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How does the development of fintech affect financial efficiency? Evidence from China

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ABSTRACT

The rapid development of fintech is transforming the global financial system. However, how does fintech impact financial efficiency? Based on the technology spillover theory, this study analysed the theoretical mechanism of fintech's impact on financial efficiency and used the text mining method to construct a fintech level index for each province in China. Using interprovincial panel data from 2008 to 2018, the study empirically tested the relationship between fintech development and financial efficiency. The results show that technology spillover theory can adequately explain the impact of financial technology on financial efficiency and that there is a U-shaped nonlinear relationship between fintech development and financial efficiency. Further analysis shows that financial decentralisation moderates the marginal effect of fintech on financial efficiency. The effect of fintech on financial efficiency is more significant in regions with greater financial decentralisation. Therefore, at this stage, the study recommends that we actively embrace fintech, continuously deepen the integration of technology and finance, promote improvement in financial efficiency, and expand the positive role of local governments in technological innovation.

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Fintech; financial efficiency; financial decentralisation

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1. Introduction

Since the global financial crisis, the continuous development of computer technology, Internet technology, and biometrics, and the emergence of new scientific and technological achievements such as artificial intelligence, cloud computing, big data, Internet of things, and blockchain have significantly reduced social costs. The development of fintech has been a product of a consensus between international financial organisations, financial regulatory authorities, and academia. Financial Stability Board (2017) proposed that fintech can create new models, businesses, processes, and products to improve the quality and efficiency of financial services. In 2019, The People's Bank of

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China issued the Fintech Development Plan (2019–2021), highlighting the new method to improve and transform finance, serve the real economy, and prevent and defuse financial risks.

Political and financial circles are optimistic about the development of fintech, believing that it can promote financial development and improve financial quality and efficiency, and have encouraged and increased investment in fintech. According to the KPMG report, The Pulse of Fintech H2 2021, global fintech investment reached $210 billion in 2021, twice that of 2020. Among developed countries, the British government attaches particular importance to the development of fintech, and has established a digital technology cluster known as Tech City in London. Due to strong financial infrastructure and active government support policies, the UK has developed into a world fintech centre and become one of the top fintech countries with a high digitalization level of financial services (Pakhnenko et al., 2021). In China, local governments and financial institutions have recently increased investment in fintech. Beijing, Shanghai, and Shenzhen, among others, have issued preferential policies to promote the development of fintech to attract fintech companies. Commercial banks have also actively increased the outlays on fintech. By the end of 2021, at least 16 commercial banks had established fintech subsidiaries.

However, the development of fintech brings positive effects as well as challenges for the financial industry, financial supervision, financial stability, and monetary policy. Therefore, it is necessary to quantitatively evaluate the impact of fintech based on qualitative analysis, to provide support for a rational examination of the opportunities and challenges presented by fintech. Some scholars believe that the application of fintech has improved financial efficiency through financial innovation and technology spillover, reducing service costs and information asymmetry (e.g., Mengfei & Wei, 2020; Yue & Pin, 2015). Some others believe that the development of fintech has spawned many enterprises, new service models, and new financial products. However, it has also caused a certain negative – even subversive – impact, on the financial system, hindering efficiency improvement (Bin & Xiping, 2021; Yun & Xin, 2019). Existing research on the impact of fintech on financial efficiency include theoretical and qualitative analyses, but the empirical analysis is still inadequate. Accurately measuring the development level of fintech and the resultant financial efficiency, especially the quantitative analysis of the impact of fintech on financial efficiency, has always been difficult. Therefore, a study of the impact of fintech on financial efficiency can fill the current research gap, and provide quantitative data support for the decision-making of governments and financial institutions.

The contributions of this study are as follows. First, based on the existing literature, this study uses web crawler technology to improve the 'text mining method', constructs indicators for the level of fintech development in each province in China, and fills in the corresponding research gaps. Second, using the technology spillover theory, from the micro perspective of commercial banks' capital flows, this study explores the impact of fintech on financial efficiency in stages by evaluating the economic and financial benefits of the development of fintech. Third, the study explores whether the degree of financial decentralisation in different regions moderates the impact of fintech on financial efficiency.

2. Literature review and theoretical analysis

Bain (1981) divides financial efficiency into macro and micro financial efficiency. However, due to China's unique national conditions and system, domestic scholars mainly use the loan-to-deposit ratio index to measure financial efficiency; the index reflects the efficiency and ability of financial institutions to convert deposits into loans. Yingjun et al. (2021) report that China's financial system is dominated by indirect finance; as the choice of deposits reflects the financial system's ability to absorb funds and the choice of loans reflects the financial system's ability to use funds, the loan-to-deposit ratio index reflects the efficiency of capital absorption and operation of the system. This index not only reflects competition among financial institutions but also the efficiency of regional financial resource allocation to a certain extent; therefore, this study defers to Dantao (2008) in using the loan-to-deposit ratio to measure the efficiency of financial development.

