

# Research on the impact of digital finance on the innovation performance of enterprises

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## Abstract

**Purpose** – The purposes of this paper are to analyze whether digital finance can contribute to enterprises' innovation performance and to determine the mediating effect of government subsidies.

**Design/methodology/approach** – This paper empirically examines the impacts of digital finance on enterprises' innovation performance by looking at Chinese companies listed on the SME and GEM boards from 2011 to 2018 to build an econometric model to test our hypotheses. The mediating effect of government subsidies, the moderating effect of financial constraints are examined, as well as shareholding of the largest shareholders in each selected company and the asset-liability ratio.

**Findings** – The results show that digital finance has a significant promotional effect on firms' innovation performance and that government subsidies play a partial mediating role in digital finance's contribution to firms' innovation performance. In addition, financial constraints and the shareholding of the largest shareholders in each selected company have a negative moderating effect on the relationship between government subsidies and firms' innovation performance. On the contrary, the asset-liability ratio is found to positively affect the relationship.

**Originality/value** – There has been limited research to date on the relationship between digital finance and firms' innovation performance, particularly with regard to the extent to which digital finance can influence innovation performance and the mechanisms for doing so. Therefore, it is of great significance to examine the relationship between digital finance and enterprises' innovation performance, which can also provide guidance for both the Chinese government and enterprises.

**Keywords** Digital finance, Government subsidy, Financial constraints, Enterprise innovation performance

**Paper type** Research paper

## 1. Introduction

As the most dynamic part of the market economy, small- and medium-sized enterprises (SMEs) play an indispensable role in promoting Chinese innovation ability. According to the National Development and Reform Commission, SMEs register 65% of China's invention patents over all and more than 75% of its technological patents and 80% of new product research and development patents (Xinhua News Agency, 2019). However, due to their obvious disadvantage in financing compared to larger enterprises, SMEs' innovation activities are often restricted. According to the Peking University Chinese Enterprise Innovation and Entrepreneurship Survey (ESIEC), 69.7% of Chinese SMEs have experienced cash flow shortages during the COVID-19 pandemic (Zhang, 2018). Therefore, finding ways



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to improve the financial markets to alleviate the financial constraints of SMEs and enhance their innovation performance have long been the focus of theoretical and practical circles alike.

Ramlee and Berma (2013) found an imbalance between financial supply and demand under the traditional financing model, which could not solve the financing problems of SMEs. To be more specific, the foremost problem here is the mismatch between supply and demand. The market tends to favor large-scale enterprises with lower risks and greater profitability and such enterprises tend to have less trouble with capital shortages. However, small and medium-sized enterprises with more serious capital shortages find it difficult to obtain sufficient financing. Another problem is the domain mismatch. In particular, mature industries tend to be favored by financial institutions, while many SMEs with huge potentials or those in their growth stage suffer financial rejection and face difficulties in obtaining financing. In recent years, the Chinese government has continuously promoted the innovation of financial service models in order to effectively alleviate the financial constraints of SMEs and digital finance has been a popular model in this regard. Digital finance represents a new generation of financial services combining the Internet, cloud computing, Big Data, artificial intelligence (AI), blockchain and other forms of information technology with traditional financial services (Research Group of Internet Finance Research Center, 2021). According to recent research, as digital finance has a significant part to play in promoting financial inclusion, thus it can alleviate the financial constraints of SMEs more effectively (Lu *et al.*, 2021b).

In recent years, digital finance has attracted notable attention from academic circles. The Digital Finance Research Center of Peking University used the data provided by Ant Financial and Guo *et al.* (2020) constructed the “Digital Financial Inclusion Index” to reflect the development status of Chinese digital finance. Scholars have since widely applied the Digital Financial Inclusion Index in academic research, such as on the impact of digital finance on financing efficiency (Chang *et al.*, 2021), the relationship between digital finance and household consumption (Li *et al.*, 2020), the efficiency of household investments (Guo *et al.*, 2021; Lu *et al.*, 2021a), Chinese household leverage (Wang *et al.*, 2021), the effects of digital finance on pollutants (Wan *et al.*, 2022), rural consumption structure (Yu *et al.*, 2022), manufacturing servitization (Chen and Zhang, 2021), transformation and upgrading of regional industry and the improvement of total factor productivity (Wang and Fu, 2022; Trinugroho *et al.*, 2021). The existing research helps the academic community to further understand how digital finance promotes enterprises’ innovation and economic development. However, the following questions have not been fully answered: What mechanism is used to allow digital finance to contribute to enterprises’ innovation performance? Which environmental factors will influence the impact of digital finance on enterprises’ innovation performance? Further discussion and research are needed to find the relevant answers.

