

The Impact of Financial Technology on Enterprise Innovation: An Empirical Analysis of China's A-Share Public Firms (2012–2023)

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Abstract. The emergence of Fintech provides a newly emerged chance to relax enterprises' financing restrictions and give strength to enterprise innovation. By utilizing an overall data collection of Chinese A-share publicly firms which cover years from 2012 to 2023, this research carries out a systematical inquiry into the influence that Fintech brings to enterprise innovation and its basic passing mechanisms. The experiment-based outcomes prove that Financial Technology notably pushes forward the company innovation production. This result still keeps strong after a group of robustness examinations, including changing the dependent variable, using a one-period delayed explanation variable, and removing extreme numerical values. Mechanism researches make sure that promoting total factor productivity and fostering new productive forces are two important channels by which Fintech pushes enterprise innovation. In addition, heterogeneity analyses have discovered that the promotion function of Fintech has obvious asymmetric features. Concretely speaking, this positive effect of empowerment is mainly gathered in enterprises which have effective internal controls and good operation conditions, hence it is not meaningful for companies which have ineffective internal controls or those which are in finance difficulty.

Keywords: FinTech, Corporate Innovation, New Productive Forces, Total Factor Productivity (TFP)

1. Introduction

Innovation is not merely the first propelling force for development, it is also the micro-level foundation for fostering new quality productivity and promoting overall factor productivity. In the key time period when China's economy is carrying out transition toward high-quality development, enhancing the leading function of enterprises in innovation work and pushing the gathering of all kinds of innovative factors inside enterprises are very important for constructing a new development pattern. However, the innovation activities of enterprises have the features of high investment, long periods, and high uncertainty, and the built-in information asymmetry can easily cause adverse selection and moral hazard, therefore it brings relatively obvious external financing restrictions for enterprises. These financial obstacles not only restrict the size of enterprise research and development but also, on a deeper level, bound the capability of enterprises to promote total factor

productivity through optimized resource distribution, therefore thus hindering the fast shaping of new quality productivity. Therefore hence, looking for financial service tools which balance "funding supply" and "efficiency empowerment" has become a key central point for government together with academia.

The emergence of Fintech has offered a new chance for resolving the aforementioned issues. As a deep combination of information technology and financial service, Fintech uses many technical innovations, including AI and large-scale data processing, to not only effectively recognize enterprise information and reduce financing thresholds, but also to construct a beneficial financial ecological environment for enterprise innovation through optimizing resource allocation efficiency. However, the currently existed researches mainly place focuses on traditional financial structures and bank competition, and the inspection for the inner relationship between Fintech and enterprise innovation is not enough.

Driven by these empty spaces, the present study strictly makes an investigation into the way that digital finance influences innovation at the level of enterprises and the inner channels which push this connection forward. Concretely speaking, we research the following core questions: First, whether Fintech has obvious influence on the degree of enterprise innovation? Second, by which roads does Fintech exert influence on the innovation of enterprises? Third point, whether these influences have obvious differences among different kinds of enterprises? The solving of this group of problems possesses important significance in theory and practice. In the aspect of theory, this paper has the contribution to the enrichment and development of financial development theory and enterprise innovation theory, thus in the aspect of practice, it provides decision-making reference materials for government departments to optimize Fintech regulatory policies and for enterprises to promote innovation efficiency by the use of Fintech tools.

The possible additional marginal value which is brought by this research can be concluded in several different aspects. At the beginning, this research uses the visual angles of total factor productivity and new quality productivity, it examines their intermediary transmission mechanisms between Fintech and enterprise innovation, it expands the research boundaries and enriches the related influence paths. Second, on the foundation of the Fintech development index and by using econometric methods to confirm causal effects, therefore the robustness and reliability of the conclusions are promoted. In addition, this research has discovered the not symmetric features of how Fintech pushes enterprise innovation, it clearly shows that its active influences are mainly gathered in enterprises which have useful inside control and fine operation situations, hence it gives reference for decision making on accurately giving power to enterprise innovation.