The impact of fintech on financial efficiency is generally analysed from the perspective of disruptive innovation and technology spillover theories. In the initial stages, the purpose of fintech is to bring about disruptive innovation. Through innovation, it introduces simpler and more customer-oriented products and services to serve the 'long-tail customers' who are not effectively covered by traditional financial products. Gradually, it replaces the dominant traditional institutions and products. For example, Ping (2014) pointed out that Internet finance based on fintech is 'the third financing mode different from the indirect financing represented by banks and direct financing represented by capital market, which is a subversion of the traditional financial industry'. Yunda et al. (2020) believe that the positive spillover of bank fintech investment on productivity is not obvious and involves a productivity paradox to an extent. As traditional financial institutions gradually increase investment in fintech, the integration of emerging technologies and traditional financial services increases, which better reflects the technology spillover effect and improves the efficiency of financial institutions. For example, Lee and Shin, (2018) believe that information technology used in fintech can promote innovative products and services in the financial industry. Ntwiga (2020) found that collaboration between fintech and banks can improve bank efficiency.

The impact of fintech on the financial industry differs according to market characteristics (Stankevičienė & Kabulova, 2022) and stages of fintech development. Therefore, to analyse the impact, we first need to clarify how China's fintech industry evolved. The evolution of fintech in China can be roughly divided into three stages. The first stage (Fintech 1.0) is the period of financial informatisation, in which financial institutions, such as the banking industry, use IT and the Internet to provide online services to financial users, changing the traditional counter-based service model. The second stage (Fintech 2.0) saw rapid development in Internet finance. At this stage, Internet platforms and other technology companies bring fintech into the credit and savings markets, reduce information asymmetry and transaction costs in the credit market, and positively compete with the traditional financial institutions' credit and savings businesses.

The third stage (Fintech 3.0) is the period of deep integration between the financial industry and fintech. Traditional financial institutions further increased

investment in fintech, innovated financial products, and improved financial services through technologies such as big data, and blockchain, improving the operational efficiency of the social financial industry, that is, the allocation efficiency of social funds (Yang & Chaolun, 2018).

Based on the technology spillover theory, this study analyses the mechanism of fintech's impact on financial efficiency from the asset and liability sides of financial institutions. According to technology spillover theory, fintech affects financial efficiency in four ways: competition effect, demonstration effect, personnel mobility effect, and correlation effect (Ya & Qian, 2021). Depending on the three stages of fintech development, the impact mechanism and effect of fintech on financial efficiency differ. In Fintech 1.0, the impact of fintech is on the information transformation of the internal business of the traditional financial industry, and the impact on the efficiency of capital allocation may not be significant. In Fintech 2.0, fintech companies (including Internet banks such as Internet Commercial Bank and WeBank) change the allocation structure between credit assets and securities investment assets of traditional financial institutions by using technological advantages and financial innovation, negatively impacting financial efficiency. Fintech companies (including Internet banks) use information advantages to not only open new credit markets, but also seize the stock customers of some traditional financial institutions, especially small and medium-sized banks, thereby reducing loan issuance by traditional banks. Moreover, they also issue interbank certificates of deposit and asset securitisation products, absorbing funds from traditional financial institutions in the financial market and reducing the loanable funds of traditional banks; this negatively impacts the credit business of traditional banks. In addition, fintech companies use P2P platforms to divert bank deposits and loans, worsening the banking sector's debt-side and asset-side business, thereby affecting financial efficiency (loan-to-deposit ratio). In FinTech 3.0, as the continuous investment in fintech by traditional financial institutions accumulates and changes from quantitative to qualitative, the availability of credit resources for specific groups improves and the financing cost reduces, thus improving social welfare (Philippon, 2020).

The above analysis shows that the rapid development of fintech is a double-edged sword for traditional financial institutions. On the one hand, it forces traditional financial institutions to transform and upgrade, improve service quality and efficiency, and optimise the allocation of financial resources. On the other hand, it divides up the share of traditional financial institutions in the credit market and reduces their living space and profits. At the same time, it also leads to the circulation of new funds in the financial system, which hides financial risks. Generally speaking, the combination of traditional financial institutions and fintech has experienced the development stages of negative impact, competition and cooperation, and integration and symbiosis. Therefore, the following assumptions were made.

Hypothesis 1: Fintech has a 'U-shaped' nonlinear impact on financial efficiency. In the early stages of development, it has a negative impact on financial efficiency, and with deep integration between fintech and the financial industry, the impact of fintech on financial efficiency is positive.

Due to significant differences in the economic development levels, marketisation processes, and government intervention in different regions of China, the financing constraints faced by enterprises in different regions vary; this can also be understood as the different degrees of regional financial deepening and decentralisation that may have an impact on financial efficiency. In financially developed areas, the spillover effect brought about by management and institutional innovation often enables financial institutions and related industries to share information through public infrastructure and network systems, increase capital supply to enterprises with a high market competitiveness and return on investment, accelerate the transfer of production factors to efficient industries, and improve the financial efficiency of various regions (Binbin, 2017). Financial institutions in financially developed areas are larger and stronger, invest more money in fintech, integrate deeper with financial technology, and possess a higher technology absorption capacity. Therefore, in financially developed areas, fintech has a more significant impact on improvement in financial efficiency through a technology spillover effect (Mengfei et al., 2021; Yue & Pin, 2015).

