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Financial Technology, Macroeconomic Uncertainty, and Commercial Banks' Proactive Risk-Taking in China

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Abstract: In this paper, we collect the annual data of 145 commercial banks in China from 2010 to 2019 and use a panel data fixed-effect model to study how fintech (financial technology) affects the influence of macroeconomic uncertainty on commercial banks' proactive risk-taking. We find that the development of fintech mitigates the dampening effect of macroeconomic uncertainty on commercial banks' proactive risk-taking. Specifically, fintech plays a mitigating role by motivating commercial banks to issue loans and hold transactional financial assets. With the increase of commercial banks' proactive risk-taking, the mitigation effect of fintech monotonically diminishes. This mitigating effect is heterogeneous across different types of commercial banks, as it is relatively weak for banks with high capital adequacy ratios and large state-owned banks.

Keywords: macroeconomic uncertainty; digital transformation; proactive risk-taking

JEL Classification: E32, E44, E51

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1. Introduction

When macroeconomic uncertainty increases, commercial banks are reluctant to lend, as they seek to avoid risks (Christiano et al., 2014) and reduce their level of proactive risk-taking, which inhibits the ability of financial intermediaries to serve the real economy. Enterprises are restrained in their investment decisions at times of rising macroeconomic uncertainty (Bernanke, 1983; Gulen & Ion, 2016), and commercial banks shrinking their credit further reduces the willingness and ability of enterprises to invest. In developing countries such as China, the level of macroeconomic uncertainty is usually high (Bloom, 2014). Studying how to alleviate the dampening effect of macroeconomic uncertainty on commercial banks' proactive risk-taking will enhance financial integration and promote the ability of financial intermediaries to serve the real economy (Huang and Huang, 2018), which has important practical and policy significance.

Commercial banks face the problem of information asymmetry when granting loans, which affects commercial banks' lending requirements and proactive risk-taking behavior (Delis & Kouretas, 2011). For commercial banks facing the problem of information asymmetry, macroeconomic uncertainty amplifies the procyclicality of lending behavior and hinders financial integration. Fintech developments can help address this problem by mitigating information asymmetry. The application of fintech can effectively promote the collection and processing of information about collateral, transaction records, and relationship loans by banks, and thus mitigating information asymmetry (Cenni et al., 2017; Mocetti et al., 2017). When macroeconomic uncertainty increases, commercial banks' reluctance to lend is mitigated by a deeper and timelier understanding of a potential lendee company's situation. In addition, the development of fintech can reduce the dependence of credit decision-making on the value of corporate assets (Gambacorta et al., 2020) and mitigate the impact of macroeconomic fluctuations on commercial banks' proactive risk-taking.

The 'Guiding Opinions of the General Office of the China Banking and Insurance Regulatory Commission on the Digital Transformation of the Banking and Insurance Industry' issued in 2022 stated that 'digital transformation will promote the high-quality development of the banking and insurance industry, build a new digital financial pattern that adapts to modern economic development, and continuously improve the ability and level of financial services for the real economy'. Accordingly, China's commercial banks have been promoting digital transformation and fintech services based on big data and new algorithms. This paper addresses the following research questions related to these developments: Can the development of fintech mitigate the dampening effect of macroeconomic uncertainty on the proactive risk-taking of

commercial banks? What are the specific channels and mechanisms of this mitigation? Is there any heterogeneity across different types of commercial banks? When the proactive risk-taking of commercial banks is at different levels, what is the difference in the marginal impact of fintech development?

To address the above research questions, we collect the annual data of 145 commercial banks from 2010 to 2019 and use a panel data fixed-effect model to test how fintech affects the negative impact of macroeconomic uncertainty on commercial banks' proactive risk-taking. We test the robustness of our findings by using instrumental variables and two-stage least squares (2SLS) regression, and by replacing fintech and macroeconomic uncertainty measurements. In addition, we explore the heterogeneity across different types of commercial banks through group regression. Furthermore, we examine the marginal impact of fintech development on commercial banks with different levels of proactive risk-taking through panel quantile regression.

We find that the development of fintech can alleviate the dampening effect of macroeconomic uncertainty on the proactive risk-taking behavior of commercial banks, and this mitigation effect is still significant when we control bank and macro-level variables. Using alternative variable construction methods or further considering endogeneity issues does not affect the robustness of the main finding. As the marginal effect of fintech diminishes when the level of commercial banks' proactive risk-taking increases, the development of fintech does not lead commercial banks to take excessive risks. Furthermore, we find that the digital transformation of commercial banks alleviates the negative impact of macroeconomic uncertainty by motivating commercial banks to issue loans, and to increase their holdings of transactional financial assets and thus expands the scale of credit risk-weighted assets and market risk-weighted assets held by commercial banks. The mitigating effect of fintech is heterogeneous across different types of commercial banks, with a weaker impact on commercial banks with high capital adequacy ratios and on large state-owned banks.

The main contributions of this paper are threefold. First, this paper compares the marginal effects of the development of fintech on commercial banks with different proactive risk-taking levels and finds that the mitigation effect of fintech decreases as the level of proactive risk-taking increases. This finding has critical practical implications, as it indicates that the development of fintech does not promote excessive risk-taking by commercial banks. Second, this paper uses digital transformation data that are accurately matched to each commercial bank to more directly and accurately reflect the level of fintech development

of each commercial bank. The conclusions obtained in this paper are thus more convincing than those that would be obtained with a less precise matching. Third, an increase in macroeconomic uncertainty reduces the level of proactive risk-taking by commercial banks and weakens commercial banks' ability to serve and support the real economy. In developing countries such as China, the level of macroeconomic uncertainty is usually high. In this context, the conclusions drawn from this study of how to mitigate the dampening effect of macroeconomic uncertainty on the proactive risk-taking of commercial banks provide empirical support and a practical basis for effectively enhancing banks' ability to serve the real economy.

This paper proceeds as follows. In Section 2, we discuss the theoretical mechanisms by which fintech might have an effect on the relationship between macroeconomic uncertainty and commercial banks' proactive risk-taking. Section 3 describes our data and empirical strategy. Section 4 reports the baseline empirical results, robustness checks, and results of further studies. Section 5 concludes the paper.

