

Exploring the impact of the level of financial technology on the total factor productivity of firms based on heterogeneity analysis

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Abstract. This paper examines how financial technology (fintech) affects the total factor productivity (TFP) of firms using a sample of 370 GEM-listed companies in China from 2015 to 2020. The results indicate that fintech level has increased steadily over this period and has a positive and significant effect on TFP. The paper further investigates the underlying mechanisms and finds that fintech enhances TFP by easing financing constraints and lowering agency costs. Moreover, the paper conducts heterogeneity analysis and reveals that fintech has a larger impact on TFP for firms located in less developed regions and for private-owned firms. The paper concludes with some policy implications for leveraging fintech to improve financial inclusion and facilitate high-quality economic development in China.

Keywords: economic quality development; intermediary effect; fintech; total factor productivity.

1. Introduction

The growth and development of firms are crucial for economic development as they affect not only their own competitiveness but also their contribution to the overall economic system. In light of the current shift toward high-quality and sustainable economic development, firms face increasing international competition and need to enhance their TFP as a key strategy to improve their competitiveness.^[1] However, China's GDP growth slowed down to 2.2% in 2020 due to the outbreak of COVID-19 pandemic, which also caused negative impacts on both demand and supply sides as well as weakened expectations for future recovery. These factors pose triple challenges for China's domestic economy. In this context, fintech emerges as a vital means and a driving force for achieving economic growth by offering quality financial services that can improve both efficiency and effectiveness of service delivery in the real economy and boost TFP of firms.[2]

2. Theoretical framework and research model

2.1 The effect of fintech on firms' TFP

Fintech enables technology to be applied as a primary tool for financial innovation while finance serves as a target for fintech services. Based on technological spillover theory (TST), firms with advanced technologies may unintentionally create spillover effects when they manage their businesses. These effects may influence other firms in their industry or sector by inducing them to invest more in research and development (R&D) and thereby fostering technological progress. Fintech firms use technology to offer a service platform for both buyers and sellers that facilitates transactions by connecting data and technologies across different platforms. This enhances market activity by increasing transaction volume as well as reducing data collection costs for firms. This can be seen as an example of technological spillover effect. Furthermore, fintech contributes to lowering information asymmetry among firms and improving corporate governance by reducing agency costs associated with moral hazard or adverse selection problems between principals (e.g., shareholders) and agents (e.g., managers). Fintech also improves information quality and accuracy through

technological innovation which allows stakeholders from various parties to monitor firms' business operations more effectively. Consequently, fintech leads to an increase in TFP for firms.^[3]

2.2 Data sources and variables

This study selects firms listed on GEM from 2015 to 2020 as its sample for examining fintech's impact on TFP.^[4] The firm-level data are retrieved from Guotaian database after excluding ST or ST* firms, samples with missing key variables, and samples with less than one year of listing history. To mitigate outliers' influence, the continuous variables are winsorized at both ends, resulting in a final sample size of 2220 firms. The dependent variable is TFP measured by three different methods: LP method (TFP-LP), modified OPACF method (TFP-OPACF), and WRDG method (TFP-WRDG) as a robustness check.

The fintech indicators are constructed based on Baidu index database which provides online search volume data for various keywords related to fintech activities. Text mining using crawler software is applied to extract relevant keywords from four dimensions: payment and settlement, resource allocation, wealth management, and technological means. However, some regions have missing data due to low search volume or other reasons, so they are excluded to ensure indicator accuracy and consistency with firm-level data. Table 1 shows the list of 18 keywords derived from an original lexicon that capture the level of fintech development across different provinces and cities in China.

Table 1. Glossary of keywords for fintech indicators

Dimension		Keyword		
Payment settlement	Third party payment	Online payment	Mobile Payment	Mobile Payment
Resource Allocation	Online Loans	Crowdfunding	Internet Lending	
Wealth Management	Internet Finance	Internet Insurance	Internet Investment	Online Finance
Technology	Big Data	Cloud Computing	Artificial Intelligence	Internet of Things

This study computes information entropy for each indicator to obtain their weights and constructs fintech indicators for each province from 2015 to 2020. The logarithms of these indicators are used for empirical analysis. Several control variables are also included: size (logarithm of total assets), lev (liabilities-to-assets ratio), ROA (return on total assets), cost (logarithm of cost-to-sales ratio), growth (logarithm of annual growth rate in operating income). In addition, this study measures agency costs by overhead rate (overhead-to-operating income ratio) and financing constraints by SA index following previous literature. Table 2 summarizes variable definitions.^[5]

Table 2. Glossary of keywords for fintech indicators

	Variable name	Variable sign	Calculation method
Explained variables	Enterprise TFP	TFP-LP TFP-OPACF TFP-WRDG	The LP method, modified OPACF method and WRDG method were used to measure
Explanatory variables	fintech	ln_fintech	Determine the 18 key indicators of fintech, information entropy to determine the weight of each indicator to measure the fintech indicators, and take the logarithm for empirical research
	Enterprise size	size	Logarithm of the total assets of the enterprise at the end of the year
Control variables	Gearing Ratio	Lev	Total liabilities at the end of the year compared to total assets at the end of the previous year
	Return on Total Assets	ROA	Net profit at the end of the year compared to total assets at the end of the previous year
	Cost of sales	Cost	Natural logarithm of total cost of goods sold
	Growth	Growth	The growth rate of the enterprise's annual operating income
Mediating variable	Agency Costs	agent cost	Ratio of administrative expenses to operating income
	Financing constraints	SA	SA Index