Hypothesis 2: The level of financial decentralisation caused by fintech marginally affects financial efficiency.

2.1. Model construction and index selection

2.1.1. Model construction

Referring to Dexu and Wenlong (2016), and Chen et al. (2021), we constructed the following time and individual two-way fixed effect model to analyse the impact of fintech on financial efficiency:

$$fine_{it} = C + \alpha fint_{it} + \alpha_1 fint2_{it} + \beta X_{it} + \phi_i + \lambda_t + \varepsilon_{it} \quad \text{(a)}$$

In Formula (a), $fine_{it}$ represents the financial efficiency level of the i^{th} province in year t; α and β are the influence coefficients of each variable; C is the intercept term; X_{it} is the control variable;ϕ_I is the individual effect of the i^{th} province; λ_t is the annual effect of year t; and ε_{it} is the random error term. $Fint_{it}$ is an independent variable representing the fintech development level: $fint2_{it}$ is its square term, and α_1 is the coefficient of the square term. Ifα_1 is significantly positive; fintech and financial efficiency have a positive U-shaped nonlinear relationship. X_{it} is the control variable designed later.

2.1.2. Sample selection and data sources

The data used in this study are provincial panel data covering 31 provinces in China (excluding Hong Kong, Macau, and Taiwan). Each province's fintech development level index (region) was used to test the hypotheses. Each province's fintech development level index was constructed using the text mining method. Based on data availability, the index covers the period from 2008 to 2018. Other data in this study are from The People's Bank of China, the National Bureau of Statistics, and the Wind database.

Table 1. Variable definition and description.

	Variable name	Variable symbol	Variable definition	References
Dependent variable	Financial efficiency	fine	Loan balance/deposit balance by region	Biyun and Hejing (2019), Dantao (2008), Xuefang and Wei (2020), Hongdan and Xianping (2015), Zhenxin and Xiangguang (2019)
Independent variable	Development level of fintech	fint	Based on the data source of China Daily Network, the CRITIC method is used to construct the database.	New to this article
		rfint	Based on the People's Network data source, the CRITIC method is used to construct (robustness test).	New to this article
Control Variable	Financial decentralisation	fd	Regional loan balance/national loan balance * 100	Dexu and Wenlong (2016); Xiaoguang et al. (2018)
	Fiscal decentralisation	fiscd	Fiscal revenue of each region/ national fiscal revenue * 100	
	Economic development level	lnpgdp	Ln (real GDP of each region/ total population)	Shaokai et al. (2020), Wanjun et al. (2020), Xianzhu and Lei (2019)
	Industrial structure level	indstr	1 * Proportion of the primary industry in each region + 2 * Proportion of the secondary industry in each region + 3 * Proportions of the tertiary industry in different regions	Lanping et al. (2020), Xianzhu and Lei (2019)
	Degree of financial development	fdev	Value added by financial industry by region/GDP	Ren et al. (2019)
	Urbanisation rate	urbr	Urban population by region/total population * 100	
	Marketisation level	mktpro	Marketisation process scores by region	New to this article
	Government intervention	gov	Fiscal expenditure by region/GDP by province	Shuai et al. (2013)

Source: own study.

2.1.3. Description of variables

Based on the need to test the research hypotheses and refer to the existing literature, the dependent variables, independent variables, and control variables were designed as shown in Table 1.

2.1.4. Dependent variable

Financial efficiency (fine), referring to Biyun and Hejing (2019), Dantao (2008), Xuefang and Wei (2020), Hongdan and Xianping (2015), Zhenxin and Xiangguang (2019), and other studies, is replaced by regional loan balance/deposit balance, mainly because banks still dominate China's financial system. The conversion rate of savings to investments (loans) in the banking system reflects the level of financial efficiency.

2.1.5. Control variables

Guangming et al. (2018) and other studies suggest that the industrial structure, government intervention, and the economic development scale of provinces (cities and

districts) have a significant positive or negative effect on the efficiency of the financial industry. Accordingly, in this study, local financial decentralisation level, economic development level, industrial structure level, fiscal decentralisation level, financial development level, urbanisation rate, and marketisation level were selected as control variables. See Table 1 for specific indicators.

2.1.6. Independent variable

The independent variable is the fintech development level index (fint), which does not exist in the regions. Existing research uses two methods to measure the development level of fintech: the first uses the digital inclusive finance index of Peking University compiled by Feng et al. (2020) and based on the micro data of the Ant Group. To measure the index level, Feng et al. (2020) choose three dimensions, namely, the coverage, depth, and digitisation of Internet financial services. The second method uses text mining to construct the fintech index by counting the number of times fintech related keywords were used in the news, based on the work of Yue and Pin (2015). The first method pays attention to the inclusive characteristics and ignores the technological attributes, while the second method selects the keywords related to the development of fintech, which can more comprehensively reflect the development level of fintech. Scholars generally choose the second method to construct the fintech index. We referred to Chen et al. (2021), Pin and Yue (2015), and Zhonglu (2016), and used text mining to construct the fintech level index for each province. The general idea was to construct keywords, crawl unstructured text sets from China Daily (Web pages), analyse the frequency of keywords in each region and each year, summarise them weighted by the CRITIC method, and obtain the fintech index of each province in each year (the fintech indexes of some provinces are shown in Figure 1). The specific steps were as follows.