2. Mechanism analysis and hypothesis development

2.1. Fintech, macroeconomic uncertainty, and commercial banks' proactive risk-taking

Macroeconomic uncertainty mainly inhibits the proactive risk-taking behavior of commercial banks through the real option mechanism and the precautionary savings mechanism. First, risk assets such as loans are irreversible assets for commercial banks. According to the real option theory, when faced with uncertainty, commercial banks may choose to wait for the uncertainty to disappear (Wu et al., 2020). Under the effect of the real option mechanism, the rise of macroeconomic uncertainty increases the volatility of loan income, reduces the loan investment of commercial banks, and inhibits the proactive risk-taking behavior of commercial banks. Second, economic uncertainty can affect investment behavior through precautionary savings mechanisms. In the face of rising macroeconomic uncertainty, commercial banks have an incentive to hold more safe and liquid assets by such means as increasing cash, depositing central bank funds, and depositing interbank funds, and to reduce the size of risk assets such as trading financial assets and fixed assets.

The development of fintech can affect the dampening effect of macroeconomic uncertainty on commercial banks' proactive risk-taking by participating in the above mechanisms. For the real option mechanism, when commercial banks are faced with the uncertain loan returns brought about by the rise of macroeconomic uncertainty, fintech can enhance these banks' ability to collect and analyze information and promote their issuing of loans, thereby alleviating the dampening effect of macroeconomic uncertainty on

commercial banks' proactive risk-taking. Fintech can broaden commercial banks' information channels, expand their data range, and increase their information sources (Xie and Zou, 2012). The application of fintech can enhance the ability of commercial banks to process information (Cenni et al., 2017). Fintech promotes the credit supply of commercial banks by enhancing their ability to collect, analyze, and process information (Sheng and Fan, 2020). Therefore, improvements in the application of fintech in commercial banks are likely to alleviate the real option effect, expand the credit scale of commercial banks, and thus alleviate the dampening effect of macroeconomic uncertainty on commercial banks' proactive risk-taking.

Regarding the precautionary savings mechanism, in the face of macroeconomic uncertainty, we expect that fintech can improve commercial banks' risk management and liquidity management capabilities, weaken their motivation to carry out precautionary savings, and incentivize them to increase their holdings of risk assets such as transactional financial assets, thereby mitigating the dampening effect of macroeconomic uncertainty on their proactive risk-taking. Fintech affects not only the behavior of commercial banks when facing asset-liability decisions but also their organizational structure, operating efficiency, and scope of services (Mocetti et al., 2017). Fintech can also improve the risk management capability and operating efficiency of banks (Delis & Kouretas, 2011; Liu, 2016). Therefore, improvements in the application of fintech in commercial banks are likely to weaken the motivation of precautionary savings, expand the scale of risk assets such as transactional financial assets, and thus alleviate the dampening effect of macroeconomic uncertainty on commercial banks' proactive risk-taking.

Accordingly, we put forward the following research hypotheses:

Research Hypothesis 1: The development of fintech alleviates the dampening effect of macroeconomic uncertainty on commercial banks' proactive risk-taking.

Research Hypothesis 1a: In the face of macroeconomic uncertainty, the development of fintech alleviates the dampening effect of macroeconomic uncertainty on commercial banks' proactive risk-taking by motivating commercial banks to issue loans.

Research Hypothesis 1b: In the face of macroeconomic uncertainty, the development of fintech alleviates the dampening effect of macroeconomic uncertainty on commercial banks' proactive risk-taking by motivating commercial banks to increase their holdings of transactional financial assets.

Research Hypothesis 1c: In the face of macroeconomic uncertainty, the development of fintech alleviates the dampening effect of macroeconomic uncertainty on commercial banks' proactive risk-taking

by expanding their scale of fixed assets.

2.2. The marginal impact of fintech and macroeconomic uncertainty on different levels of the proactive risk-taking of commercial banks

There are significant structural differences in the marginal impact of economic uncertainty on banks' asset-liability allocation behavior. Tian and Li (2020) study the evolution of the marginal effect of economic policy uncertainty on different levels of bank liquidity creation and find that as the level of liquidity creation increases, banks' liquidity creation becomes more sensitive to the negative impact of economic policy uncertainty. Commercial banks have different degrees of willingness to take further risks at different risk-taking levels. The higher the level of proactive risk-taking, the more cautious commercial banks are in the allocation of risk assets and the more sensitive are they to the negative impact of macroeconomic uncertainty. To avoid taking extreme risks, banks with low market power adjust their asset–liability allocation to alleviate the negative impact of economic uncertainty by restricting the amount of excessively risky and long-term assets and shrinking the liability business with long-run risk (Jiang et al., 2019).

Therefore, we expect the marginal effect of fintech to differ at different risk-taking levels of commercial banks. The higher the level of proactive risk-taking of commercial banks, the lower is their willingness to take further risks, the more sensitive they are to the negative impact of macroeconomic uncertainty, and the more limited the ability of fintech development is to alleviate this impact. That is, although fintech can increase commercial banks' level of proactive risk-taking by mitigating the negative impact of macroeconomic uncertainty, the magnitude of the marginal effect of fintech decreases as the level of risk-taking increases. It is therefore likely that the development of fintech does not promote excessive risk-taking by commercial banks. Accordingly, we propose the following research hypothesis:

Research Hypothesis 2: As the level of proactive risk-taking of commercial banks increases, the mitigation of fintech development on the dampening effect of macroeconomic uncertainty on commercial banks' proactive risk-taking diminishes marginally.