Therefore, this paper intends to systematically explore the relationship between digital finance and enterprises’ innovation performance. Firstly, it matches the Digital Financial Inclusion Index constructed by Peking University with the patent data of SMEs to study the direct impact of digital financial development on enterprises’ innovation performance. Secondly, government subsidies represent one of the most important avenues through which enterprises obtain external funds and thus improve their innovation performance. This paper chooses government subsidies as the mediating variable to determine the mediating effect of such subsidies on digital finance and enterprises’ innovation performance. Finally, environmental variables such as financial constraints, asset-liability ratio and shareholding of the largest shareholder in each selected company have been selected to enable further discussion as to whether the impact of digital finance on corporate innovation performance is affected by such variables.

In general, our research contributes to the fields of both digital finance and innovation performance. From a theoretical perspective, this paper comprises a systematic study of the relationship between digital finance and enterprises' innovation performance. Until now, the literature has examined catalysts and factors contributing to innovation. However, how digital finance influences innovation performance has not been afforded much scholarly attention. Our research will assist those in academia to better understand the internal mechanisms of digital finance affecting enterprises' innovation performance and will enrich the existing research. From a practical perspective, this paper opens up a new path through which enterprises can improve their innovation performance via digital finance and it also provides countermeasures and suggestions for the Chinese government to consider further improve its digital finance development policies.

The structure of this paper proceeds as follows: [Section 2](#) outlines the relevant theories and presents a review of the literature related to digital finance, innovation performance and government subsidies before developing the hypotheses; [Section 3](#) describes the data and methodology; [Section 4](#) presents and discusses the empirical results as well as the robustness test; [Section 5](#) contains further discussion about the mechanisms through which government subsidies influences innovation performance; and, finally, [Section 6](#) concludes the research and proposes possible recommendations for the Chinese government and relevant SME managers as well as admitting limitations and proposing suggestions for future research.

## 2. Literature review

Since the Chinese government placed an emphasis on digital transformation as one of its vital strategies, digital finance has garnered widespread attention from academic circles. Indeed, scholars have conducted much research about the relationship between digital finance and innovation.

### 2.1 Digital finance and government subsidy

Government subsidies are one of the most important means of making up for the financial shortcomings of enterprises seeking to develop and improving the competitiveness and innovation ability of such enterprises, while the development of digital finance can effectively promote local government subsidies. First, from a government social responsibility perspective, optimizing the redistribution of resources is one of the main purposes of government subsidies. Regions with better digital finance development will enjoy more positive spillover effects for the local economy, which is then conducive to improving local government performance. [Borrás and Edquist \(2013\)](#) found that government subsidies can promote enterprises' willingness to engage in technological innovation and R&D investment. Meanwhile, [Qian and Weingast \(1997\)](#) discovered that more subsidies are likely to be provided to local enterprises when local governments perform better, thus representing a virtuous cycle. Second, in terms of enterprises, the more developed their digital finance is, the more they can benefit from local governments. As a result, companies generate more taxes and ultimately improve local governments performance, which also helps companies to expand their own living space. [Lei \(2021\)](#) asserted that the virtuous cycle procedure would bring governments and enterprises much closer and facilitate the acquisition of subsidies. Finally, the development of digital finance makes enterprises' financial demands more public and informationized, allowing local governments to access enterprises' business data and better understand their actual needs. Moreover, it will help local governments to better achieve their subsidy targets ([Tang et al., 2020](#)). Therefore, this study proposes the following hypothesis.

*H1.* The development of digital finance plays a significant positive role in promoting government subsidies.

