationship between fintechs and credit risk within the BRICS economies (Brazil, Russia, India, China, and South Africa), indicating a primary mitigating effect that eventually evolves into elevated risk upon surpassing a fintech threshold, utilizing data from 1995-2018. Meanwhile, Cheng and Qu (2020), through an analysis of 2008-2017 data, proposed that bank fintech diminishes credit risk among Chinese banks, albeit less effectively in larger or listed entities. Moreover, employing data from 19 banks between 2011-2020, Chen et al. (2022) highlighted an inverted U-shaped pattern linking fintech and bank finance risk in China. In line with these previous researches that looked at the

nonlinear relationship, our study focuses on the inverted U-shaped dynamic. This helps us understand things more deeply by looking at mediation and heterogeneity in more detail than other studies did.

4.2. Regression Result

The regression findings are presented in Table 3. This regression table provides the results for two models where the dependent variable is LAR, presumably a measure of bank risk. Column 1 includes Fintech1 and a set of control variables. Here, we can see that an increase in the fintech level (Fintech1) is significantly associated with an increase in bank risk (LAR), as the coefficient is positive (0.053) and statistically significant (t-value is 15.480). Other significant variables at the 0.01 level include M2, HHI, DG, LG, and AS. Column 2 introduces the square of the fintech ($Fintech1^2$) to the first model to test the hypothesis of an "inverse U-shaped" relationship between fintech level and bank risk. The coefficient for $Fintech1^2$ is negative (-0.003) and significant, implying that after a certain point, an increase in fintech level is linked to a reduction in bank risk, confirming the "inverse U-shaped" relationship. This finding supports Hypothesis 1. The R-squared values indicate that both models explain a fair proportion of the variation in bank risk, with Equation 2 (R-squared = 0.384) performing slightly better than Equation 1 (R-squared = 0.379).

So, the regression analysis supports the hypothesis that the relationship between fintech and bank risk is "inverse U-shaped". This implies that as banks initially increase their fintech level, the risk increases, but after a certain point, further increases in fintech level lead to a decrease in risk.

Table 3. Regression result.

Variables	(1)	(2)
	LAR	LAR
Fintech1	0.053***	0.081***
	(15.480)	(8.501)
$Fintech1^2$		-0.003***
		(-3.113)
M2	0.015***	0.016***
	(10.880)	(11.355)
GDP	0.002	0.002*
	(1.356)	(1.754)
HHI	-1.037***	-1.225***
	(-5.909)	(-6.621)
DG	0.081***	0.084***
	(4.214)	(4.409)
LG	0.200***	0.202***
	(10.936)	(11.068)
AS	-0.087***	-0.087***
	(-8.504)	(-8.519)
Constant	2.409***	2.347***
	(9.568)	(9.327)
Observations	1,477	1,477
R-squared	0.379	0.384

Note: T-statistics in parentheses, *** p<0.01, * p<0.1. LAR = Total loan /Total Asset, Fintech1 = financial technology index1, lnEPU= log(EPU Index), $M2=(M2_t - M2_{t-1})/M2_{t-1}$, $GDP=(GDP_t - GDP_{t-1})/GDP_{t-1}$, HHI= Hirschman-Herfindahl index, $DG = (D_t - D_{t-1}) / D_{t-1}$, $LG = (L_t - L_{t-1}) / L_{t-1}$, AS= log (Total assets).

4.3. Mediation Effect

The liability structure was added as a mediating variable to the benchmark model to see its effect. The results are shown in Table 4.

A coefficient of 0.081 and confirmation at a 1% significance level show that Fintech1 in the first column of Table 4 exhibits a significant positive correlation with bank risk (LAR). It suggests an elevation in banks' risk levels

concurrent with fintech advancements. The coefficient of -0.009 and the significance level of 1% in column (2) demonstrate that Fintech1 significantly negatively impacts the liability structure (ALR).

This implies that the advancement of financial technology will lead to a decrease in the liability framework of commercial banks. The results indicate that the liability structure (ALR) in column (3) exerts a substantial adverse influence on bank risk (LAR), as evidenced by a coefficient of -1.492, which is statistical. This implies that an augmentation in the liability framework will mitigate the risk associated with commercial banks. In addition, the square term of Fintech1 negatively impacts bank risk in columns (1) and (3), albeit at a slightly lower level of significance. This finding suggests that the relationship between the advancement of financial technology and bank risk is not linear but exhibits a point of inflection. When the financial technology index surpasses a specific threshold, the advancement of fintech could potentially mitigate the risk commercial banks face. Through careful examination of the table's results, we can say that the liability structure (ALR) acts as a go-between for the effects of fintech on bank risk, which supports the development of hypothesis H2. Fintech reduces the risk for banks by reducing their liability structure. Higher levels of fintech are associated with changes in the bank's liability structure, which in turn affect bank risk.