3. Methodology and data

3.1. Model setting

In this paper, the proactive risk-taking of commercial banks is the dependent variable. Following Liu et al. (2019), we introduce the interaction term of the development level of fintech and macroeconomic uncertainty and construct the following baseline regression model:

$$risk_{it} = \beta_0 + \beta_1 fintech_{i,t-1} + \beta_2 eu_{t-1} + \beta_3 fintech_{i,t-1} \times eu_{t-1} + \gamma X_{i,t-1} + \lambda Y_{t-1} + \beta_4 t + \mu_i + \varepsilon_{it} \quad (1)$$

where the subscripts i and t denote the bank and the year, respectively; *risk*, *fintech*, and *eu* represent the proactive risk-taking of commercial banks, the degree of fintech development, and macroeconomic uncertainty, respectively; X contains control variables at the bank level; Y contains control variables at the macro level; t is the time trend item; and μ_i is the individual fixed effect. As there is no difference in the cross-section of the macroeconomic uncertainty index, the time fixed effect cannot be controlled. Following Gu and Yu (2019), we control the macro variables to alleviate potential endogeneity problems caused by omitted variables. Following Ji et al. (2018) and Qiu et al. (2018), the independent variable is lagged in time to alleviate the potential endogeneity problem caused by reverse causality.

This paper is mainly concerned with the estimated coefficient β_3 of the interaction term of fintech and macroeconomic uncertainty, which is expected to be significantly positive according to research hypothesis 1.

3.2. Variable description

3.2.1. Dependent variables

The dependent variable is the risk-taking of commercial banks. This paper studies whether fintech can alleviate the dampening effect of economic uncertainty on the proactive risk-taking behavior of commercial banks. Therefore, we use the risk-weighted asset ratio (*rwar*), which measures proactive risk-taking behavior, as the dependent variable. The data for most commercial banks are directly obtained from the BankFocus database. Following Gu and Yu (2019) and Tian and Li (2020), we collect the remaining data by manually reviewing bank annual reports. To examine the robustness of the results, we follow Fang et al. (2012) in computing the indirect measure of the risk-weighted asset ratio (*rwar2*) as total equity/capital adequacy ratio/total assets. A greater risk-weighted asset ratio indicates a higher degree of proactive risk-taking by commercial banks. Both variables are multiplied by 100 when used.

According to the 'Commercial Bank Capital Management Measures (Trial)' issued by the China Banking Regulatory Commission, the risk-weighted assets of commercial banks are composed of credit risk-weighted assets (*crwa*), market risk-weighted assets (*mrwa*), and operational risk-weighted assets (*orwa*). We follow Liu et al. (2019) in using the size of three risk-weighted assets to reflect the risk management decisions of commercial banks and study the effects of fintech and macroeconomic uncertainty

on the asset side of commercial banks to analyze the mitigation channels of fintech. Credit risk assets refer to assets that bear credit risk on and off the balance sheet of a bank, mainly including loans. Market risk assets include financial instruments and commodity positions held for trading purposes or to hedge against risks. Furthermore, we specifically consider the effects of fintech and macroeconomic uncertainty on commercial bank loans and transactional financial assets. For the asset side of commercial banks, we consider fixed assets in addition to transactional financial assets. The data of credit risk-weighted assets, market risk-weighted assets, operational risk-weighted assets, loans (*loan*), transactional financial assets (*financial*), and fixed assets (*fixed*) of commercial banks are obtained from the China Stock Market & Accounting Research (CSMAR) database.

3.2.2. Independent variables

The first independent variable is macroeconomic uncertainty (*eu*). In this paper, we use the macroeconomic uncertainty index for China constructed by Huang et al. (2018). The index includes 159 Chinese macro variables and 65 additional variables. The macro variables are industrial added value, output of energy and industrial products, price index, import and export indicators, and financial status. Additional variables include Chinese stock market factors and important economic indicators of the United States and the world. The index represents the forecast of the uncertainty of the future h periods based on the information set in the current period. In this paper, the uncertainty forecast of one period is used, with the arithmetic mean of the monthly data used to obtain the annual index.

The second independent variable is the fintech development index (*fintech*). In this paper, we use the Peking University China Commercial Bank Digital Transformation Index (Xie and Wang, 2022), *trans*, which can be accurately matched to the bank level. This index covers 228 commercial banks and is composed of three sub-indexes: digital financial cognition (accounting for 20% of the total index), digital financial organization (40%), and digital financial business (40%).

For robustness checks, we replace the representative variable of the development of fintech with the degree of digital construction of listed banks (*digital*). The data are obtained from the Digital Construction Degree of Listed Financial Companies Index in the fintech database established by CSMAR. We match this indicator with the industry code of listed companies to obtain the degree of digital construction of listed banks. To alleviate the potential endogeneity problem, we use as instrumental variables the U.S. macroeconomic uncertainty index (*usmu*) proposed by Jurado et al. (2015), the number of mobile phone

users (*mobile*) at the end of the year in the city where the commercial bank headquarters are located, and the interaction term of the two. The data source of the number of mobile phone users at the end of the year in the city where the commercial bank headquarters are located is consistent with Huang et al. (2021).

3.2.3. Controls and moderators

Following Qiu et al. (2018), Gu and Yu (2019), Guo and Shen (2020), and Li and Tian (2020), we first control bank-level characteristics. (1) The size of the bank (*size*), expressed as the natural logarithm of the total assets of the bank where the unit of total assets is tens of billions of RMB. (2) The profitability and operating capacity (*roa*) of the bank, expressed as return on total assets. (3) The bank's liquidity level (*ldr*), expressed by dividing the bank's loan amount by its deposit amount (loan-to-deposit ratio). The larger the indicator, the worse the bank's liquidity is. (4) The bank's leverage level (*lev*), expressed as the ratio of total equity to total liabilities of a bank. The larger the value, the lower the leverage level of the bank is. This indicator can also reflect the capital adequacy of the bank. (5) Following Qiu et al. (2018), we also control the bank's liability-side structure (*dl*), expressed as the ratio of deposits to total liabilities.

As the macroeconomic uncertainty index (*mu*) does not differ across the cross-section and only changes over time, time fixed effects cannot be controlled in the regressions. Therefore, the following macro variables are controlled in this paper. (1) The year-on-year growth rate of M2 (*m2g*) is used to control the quantity-based monetary policy, and the Shanghai Interbank Offered Rate (*shibor*) is used to control the price-based monetary policy. (2) GDP per capita (*agdp*) is used to control the level of economic development, and the ratio of added value of the financial industry to GDP (*finance*) is used to control the level of financial development. We also use a time trend term (*t*) to control other factors that change over time.