### 2.2 Digital finance and SME innovation performance

According to financial exclusion theory, some vulnerable groups in economic activities, such as SMEs, vulnerable groups and subjects in rural and remote areas, are unable to obtain normal financial services due to various factors including their own shortcomings in terms of knowledge and competence as well as flaws in the financial system itself, thereby becoming victims of the so-called “80–20” rule in financial activities. Wang and Zhang (2003) found that due to marked financial constraints, the innovation activities of SMEs are often restricted. Here, the development of digital finance could alleviate such constraints faced by enterprises to some extent and may even achieve the purpose of improving the innovation performance of the enterprises themselves. First, according to the long tail theory, the demand curve is represented by the pareto law, with a small proportion of head groups who have sufficient funds. However, there is a large quantity of long-tail groups in the financial markets, with scattered small-scale investors. However, the traditional financial market cannot serve these investors efficiently due to the limitations in technology and relatively high costs, resulting in a certain degree of inefficiency. Digital finance could address the shortcomings of traditional financial services, reduce the threshold and cost of financial services and reach a broader tail group, thereby broadening the financing channels of enterprises, alleviating the financial constraints of enterprises and improving the innovation performance of enterprises. On the other hand, the information asymmetry between enterprises and the external environment is also an important factor affecting their financing (Guo *et al.*, 2016). Digital finance relies on Big Data technology to integrate the data of different enterprises, which can help investment institutions to obtain a clearer understanding of the actual demand of enterprises, to effectively relieve the information asymmetry and to ultimately improve the willingness of institutions to invest. In general, digital finance can ease the financial constraints of enterprises and further improve their innovation performance. Bearing in mind the analysis above, this research proposes the following hypothesis:

*H2.* The development of digital finance has a significant positive effect on the innovation performance of SMEs.

### 2.3 The mediating effect of government subsidies between digital finance and enterprises' innovation performance

Government subsidies are a means of state support for important industries and enterprises. To date, studies have put forward three different views towards the relationship between government subsidies and enterprises' innovation performance. The first is that government subsidies have a positive effect on firms' innovation performance. Innovation is characterized by high risk, high cost and high uncertainty. Thus, government subsidies including direct transfer payments or indirect tax reductions can ease the pressure on R&D. Myers *et al.* (1984) claimed that government subsidies could effectively alleviate the financial constraints of enterprises. In addition, with the help of digital finance, subsidies can be made more appropriate for their recipients, even allowing innovative enterprises to free themselves of financial constraints. The cost of the initial innovation would be gradually amortized and this may even promote the spontaneous innovation activities on the part of enterprises. Furthermore, according to signaling theory, government subsidies send out a positive signal that the companies and industries being subsidized have bright prospects (Wolf and Reinthaler, 2008; Sopha *et al.*, 2016; Sun *et al.*, 2019). With such tacit government recognition, the research and development risk can be lowered, the scale of innovation can be expanded and the transfer of innovation achievements can be accelerated (Almus and Czarnitzki, 2003). However, the second view prevalent in the literature conveys the contrasting opinion that government subsidies have a negative impact on enterprises' innovation performance. In particular, it was argued by Zhao *et al.* (2018) that government subsidies have

a “crowding out effect” on the original funds of enterprises. That is, government subsidies will replace or “crowd out” the capital investment originally earmarked for innovation, resulting in an excessive dependence of enterprises on government subsidies and may even encourage cheating behavior on the part of enterprises, which is not conducive to the improvement of enterprises’ innovation performance. The third view presented in the literature so far is that the effect of government subsidies on enterprises’ innovation performance is nonlinear. According to this view, moderate government subsidies can improve enterprises’ innovation performance, but excessive government subsidies will have a negative impact on enterprises’ innovation (Liu *et al.*, 2019; Yi *et al.*, 2021).

Based on the analysis above, the development of digital finance is an important factor affecting government subsidies. If SMEs use government subsidies for activities other than R&D courtesy of the convenience offered by digital finance and the local government lacks effective supervision over the use of funds, in this case, government subsidies would not play an intermediary role connecting digital finance and innovation performance. If SMEs want to realize sustainable development through technological progress, whether through becoming innovative enterprises actively in their own development strategy or becoming passive innovative enterprises under the guidance of the local government, then they must strictly use the subsidies for R&D activities. Under such circumstances, government subsidies will play a mediating effect between digital finance and SMEs’ innovation performance. Taking into account the above analysis, this research proposes the following two alternative hypotheses:

- H3a.* Government subsidies play a mediating role between digital finance and SMEs innovation performance.
- H3b.* Government subsidies do not play a mediating role between digital finance and SMEs innovation performance.

### 3. Methodology

#### 3.1 Sample selection and data sources

SMEs’ financing has long been a hotly debated issue in academic circles. This research selects Chinese A-share listed companies on the SME Board and GEM Board as samples, for the years ranging from 2011 to 2018. Patent numbers, financial data and other micro data are obtained from the China Stock Market Accounting Research Database (CSMAR). Meanwhile, digital financial data are acquired from the report compiled by The Digital Finance Research Center of Peking University (Guo *et al.*, 2020).

