

Digital Finance Development and Enterprise R&D Investment

Shuochong Wang *

Hunan Agricultural University, Changsha, China

* Corresponding Author Email: 1967823406@qq.com

Abstract. With the development of information technology and the popularity of the Internet, digital finance has become an important source of credit funds and an important thrust of economic development in China. This paper studies the impact of the development of digital finance on enterprise R&D innovation. This paper matches the city level digital finance indicators of Peking University Digital finance research center and CSMAR listed company database, and carries out empirical research. It is found that the development of digital finance can promote innovation by increasing enterprise R&D investment. This paper also finds that the internal transmission mechanism of the development of digital finance affecting the R&D investment of enterprises is to increase operating profits and liquid assets, and the external transmission mechanism is to increase the scale of urban science and technology expenditure and human capital. In general, the research of this paper provides effective evidence that digital finance contributes to long-term economic development from the perspective of enterprise R&D innovation.

Keywords: Digital finance; R&D Investment; innovation.

1. Introduction

In recent years, the most prominent feature of the global financial sector has been the widespread use of digital technology, which has contributed to the development and popularization of digital finance. Development economics emphasizes the important role of financial development in regulating the supply and demand of funds and economic development [1]. In China, financial development also plays a corresponding role in promoting economic development. However, the duality and relative backwardness of financial development also hinder the improvement of the allocation efficiency of credit funds [2].

Digital finance may effectively solve this problem. Through digital information technology to reduce financial transaction costs and increase the source of credit, residents and enterprises can obtain more credit funds, reflecting the inclusive characteristics of finance. For enterprises, the comprehensive coverage of digital financial development not only increases their own financing channels, but also changes the external market environment, which directly or indirectly affects and promotes the development of enterprises. In this paper, we study the impact of digital finance development on R&D investment and innovation of enterprises in a sample of listed companies, and elucidate the internal and external transmission mechanism, so as to provide a clear path to understand how digital finance affects the long-term development of enterprises.

2. Literature Review

In the traditional financial system, banks, as the intermediary of funds supply and demand, are the main source of enterprise credit financing [3, 4]. However, at the same time, banks have problems of information asymmetry and high cost in credit, which still can't achieve the optimal effect of alleviating enterprise financing constraints [5]. The advantage of digital finance lies in the use of Internet technology to break through the limitations of traditional finance, reduce information and space-time costs through the digitization of financial services, thus constituting an effective complement to the financial system and expanding the coverage of credit services, which helps to promote the development of the economy exhibition [6-8].

Enterprise R&D investment and innovation are affected by many factors, among which credit capital support from financial institutions is an important driving force [9, 10], so the problem of

financing constraints can also constrain enterprise R&D investment [11]. In China, the financial system also provides a source of financing for corporate R&D innovation, especially the banking system. However, the asymmetry problem in the banking system itself also generates innovation dilemmas, thus requiring other financing channels to supplement the promotion of enterprise R&D innovation. There is a multi-agent problem for enterprises to obtain R&D investment credit from financial institutions, which may have a negative effect, but digital finance can improve the efficiency of financial institutions and alleviate the negative agency effect by reducing the cost of information, and thus can help to provide a source of credit for R&D investment of enterprises. Digital finance also provides new financing channels for enterprise R&D investment and innovation. On the one hand, it can increase R&D and innovation investment by alleviating enterprise financing constraints, thus helping to provide credit sources for enterprise R&D investment. On the other hand, it can also improve the effect of innovation investment by adjusting resource allocation. Thus in general digital financial development is considered to be an important source for realizing innovation in companies.

3. Data and methodology

3.1. Data source

In order to test the impact of digital finance development on R&D investment and innovation of enterprises, this paper conducts an empirical study by matching the city-level digital finance indicators of Digital Finance Research Center of Peking University and the China Stock Market & Accounting Research Database (CSMAR). The indicator system constructed by the Digital Finance Research Center of Peking University comprehensively measures the degree of China's digital finance development from multiple dimensions, including provincial, city and county levels. The indicators measure the breadth of coverage, depth of use and degree of digitization in three dimensions, each of which contains a number of specific indicators, which are ultimately weighted and synthesized into a systematic indicator system to measure the degree of digital financial development after dimensionless data processing. This indicator system has become the most widely used quantitative measurement in the current domestic empirical research on digital finance. This paper matches the data of overall indicators of digital financial development with the R&D investment data, patent data and basic financial data of listed companies from the CSMAR, and the data year range is 2011-2019.