1. *Keywords.* At the technical level, this study chose: blockchain, cloud computing, big data, Internet of things, face recognition, fingerprint recognition, biometrics, identity recognition, live detection, deep learning, robotics, character recognition, encryption, distributed computing, PaaS, baas, SAAS, laas, 5G, API, and financial cloud.

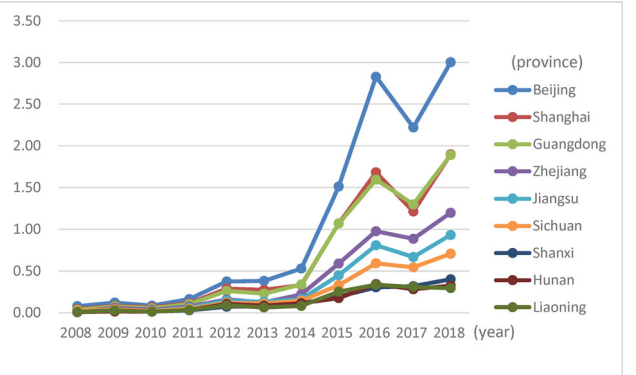

Figure 1. The fintech indexes of some provinces (2008–2018).
Source: own study.

In terms of fintech innovation of traditional financial institutions, this study chose: electronic banking, online banking, smart banking, digital banking, online banking, mobile banking, Internet banking, open banking, smart outlets, online payment, online account opening, smart claims, and insurance technology.
In terms of fintech innovation of emerging institutions, this study chose: third-party payment, online lending, online financing, online investment, online wealth management, Internet wealth management, intelligent investment, intelligent customer service, intelligent risk control, Internet banking, mobile payment, Internet insurance, Internet small loans, Internet securities, Internet funds, quantitative trading, crowdsourcing, online credit products, and online wealth management. After emerging institutions implement these related innovations, traditional institutions also wait for opportunities to follow up. Therefore, this study classified the keywords shared by both institutions into the fintech innovation of emerging institutions.

2. *Raw data generation.* First, an unstructured text set was crawled from the China Daily website (Webpage), and the keyword frequency of each city in each year was analysed according to 'city name and keyword'. Second, the above three dimensions of keyword frequency were summarised to form three original indicators of each city.
3. *Index weight.* To generate a fintech index from the original indicators ($fint\_1_{it}$, $fint\_2_{it}$, and $fint\_3_{it}$), the weight of each original indicator needs to be considered. We referred to Dilong and Shuanglian (2015) and used the CRITIC method to generate the weights of the three original indicators, where the weight of the i^{th} original indicator is

$$W_k = \frac{C_k}{\sum_j^3 C_j}, \mathrm{k} = 1, 2, 3 \qquad \text{(b,}$$

where $C_k = \sigma_k \sum_j^3 (1 - r_{kj})$, $k = 1,2,3.\ k \neq j$, σ_k is the standard deviation of the original index K, and r_{kj} is the correlation coefficient between the original index K and the original index J. When calculating the weight of the original indicators, for the sake of horizontal and vertical comparability, we selected three original indicators from 2008 to 2018 for calculation after standardisation.
4. *Fintech index generation.* After generating the original indicators ($fint\_1_{it}$, $fint\_2_{it}$, and $fint\_3_{it}$)and the corresponding weights w_1, w_2, and w_3, the Fintech index of the i^{th} province and city in year t could be calculated by standardising the three indicators and subsequently, weighting the normalised draw metrics to generate the fintech index (fint).

First, the original index was standardised according to formulas (c) to (e).

$$\mathrm{stdfint}_{1_{it}} = (\mathrm{fint}_{1_{it}} - \min(\mathrm{fint}_{1_{it}}))/(\max(\mathrm{fint}_{1_{it}}) - \min(\mathrm{fint}_{1_{it}})) \qquad \text{(c)}$$

$$\boldsymbol{stdfint}_{2_{it}} = (\boldsymbol{fint}_{2_{it}} - \boldsymbol{min}(\boldsymbol{fint}_{2_{it}}))/(\boldsymbol{max}(\boldsymbol{fint}_{2_{it}}) - \boldsymbol{min}(\boldsymbol{fint}_{2_{it}})) \qquad \text{(d)}$$

Table 2. Descriptive statistics of main variables.