In addition, samples needed to meet various requirements. First, listed companies with “ST”, “\*ST”, “PT” have been excluded. Second, companies listed in financial sectors have also been excluded. Third, companies who are listed in B shares and other overseas markets at the same time are not considered. Besides, samples with missing financial data were discarded. In addition, in order to eliminate the influence of extreme values on this study, 1 and 99% of the main continuous variables of the sample were tailed. Overall, 5,972 samples were obtained.

#### 3.2 Variable description

*3.2.1 Dependent variable.* Enterprise innovation performance (INN): The technological innovation activities of an enterprise include three stages: early innovation input; middle-stage innovation output; and commercialization of innovation. Patents, seen as an intermediate achievements of the enterprises’ technological innovation activities, can represent the enterprises’ technological innovation performance to some extent (Acs *et al.*, 2002). Therefore, many existing studies have considered the number of patents granted as an

important proxy variable for a firm's innovation performance. [Zhu and Hu \(2020\)](#) stated that although there are some limitations in using the number of patents to measure enterprises' innovation performance, the number of patent applications is still an effective proxy variable for enterprises' innovation performance in terms of data availability and continuity. Patents are divided into invention patents, utility model patents and design patents. Compared with utility model patents and design patents, invention patents have undergone a more substantial review and overall their innovation quality is higher. Based on existing research and data availability, this study uses the number of invention patent applications to measure innovation performance.

*3.2.2 Independent variables.* Digital finance (DF): The research center for Internet finance of Peking University compiled the Digital Finance Inclusion Index, which is used to measure the degree of development of digital finance at provincial and city levels in China (Hong Kong, Macao and Taiwan are not covered) ([Research group of Internet Finance Research Center, 2021](#)). Based on the data provided by Ant Financial, 33 indicators were selected to construct the "Digital Finance inclusion Index (2011–2018)", reflecting the actual situation in China across three dimensions, namely coverage, depth of use and degree of digital support services on the basis of the establishment method of financial inclusion indicators in the existing literature. As of December 2020, the index covered 31 provinces and 337 cities at prefecture-level and above, providing reliable data support for research in the field of digital inclusive finance. [Chen and Zhang \(2021\)](#) pointed out that the Digital financial Inclusion Index has become an important means through which to study the development of digital finance. Referring to the existing literature, this paper takes this index as a proxy variable for digital finance development.

*3.2.3 Mediators and control variables.* This paper takes government subsidies as the mediator. Referring to the existing literature, the control variables added in this research include: (1) net profit growth rate (NPR), calculated as:  $(\text{net profit of the current period} - \text{net profit of the previous period}) / \text{net profit of the previous period} * 100\%$ ; and (2) financial expenses ratio (FA), financial expenses can reflect various costs incurred by enterprises in the course of financing to a certain extent, which is measured by the proportion of financial expenses against the operating revenue; and (3) capital intensity, represented by the ratio of total assets to the main business income; and (4) degree of integration of chairman and CEO in the given enterprise. If the chairman and CEO of an enterprise are the same person, the variable is set to 1; otherwise, the variable is set to 0.

#### *3.2.4 Moderators.*

- (1) Financial constraints (SA index): The existing research mainly uses the following four methods to measure the financial constraints of enterprises. The first entails building a model according to the internal cash flow of the enterprise, then measuring the financial constraint of enterprises with the help of model coefficients. The second involves using various corporate indicators to construct relevant indexes such as the KZ index ([Whited and Wu, 2006](#)), the WW index ([Owen et al., 2001](#)) and the SA index. The third revolves around surveying the enterprise's management on the financial situation and gleaning the data therefrom. The last method is text-based measurement by collecting key factors from the annual report. The procedure includes two steps, parsing annual reports and generating the financial constraint variable from the 10 Ks ([Mishra and Ewing, 2020](#)). The construction of the KZ index and the WW index requires the use of some endogenous variables, which may cause errors and the survey data stemming from management's perceptions of financial constraints also has a certain subjectivity. Therefore, the SA index with its strong externality and easy calculation was selected for this research to measure the financial constraints of enterprises. The SA index was proposed and constructed by

Hadlock and Pierce (2010). Herein, the absolute value of the value obtained in the final calculation is taken. The larger the absolute value, the greater the financial constraint. The calculation formula is shown below:

$$SA = -0.737 * Size + 0.043 * Size^2 - 0.04 * Age \quad (1)$$

- (1) Corporate leverage (Lev): Adopting the asset-liability ratio to measure the debt constraints faced by enterprises, which can reflect the degree of leverage possessed by corporate assets.
- (2) Shareholding ratio of the largest shareholder (Mshare): Expressed as the percentage of the number of shares held by the largest shareholder against the total number of shares. A summary of variables in this research is shown in Table 1.