3.2. Methodology

This paper constructs the following regression equations:

$$\ln RD_{ijt} = \alpha_0 + \alpha_1 DF_{jt} + \theta Controls + \varepsilon_{ijt} \quad (1)$$

$$\ln PAT_{ijt} = \beta_0 + \beta_1 DF_{jt} + \theta Controls + \varepsilon_{ijt} \quad (2)$$

$$\ln PAT_{ijt} = \gamma_0 + \gamma_1 \ln RD_{ijt} + \gamma_2 DF_{jt} + \theta Controls + \varepsilon_{ijt} \quad (3)$$

In the regression equation, the subscripts i, j, and t represent firms, cities, and years, respectively. The explanatory variable $\ln RD_{ijt}$ is the logarithmic value of the R&D investment of enterprises (yuan), which measures the status of R&D investment of enterprises. The explanatory variable $\ln PAT_{ijt}$ is the logarithm of the number of invention patent applications, which measures the R&D status of enterprises. The core explanatory variable DF_{jt} is the indicator of digital financial development at the city level of Digital Finance Development Research Center of Peking University, and the original indicator values are divided by 100 to reduce the regression standard deviation.

Controls is the set of control variables, including the following variables: $\ln SCA_{ijt}$, logarithmic value of enterprise total asset size (yuan); ROA_{ijt} , net profit on total assets; RAL_{ijt} , enterprise gearing ratio; CA_{ijt} , logarithmic value of the enterprise's capital intensity (yuan/person); $\ln AGE_{ijt}$, logarithmic value of the firm's years of existence (in years); TF_{jt} , the savings balance per capita at the end of the year in the city where the enterprise is located (yuan per person, logarithmic value).

4. Result

In order to test the impact of digital financial development on enterprise R&D investment and innovation, this paper regresses equations 1-3, and the results in Table 1 are obtained.

Table 1. Benchmark Regression Results.

	R&D Investment		Innovation		Innovation	
DF_{jt}	0.352*** (18.94)	0.618*** (7.29)	0.455*** (12.96)	0.518*** (2.98)	0.369*** (10.69)	0.353** (2.07)
$lnRD_{ijt}$					0.306*** (14.90)	0.294*** (13.95)
$lnSCA_{ijt}$	0.640*** (62.47)	0.677*** (68.76)	0.324*** (15.44)	0.339*** (16.07)	0.132*** (5.34)	0.149*** (5.86)
ROA_{ijt}	-0.233*** (-5.16)	-0.231*** (-5.15)	-0.104 (-0.82)	-0.128 (-1.01)	-0.065 (-0.51)	-0.098 (-0.77)
RAL_{ijt}	-0.250*** (-5.91)	-0.234*** (-5.61)	-0.166** (-1.91)	-0.119 (-1.37)	-0.122 (-1.41)	-0.095 (-1.09)
CA_{ijt}	0.001*** (4.88)	0.001*** (5.31)	0.019*** (6.64)	0.019*** (6.85)	0.016*** (5.23)	0.016*** (5.29)
$lnAGE_{ijt}$	-0.125*** (-6.98)	-0.070*** (-4.18)	0.020 (0.67)	0.041 (1.33)	0.0037 (0.27)	0.040 (1.36)
TF_{jt}	0.025 (0.73)	0.033 (0.96)	0.136** (2.42)	0.179*** (2.67)	0.098* (1.85)	0.166** (2.56)
Year	No	Yes	No	Yes	No	Yes
Industry	No	Yes	No	Yes	No	Yes
R ²	0.329	0.471	0.141	0.176	0.226	0.246
Obs	15308	15308	7059	7059	6952	6952

Note: Numbers in brackets are t-values. *, **, *** denote statistical significance at the 0.1, 0.05, and 0.01 levels, respectively.

In Table 1, the first two columns of the regression show that the coefficient of DF_{jt} is significantly positive, indicating that the development of digital finance can increase the R&D investment of enterprises. The third and fourth columns of regression show that the coefficient of DF_{jt} is significantly positive, indicating that the development of digital finance can promote enterprise innovation. In the last two columns of regression, the explanatory variable is still enterprise innovation $lnPAT_{ijt}$, but R&D investment is added as an explanatory variable, and the results show that the coefficient of $lnRD_{ijt}$ is significantly positive, indicating that R&D investment can promote innovation. The coefficient of DF_{jt} is still significantly positive, but the value of the coefficient decreases compared with the corresponding third and fourth columns. Therefore, the combination of the six columns of regression results can reflect that the development of digital finance can promote enterprise innovation through increasing R&D investment.

In order to test whether the impact of digital financial development on enterprise R&D investment and innovation has continuity, this paper use the lagged one period value of digital financial development indicators and the lagged one period value of all control variables, and then regress equations 1-3 again. The results found that the coefficients of DF_{jt} and $lnRD_{ijt}$ are still significantly positive, indicating that there is a continuity of the impact of digital financial development on promoting innovation through increasing R&D investment of enterprises.