Variable name	Observed value	Mean value	Standard deviation	Minimum value	Maximum value
Financial efficiency (fine)	341	72.5309	14.1590	24.6087	114.3845
Fintech (fint)	341	0.1897	0.3207	0.0041	3.003
Fintech level surrogate variable (rfint)	341	2.2952	6.6317	0.0000	48.8085
GDP per capita (lnpgdp)	341	1.3244	0.5217	−0.0096	2.6317
Industrial structure level (indstr)	341	2.3451	0.1410	2.1265	3.2199
Financial decentralisation (FD)	341	3.0745	2.4098	0.0746	10.2325
Quadratic term of financial decentralisation (fd2)	341	15.2423	23.4156	0.0056	104.7044
Scale of financial development (fdev)	341	6.0744	2.9637	1.8730	17.4013
Fiscal decentralisation (fiscd)	341	1.6499	1.2972	0.0527	6.1515
Urbanisation rate (urbr)	341	54.3215	13.9169	22.7273	89.6066
Marketisation level (mktpro)	341	6.1502	2.0651	0.3900	10.1300
Government intervention (gov)	341	0.2657	0.1943	0.0874	1.3792

Source: own study.

$$\mathrm{stdfint}_{3_{it}} = (\mathrm{fint}_{3_{it}} - \min(\mathrm{fint}_{3_{it}}))/(\max(\mathrm{fint}_{3_{it}}) - \min(\mathrm{fint}_{3_{it}})) \tag{e}$$

Second, the normalised draw metrics were weighted:

$$\mathbf{fint_{it}} = (\mathbf{stdfint_{1_{it}}} * \mathbf{w_1} + \mathbf{stdfint_{2_{it}}} * \mathbf{w_2} + \mathbf{stdfint_{3_{it}}} * \mathbf{w_3}) * \mathbf{100} \tag{f}$$

3. Empirical analysis

3.1. Descriptive statistics

The descriptive statistics for the primary variables are presented in Table 2. The mean value of financial efficiency (fine) is 72.5309%; the minimum value is 24.6087%, and the maximum value is 114.3845%. The average value of the fintech index (fint) is 0.1897; the minimum value is 0.0041 and the maximum value is 3.003, which indicates that development levels of financial industry and fintech vary substantially across provinces. This is consistent with the fact that China's regional economic and financial development is unbalanced.

3.2. Benchmark regression

Model (a) can be estimated using the individual fixed effects (FE) and random-effects (RE) models. In this study, we use the Hausmann test to test the FE and RE estimation results. The *p*-value of the Hausmann test is less than 0.0001, but Stata reports that 'V _ b-V _ B matrix is not positive definite', which is difficult to judge. Considering that FE can alleviate the endogenous problem caused by missing variables, this study uses FE to estimate and RE to test the robustness. Table 3 shows the results of FE estimation of Model (a) by gradually increasing the number of control variables.

Model (a) examines the impact of the key explanatory variables (fint) on financial efficiency (fine) and adds a quadratic term. To verify the influence of other control variables on the explained variables, this study adds several control variables: per capita GDP (lnpgdp) and industrial structure level (indstr), financial decentralisation

Table 3. FE regression results for Model (a).

Variable name	(1) fine	(2) fine	(3) fine	(4) fine	(5) fine
Fintech (fint)	−4.046***	−4.169***	−3.080***	−2.949**	−2.812**
	(1.210)	(1.068)	(1.050)	(1.187)	(1.093)
Fintech quadratic term (fint2)	0.135**	0.127***	0.0882**	0.0858**	0.0682**
	(0.0494)	(0.0374)	(0.0333)	(0.0358)	(0.0324)
GDP per capita (lnpgdp)		−22.07**	−39.99***	−39.07***	−32.82***
		(10.03)	(8.459)	(8.975)	(8.311)
Industrial structure level (indstr)		−7.077	−14.68	−14.17	−15.85
		(11.66)	(11.48)	(12.08)	(12.17)
Financial decentralisation (FD)			27.56***	28.25***	30.53***
			(4.776)	(4.465)	(4.770)
Quadratic term of financial decentralisation (fd2)			−1.737***	−1.751***	−1.876***
			(0.383)	(0.377)	(0.397)
Financial development (fdev)			2.413***	2.351**	2.206**
			(0.825)	(0.890)	(0.927)
Fiscal decentralisation (fisd)				−1.403	−0.734
				(2.860)	(2.937)
Urbanisation rate (urbr)					−0.716**
					(0.331)
Marketisation level (mktpro)					0.239
					(0.638)
Constant term	65.54***	100.2***	66.01**	64.54**	91.09**
	(0.826)	(32.09)	(26.54)	(27.91)	(34.25)
Individual effect	YES	YES	YES	YES	YES
Annual effect	YES	YES	YES	YES	YES
Observed value	341	341	341	341	341
Number of provinces, cities, and districts	31	31	31	31	31
R^2 *(adjusted)*	0.644	0.660	0.761	0.761	0.770

Note: * * *, * *, and * represent significance levels of 1%, 5%, and 10%, respectively; the robust standard error of double clustering is presented in parentheses.
Source: own study.