### 3.3 Model setting and empirical strategy

3.3.1 *Standard regression model.* To test the direct impact of digital finance development on an enterprise's technological innovation, the following regression model was constructed:

$$Innovation = \alpha_0 + \alpha_1 DF + \alpha_2 Control + \varepsilon_1 \quad (2)$$

In regression equation (2), the dependent variable is the enterprise's innovation performance (*INN*) and the independent variable is the digital finance index (*DF*, provincial level). The control variables include the net profit growth rate (*NPR*), the financial expense ratio (*FA*), capital intensity (*Capital*) and the degree of integration of chairman and CEO in an enterprise (*Merge*).  $\varepsilon$  is the random error of the model. In the regression analysis, the research also carries out the following processing: considering the time lag of digital finance's impact on enterprises' technological innovation activities, the research conducts a one-stage lag processing on the digital finance index, which can also prevent the problem of endogeneity in the model.

3.3.2 *Mediating effect model.* Based on the methods of Baron and Kenny (1986), this research uses the mediation effect analysis method to test the mediation effect of government subsidies in three steps. The model is set as follows:

Variable type	Variable name	Variable symbol	Variable definition
Dependent variable	Enterprise's innovation performance	<i>INN</i>	Number of invention patent applications granted for the given enterprise
Independent variable	Digital finance index	<i>DF</i>	The development of digital finance in various regions
Control variable	Net profit growth rate	<i>NPR</i>	The increase in net profit compared with the previous year
	Financial expense ratio	<i>FA</i>	Financial expenses/total expenses
	Capital intensity	<i>Capital</i>	Total asset/revenue
	Degree of integration of chairman and CEO in an enterprise	<i>Merge</i>	If the chairman and general manager of an enterprise are the same person, the variable is set to 1; otherwise, the variable is set to 0
Mediator variable	Government subsidies	<i>Subsidy</i>	Subsidies acquired from the government
Moderator variables	Financial constraints	<i>SA</i>	Financing ability
	Corporate leverage	<i>LEV</i>	Degree of corporate leverage
	Shareholding ratio of the largest shareholder	<i>Mshare</i>	Ownership concentration of the largest shareholder

**Table 1.**  
Definitions of variables

$$\text{Subsidy} = \beta_0 + \beta_1\text{DF} + \beta_2\text{Control} + \varepsilon_2 \tag{3}$$

$$\text{Innovation} = \alpha_0 + \alpha_1\text{DF} + \alpha_2\text{Control} + \varepsilon_1 \tag{4}$$

$$\text{Innovation} = \theta_0 + \theta_1\text{DF} + \theta_2\text{Subsidy} + \theta_3\text{Control} + \varepsilon_3 \tag{5}$$

If the coefficient  $\alpha_1$  of DF in model (2) is significantly positive, it indicates that digital finance has a significant promotional effect on government subsidies and hypothesis 1 is true. If the coefficient  $\beta_1$  of DF in model (3) is significantly positive, it indicates that digital finance has a significant promotional effect on an enterprise’s innovation performance and hypothesis 2 is valid. When hypothesis 1 and 2 are proved, we next test the mediation effect of government subsidies through model (2)–(4). If the coefficients of  $\theta_1$ ,  $\theta_2$ ,  $\theta_3$  are all significant in model (4) at the same time, it can be concluded that the government subsidies have a mediating effect on the relationship between digital finance and enterprises’ innovation performance. Then, hypothesis 3a is true, otherwise the opposite hypothesis 3b is accepted.

#### 4. Empirical analysis

##### 4.1 Descriptive statistical features

The descriptive statistical results of the main variables in this research are shown in Table 2. The results show that the mean value of enterprise invention patents is 21.8848, with the maximum value being 998, the minimum value being 1 and the standard deviation being 51.4189. There are significant differences in innovation ability among listed companies. The maximum value of government subsidies is 2028638780, while the minimum value is 0 and the mean value is 26054381.7854. The data shows that the scale of government subsidies obtained by different enterprises varies greatly and the standard deviation is large. The statistical results of the other control variables, such as the net profit growth rate and the integration of two jobs, are close to the existing research results and are within a reasonable range.