2.3 Model specification

Based on previous theoretical and empirical studies, this study specifies an econometric model with TFP as dependent variable and fintech indicator as key independent variable while controlling for other factors.

$$TFP_{it} = \beta_0 + \beta_1 \ln_fintech_{it} + \beta_2 size_{it} + \beta_3 lev_{it} + \beta_4 ROA_{it} + \beta_5 \ln_cost_{it} + \beta_6 growth_{it} + \theta_i + \varepsilon_{it} \quad (1)$$

where TFP denotes firm-level tfp; $\ln_fintech$ denotes provincial-level fintech indicator; size denotes firm size; lev denotes leverage ratio; ROA denotes return on total assets; $\ln_cost$ denotes cost efficiency; $\ln_growth$ denotes growth potential; i denotes firm subscript; t denotes time subscript; β_0 denotes constant term; θ_i denotes individual fixed effect; $\varepsilon_{(i,t)}$ denotes error term.

To examine how fintech influences firm-level TFP through different channels, this study adopts a mediation analysis approach based on the following model.

$$TFP_{it} = a_1 + c \ln_fintech_{it} + \gamma_1 X_{it} + e_1 \quad (2)$$

$$M_{it} = a_2 + a \ln_fintech_{it} + \gamma_2 X_{it} + e_2 \quad (3)$$

$$TFP_{it} = a_3 + c' \ln_fintech_{it} + b M_{it} + \gamma_3 X_{it} + e_3 \quad (4)$$

Where TFP_{it} denotes TFP for firm i in year t; $\ln_fintech_{it}$ denotes provincial-level fintech indicator for firm i in year t; M_{it} denotes mediator variables, namely financing constraint index SA and agency cost; other variables are defined as before.

Equation 2 estimates the total effect © of fintech on TFP; Equation 3 estimates how fintech affects mediator variables (a); Equation 4 estimates how mediator variables affect TFP after controlling for fintech (b) and the direct effect of fintech on TFP (c'). The relationship among these effects can be expressed as $c=c'+ab$. The mediation effects are represented by ab, which measure how much variation in TFP can be explained by mediator variables. The proportion mediated can be calculated by ab/c .

To test for mediation effects, this study follows these steps: first, test whether c is significantly different from zero; second, test whether a and b are both significantly different from zero; third, if two or three coefficients among a, b and c are nonzero, conclude that there are significant mediation effects; fourth, if c' becomes insignificant when mediators are included, conclude that there are full mediation effects.

3. Empirical Validation and Results Analysis of the Model

3.1 Results Analysis of Individual Fixed Effects Regression

To avoid spurious regression and ensure the validity of empirical estimation, this paper first conducts unit root tests for time series and panel data. This paper adopts four methods for unit root tests: LLC, IPS, ADF-Fisher and PP-Fisher, which are applicable to homogeneous and heterogeneous panel assumptions respectively. The test results show that under all four methods, all variables reject the null hypothesis of unit root at 1% significance level, indicating that all variables are stationary and can be used for further empirical research.^[6]

To examine whether there is a long-run equilibrium relationship among the variables, this paper employs three methods for cointegration tests: KAO, Pedroni and Westerlund. The results of all three methods reject the null hypothesis of no cointegration relationship at 1% significance level, strongly suggesting the existence of a long-run cointegration relationship among the non-stationary panel data variables.^[7]

This paper selects the model controlling for individual fixed effects for empirical analysis, and presents the results in Table 3.

Table 3. Individual fixed effects regression results

Variables	TFP-LP(1)	TFP-LP(2)	TFP-OPACF(3)	TFP-OPACF(4)
ln_fintech	0.451*** (11.95)	0.214*** (5.99)	0.387*** (10.56)	0.237*** (6.23)
Size		0.282*** (8.39)		0.172*** (4.65)
Lev		0.311*** (2.65)		0.236* (1.78)
ROA		0.703*** (5.59)		0.702*** (5.38)
ln_cost		0.221*** (9.51)		0.181*** (7.60)
Growth		0.0498** (2.10)		0.0426* (1.88)
_cons	12.14*** (59.79)	3.169*** (5.22)	10.81*** (54.72)	4.508*** (6.60)
N	2220	2220	2220	2220
R ²	0.1503	0.495	0.1214	0.3384

Table 3 presents the results of the benchmark regressions with the core explanatory variables being the results measured by the LP method and OPACF method. First, regarding the effect of fintech (ln_fintech) on firms' TFP, the coefficients of ln_fintech on TFP-LP and TFP-OPACF are 0.451 and 0.387 in columns (1) and (3), respectively, which are both statistically significant at the 1% level; in columns (2) and (4), after controlling for other variables, the coefficients of ln_fintech on TFP-LP and TFP-OPACF are 0.214 and 0.237, respectively, which remain statistically significant at the 1% level but slightly decrease. Regardless of the measurement method employed, ln_fintech has a positive and robust effect on firms' TFP, thus confirming Hypothesis 1.