(FD), quadratic term of financial decentralisation (fd2), degree of financial development (fdev), fiscal decentralisation (fisd), urbanisation rate (urbr), and marketisation level (mktpro). The regression results obtained are in Columns (1) to (5) of Table 3, and the baseline regression result is in Column (5).

The results in Columns (1)–(5) in Table 3 show that the coefficients of the key explanatory variable fint are significantly negative at the 5% level, while the quadratic coefficients of fint are significantly positive at the 5% level; therefore, fintech development has a U-shaped effect on financial efficiency, implying it first inhibits and then promotes financial efficiency. As fintech development level increases, financial efficiency declines at first, but after a certain critical point, improves. This is consistent with Hypothesis 1 and the conclusion of Hongwei et al. (2020). Empowered with advanced fintech, fintech companies compete fiercely with traditional financial institutions, and the financial ecosystem improves the financial ecological function through self-regulation to improve the efficiency of financial resource allocation.

Table 3 also shows that the impact of per capita GDP on financial efficiency was significantly negative at the 5% level. The reason may be that the greater the per capita GDP of the region, the more developed the economy and the greater the investment in fintech in the region. Fintech companies compete for banks' deposit resources and are constrained by the deposit-loan ratio, which further reduces banks' resources, thus reducing the efficiency of financial resource transformation. The influence coefficient of financial decentralisation on financial efficiency is significantly

positive at the 1% level, and the quadratic coefficient is significantly negative at the 1% level, indicating that financial decentralisation has an inverted U-shaped effect on financial efficiency. This may be due to the improved level of financial decentralisation, reflecting the relatively rapid growth of loans that improve the conversion rate of financial resources and financial efficiency (Min et al., 2017; Zongfan & Junsong, 2016). While the continuous improvement of financial decentralisation may bring about the growth of both loans and deposits due to the easing of monetary policy, the growth of deposits is higher, which later leads to a decline in financial efficiency.

The impact of financial development on financial efficiency is significantly positive at the 5% level, which may be because the level of financial development in this study is reflected in the proportion of the added value of the financial industry to GDP, and the high degree of financial development indicates that the overall financial industry is relatively active, while the deposit and loan business of the banking industry still accounts for the largest proportion of the entire financial business, thus bringing about the efficiency improvement of savings into loan investments.

The influence coefficient of the urbanisation rate on financial efficiency is negative at the 5% level, indicating that the urbanisation rate has a negative impact on the improvement of financial efficiency. This may be due to the higher income of residents in areas with higher urbanisation rates, which leads to higher corresponding deposits and a growth rate of deposits that exceeds that of loans.

3.3. Endogenous treatment

Endogenous variables were lagged for one period to alleviate endogeneity by substituting the fintech development level lagging for one period and its quadratic term into Model (a). The results are shown in Column (1) in Table 4. The impact of the fintech development level lagged for one period on financial efficiency is significantly negative at the 1% level, and the effect of the quadratic term is significantly positive at the 5% level.

This study refers to Chen et al. (2021) and Kim et al. (2014), and uses the average value and quadratic term of fintech development level of other provinces in the same

Table 4. Endogenous treatment results.

Variable name	(1) lag fine	(2) iv1 fine	(3) iv2 fine
Fintech		−3.648***	−3.648***
		(1.056)	(1.005)
Fintech quadratic term		0.105**	0.105**
		(0.0460)	(0.0484)
Fintech lags for a period of time	−2.763***		
	(0.743)		
Fintech lags behind the first-order quadratic term	0.0786**		
	(0.0308)		
Constant term	127.8***		59.28**
	(43.48)		(29.87)
Individual effect	YES	YES	YES
Annual effect	YES	YES	YES
Observed value	310	341	341
Number of provinces, cities, and districts	31	31	
R^2 *(adjusted)*	0.739	0.743	0.925

Note: *, * *, and * * * indicate significance at the 10%, 5%, and 1% levels, respectively.
Source: own study.

year as instrumental variables to conduct the endogeneity test. The results are shown in Column (2) of Table 4. In addition, we use a more robust standard error as a substitute variable for regression, and the results in Column (3) are obtained. From the results of Columns (2) and (3) in Table 4, it can be seen that the influence coefficient of the fintech development level is significantly negative at the 1% level, and the quadratic coefficient is significantly positive at the 5% level. The test results of Columns (1), (2), and (3) in Table 4 are consistent with the benchmark regression results in Table 3. In the case of excluding endogeneity, the fintech development level has a U-shaped effect on financial efficiency, which is initially inhibited and then promoted.

3.4. Robustness test

To further verify the reliability of the research conclusions, this study uses more robust standard errors, replaces key explanatory variables, adds control variables, and uses FE models to test robustness. The results indicate that the basic conclusions are robust.

3.4.1. Using a more robust standard error

Double clustering adjustment of standard error in individual and time can overcome the influence of autocorrelation and heteroscedasticity on statistical results (Petersen, 2009). In this study, the double clustering robust standard error was used to re-estimate Model (a), and the regression results are shown in Column (1) of Table 5. The impact coefficient of fintech is significantly negative at the 1% level, and the impact coefficient of the quadratic term is significantly positive at the 1% level, which is consistent with the results in Table 3, indicating that the benchmark regression conclusion in Column (5) of Table 3 is robust.