##### 4.2 Standard regression results

Table 3 presents the empirical test results for all of the hypotheses. The results in column (1) show that digital finance development (DF) is significantly positively correlated with government subsidies at the level of 1%, that is, digital finance can help significantly to ensure government subsidies reach mre enterprises and hypothesis (1) has been verified. The results in column (2) show that digital finance (DF) is significantly positively correlated

Variables	Obs.	Min.	Max.	Mean	Std.
INN	5,972	1.00	998.00	21.8848	51.4189
LEV	5,972	0.01	1.04	0.3443	0.1811
NPR	5,972	-195.11	40,867.23	7.0688	528.9084
FA	5,972	-0.40	7.27	0.0075	0.1012
Capital	5,972	0.00	289.89	2.3958	4.0841
Merge	5,972	0.00	1.00	0.3056	0.4607
Mshare	5,972	3.00	86.49	32.6565	13.9328
Subsidy	5,972	0.00	2,028,638,780.00	26,054,381.7854	72,700,047.0953
SA	5,972	2.79	5.20	3.6580	0.2210
DF	5,972	0.00	377.73	222.4020	82.5644

**Table 2.** Results of descriptive statistics features



with enterprises' innovation performance (*INN*) at the level of 1%, indicating that the development of digital finance contributes to the improvement of enterprises' innovation performance and thus, [hypothesis 2](#) is confirmed. Columns (1)–(3) verify the mediating effect of government subsidies on digital finance and enterprises' innovation performance. The results show that the column (2) of the digital finance index (*DF*) impacts on the enterprises' innovation performance at a significance level of 1%. After the intermediary variable of government subsidies is added in column (3), the impact of digital finance on the enterprises' innovation performance significantly declines but remains significant. It shows that the government subsidies play a partial intermediary role in the contribution of digital finance to an enterprise's innovation performance. Therefore, [hypothesis 3a](#) is proved.

#### 4.3 Robustness test

In order to enhance the robustness of the conclusions in this research, the robustness test is carried out by removing some influential factors. The relationship between digital finance and enterprises' innovation performance is closely related to the stability of the financial markets and even the global financial situation. Ignoring such factors may have a significant bearing on the robustness of the regression results. The impact of China's stock market crash on the financial markets in 2015 is an event typical of financial market instability. Therefore, this study excluded the impact of stock market crashes on the financial markets, further deleted the samples of subsequent years and limited the period of regression test data to 2011–2014, so as to eliminate the after-effect interference of stock market crashes as much as possible. The test results in [Table 4](#) show that all of which were verified above are still valid.

**Table 3.**  
Regression results for  
digital finance

Variables	(1) Subsidy	(2) INN	(3) INN
Subsidy			1.999E-7*** (0.000)
NPR	1,123.862 (0.522)	0.001 (0.809)	−0.001 (0.661)
FA	102,610,705.833*** (0.000)	47.151*** (0.000)	26.641** (0.03)
Capital	−703,822.341 (0.112)	−1.287*** (0.000)	−1.146*** (0.000)
Merge	−6,045,452.059*** (0.003)	−1.572 (0.276)	−0.364 (0.793)
DF	89,616.618*** (0.000)	0.036*** (0.000)	0.018** (0.02)
Constant	8,881,697.076*** (0.002)	17.094*** (0.000)	15.319*** (0.000)
Obs.	5,972	5,972	5,972

**Note(s):** \*\*\*, \*\* and \* represent significance at the 1, 5 and 10% levels respectively

**Table 4.**  
Results of  
robustness test

Variables	(1) Subsidies	(2) INN	(3) INN
Subsidies			4.183E-7*** (0.000)
NPR	75,124.948 (0.561)	0.074 (0.622)	0.042 (0.762)
FA	52,336,996.990** (0.013)	6.047 (0.803)	−15.846 (0.484)
Capital	−666,057.207 (0.238)	−1.975*** (0.003)	−1.696*** (0.000)
Merge	−5,100,439.137*** (0.002)	0.018 (0.992)	2.152 (0.217)
DF	28,601.563** (0.027)	0.052*** (0.001)	0.040*** (0.004)
Constant	16,045,519.461*** (0.000)	14.736*** (0.000)	8.025*** (0.003)
Obs.	2,633	2,633	2,633