Table 4. Mediation effect.

Variables	(1)	(2)	(3)
	LAR	ALR	LAR
Fintech1	0.081***	-0.009***	0.066***
	(8.501)	(-5.060)	(6.399)
Fintech1^2	-0.003***	0.000**	-0.002**
	(-3.113)	(1.998)	(-1.989)
ALR			-1.492***
			(-8.280)
Constant	2.347***	0.689***	2.953***
	(9.327)	(15.132)	(9.490)
Observations	1,477	1,476	1,173
R-squared	0.384	0.106	0.455
Control	Yes	Yes	Yes

Note: T-statistics in parentheses, *** p<0.01, ** p<0.05. LAR = Total loan /Total Asset, Fintech1 = financial technology index1, ALR= Asset liability ratio.

4.4. Heterogeneity Analysis

To delve deeper into how financial technology development influences the risk profiles of various commercial banks, we categorized our bank samples into national banks and regional banks. We then ran separate regression tests for each category. Table 5 elucidates these findings: Column 1 highlights the effect of fintech on national banks' risk, revealing that both Fintech1 and its squared coefficients are not statistically significant. In contrast, column 2, which focuses on regional banks, indicates that Fintech1 and its squared coefficients are significant. Notably, the squared coefficient for Fintech1 is negative, suggesting that the influence of fintech on the risk for regional banks follows an "inverted U" trajectory".

The heterogeneity analysis results show that national banks have apparent advantages such as large asset sizes, a stable customer base, strong government support, and strong resistance and are less affected by fintech. Hence, the varying financial technology advancements have distinct effects on different types of commercial banks, with a particularly pronounced influence on regional banks. Consequently, hypothesis H3.1 is confirmed. In summary, this research's findings indicate that financial technology's influence on bank risk varies among different types of banks. Financial technology (fintech) has been found to have a notable positive influence on the risk levels of regional banks, although its impact on national banks is not deemed substantial. Furthermore, the influence of fintech on the risk levels of regional banks exhibits a pattern characterized by an inverted U-shaped trajectory. Conversely, no comparable pattern has been detected in the case of national

banks. In summary, these results suggest heterogeneity in the correlation between the level of fintech and bank risk is contingent upon the type of bank, supporting Hypothesis 3.1. Specifically, the relationship is not statistically significant for national banks, while it is "inverse U-shaped" for regional banks. This indicates that fintech's impact on bank risk differs between national and regional banks.

It is worth noting that while our findings corroborate the inverted U-shaped relationship mentioned by Chen et al. (2022), we emphasize the relationship, especially for regional banks, thus providing a more nuanced perspective on the influence of fintech in various banking environments.

Table 5. Impact of fintech on bank risk in banks of different natures.

Variables	(1)	(2)
	National banks	Regional banks
Fintech1	0.003	0.084***
	(0.066)	(8.520)
Fintech1²	0.005	-0.003***
	(1.118)	(-3.404)
Constant	5.494***	2.178***
	(5.994)	(8.408)
Observations	71	1,406
R-squared	0.618	0.385
Control	Yes	Yes

Note: T-statistics in parentheses, *** p<0.01. Fintech1 = Financial technology index1.

The samples about commercial banks have been categorized into two distinct groups: the influence of fintech on the risk of non-listed commercial banks and listed banks. The regression analysis result is presented in Table 6. For listed banks, Fintech 1 and Fintech1² are also significant. Fintech1 has a positive coefficient (0.135) and is significant. Fintech1² has a negative coefficient (-0.006) and is also significant. This again suggests an "inverse U-shaped" relationship for listed banks. However, the size of the Fintech1² coefficient (-0.006) is more significant (in absolute terms) for listed banks than for non-listed banks (-0.003), indicating that the decrease in risk associated with increasing fintech, after a certain point, is more significant for listed banks. The R-squared values suggest that the models explain a good proportion of the bank risk variation for non-listed (R-squared = 0.379) and listed banks (R-squared = 0.445).