Table 5. Results of the robustness test.

Variable name	(1) stderr fine	(2) rfint fine	(3) gov fine	(4) re fine
Fintech	−2.812***		−2.490***	−3.727***
	(0.604)		(0.615)	(0.630)
Fintech quadratic term	0.0682***		0.0591***	0.109***
	(0.0207)		(0.0214)	(0.0249)
Fintech substitute variable		−0.530***		
		(0.198)		
Fintech surrogate variable quadratic		0.00670*		
		(0.00378)		
Government intervention			21.02**	
			(8.619)	
Constant term	91.09***	63.09***	78.85***	95.03***
	(22.51)	(19.36)	(21.77)	(21.16)
Individual effect	YES	YES	YES	YES
Annual effect	YES	YES	YES	YES
Observed value	341	341	341	341
R^2 (*adjusted*)	0.784	0.749	0.792	
Number of provinces, autonomous regions, and municipalities	31	31	31	31

Note: *, * *, and * * * indicate significance at the 10%, 5%, and 1% levels, respectively.
Source: own study.

3.4.2. Replacement of key explanatory variable

In this study, the People's Daily Online's data source is used for text mining to obtain the proxy index (rfint) of the fintech development level, which is added to Model (a) for re-estimation, and the results are shown in Column (2) of Table 5. The impact coefficient of the replaced Fintech development index on financial efficiency is negative at the 1% and positive at the 10% level. The results are consistent, indicating that the conclusions of the benchmark regression are still robust even after replacing the key explanatory variables.

3.4.3. Add control variables

China's regional economic development is not balanced, and the degree of local government intervention in economic activities varies from province to province, which may impact financial efficiency. In 2018, the governor of The People's Bank of China, Yi Gang, first proposed a 'several lifts' mechanism to give full play to the joint efforts of the Bank, Finance Ministry, and regulatory authorities to motivate the positivity of commercial banks and establish a long-term financing mechanism arrangement (Financialnews, 2018). In practice, many local governments have introduced policies and measures such as fiscal interest discounts and risk compensation to guide financial institutions into issuing loans to support agriculture and small businesses. Therefore, government intervention (gov) is added as a control variable in Model (a), and the regression results are shown in Column (3) of Table 5. The results show that after controlling for government intervention, the impact coefficient of fintech is significantly negative at the 1% level, and the impact coefficient of the quadratic term is significantly positive at the 1% level, indicating that the regression results are robust.

3.4.4. Using a random-effect model

The RE model was used for estimation, and the regression results are shown in Column (4) of Table 5. The impact coefficient of fintech is significantly negative at the 1% level, and the impact coefficient of the quadratic term is significantly positive at the 1% level. The conclusion drawn using the RE model was consistent with that of the fixed effect model and the conclusion of Hypothesis 1 is proven to be robust.

4. Testing the moderating effect of financial decentralisation

There is no authoritative definition of financial decentralisation. The definition generally accepted in academic circles is: financial decentralisation is the institutional arrangement for the distribution of financial resources among governments and between the government and the market (Hu & Kunrong, 2019; Lixuan & Yaodong, 2018).

To achieve economic growth under the pressure of local fiscal revenue constraints and government officials' promotion evaluation mechanism, local governments often expand investment by increasing infrastructure construction among other ways, which creates demand for funds, and promotes financial decentralisation (Zhihui, 2008; Zilong et al., 2019). Financial decentralisation is the direct result of financial competition among local governments, which participate in or control city commercial banks to be the competition, or even make it a potential source of 'second

finance' to develop the local economy (Dexu & Wenlong, 2016). Scholars believe that financial decentralisation enables local financial regulatory authorities to gain greater authority in financial resource allocation, which helps to fully exploit the information advantages of local financial institutions, improve the efficiency of financial resource allocation (Zongfan & Junsong, 2016) and the level of urban innovation (Meiling et al., 2019), and boost the enthusiasm of local governments to increase financial expenditure (Min et al., 2017) to promote economic growth. Financial decentralisation is an important form of economic decentralisation. Scholars have studied the impact of economic decentralisation in other countries and reached similar conclusions as China, that economic decentralisation enhances the spending capacity and effort of local governments, helps to fully exploit the information advantages of local governments, and improves the efficiency of government expenditure and supply quality of public goods (Grisorio & Prota, 2015; Tiebout, 1956).

In China, because of the unequal development of the financial industry in different provinces, the degree of development of direct and indirect financing markets and the degree of government participation in providing service support are different, the latter being reflected in the various degrees of financial decentralisation. Thus, financial decentralisation may also interfere with the impact of fintech on financial efficiency. For example, the Guangdong provincial government actively supports the cooperation between banks and enterprises. The Science and Technology Department of Guangdong and Guangdong Institute of Finance have jointly built a comprehensive information service platform for science and technology, and finance, which can provide certain credit analysis services for the financing of small and micro enterprises in Guangdong. There are more than 2,000 registered enterprises on the platform, and about 10 banks provide loans on the platform, effectively improving financing efficiency.