The moderating effect of the following variables are also considered. (1) The capital adequacy ratio of the bank (*car*). (2) Whether the bank is listed (*lc*), with the variable set to 1 for listed (including A shares and H shares) in this period, and otherwise 0. (3) Bank type (*type*), with the sample including state-owned banks, joint-stock banks, city commercial banks, and rural commercial banks.

3.3. Sample and data sources

The data used in this paper fall into four categories. The first is the financial data of commercial banks. We collect the data of China's commercial banks from two databases, BankFocus and CSMAR, and manually consult a large number of bank annual reports to fill in missing values. Policy banks, foreign

banks, and private banks are excluded. To prevent double counting, we use consolidated financial statement data when collecting commercial banks' financial data, following Delis and Kouretas (2011). To alleviate the impact of outliers, we eliminate samples with a duration of less than three years and winsorize the financial data of all continuous commercial banks at the upper and lower 1% quantiles, following Tian and Li (2020). The second and third categories of our data are economic uncertainty data and fintech development data, respectively. The fourth category of data contains macro variables, which we obtain from Wind and CEIC.

This paper uses the annual unbalanced panel data of 145 commercial banks from 2010 to 2019: 6 large state-owned banks, 12 joint-stock banks, 99 city commercial banks, and 28 rural commercial banks. As all of the independent variables are lagged by one period, the independent variables actually use the data from 2010 to 2018. At the end of 2018, the total assets of the commercial banks in our sample were 190.61 trillion yuan, accounting for 90.8% of the total assets of China's commercial banks; therefore, the empirical sample is highly representative. Table 1 presents the definitions and descriptive statistics of the variables.

Table 1 Descriptive statistics

Variable	Definition	Min.	Mean	Max.	Std. Dev.	Obs.
Dependent variables						
rwar	risk-weighted asset ratio (%)	31.31	62.71	87.97	10.84	1257
rwar2	indirect measure of *rwar* (%)	23.45	54.48	110.14	10.06	1254
crwa	credit risk-weighted assets (tens of billions of RMB)	0.07	63.08	1378.88	150.02	486
mrwa	market risk-weighted assets (tens of billions of RMB)	0	0.86	24.38	2.08	470
orwa	operational risk-weighted assets (tens of billions of RMB)	0.10	5.03	91.57	12.64	485
loan	loans (tens of billions of RMB)	-0.01	54.16	1632.66	180.56	1314
financial	transactional financial assets (tens of billions of RMB)	0	2.50	96.21	9.10	1222
fixed	fixed assets (tens of billions of RMB)	0	0.81	25.35	3.00	1314
Independent variables						
mu	macroeconomic uncertainty	0.63	0.68	0.75	0.05	1207
trans	commercial bank digital transformation index	0.00	0.48	2.35	0.40	1158

digital	degree of digital construction of listed banks	0.10	1.05	6.80	1.26	167
usmu	U.S. macroeconomic uncertainty index	0.57	0.61	0.68	0.03	1284
mobile	number of mobile phone users	4.02	6.63	8.31	0.74	471
Controls						
size	natural logarithm of total assets	0.45	2.94	7.65	1.54	1282
lev	ratio of total equity to total liabilities	0.04	0.08	0.15	0.02	1282
roa	returns on total assets	0.07	0.95	2.05	0.36	1282
ldr	loan-to-deposit ratio	29.02	64.37	100.35	12.61	1283
dl	ratio of deposits to total liabilities	27.90	67.50	97.61	16.77	1282
m2g	growth rate of M2	7.28	13.77	22.32	4.63	1284
shibor	Shanghai Interbank Offered Rate	2.40	3.29	4.81	0.78	1284
agdp	GDP per capita (tens of thousands of RMB)	1.31	5.79	16.42	2.33	1284
finance	added value of the financial industry to GDP (%)	1.96	6.50	18.50	2.27	1284
Moderators						
car	capital adequacy ratio (%)	9.80	13.15	20.32	1.82	1255
lc	listed (dummy)	0.00	0.16	1.00	0.37	1284

4. Empirical analysis

4.1. Baseline results

Table 2 reports the baseline results, with columns (1), (2), and (3) showing the regression results of risk-weighted asset ratios on *trans* and *mu*. The results show that the development of fintech has a significantly positive effect on the proactive risk-taking of commercial banks and that macroeconomic uncertainty has a significantly negative impact on the risk-taking of commercial banks, which is consistent with the literature.

Columns (4), (5), and (6) include both *trans* and *mu*, and successively add the interaction term of fintech development level and economic uncertainty, bank-level control variables, and macro-level control variables. The results show that macroeconomic uncertainty has a significant dampening effect on the proactive risk-taking of commercial banks. The coefficient of the interaction term of macroeconomic

uncertainty and fintech development is significantly positive, which is in line with expectations and shows that the development of fintech can indeed alleviate the dampening effect of macroeconomic uncertainty on the proactive risk-taking behavior of commercial banks.

According to the descriptive statistical results and baseline regression, when the degree of digital transformation of commercial banks is at the sample mean of 0.48, the marginal effect of macroeconomic uncertainty is -28.2491.[5] When increasing the development level of fintech by one standard deviation of 0.40, the mitigation of the dampening effect of macroeconomic uncertainty is 7.0672.[6] Increasing the development level of fintech by one standard deviation from the sample mean can thus alleviate the marginal negative impact of 25% economic uncertainty. It can be seen that fintech can significantly alleviate the dampening effect of macroeconomic uncertainty on commercial banks' proactive risk-taking not only in the statistical sense but also in the economic sense, and can motivate commercial banks to invest funds in the real economy. The sign and significance of the control variables are consistent with the literature.