These results support Hypothesis 3.2, indicating that the decrease in bank risk associated with higher fintech levels (after a certain point) is more significant for listed banks than non-listed banks. Due to better access to resources, listed banks have more effective strategies for leveraging fintech to reduce risk. These results confirm Berger and Mester (1997) view of banks' improved operational efficiency after listing and that listed banks indirectly benefit from fintech and improve their risk control capabilities.

Table 6. Impact of Fintech on bank risk of non-listed banks and listed banks.

Variables	(1)	(2)
	Non-listed banks	Listed banks
Fintech1	0.076***	0.135***
	(6.812)	(5.445)
Fintech1²	-0.003**	-0.006***
	(-2.473)	(-2.750)
Constant	2.217***	3.086***
	(7.737)	(5.872)
Observations	1,186	291
R-squared	0.379	0.445
Control	Yes	Yes

Note: T-statistics in parentheses, *** p<0.01, ** p<0.05.Fintech1 = financial technology index1.

4.5. The Moderating Effect of Economic Uncertainty

Table 7 provides an in-depth analysis of the moderating effect of economic uncertainty. As illustrated in Column 1, the coefficients of Fintech1 and Fintech1² are 0.0814 and -0.0039, respectively. The significance of these values at the 1% level is noteworthy as it implies that financial technology has an inverted U-shaped impact on commercial bank risk. Equally importantly, the coefficient of economic uncertainty (EPU) is 0.0002, again highlighting its significance at the 1% level, suggesting that economic uncertainty plays a role in commercial bank risk. Turning to Column 2, after adding the interaction term of economic uncertainty and financial technology (EPU_Fintech1). We note that the coefficients of Fintech1, the square term of Fintech1, the coefficient of EPU, and the interaction term of economic uncertainty and financial technology all achieve significance at either the 1% or 5% level. These results strongly corroborate hypothesis H4, which posits that economic uncertainty moderates fintech's impact on bank risk.

In contrast to Deng et al. (2021), who pinpointed a straightforward risk-reducing impact of fintech on Chinese banks, our study unravels a more intricate narrative. Our research shows that economic uncertainty plays a moderating role in shaping the relationship between fintech and bank risk. This adds another layer of understanding to the current conversation.

Table 7. The moderating effect of economic uncertainty.

Variables	(1)	(2)
	LAR	LAR
Fintech1	0.0814***	0.1096***
	(8.590)	(7.350)
Fintech1²	-0.0039***	-0.0071***
	(-3.850)	(-4.281)
lnEPU	0.0002***	0.0001**
	(3.424)	(2.023)
EPU_Fintech 1		0.0001**
		(2.445)
Constant	2.2240***	2.1583***
	(8.786)	(8.496)
Observations	1,477	1,477
R-squared	0.390	0.393
Control	Yes	Yes

Note: LLAR = Total loan /Total Asset, Fintech1 = Financial technology index1 ,lnEPU= log(EPU Index).

The accompanying figure illustrates the moderating role of economic uncertainty on fintech's impact on commercial banks' risk, in alignment with Hypothesis H4. The moderating effect is visualized relative to different levels of economic policy uncertainty (EPU). Specifically, each line represents fintech's impact (Fintech1) on commercial bank risk (LAR) at a specific percentile of economic uncertainty (25%, 50%, 75%). These plotted lines reveal how the effect of fintech on commercial bank risk evolves at different levels of economic uncertainty. Finally, in the same figure, we display the original observational data (as scatter points) alongside prediction lines at different EPU values. In Figure 1 (Fintech1 vs LAR), we can observe an "inverse U-shaped" pattern as fintech's impact on banks' risk appears to increase with economic uncertainty (from the first quartile (Q1) to the third quartile (Q3)).