**Note(s):** \*\*\*, \*\* and \* represent significance at 1, 5 and 10% levels respectively

## 5. Further discussion

The empirical results above show that the more developed digital finance is in a region, the higher the innovation performance of the enterprises therein. Besides, government subsidies play a mediating role between digital finance and enterprises' innovation performance, whereby digital finance promotes the government to increase subsidies, in turn stimulating enterprises to carry out more innovation activities. Since the mediating effect of government subsidies on the relationship between digital finance and enterprises' innovation performance has been established, an enterprise's financial status including financial constraints, leverage as well as shareholding ratio of the largest shareholder are the important factors influencing the enterprises' innovation performance. Therefore, this study discusses in more detail the moderating effects of these three factors. Referring to the mediation effect test described above, the research proposes the models (4)–(7) to inspection moderating effects:

$$\text{Innovation} = \alpha_0 + \alpha_1\text{DF} + \alpha_2\text{M} + \sum \text{Controls} + \varepsilon_1 \quad (6)$$

$$\text{Subsidy} = \beta_0 + \beta_1\text{DF} + \beta_2\text{M} + \sum \text{Control} + \varepsilon_2 \quad (7)$$

$$\text{Innovation} = \theta_0 + \theta_1\text{DF} + \theta_2\text{Subsidy} + \theta_3\text{M} + \sum \text{Control} + \varepsilon_3 \quad (8)$$

$$\text{Innovation} = \gamma_0 + \gamma_1\text{DF} + \gamma_2\text{Subsidy} + \gamma_3\text{M} + \gamma_4\text{M} * \text{Subsidy} + \sum \text{Control} + \varepsilon_3 \quad (9)$$

Among these, M is the moderating variable including financial constraints (SA), leverage (LEV) and the shareholding ratio of the largest shareholder (Mshare). The specific inspection steps are, first, verifying the significance of DF coefficients in models (5) and (6). Then, the coefficient in model (7) is verified to prove the existence of the mediation effect. Finally, checking whether the product term M\*Subsidy coefficient in model (8) is checked for significance, so as to find out whether the regulatory effect exists. The results are presented below.

First, financial constraint has a negative moderating effect. Indeed, columns (1) and (2) of Table 5 show the moderating effect of financial constraint (SA). In Column (2), the coefficient of the product of financial constraint and government subsidies (SA\*subsidy) is significantly negative at the 5% level. This shows that financial constraints have a negative moderating effect on the mediating effect of government subsidies. This means that after receiving the same degree of government subsidy, the higher the financial constraint, the lesser the improvement of innovation performance. Alvarez and Crespi (2015) and Wu (2021) asserted that R&D investment is the premise for enterprises to implement innovation and financial constraint has a restraining effect on enterprises' R&D investment to some extent. Enterprises with greater financial constraints have less R&D investment intention, which ultimately leads to lower innovation output. According to the report of the World Bank (Claessens and Tzioumis, 2006), about 75% of Chinese listed companies have financial constraints of varying degrees. Financial constraints are among the important factors restricting enterprise innovation at the present stage, which is also consistent with the research conclusions of Zhang and Jin (2021), Zhang (2021), Yin *et al.* (2019), Li *et al.* (2021) and Amara *et al.* (2016).

Second, leverage has a positive moderating effect. Columns (3) and (4) depict the results of testing the moderating effect of corporate asset-liability ratio. In column (4), the coefficient of the asset-liability ratio of an enterprise plus the government subsidies (LEV\*Subsidy) is significantly positive at the level of 1%, which means the asset-liability ratio of enterprises has a positive moderating effect. When receiving the same level of government subsidies, enterprises with high leverage tend to have better innovation performance. The conclusion