Table 2 Baseline results

	(1)	(2)	(3)	(4)	(5)	(6)
Variables			*rwar*			
trans	9.2838***		9.0842***	-15.4227**	-11.7721**	-13.2251**
	(1.0110)		(0.9906)	(7.3559)	(5.5863)	(5.5463)
mu		-32.8899***	-28.7913***	-51.1308***	-31.5672***	-36.7298***
		(4.0763)	(3.7752)	(8.5537)	(7.3524)	(8.9312)
trans×mu				35.5177***	15.8676**	17.6682**
				(10.7685)	(7.8076)	(7.8797)
size					9.2311***	8.0038***
					(1.0516)	(2.0986)
roa					1.4395	1.8567
					(1.2737)	(1.3805)
ldr					0.2162***	0.2069***
					(0.0456)	(0.0497)
lev					61.9159**	56.5229**
					(25.0361)	(24.2871)
dl					0.1479***	0.1347***
					(0.0391)	(0.0400)
m2g						0.0969
						(0.1903)

[5] When the degree of digital transformation of commercial banks is at the sample mean of 0.48, the marginal effect of macroeconomic uncertainty is $-36.7298 + 17.6682 \times 0.48 = -28.2491$.

[6] When increasing the development level of financial technology by 1 standard deviation of 0.40, the mitigating effect on the dampening effect of macroeconomic uncertainty is $17.6682 \times 0.40 = 7.0672$.

shibor						-0.2847
						(0.5039)
agdp						0.1575
						(0.6010)
finance						1.0220**
						(0.4185)
t						-0.0527
						(0.6143)
Constant	59.4496***	85.8818***	79.0144***	94.3576***	28.4184***	29.5895***
	(0.4742)	(2.7577)	(2.5320)	(5.8053)	(7.0394)	(8.6987)
Individual	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1085	1117	1085	1085	1083	1083
R^2	0.1826	0.0415	0.2161	0.2248	0.3873	0.3966

Note: In this and the subsequent tables, *, **, and *** indicate significance at the 0.1, 0.05, and 0.01 levels, respectively.

4.2. Robustness and endogeneity

4.2.1 Robustness checks

To test the robustness of the empirical results in this paper, we use alternative variable construction methods and data sources. The first robustness test is to construct alternative macroeconomic uncertainty measures. The original data of the index include not only the one-period-ahead uncertainty measurement but also the uncertainty forecasts from each period to the next 12 periods. In the baseline regression, we use the one-period-ahead uncertainty forecast and then calculate the annual index by taking the arithmetic mean. To examine the robustness of the baseline results, in this section, we make full use of the uncertainty forecasts from each period to the next 12 periods and take the arithmetic mean of $12 \times 12 = 144$ forecasts in the year to obtain the macroeconomic uncertainty index (*mua*) covering more information, with the results shown in column (1) of Table 3. We find that the sign and significance of the coefficients of fintech development, macroeconomic uncertainty, and the interaction term of the two are consistent with the baseline results, and thus our main findings are robust to different constructions of the macroeconomic uncertainty measurement.

Table 3 Robustness checks

	(1)	(2)	(3)
Variables	*rwar*	*rwar*	*rwar2*
trans	-52.9097***		-20.4238***
	(16.3432)		(6.9494)
mua	-83.0493***		

	(21.4014)		
trans×mua	58.4280***		
	(18.4405)		
trans×mu			30.8117***
			(10.0598)
mu		-60.3680***	-48.9715***
		(11.3564)	(9.8468)
digital		-7.8607***	
		(2.4264)	
digital×mu		10.8685***	
		(3.3832)	
Bank controls	Yes	Yes	Yes
Macro controls	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes
Observations	1083	133	1083
R^2	0.3978	0.5808	0.2078

The second robustness test is to use the digital construction level of listed banks as an alternative proxy of fintech development to test whether our main findings depend on the measure of fintech. The data come from the Digital Construction Degree of Listed Financial Companies Index in the fintech database established by CSMAR. We match this indicator with the industry code of listed companies to obtain the degree of digital construction of listed banks. The degree of digital construction of listed banks can be directly used for matching at the bank level to provide an accurate measure of the fintech development level of commercial banks. The corresponding results are reported in column (2) of Table 3 and show that our main findings are robust to different measures of fintech development.

In the third robustness test, we use *rwar2* obtained by the indirect method (risk-weighted asset ratio = total equity/capital adequacy ratio/total assets) as the dependent variable to perform regression (1), with the results shown in column (3) of Table 3. We find that the sign and significance of the coefficients are consistent with the baseline results, showing the robustness of the conclusions.

4.2.2. Endogeneity

The assumption in the analysis of the baseline regression is that by controlling variables at the macro and bank levels and adding fixed effects, the degree of digital transformation of commercial banks and macroeconomic uncertainty are exogenous. However, it is not possible to control all of the variables that simultaneously affect the degree of digital transformation of commercial banks and the proactive risk-taking of commercial banks, as well as the variables that simultaneously affect macroeconomic uncertainty and

proactive risk-taking of commercial banks. Endogeneity problems caused by omitted variables or reverse causality will bias the estimation results, although lagging independent variables for one period can partially mitigate the endogeneity problems caused by reverse causality (Wooldridge, 2010). On this basis, we conduct the following tests to obtain more robust results.

Ji et al. (2018) and Gu and Yu (2019) suggest that the economic policy uncertainty of the United States affects China's economic policy uncertainty but does not directly affect the investment behavior of commercial banks and enterprises in China. Similarly, the macroeconomic uncertainty of the United States and China's macroeconomic uncertainty are correlated but the macroeconomic uncertainty of the United States does not directly affect the decision-making of commercial banks in China. According to Huang et al. (2021), mobile phones are the main channel for users to use commercial banks' digital products, and the degree of digital transformation of commercial banks is closely related to the number of mobile phone users in the city where the commercial bank headquarters is located. After controlling the local macro indicators, the number of mobile phone users will not affect the proactive risk taking of commercial banks through channels other than the degree of digital transformation of commercial banks.

Therefore, in this section, we use the macroeconomic uncertainty in the United States, the number of mobile phone users at the end of the year in the city where the commercial bank headquarters is located, and the interaction term of the two as instrumental variables (also lagged by one period), and we use the 2SLS method to check the robustness of our main findings. Specifically, we use the macroeconomic uncertainty index constructed by Jurado et al. (2015) as the proxy of the U.S. macroeconomic uncertainty (*usmu*) and calculate the average of monthly uncertainty data to obtain the annual value. The data source of the number of mobile phone users (*mobile*) at the city where the commercial bank headquarters are located is consistent with Huang et al. (2021).