5. Discussion

The results of the benchmark regression indicate that digital financial development can promote firm innovation by increasing firms' R&D investment. We next analyze the internal and external transmission mechanisms through which digital financial development increases firms' R&D investment.

5.1. Internal mechanisms

In terms of internal mechanisms, the easing of financing constraints and the lowering of financing costs generated by digital finance can affect R&D investment by firms in a number of ways. On the one hand, as part of the enterprise's operating costs, the reduction of financing costs will also increase the enterprise's operating profits, thus accumulating capital resources for R&D investment. On the other hand, the easing of credit constraints increases an enterprise's liquid assets, which can be used more flexibly for R&D and innovation.

In order to test the internal transmission mechanism of R&D investment of enterprises affected by the development of digital finance, this paper constructs the following regression equations.

$$\ln TP_{ijt} = \alpha_0 + \alpha_1 DF_{jt} + \theta Controls + \varepsilon_{ijt} \tag{4}$$

$$\ln RD_{ijt} = \beta_0 + \beta_1 \ln TP_{ijt} + \beta_2 DF_{jt} + \theta Controls + \varepsilon_{ijt} \tag{5}$$

$$\ln FC_{ijt} = \gamma_0 + \gamma_1 DF_{jt} + \theta Controls + \varepsilon_{ijt} \tag{6}$$

$$\ln RD_{ijt} = \lambda_0 + \lambda_1 \ln FC_{ijt} + \lambda_2 DF_{jt} + \theta Controls + \varepsilon_{ijt} \tag{7}$$

Where the variable $\ln TP_{ijt}$ is the logarithm value of total profit (yuan), $\ln FC_{ijt}$ is the logarithm value of the firm's current assets, both of which are the mediating variables of the internal transmission mechanism, respectively. Equations 4 and 5 test the internal transmission mechanism of operating profit, while equations 6 and 7 test the internal transmission mechanism of liquid assets.

Table 2. Regression Results of Internal Transmission Mechanism.

	operating profit		liquid assets	
	operating profit	R&D Investment	liquid assets	R&D Investment
DF_{jt}	0.144** (2.40)	0.499*** (7.56)	0.070** (2.64)	0.497*** (7.67)
$\ln TP_{ijt}$		0.050*** (7.34)		
$\ln FC_{ijt}$				0.275*** (19.58)
control variables	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes
R ²	0.606	0.509	0.793	0.509
Obs	23253	15308	25983	15308

Note: Numbers in brackets are t-values. *, **, *** denote statistical significance at the 0.1, 0.05, and 0.01 levels, respectively.

In Table 2, the first and second columns present the results of regressions of 4 and 5 respectively, testing the operating profit transmission mechanism. The result in the first column of the regression shows that the coefficient of DF_{jt} is significant positive, indicating that the development of digital finance helps to increase the operating profit of enterprises. The results of the second column regression shows that the coefficient of $\ln TP_{ijt}$ is significantly positive, indicating that the operating profit can increase the enterprise R&D investment. The coefficient of DF_{jt} in second column is still significantly positive, but the value of the coefficient is weakened compared with the corresponding results of the benchmark regression in Table 1, indicating that part of the effect is transmitted through operating profit. The combined results of the first and second columns indicate that operating profit is one of the internal transmission mechanisms of digital financial development to increase enterprise R&D investment.

Similarly, the third and fourth columns are the regressions of 6 and 7 respectively, testing the transmission mechanism of liquid assets. The result in the first column of the regression shows that the coefficient of DF_{jt} is significantly positive, indicating that the development of digital finance

can increase the liquid assets of enterprises. The results of the fourth column of regression shows that the coefficient of $lnFC_{ijt}$ is significantly positive, the coefficient of DF_{jt} is still significantly positive, but the value of the coefficient is reduced compared with the corresponding results of the benchmark regression in Table 1. The combined third and fourth columns of the regression suggest that liquid assets are another internal transmission mechanism through which digital financial development increases firms' R&D investment.

5.2. External mechanisms

Digital financial development can also provide incentives for firms to invest in R&D from the external mechanisms. Similar to traditional finance, digital finance can contribute to regional economic growth and increase local tax revenues. Local economic development is an important source of fiscal spending, including spending on science and technology and human capital education. On the one hand, government spending on science and technology not only directly creates a source of subsidies for R&D, but also brings about indirect positive externalities, both of which contribute to the increase in R&D investment by enterprises. On the other hand, investment in education can form the scale of human capital to optimize the conditions for enterprise R&D, thus providing incentives to increase R&D investment.