2. Literature review

A great many of existing research documents show that progresses in financial technology can promote the development of whole national economy. Research workers have broken through the one-dimensional limitation of financial development, and have explored the micro-level connection between Fintech and enterprise innovation from many different sub-perspectives. Reference [1] began at the special meaning of Fintech and hence proved its obvious positive pushing function for enterprise technology innovation, which is pushed by factors such as depth of application, range of covering, and level of digital transformation. Reference [2] has put its focus on the micro-supply side angle, and hence discovered that Fintech in banks, through the restructuring of credit models, effectively pushes forward the technology research and development of enterprises.

In addition, the discussions which are carried out from the angle of enterprise difference have made the academic documents plentiful. Literature [3,4], from the angles of pollution degree and

innovation ability life circle, separately showed the non-symmetric promotion action that financial technology has on technical innovation. Other researches have emphasized the particular paths through which Fintech gives power to enterprise innovation activities. Among these, relieving financing restrictions and cutting transaction expenses are broadly verified as basic paths that give key financial backing for raising the innovation quality of "specialized, refined, distinctive, and innovative" small and medium-sized enterprises [3]. Based on this foundation [5], hence further found that Fintech can help enterprises complete digital transformation by means of technology spillovers, hence it promotes the elevation of enterprises' technological and green innovation levels.

On another hand, from the visual angle of resource matching and innovation governance [6], have confirmed the information matching optimization function of Fintech. The researches which are related have also pointed out that Fintech is able to make up the positive externalities which are brought by innovation, and correct the innovation of low quality through the enhancement of the external public supervision. To give the summary, Fintech not only pushes enterprise innovation via multidimensional direct incentive angles but also promotes the substantial output and quality of enterprise innovation through indirect mechanisms such as easing financing restrictions, giving power to digital transformation, and optimizing resource distribution.

3. Research design

3.1. Model specification

For deeper exploring the inherent connection between Fintech and the innovation achievement of enterprises, this research puts forward the following two-way fixed effects model:

$$Patent_{it} = \alpha_0 + \beta_0 Fintech_{it} + \sum \gamma_k Control_{it} + \lambda_t + \delta_i + \varepsilon_{it} \quad (1)$$

In this place, $Fintech_{it}$, $Patent_{it}$, and $Control_{it}$ separately stand for Fintech development level, enterprise innovation achievement, and a group of control variables. λ_t represents the fixed effect of time, δ_i represents the fixed effect of individual (enterprise), and ε_{it} is the error item. α_0 is on behalf of the constant term, and β_0 and γ_k are on behalf of the coefficients that belong to each corresponding variable.

3.2. Variable definitions

With respect to the dependent variable—enterprise innovation (Patent), this research uses the natural logarithm of the total number of design, utility model, and invention patents that are submitted, after adding 1 to the value, to measure it.

With respect to the core explaining variable, the degree of financial technology (Fintech), this research utilizes the method which was put forward by [7]. We give quantification to this variable through the calculation of the natural logarithm of the occurrence frequency of digital finance terms that are discovered inside every enterprise's annual corporate declaration documents. With concrete elaboration, through utilizing machine learning calculation methods, we find out 124 particular terms in six main categories: large-scale data analysis, cloud structure, block chain, artificial intelligence, and also net and mobile-based tools. The algorithm carries out parsing work on each company's annual reports for counting these terms, therefore the obtained raw counts accept a logarithmic transformation, hence the annual Fintech index for each single enterprise is established.

As for control variables, the present study chooses a group of control variables on enterprise and macro aspects, these include: (1) Variables at enterprise level: scale of enterprise (Size), profit rate on assets (ROA), proportion of debt (Leverage), fluidity (Liquidity), age of enterprise (Age), size of board (Board), payment for executives (Salary), concentration of stock right (Top5), ratio of price to profit (PE); (2) Grand-score variables: region economy development degree (GDP), the area's industry composition (Industry), region money development degree (Finance).

In the aspect of mechanism variables, this research chooses new quality productivity and total factor productivity to be the mediating variables. Firstly, with respect to enterprise new quality productivity (NQPF), the present study follows the method of [8] and builds a comprehensive index system on the basis of the high-tech, high-efficiency, high-quality features of new quality productivity, which includes dimensions such as green development, innovation-driven development, digital transformation and human capital. The entropy method is utilized by us to give objective weight values to these indexes, and the comprehensive scoring for each enterprise's new quality productivity in each year is got through calculation of the information entropy and weight value of each index. Second, with respect to enterprise total factor productivity (TFP_FE), the present study employs the fixed effects method to carry out estimation.