Does financial decentralisation adjust the marginal effects of fintech on financial efficiency? To re-estimate, this study adds the interaction term of financial decentralisation and fintech to the benchmark Model (a). The results in Column (1) of Table 6 show that the development level of fintech still has a U-shaped relationship with financial efficiency, restrained at first and promoted later. The coefficient of the cross term of fintech and financial decentralisation (fdfint) is significantly positive at the 1% level. To test the robustness, this study uses alternative core explanatory variables (replaced by the rfint index obtained from another data source, People's Daily Online) to conduct a regression analysis. As shown in Column (2) of Table 6, the development level of fintech has a U-shaped impact on financial efficiency, which is first inhibited and then promoted. The coefficient of the cross term of fintech and financial decentralisation (fdrfint) is significantly positive at the 1% level, indicating that the regression results are robust.

Columns (1) and (2) of Table 6 show that financial decentralisation can adjust the marginal effect of fintech on financial efficiency. With greater financial decentralisation, fintech's effect on improving financial efficiency is more significant. The reason may be that financial decentralisation can significantly promote urban and enterprise innovation (Jingjing et al., 2021; Meiling et al., 2019). Greater financial decentralisation indicates that the financial industry is much more developed, financial

Table 6. Test of the regulatory effect.

Variable name	(1) fdfint fine	(2) fdrfint fine
fint	−47.84***	
	(8.854)	
fint2	8.998***	
	(2.360)	
fdfint	2.178***	
	(0.539)	
lnpgdp	−30.43***	−34.97***
	(5.641)	(6.728)
indstr	−19.62***	−9.275
	(7.520)	(7.434)
fd	27.02***	33.55***
	(2.698)	(3.212)
fd2	−1.620***	−1.618***
	(0.210)	(0.227)
fdev	2.479***	1.811***
	(0.473)	(0.461)
fiscd	−0.285	−5.996***
	(1.765)	(1.660)
urbr	−0.751***	−0.636***
	(0.182)	(0.181)
mktpro	0.486	0.151
	(0.465)	(0.526)
rfint		−1.451***
		(0.408)
rfint2		0.00813**
		(0.00358)
fdrfint		0.157***
		(0.0560)
Constant term	102.8***	70.10***
	(22.20)	(20.66)
Individual effect	YES	YES
Annual effect	YES	YES
Observed value	341	341
Number of provinces, cities, and districts	31	31
R^2 *(adjusted)*	0.783	0.737

Note: *, * *, and * * * indicate significance at the 10%, 5%, and 1% levels, respectively.
Source: own study.

innovation is more active, and the positivity and ability of financial institutions and local governments to get involved in fintech are relatively stronger. Therefore, it is conducive to adjust the marginal effect of fintech on financial efficiency for deep integration of financial industry and fintech.

5. Conclusions

This study used the text mining method to construct China's provincial fintech development level. By collecting provincial panel data from 2008 to 2018, this study empirically tested the nonlinear relationship between fintech innovation and financial efficiency in different stages of development using a dynamic panel model. The development of fintech has a U-shaped effect on financial efficiency, which it first inhibits and then promotes. With improvement in the fintech development level, financial efficiency declines initially, but after crossing a critical point, improves. This proves

that the technology spillover theory applies to the impact of fintech on financial efficiency. The impact of fintech in the early stages and in the middle and later stages of development is mainly reflected in the competitive effect, and the demonstration and correlation effects, respectively. In addition, both the regional economic development level and the rate of urbanisation have a negative impact on financial efficiency. Financial decentralisation can adjust the marginal effect of fintech on financial efficiency. In regions with greater financial decentralisation, the effect of fintech on improving financial efficiency is more significant.

Based on the above findings, this study provides the following implications and suggestions. First, we should correctly understand the impact of fintech companies on traditional financial institutions. Fintech may bring more harm than good to traditional financial institutions in the early stages. However, with the weakening of the competitive effect, the demonstration effect becomes prominent gradually, and the technology absorption and transformation abilities of traditional financial institutions improve such that these institutions gradually innovate the traditional business model, transform and upgrade themselves, and then improve financial efficiency. Second, the regulatory authorities should strengthen the corresponding regulatory measures, standardise a healthy competition in the financial industry, guide a positive spillover of fintech, and facilitate releasing the enabling potential of fintech to the greatest extent. In addition, the local government should give full play to the positive role of promoting scientific and technological innovation, further improve the level of financial decentralisation, and thus encourage enhanced regional financial efficiency. Third, we should continue to support and encourage the development of fintech. At the regional level, the more developed the financial industry, the more favourable it is to integrate with fintech, which can adjust the marginal effect of fintech on financial efficiency. While actively preventing financial risks, we should issue business licences to more compliant fintech companies, continuously improve the efficiency of resource allocation, and promote the process of financial marketisation.

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Data availability

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Disclosure statement

There are no competing interests to declare.

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