The results are presented in Table 4. The p-values of the Kleibergen–Paap rk LM statistics are close to 0 regardless of whether control variables are added, indicating that the null hypothesis of insufficient identification of instrumental variables is rejected and that the selection of instrumental variables is therefore reasonable. After considering the endogeneity problem, the sign and significance of the coefficient of the interaction term of the digital transformation and macroeconomic uncertainty are the same as the baseline results, which verifies the robustness of the results.

Table 4 Endogeneity tests

	(1)	(2)
Method	2SLS	2SLS
Variable	*rwar*	
trans	-105.2071*	-160.3005**
	(61.3175)	(72.2994)
mu	-137.5344***	-229.7085**
	(45.0832)	(92.2568)
trans×*mu*	181.5262**	291.5149**
	(90.4482)	(130.7137)
Bank controls	No	Yes
Macro controls	No	Yes
Fixed effects	Yes	Yes
Observations	407	407
Kleibergen–Paap rk LM p-value	0.0000	0.0781

4.3. Channels and mechanisms

From the above discussion, we obtain a robust finding that the development of fintech can alleviate the dampening effect of macroeconomic uncertainty on commercial banks' proactive risk-taking. However, the exact channels and mechanisms of the influence are unclear. This section therefore attempts to answer the following question: How does the development of fintech alleviate the dampening effect of macroeconomic uncertainty on commercial banks' proactive risk-taking?

According to the 'Commercial Bank Capital Management Measures (Trial)' by the China Banking Regulatory Commission, the risk-weighted assets of commercial banks include credit risk-weighted assets, market risk-weighted assets, and operational risk-weighted assets.[7] It is of interest to study what type of risk-weighted assets will be affected by macroeconomic uncertainty and the digital transformation of commercial banks. Following Liu et al. (2019), we take credit risk-weighted assets, market risk-weighted assets, and operational risk-weighted asset scales of commercial banks as dependent variables, and we use the variables on the right side of formula (1) as independent variables, with the corresponding results reported in Table 5. As shown by the results reported in columns (1) and (2), macroeconomic uncertainty has a significant negative impact on credit risk-weighted assets and market risk-weighted assets of commercial banks, and the development of fintech can alleviate this dampening effect. The results in column (3) show that for the operational risk-weighted assets of commercial banks, the coefficients of macroeconomic uncertainty, digital transformation of commercial banks, and their cross-products are not

[7] http://www.gov.cn/gongbao/content/2012/content_2245522.htm

significant.

Table 5 The impact of macroeconomic uncertainty and fintech on the compositions of risk-weighted assets of commercial banks

	(1)	(2)	(3)
Variable	*crwa*	*mrwa*	*orwa*
trans	-109.6558*	-23.7477**	-7.0446
	(55.2932)	(11.5948)	(30.2810)
mu	-83.1825*	-34.4669*	54.6037
	(48.3619)	(19.0488)	(48.1657)
trans×*mu*	205.8872**	47.0208**	48.0834
	(95.2321)	(18.6146)	(43.1144)
Bank controls	Yes	Yes	Yes
Macro controls	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes
Observations	465	451	466
R^2	0.3948	0.2009	0.1293

Credit risk assets refer to the assets on and off the balance sheet of a bank that bear credit risk, mainly including loans. Market risk refers to the risk of losses in the on- and off-balance sheet business of commercial banks due to adverse changes in market prices (interest rates, exchange rates, stock prices, and commodity prices). Market risk assets mainly include items in trading accounts for trading purposes or hedging, usually financial instruments and commodity positions. Therefore, we specifically consider the role of fintech and macroeconomic uncertainty on commercial banks' loans and transactional financial assets to analyze the mitigation channels of fintech. For the asset side of commercial banks, we consider fixed assets in addition to transactional financial assets.

We respectively take the scale of loans issued by commercial banks, the scale of transactional financial assets, and the scale of fixed assets as dependent variables. Table 6 reports the results. As shown in columns (1) and (2), a rise in macroeconomic uncertainty significantly inhibits commercial banks from issuing loans and holding transactional financial assets, and the digital transformation of commercial banks can effectively alleviate the dampening effect. The results in column (3) show that for the fixed assets, the impacts of macroeconomic uncertainty, digital transformation, and the cross-product of the two are not significant.

To summarize, in the face of macroeconomic uncertainty, digital transformation can promote commercial banks to issue loans and to increase their holdings of transactional financial assets, thus

expanding commercial banks' holdings of credit risk-weighted assets and market risk-weighted assets and thereby alleviating the dampening effect of macroeconomic uncertainty on commercial banks' proactive risk-taking. Therefore, the development of fintech does motivate commercial banks to invest funds in the real economy and improves the ability of commercial banks to serve the real economy.

Table 6 The impact of macroeconomic uncertainty and fintech on loans, transactional financial assets, and fixed assets

	(1)	(2)	(3)
Variable	*loan*	*financial*	*fixed*
trans	-65.9178*	-19.1374***	-64.1858
	(34.4690)	(6.4702)	(96.2010)
mu	-135.9952***	-41.9956***	-72.5921
	(43.6872)	(7.0217)	(138.9133)
trans×*mu*	187.0270***	40.6819***	193.9680
	(58.0971)	(9.6441)	(139.6575)
Bank controls	Yes	Yes	Yes
Macro controls	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes
Observations	1041	965	1041
R^2	0.3203	0.3548	0.0742

4.4. Heterogeneity analysis

After studying the role of fintech and macroeconomic uncertainty on commercial banks' proactive risk-taking, we further explore whether this effect is heterogeneous for different commercial banks. We use the capital adequacy ratio (*car*), whether listed (*lc*), and bank type (*type*) as moderators. For the capital adequacy ratio, we divide the sample into two groups by the median of the capital adequacy ratio and perform regression (1) in each group. For the bank category, on the basis of formula (1), we add the interaction term of the bank category dummy variable and *trans*×*mu*. The regression uses rural commercial banks as the reference group. The coefficients of fintech development level (*trans*) and macroeconomic uncertainty (*mu*) are consistent with the previous results and are omitted from Table 7.