Second, from the perspective of control variables, under the LP method, firm size (size), leverage (lev), return on total assets (ROA), cost of goods sold (ln_cost), and growth (growth) are all positively associated with firms' TFP at the 5% significance level or higher; under the OPACF method, except for growth which is positively associated with firms' TFP at the 10% significance level, all other control variables are positively associated with firms' TFP at the 1% significance level. Under both methods, all five control variables have a positive impact on firms' TFP and meet the significance criterion. In addition, there are some differences in the coefficients of the control variables under the two methods. Compared to under the LP method, each control variable has a larger impact on firms' TFP under the OPACF method.

3.2 Heterogeneity analysis based on the level of economic development

In this paper, we classify the regions into economically developed regions (dev=1) and economically less developed regions (dev=0) according to whether their GDP per capita is higher or lower than the average level of GDP per capita in each province and city. The final regression results are reported in Table 4.

Table 4. Baseline regression analysis

Variables	TFP-LP(1) dev=1	TFP-LP(2) dev=0	TFP-OPACF(3) dev=1	TFP-OPACF(4) dev=0
ln_fintech	0.201*** (4.80)	0.296*** (4.55)	0.227*** (4.95)	0.303*** (4.87)
Size	0.277*** (7.17)	0.285*** (4.36)	0.165*** (3.75)	0.177** (2.60)
Lev	0.338** (2.33)	0.286 (1.33)	0.251 (1.54)	0.241 (1.01)
ROA	0.581*** (4.63)	1.142*** (3.50)	0.582*** (4.37)	1.156*** (3.55)
ln_cost	0.201***	0.262***	0.161***	0.225***

	(7.27)	(6.73)	(5.52)	(5.71)
Growth	0.0621*	0.0373	0.0513	0.0315
	(1.65)	(1.44)	(1.29)	(1.28)
_cons	3.696***	1.992*	5.062***	3.334***
	(5.22)	(1.82)	(6.06)	(3.02)
N	1668	552	1668	552
R ²	0.442	0.6273	0.2836	0.5046

Table 4 displays the baseline regression results with the core explanatory variables being the results measured by LP method and OPACF method, and grouped by dev. First, regarding the effect of fintech ($\ln_fintech$) on firms' TFP, the coefficient of $\ln_fintech$ is positive and statistically significant under both methods and is slightly larger in economically less developed regions than in economically developed regions. Specifically, under the LP method, the coefficients of $\ln_fintech$ on TFP-LP for $dev=1$ and $dev=0$ are 0.201 and 0.296, respectively; under the OPACF method, the coefficients of $\ln_fintech$ on TFP-OPACF for $dev=1$ and $dev=0$ are 0.227 and 0.303, respectively. This suggests that $\ln_fintech$ has a positive impact on firms' TFP and contributes to different degrees of convergence between the two regions.

Second, from the perspective of control variables, firm size ($size$), return on total assets (ROA), and cost of sales ($\ln_cost$) are positively associated with firms' TFP in both regions under both methods. Leverage (lev) and growth ($growth$), however, exhibit different degrees of variation under the different methods. Under the LP method, lev and $growth$ have a larger and more significant positive effect on firms' TFP in economically developed regions, but less significant in economically less developed regions; under the OPACF method, conversely, lev and $growth$ have a larger and more significant positive effect on firms' TFP in economically less developed regions, but less significant in economically developed regions.

In summary, $\ln_fintech$ has a larger and more significant contribution to firms' TFP in economically less developed regions compared to economically developed regions. This may be due to the fact that economically less developed regions have larger gaps in the level of $\ln_fintech$ and firms' TFP compared to economically developed regions, and have more potential room for improvement. In recent years, with the advancement of technological progress and innovation, the level of $\ln_fintech$ has achieved a certain degree of convergence between the two regions, and has enhanced firms' TFP.

4. Conclusion

Using the panel data of GEM listed companies from 2015-2020, this paper empirically examines the mechanism of the effect of fintech on firms' TFP by applying the individual fixed effects model and the mediation effects model. It finds that fintech has a significant positive impact on firms' TFP, and there are significant differences among firms in different regions and with different ownership types. Specifically, in terms of the level of fintech, there are large disparities among provinces and cities; in terms of firms' TFP, it is relatively balanced. The heterogeneity analysis shows that, in terms of economic development level, the positive effect of fintech on firms' TFP is more pronounced in less developed regions; in terms of ownership type, the positive effect of fintech on firms' TFP is stronger for private enterprises. Therefore, it is necessary to introduce relevant policies and regulations according to local conditions to facilitate the development of fintech, improve the regulatory mechanism of fintech, establish a supervision system with the participation of multiple actors, and government departments at all levels should pay great attention to the cultivation of fintech talents at the strategic level. The government should take the responsibility of cultivating fintech talents and collaborate with major universities to deliver interdisciplinary talents integrating finance and technology to society.

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