3.3. Data sources and descriptive statistics

Our beginning research sample includes publicly held A-share enterprises that are listed on the Shanghai and Shenzhen exchange boards, which covers the time period from 2012 to 2023. For guaranteeing the validity of data, observations which possess large amounts of missing values have been eliminated, after that a strict matching procedure on all included variables is conducted. With respect to the coming place of our measurement norms, enterprise financial technology index numbers are taken out directly from the enterprises' annual financial report papers. In addition, the CSMAR and Wind databases are respectively the storage places for other features that belong to firms and macroeconomic index data. In Table 1, the comprehensive statistics decomposition of every main variable is given.

Table 1. Descriptive statistics of variables

Variable Type	Variable Symbol	Observations	Mean	Standard Deviation	Min Value	Max Value
Dependent Variable	Patent	24,983	2.821	1.745	0.000	9.406
	InnoEff	22,297	0.168	0.082	0.000	0.441
Explanatory Variable	Fintech	25,701	3.496	1.323	0.000	6.263
	Size	25,486	3.093	0.061	2.848	3.357
	ROA	25,485	0.052	0.061	-0.163	0.171
	Leverage	22,908	1.172	0.564	0.630	4.947
	Liquidity	25,457	0.780	2.047	-5.723	8.204
	Board	17,692	8.331	1.646	0.000	17.000
	Control Variable	Salary	17,644	0.312	0.376	0.005
	Age	25,483	9.213	8.380	0.000	27.000
	PE	21,658	58.711	86.751	6.843	550.452
	Top5	25,241	0.483	0.187	0.200	0.991
	Industry	25,691	55.495	10.550	34.500	84.800

Table 1. (continued)

GDP	25,691	10.775	0.748	6.565	11.818
Finance	25,691	1.702	0.440	0.701	2.998

4. Empirical analysis

4.1. Basic regression analysis

Table 2 has reported the estimated coefficient values that come from our main empirical model. The first column gives a one-variable regression which only contains the core explaining variable. Columns from (2) to (4) in order add control variables on the enterprise financial characteristic, company governance structure, and macroeconomic level aspects. The empirical outcome shows that the regression coefficient of Fintech is always obviously positive on the 1% statistics level, hence it shows that Fintech assists in boosting substantive innovation of enterprises. Furthermore, when control variables are gradually added in, the model's degree of fitting increases continuously from 0.158 to 0.225, thus it provides further proof for the explanatory ability of the baseline model and the robustness of the obtained results.

Table 2. Baseline regression results

VARIABLES	(1)	(2)	(3)	(4)
	Patent	Patent	Patent	Patent
Fintech	0.1698*** (15.86)	0.1062*** (9.24)	0.1107*** (8.11)	0.1094*** (8.02)
Size		9.6103*** (23.39)	9.1864*** (17.60)	9.3587*** (17.90)
ROA		0.0121 (0.05)	0.2863 (0.95)	0.2640 (0.88)
Leverage		-0.0334** (-2.29)	-0.0718*** (-3.58)	-0.0712*** (-3.55)
Liquidity		-0.0076** (-2.29)	-0.0111*** (-2.74)	-0.0110*** (-2.72)
Board			0.0070 (0.74)	0.0059 (0.62)
Salary			-0.1089** (-2.08)	-0.1055** (-2.02)
Age			0.0197 (0.64)	0.0301 (0.99)
PE			0.0004*** (3.25)	0.0004*** (3.31)
Top5			0.0047 (0.05)	0.0168 (0.18)
Industry				0.0172***

Table 2. (continued)

				(3.17)
GDP				-0.0113
				(-0.10)
Finance				-0.3685***
				(-5.05)
Constant	1.6225***	-27.6138***	-26.2664***	-27.0262***
	(38.23)	(-22.07)	(-16.42)	(-13.41)
Observations	24,983	22,193	15,100	15,094
R-squared	0.158	0.216	0.223	0.225
Number of enterprise	5,105	4,981	3,147	3,143

Note: t-statistics in parentheses, *** p<0.01, ** p<0.05, * p<0.1

4.2. Robustness check

For the confirmation of the reliability of our starting baseline estimations, this study carries out robustness inspections in three aspects: replacing the dependent variable, adding the lag influences of explanatory variables, and dealing with outlier disturbance.