Columns (1) and (2) in Table 7 show the results of the group regressions, columns (3) and (4) report the results of the regression according to listed status, and column (5) presents the results for different types of commercial banks. Fintech has a significant positive effect for commercial banks with low capital adequacy ratios, but the effect of fintech is not significant for commercial banks with high capital adequacy

ratios. Furthermore, fintech has a significant positive effect among unlisted commercial banks, but this effect is not significant among listed commercial banks. According to the p-value of Fisher's permutation test, there are significant differences in the coefficients between groups of different asset adequacy ratios but no significant difference in the coefficients between the listed and unlisted groups. With the rural commercial banks used as the reference group in column (5), the results show that there is no significant difference in the effect of fintech among joint-stock banks, city commercial banks, and rural commercial banks. However, under the same level of fintech application, the effect brought by the application of fintech is significantly smaller for state-owned banks than for rural commercial banks.

Table 7 Heterogeneity analysis

	(1)	(2)	(3)	(4)	(5)
	Low *car*	High *car*	Unlisted	Listed	Full sample
Variable			*rwar*		
trans×*mu*	47.0889***	6.2602	34.8762**	5.1842	25.3959***
	(15.7415)	(10.7990)	(14.5777)	(12.0040)	(8.9434)
trans×*mu*×*state-owned banks*					-6.0382**
					(2.5087)
trans×*mu*×*joint-stock banks*					-4.0820
					(3.0168)
trans×*mu*×*city commercial banks*					2.5803
					(2.7639)
Bank controls	Yes	Yes	Yes	Yes	Yes
Macro controls	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes
Fisher's permutation test p-value	0.080		0.195		
Observations	549	534	888	195	1083
R^2	0.3169	0.4589	0.3856	0.4037	0.4037

4.5. The marginal impact under different risk-taking levels

The above results show that fintech and macroeconomic uncertainty affect the level of risk-weighted assets of commercial banks, but the discussion is about the impact on the average level and does not answer the question of the difference of marginal impacts under different risk-taking levels. To answer this question, we use panel quantile regressions:

$$Q_\tau(risk_{it}) = \beta_{\tau 0} + \beta_{\tau 1} fintech_{i,t-1} + \beta_{\tau 2} eu_{t-1} + \beta_{\tau 3} fintech_{i,t-1} \times eu_{t-1}$$

$$+\gamma_\tau X_{i,t-1} + \lambda_\tau Y_{t-1} + \beta_{\tau 4} t + \mu_i + \varepsilon_{it} \quad (2)$$

where τ represents different quantiles. Following Tian and Li (2020), we use five quantiles of 10%, 25%, 50%, 75%, and 90% for the regressions, and the standard error is obtained through the Markov Chain Monte Carlo (MCMC) method.

The regression results are shown in Table 8. Regardless of the level of risk-taking, the sign and significance of the marginal impact of fintech and macroeconomic uncertainty are consistent with the above findings. The rise of macroeconomic uncertainty inhibits the proactive risk-taking behavior of commercial banks, and the development of fintech can alleviate this negative effect. As the level of proactive risk-taking of commercial banks increases, the mitigation effect of fintech decreases monotonically. The higher the level of proactive risk-taking, the more cautious commercial banks are about taking excessive risk, the greater the impact of macroeconomic uncertainty is, and the more limited the ability of fintech is to mitigate this impact. Therefore, the development of fintech does not promote excessive risk-taking by commercial banks.

Table 8 Marginal impacts under different risk-taking levels

	(1)	(2)	(3)	(4)	(5)
Quantiles	10%	25%	50%	75%	90%
Variable			*rwar*		
trans×*mu*	31.0595***	24.3941***	18.3414***	14.7076***	13.7238***
	(0.0327)	(0.1080)	(0.4602)	(0.1729)	(0.0473)
mu	-17.8835***	-33.4130***	-29.3987***	-29.9587***	-18.9906***
	(0.0343)	(0.0563)	(0.9023)	(0.1781)	(0.0522)
trans	-23.1461***	-19.2546***	-14.7540***	-12.1394***	-12.4489***
	(0.0252)	(0.0668)	(0.3312)	(0.1239)	(0.0330)
Bank controls	Yes	Yes	Yes	Yes	Yes
Macro controls	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	1083	1083	1083	1083	1083

5. Conclusion

This paper studies the impact of the digital transformation of commercial banks on the proactive risk-taking behavior of commercial banks in the face of macroeconomic uncertainty. We construct an annual

panel of 145 commercial banks from 2010 to 2019 and use a fixed-effect model. We test the robustness of our findings using instrumental variable regressions and alternative measurements. We also explore the heterogeneity across different types of commercial banks through group regression. Furthermore, we examine the marginal impact of fintech development on commercial banks with different levels of proactive risk-taking through panel quantile regression.

We find that the development of fintech can alleviate the dampening effect of macroeconomic uncertainty on the proactive risk-taking behavior of commercial banks, and this mitigation effect is still significant when we control bank- and macro-level variables. Changing the variable construction method and considering endogeneity issues do not affect the robustness of this conclusion. As the level of proactive risk-taking increases, the marginal effect of fintech diminishes; therefore, the development of fintech does not lead commercial banks to take excessive risks. Furthermore, we find that the digital transformation of commercial banks alleviates the dampening effect of macroeconomic uncertainty by promoting commercial banks to issue loans, to increase their holdings of transactional financial assets, and thus to expand the scale of credit risk-weighted assets and market risk-weighted assets. The mitigating effect of fintech is heterogeneous across different types of commercial banks, and the impact on commercial banks with high capital adequacy ratios and large state-owned banks is relatively weaker.