In order to test the external transmission mechanism of digital finance development affecting enterprise R&D investment, this paper constructs the following regression equations.

$$lnGR_{jt} = \alpha_0 + \alpha_1 DF_{jt} + \theta X_{jt} + \varepsilon_{ijt} \tag{8}$$

$$lnRD_{ijt} = \beta_0 + \beta_1 lnGR_{jt} + \beta_2 DF_{jt} + \theta Controls + \varepsilon_{ijt} \tag{9}$$

$$lnGH_{jt} = \gamma_0 + \gamma_1 DF_{jt} + \theta X_{jt} + \varepsilon_{ijt} \tag{10}$$

$$lnRD_{ijt} = \lambda_0 + \lambda_1 lnGH_{jt} + \lambda_2 DF_{jt} + \theta Controls + \varepsilon_{ijt} \tag{11}$$

Where the variable $lnGR_{jt}$ is the logarithmic value of the city's financial expenditure on science and technology (10,000 yuan), $lnGH_{jt}$ is the number of university students in the city (person), which is used to measure the scale of human capital, and both of them are the mediating variables of the external transmission mechanism. Equations 8 and 9 test the external transmission mechanism of financial science and technology expenditures, and equations 10 and 11 test the external transmission mechanism of human capital scale. The data samples of equations 8 and 9 are city panel data, so the set of control variables X_{jt} are also city-level variables, including the following: $lnPGDP_{jt}$ logarithmic value of urban GDP per capita (yuan/person); $lnDP_{jt}$ urban population density (persons/km²).

Table 3. Regression Results of External Transmission Mechanism.

	financial science and technology expenditures		human capital scale	
	financial science and technology expenditures	R&D Investment	human capital scale	R&D Investment
DF_{jt}	2.681*** (18.40)	0.328*** (4.56)	0.192** (2.21)	0.539*** (8.14)
$lnGR_{jt}$		0.064*** (6.43)		
$lnGH_{jt}$				0.485** (2.67)
control variables	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes
R ²	0.757	0.493	0.468	0.485
Obs	2529	15308	2529	15308

Note: Numbers in brackets are t-values. *, **, *** denote statistical significance at the 0.1, 0.05, and 0.01 levels, respectively.

In the regression test of external transmission mechanism in Table 3, the first and second columns show the regression results of equations 8 and 9 respectively, which test the transmission mechanism of fiscal science and technology expenditures. The first column shows that the coefficient of DF_{jt} is significantly positive, indicating that the development of digital finance can promote the increase of financial and scientific and technological expenditures. The second regression result shows that the coefficient of $\ln GR_{jt}$ is significantly positive, which indicates that the financial science and technology expenditure can increase the R&D investment of enterprises; the coefficient of DF_{jt} is still significantly positive, but the value of the coefficient is reduced compared with the corresponding result of the benchmark regression in Table 1. The regression results of the two columns indicate that the financial and scientific and technological expenditure is one of the external transmission mechanisms of the digital financial development to increase the R&D investment of enterprises.

The third and fourth columns show the regression results of equations 10 and 11, respectively, which use the number of college students as a measure to test the transmission mechanism of urban human capital scale. The third column shows that the coefficient of DF_{jt} is significantly positive, indicating that the development of digital finance can increase the size of urban human capital. The fourth regression result shows that the coefficient of $\ln GH_{jt}$ is significantly positive, indicating that the human capital scale can increase the R&D investment of enterprises; the coefficient of DF_{jt} is still significantly positive, but the value of the coefficient is reduced compared with the corresponding results of the benchmark regression in Table 1. The combined results of the third and fourth columns indicate that the human capital scale is another external transmission mechanism for the increase of R&D investment in enterprises by the development of digital finance.

6. Summary

The rapid development of digital finance has benefited the human economy and society in all aspects and become an important factor to promote economic development. This paper closely follows this background and studies the impact of digital finance on enterprise R&D investment and innovation. By matching the city-level digital financial development indicators measured by the Digital Finance Research Center of Peking University with the CSMAR database of listed companies to construct the research sample, this paper finds that the development of digital finance can promote R&D and innovation of enterprises by increasing their R&D investment. This paper finds that digital financial development affects R&D investment of enterprises through the internal transmission mechanism of increasing operating profit and liquid assets, and the external transmission mechanism of increasing the city's financial expenditure on science and technology and the scale of human capital.

R&D innovation is the main source of enterprise competitiveness at the micro level, and it is the inherent requirement of economic structure optimization at the macro level. Therefore, the research in this paper generally shows that digital finance is favorable to long-term economic growth. Theoretically, the research in this paper further supplements and improves the research of digital financial development on enterprise innovation, and deepens the understanding of the influence process; practically, the research in this paper can provide the basis for the formulation and implementation of the management policy related to the linkage between digital finance and R&D innovation.

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