Firstly, the dependent variable has undergone substitution. Concretely speaking, we make use of innovation efficiency (InnoEff) to carry out a re-estimation of this model once again. The results, which are recorded in Column 1 of Table 3, show that the coefficient of Fintech development still remains obviously positive, hence there is no big change in its statistical significance.

Second, the problem of the explanatory variable's hysteresis effect is handled. We acknowledge that the influence of Fintech upon corporate innovation may need a period of time to become actual, therefore, in order to reduce the possibility of reverse causality to the greatest extent, a one-period lag for Fintech is put into this analysis by us. As what is recorded in Table 3, the second Column, this delayed parameter still keeps a robust positive result. This kind of proof not only makes our basic conclusions become stronger, but also hence shows that Fintech has a long-lasting good influence on innovation which is at the level of enterprises.

Thirdly, the influence that extreme values bring is weakened by this method. We carry out a two-sided 2% winsorization handling for all continuous model variables, limiting data points under the 2nd and over the 98th percentiles at those just threshold values. The re-calculated numbers in the third column of Table 3 show that the main explanation variable's size and statistical power very much match the baseline results. This can prove that our total deductions have strong universal application properties and are not distorted by a small number of abnormal samples.

Table 3. Robustness check

VARIABLES	(1)	(2)	(3)
	Replacing Dependent Variable	Using Lagged Explanatory Variable	Removing Extreme Values
Fintech	0.0046*** (5.59)		0.1216*** (8.61)
lag_Fintech		0.1050*** (6.69)	

Table 3. (continued)

Control variables	Yes	Yes	Yes
Observations	13,684	11,446	15,094
R-squared	0.142	0.202	0.216
Number of enterprise	3,002	2,755	3,143

Note: t-statistics in parentheses, *** p<0.01, ** p<0.05, * p<0.1

4.3. Mechanism analysis

This research further discuss the concrete routes that Fintech influences enterprise innovation from the angle of total factor productivity and new quality productivity.

Firstly, the transmission route which is based on total factor productivity. Total factor productivity can reflect the technological progress and resource allocation efficiency that lie beyond capital and labor inputs, hence it is the core driving force for the long-term development of enterprises. The first column of Table 4 has given the regression outcome of the Fintech development degree for enterprise total factor productivity (TFP_FE). We can discover that the development degree of Fintech (Fintech) obtains an obvious positive result at the 1% level, which shows Fintech evidently promotes the total factor productivity of enterprises. In column (2), we put both Fintech and total factor productivity into the model to make regression on corporate innovation (Patent). The outcome displays that the coefficient of overall factor productivity is markedly positive on the 5% level, while the Fintech coefficient still keeps significantly positive. According to the standards which we use to judge the mediation effect, this therefore shows that total factor productivity plays a part of mediating function in the process that Fintech pushes forward enterprise innovation. That is to say, Fintech promotes the whole production and distribution efficiency of the enterprise (TFP), therefore it gives more resource redundancy and higher transformation ability for research and development activities, hence it further pushes the growth of innovation output.

Second, the deliver channel that based on new quality productivity. New quality productive force is an advanced form of productive force which has the features of high technology, high efficiency, high quality, its main driving power comes from technical innovation, and it breaks away from traditional growth roads. As a deep level integration between digital technology and financial service industries, Fintech by itself is an important impetus that can push forward the development of new quality productivity. As what Table 4, Column 3 has shown, the estimated coefficient of the Fintech variable obtains high statistical significance on the 1% level. This result means that Fintech development acts as an important accelerating factor, it is actively pushing the building and quick promotion of enterprise new quality productivity. When we move to Column 4, the data make it clear that this novel quality productivity brings a very powerful beneficial effect to the innovation output of a firm, hence the Fintech parameter all along keeps its positive significance. This shows that Fintech directly changes into more innovation output through giving power to the development of enterprise new quality productivity.