The findings in this paper have the following policy implications. First, the development of fintech can alleviate the dampening effect of macroeconomic uncertainty on the proactive risk-taking behavior of commercial banks by expanding commercial banks' loans, which will indeed promote financial integration and enhance the ability of commercial banks to serve the real economy. Therefore, further fintech development efforts are needed. Second, more attention should be paid to the role of digital transformation in promoting the size of loans and transactional financial assets, as this is the main channel for the development of fintech to alleviate the negative impact of macroeconomic uncertainty on commercial banks' proactive risk-taking. Third, it is important to promote the digital transformation of rural commercial banks, support and encourage the development of fintech to help rural revitalization, and alleviate the impact of macroeconomic uncertainty on the proactive risk-taking behavior of rural commercial banks.

References

[1] Bernanke, B. S., "Irreversibility, Uncertainty, and Cyclical Investment," *Quarterly Journal of Economics*, 1983, 98(1), 85-106.

[2] Bloom, N., "Fluctuations in Uncertainty," *The Journal of Economic Perspectives*, 2014, 28(2), 153-175.

[3] Cenni, S., S. Monferrà, V. Salotti, V. Sangiorgi, and G. Torluccio, "Credit Rationing and Relationship Lending. Does Firm Size Matter?," *Journal of Banking & Finance*, 2015, 53, 249-265.

[4] Christiano, L. J., R. Motto, and M. Rostagno, "Risk Shocks," *American Economic Review*, 2014, 104(1), 27-65.

[5] Delis, M. D., and G. P. Kouretas, "Interest Rates and Bank Risk-Taking," *Journal of Banking & Finance*, 2011, 35(4), 840-855.

[6] Fang, Y., Zhao, S., and Xie, X. 2012. "Analysis of Bank Risk-taking of Monetary Policy: Discussion on the Coordination of Monetary Policy and Macro-prudential Policy," *Management World* (In Chinese), 11, 9-19.

[7] Gambacorta, L., Y. P. Huang, Z. Li, H. Qiu, and S. Chen, "Data vs Collateral," BIS Working Papers, No. 881.

[8] Gu, H., and Yu, J. 2019. "China's Economic Policy Uncertainty and Bank Risk-taking," *World Economy* (In Chinese), 11, 148-171.

[9] Gulen, H., and M. Ion, "Policy Uncertainty and Corporate Investment," *Review of Financial Studies*, 2016, 29(3), 523-564.

[10] Guo, P., and Shen, Y. 2020. "Internet Finance, Deposit Competition, and Bank Risk-taking," *Finance Research* (In Chinese), 8, 58-76.

[11] Huang, Y., Cao, X., Han B., and Xie, X. 2021. "Digital Transformation, Banking Risk 'Matthew Effect' and Formation Mechanism: Evidence from Chinese Commercial Banks," Working paper (In Chinese).

[12] Huang, Y., and Huang, Z. 2018. "Digital Finance Development in China: Present and Future," *China Economic Quarterly* (In Chinese), 4, 1489-1502.

[13] Huang, Z., C. Tong, H. Qiu, and Y. Shen, "The Spillover of Macroeconomic Uncertainty between the U.S. and China," *Economics Letters*, 2018, 171(C), 123-127.

[14] Ji, Y., Wang, X., Tan, Y., Huang Y. 2018. "Economic Policy Uncertainty, Government Implicit Guarantee, and Differentiation of Enterprise Leverage Ratio," *China Economic Quarterly* (In Chinese), 2, 449-470.

[15] Jiang, L., R. Levine, and C. Lin, "Competition and Bank Liquidity Creation," *Journal of Financial and Quantitative Analysis*, 2019, 54(2), 513-538.

[16] Jurado, K., S. C. Ludvigson, and S. Ng, "Measuring Uncertainty," *American Economic Review*, 2015, 105(3), 1177-1216.

[17] Li, S., and Tian, G. 2020. "Bank Competition and Monetary Policy Bank Risk-taking Channels: Theory and Empirical Analysis," *Management World* (In Chinese), 4, 168-187.

[18] Liu, C., Du, T., Liu, L., and Li, M. 2019. "Reform of Capital Measurement Method, Risk Preference, and Credit Allocation of Commercial Banks," *Finance Research* (In Chinese), 7, 38-56.

[19] Liu, G., Duan, Y., Liu Y. 2019. “Economic Policy Uncertainty, Asset Reversibility, and Fixed Asset Investment,” *Economic Research* (In Chinese), 8, 53-70.

[20] Liu, Z. 2016. “Study on the Impact of Internet Finance on Commercial Banks’ Risk-taking,” *Finance and Trade Economy* (In Chinese), 4, 71-115.

[21] Mocetti, S., M. Pagnini, and E. Sette, “Information Technology and Banking Organization,” *Journal of Financial Services Research*, 2017, 51(3), 313-338.

[22] Qiu, H., Huang, Y., and Ji, Y. 2018. “The Impact of Financial Technology on Traditional Banking Behavior: From the Perspective of Internet Financial Management,” *Finance Research* (In Chinese), 11, 17-30.

[23] Sheng, T., and Fan, C. 2020. “Financial Technology, Optimal Banking Market Structure, and Credit Supply of Small and Micro Enterprises,” *Finance Research* (In Chinese), 6, 114-132.

[24] Tian, G., and Li, S. 2020. “Economic Policy Uncertainty and Bank Liquidity Creation: Empirical Evidence from China,” *Economic Research* (In Chinese), 11, 19-35.

[25] Wooldridge, J. M. Econometric Analysis of Cross Section and Panel Data. Cambridge: MIT Press, 2010.

[26] Wu, J., Y. Yao, M. Chen, and B. N. Jeon, “Economic Uncertainty and Bank Risk: Evidence from Emerging Economies,” *Journal of International Financial Markets, Institutions & Money*, 2019, 68, 101242.

[27] Xie, P., and Zou, C. 2012. “Study on Internet Finance Pattern,” *Finance Research* (In Chinese), 12, 11-22.

[28] Xie, X., and Wang, S. 2022. “Digital Transformation of Chinese Commercial Banks: Measurement, Process and Impact,” *China Economic Quarterly* (In Chinese), 6, 1937-1956.