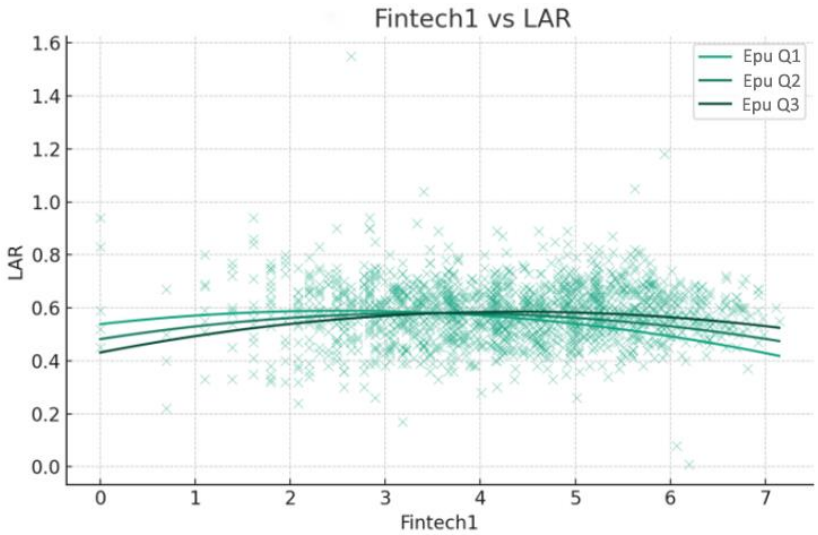

Figure 1. The moderating effect of economic uncertainty.

4.6. Robustness Check

To validate the empirical results, this research utilizes three distinct methodologies for the robustness check: Substituting the NPL ratio of commercial banks for the loan-to-asset ratio (LAR) as a replacement for the dependent variable, as shown in Table 8, Replacing the explanatory variable by substituting (Fintech2) for (Fintech1), as shown in Table 9, and processing the sample data at a 1% bilateral tail truncation level, as illustrated in Table 10. Generally, these robustness checks show a significant impact of fintech development on banking risk indicators, regardless of whether we replace the explanatory or dependent variables or process the sample data. This confirms the robustness of our findings and suggests that fintech development's impact on banking operations has considerable explanatory power.

Table 8. Robustness check 1.

Variables	(1)
	NPL
Fintech1	0.5942***
	(3.578)
Fintech1^2	-0.0807***
	(-4.702)
Constant	-2.1960
	(-0.498)
Observations	1,467
R-squared	0.093
Control	Yes

Note: T-statistics in parentheses, *** p<0.01. Fintech1 = Financial technology index1, NPL= Non-performance loan ratio.

Table 9. Robustness check 2.

Variables	(1)
	LAR
Fintech2	0.0019***
	(8.048)
Fintech2^2	-0.0000*
	(-1.729)
Constant	3.3196***
	(12.281)
Observations	1,480
R-squared	0.411
Control	Yes

Note: t-statistics in parentheses, *** p<0.01,* p<0.1. LAR = Total loan /Total asset, Fintech2= log(Fintech2).

Table 10. Robustness check 3.

Variables	(1)
	LAR
Fintech1	0.0813***
	(8.053)
Fintech1²	-0.0033***
	(-3.157)
Constant	2.1769***
	(8.894)
Observations	1,477
R-squared	0.350
Control	Yes

Note: T-statistics in parentheses, *** p<0.01. LAR = Total loan/Total asset, Fintech1 = Financial technology index1.

Table 11. Endogeneity test.

Variables	(1) Fintech1	(2) Fintech1²	(3) LAR
L.Fintech1	0.850***		
	(63.34)		
L.Fintech1²		0.933***	
		(85.83)	
Fintech1			0.196***
			(7.90)
Fintech1²			-0.0162***
			(-6.57)
M2	-0.0379***	-0.340***	0.0240***
	(-3.82)	(-4.51)	(11.03)
GDP	-0.0338***	-0.362***	0.00282
	(-4.47)	(-5.64)	(1.50)
HHI	-5.902***	-42.86**	-0.462
	(-2.72)	(-2.58)	(-0.97)
DG	-0.509***	-4.039***	0.122***
	(-3.03)	(-2.96)	(2.84)
LG	0.206	1.569	0.190***
	(1.52)	(1.39)	(4.22)
AS	0.0378***	0.358***	-0.0352***
	(4.84)	(5.39)	(-17.08)
_cons	1.239***	5.621***	0.668***
	(5.72)	(3.09)	(7.68)
N	1041	1041	1041
Adj. R2	0.913	0.926	0.344

Note: T-statistics in parentheses, *** p<0.01, ** p<0.05. LAR = Total loan /Total Asset, Fintech1 = financial technology index1, $M2=(M2_t - M2_{t-1})/M2_{t-1}$, $GDP=(GDP_t - GDP_{t-1})/GDP_{t-1}$, HHI= Hirschman-Herfindahl index, $DG = (D_t - D_{t-1}) / D_{t-1}$, $LG = (L_t - L_{t-1}) / L_{t-1}$, AS= log (Total assets).