Table 4. Mechanism test

VARIABLES	(1)	(2)	(3)	(4)
	TFP_FE	Patent1	NQPF	Patent1
Fintech	0.0312*** (7.41)	0.1102*** (7.63)	0.8340*** (11.72)	0.0992*** (7.14)
TFP_FE		0.0721** (2.17)		
NQPF				0.0162*** (8.94)
Control variables	Yes	Yes	Yes	Yes
Observations	13,567	13,556	14,450	14,450
R-squared	0.776	0.218	0.142	0.235
Number of enterprise	2,991	2,988	2,998	2,998

Note: t-statistics in parentheses, *** p<0.01, ** p<0.05, * p<0.1

4.4. Heterogeneity test

Firstly, heterogeneity analysis which is based on the effectiveness of internal control. For the purpose of exploring this thing, the dataset is divided by us into two different small samples on the basis of the effect degree of internal controls. The corresponding calculation results are recorded in Table 5, Column 1 and 2. To the grouping which has the feature of effective internal controls, the estimated coefficient which belongs to Fintech development shows a quite large positive influence, passing the 1% statistical significance threshold. With regard to the group which is called the ineffective internal control group, it is the case that this impact does not have significance. This shows that the ability of Fintech to give power to enterprise innovation, therefore, highly relies on a perfect inner governance environment. As to enterprises which have got effective inner control, a standardized governing mechanism can make sure that the resources which Fintech brings are allocated with high efficiency to R&D innovation activities, thus enhancing innovation output in a significant way. On the opposite side, for enterprises which do not have useful inner control, the absence of effective overseeing and managing systems may cause resource wrong distribution or managing disorder when financial technology is blindly brought in or excessively depended on, hence suppressing the enterprise's innovation behaviors.

Second, we carry out heterogeneity analysis which is based on enterprise operation conditions (ST/PT). For further carrying out examination on this heterogeneity, we divide the data set on basis of a firm's special treatment (ST or PT) status. As what Table 5, Columns 3 and 4 give detail to, the estimated results make known that for the group of healthy, non-ST/PT enterprises, the Fintech coefficient displays a very strong positive influence at the 1% significance level. This result is in complete accordance with our basic reasonings that we got before. However, as for the ST/PT company group, this effect does not have significance. This difference shows that the precondition for Fintech to give power to innovation is that enterprises have a normal operation state and basic resource redundancy. The enterprises which are in normal running condition are therefore more capable of utilizing the conveniences which are brought by Fintech to optimize the processes of research and development. On another hand, ST/PT enterprises which are in financial difficulty put

survival and change losses into gains at first place, they have not enough resources and willingness to turn Fintech advantages into long-term R&D input, hence hence cause the promotion function of Fintech cannot work.

Table 5. Heterogeneity test

VARIABLES	(1)	(2)	(3)	(4)
	Effective Internal Control	Ineffective Internal Control	ST or PT	Not ST or PT
Fintech	0.1091*** (7.63)	-0.2169* (-1.93)	0.0114 (0.15)	0.1129*** (8.12)
Control variables	Yes	Yes	Yes	Yes
Observations	14,256	788	397	14,697
R-squared	0.221	0.505	0.184	0.229
Number of enterprise	3,100	628	72	3,071

Note: t-statistics in parentheses, *** p<0.01, ** p<0.05, * p<0.1

5. Conclusion

By making use of a full panel data collection of publicly traded A-share companies in China which covers the time period from 2012 to 2023, this study carries out an empirical exploration on the way that financial technology exerts influence upon innovation at the level of individual firms. The research results are as follows: Firstly, the development of Fintech can obvious promote the output of enterprises' innovation. After carrying out many sensitivity analyses including changing the explained variable, adding a one-period lag to the core forecasting factor, and eliminating extreme data points, our original inferences still have not changed. This uniformity with strong evidence thus proves that financial technology can give a long-lasting and active impetus to actual innovation at the level of enterprises. Second, the promotion of corporate innovation by Fintech, it has two core transmission paths, which are promoting total factor productivity and cultivating new quality productivity. Third, the promoting action that Fintech gives to enterprise innovation shows obvious non-symmetry. This positive effect is greatly decided by a firm's fine internal management and operation environment, and is mainly gathered in firms with useful inner control and fine operation situations (non-ST/PT). By comparison, as to enterprises which have no effective inner control or unusual running situations (ST/PT), the promotion function that Fintech gives to innovation is not obvious.

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