4.7. Endogeneity Test

Lagged fintech indices—Fintech1 and its square—were used as instrumental variables in a 2SLS regression to examine endogeneity. Even after controlling for endogeneity, Fintech1 predicts bank risk, and its squared term negatively affects commercial bank risk at a 1% significance level, according to Table 11. Thus, the fintech index and commercial bank risk have a nonlinear, inverse U-shaped relationship resilient to endogeneity control.

5. CONCLUSIONS AND POLICY SUGGESTIONS

5.1. Conclusions

An existing relationship between fintech and commercial bank risk can be characterized as an "inverse U-shaped" relationship. In the early phases of fintech evolution, overlap with traditional commercial banking operations may lead to competitive substitution, potentially increasing banking risk. However, as fintech

matures and becomes more integrated, commercial banks begin to harness fintech's innovative capabilities, tapping into its technological spillover, leading to a reduction in risk. This nonlinear trajectory implies that judiciously introduced and aptly utilized fintech can bolster risk management paradigms for banks. Central to this dynamic is the pivotal role of the liability structure, which is not just a mere spectator. The liability structure conspicuously mediates the interplay between fintech proliferation and the quantum of risk banks contend with. The propensity to recalibrate the liability framework can modulate a bank's risk appetite and susceptibility. fintech's impact differs among commercial banks, with national banks manifesting resilience and regional banks finding themselves at the sharper end of fintech-induced risk oscillations. Furthermore, the equity structure is not just a passive variable; it actively modulates how fintech reshapes a bank's risk milieu. Particularly for listed banks, with their arsenal of resources, fintech's advancements translate into tangible risk reductions.

Our research indicates that fintech development significantly impacts commercial banks' risk management. However, this impact is nonlinear and influenced by various factors, including the bank's type, size, liability structure, and equity structure. Thus, to fully leverage fintech to reduce banking risk, banks must consider their specific circumstances, including managing their liability structure, selecting an appropriate development model, optimizing their equity structure, etc. We stress that the connection between fintech and banking is complex and depends on the type of bank, its liability and equity plans, as well as the overall state of the economy. Concurrently, in the backdrop of ever-shifting economic uncertainties, the onus rests on policymakers to be perspicacious, discerning the multifarious fintech repercussions. They must sculpt regulations that resonate with the dynamism of fintech and accommodate the inherent pluralism within the banking sector and its varying susceptibilities to external economic shocks. Considering the constraints of this research, it's imperative to acknowledge that while our sample spans a decade, the rapid advancement in fintech might render some insights less applicable in the future. Additionally, our focus was largely on the liability structure and economic uncertainty; future research could delve deeper into other mediating and moderating factors affecting the fintech-bank risk relationship.

5.2. Suggestions

Drawing from our empirical investigation into the influence of fintech on the banks' risk and considering the inherent limitations of this research, which focuses primarily on the liability structure and economic uncertainty without diving deeper into the operational aspects of fintech, we put forth the following policy suggestions: To begin with, commercial banks ought to increase their investments in fintech, leveraging the advantages of big data and cloud computing for thorough data analysis. This not only allows for the provision of bespoke and intelligent services but also necessitates the imperative of ensuring uncompromised data security and user privacy. Furthermore, in light of the potential vulnerabilities highlighted by our study, there is a pressing need for the integration of digital transaction, management, and risk control frameworks in tandem with fintech establishments. This will serve as a buffer against risk proliferation and bolster the bank's risk absorption capacity. Finally, echoing the sentiments from our findings and the dynamism of the fintech realm, it becomes paramount to transition from a reactive regulatory stance to a more proactive one. This transition would pave the way for instantaneous monitoring and adaptive oversight of commercial bank risk behaviors, thus enhancing compliance efficacy and building resilience against unforeseen disruptions and systemic risks.

6. FUTURE RESEARCH DIRECTIONS

To further deepen the understanding of fintech's operational dimension, future research endeavors should explore the specific aspects of how different technological innovations affect bank risks. Extending the geographical coverage of the research to other diverse settings would also contribute to a more comprehensive global perspective on fintech's influence. More nuanced inquiries into how fintech interfaces with varying sizes and types of banks and how

it navigates through different economic scenarios would add substantial depth to the existing body of knowledge on the subject.

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