**Table 5.**  
Moderating effect

Variables	(1) INN	(2) INN	(3) INN	(4) INN	(5) INN	(6) INN
Subsidy	1.989E-7 <sup>***</sup> (0.000)	5.360E-7 <sup>***</sup> (0.000)	1.933E-7 <sup>***</sup> (0.000)	-6.023E-8 <sup>**</sup> (0.05)	2.003E-7 <sup>***</sup> (0.000)	4.753E-7 <sup>***</sup> (0.000)
NPR	-0.001 (0.665)	-0.001 (0.677)	0.000 (0.700)	0.000 (0.742)	0.000 (0.683)	0.000 (0.722)
FA	27.933 <sup>***</sup> (0.023)	28.005 <sup>***</sup> (0.023)	-24.661* (0.078)	-33.122 <sup>**</sup> (0.018)	27.301 <sup>**</sup> (0.027)	25.341 <sup>**</sup> (0.037)
Capital	-1.178 <sup>***</sup> (0.000)	-1.178 <sup>***</sup> (0.000)	-0.014 (0.967)	-0.206 (0.541)	-1.171 <sup>***</sup> (0.000)	-1.222 <sup>**</sup> (0.000)
Merge	-0.436 (0.753)	-0.389 (0.779)	-0.003 (0.998)	-0.074 (0.957)	-0.228 (0.869)	0.377 (0.784)
DF	0.024 <sup>***</sup> (0.005)	0.024 <sup>***</sup> (0.005)	0.011 (0.172)	0.013* (0.096)	0.016 <sup>**</sup> (0.040)	0.016 <sup>**</sup> (0.039)
SA	-5.119 (0.114)	-2.737 (0.420)				
SA × subsidy		-9.587E-8 <sup>**</sup> (0.019)				
Mshare					-0.074 (0.112)	0.137 <sup>***</sup> (0.006)
Mshare × subsidy						-7.390E-9 (0.000)
LEV			30.864 <sup>***</sup> (0.000)	19.387 <sup>***</sup> (0.000)		
LEV × Subsidy				5.507E-7 <sup>***</sup> (0.000)		
Constant	32.790 (0.004) <sup>***</sup>	24.378 (0.039) <sup>**</sup>	4.072 (0.103)	8.750 (0.001)	18.152 <sup>***</sup> (0.000)	10.443 <sup>***</sup> (0.000)

**Note(s):** <sup>\*\*\*</sup>, <sup>\*\*</sup> and \* represent significance at the 1, 5 and 10% levels respectively

has also been reached by [Acebo et al. \(2020\)](#) and [Lin and Luan \(2020\)](#). A possible explanation for this is that compared with others, enterprises with higher leverage have a more urgent need for government subsidies and the marginal utility of government subsidies for these enterprises is also higher. According to the marginal utility theory, the marginal contribution of government subsidies to the innovation performance of these enterprises is much higher. Thus, the improvement in the innovation performance of these enterprises is more obvious.

Finally, Mshare has a negative moderating effect. Columns (5) and (6) show the moderating effect of the shareholding ratio of the largest shareholder (Mshare). In Column (6), the coefficient of the shareholding proportion of the first largest shareholder and the Mshare\*Subsidy is significantly negative at the level of 1%. This means that the shareholding ratio of the largest shareholder has a negative moderating effect on government subsidies. That is, after receiving the same level of government subsidies, the higher the proportion of shares held by the largest shareholder is, the lower the improvement of innovation performance. The result accords with that of [O'Connor and Rafferty \(2012\)](#), [Xiong et al. \(2016\)](#), [Zhu and Zhou \(2016\)](#) and [Li and Yang \(2016\)](#). A possible reason is that the phenomenon of having one dominant company is not conducive to the checks and balances among shareholders and management decisions are easily controlled by major shareholders. Moreover, due to the particularity of innovation activities, many major shareholders pursue the maximization of short-term interests and such short-sighted behavior is not conducive to promoting enterprises' innovation performance.

## 6. Conclusion

Looking at the relationships between digital finance, government subsidies and enterprises' innovation performance, this paper exclusively takes Chinese A-share listed SMEs from 2011 to 2018 as samples to discuss and test the impacts of the popularity of digital finance on SMEs' innovation performance from multiple perspectives. The results show that digital finance plays a significant role in promoting SMEs' innovation performance and that government subsidies play a mediating role in the relationship between digital finance and enterprises' innovation performance. This research has also shown that financial constraints and the shareholding ratio of the largest shareholder have a negative moderating effect on government subsidies. Indeed, enterprises with higher financial constraints record have lower innovation performance improvement when they receive the same government subsidies. Besides, the higher the shareholding ratio of the largest shareholder is, the lesser the improvement in innovation performance will be. On the contrary, the asset-liability ratio of enterprises has a positive moderating effect on government subsidies. In particular, enterprises with a high asset-liability ratio record a more obvious improvement in innovation performance after receiving government subsidies.

### 6.1 Practical implications

Based on the conclusions presented above, this paper puts forward various suggestions:

First of all, given that digital finance has a positive effect on enterprises' innovation performance, it is necessary to accelerate the construction of more modern financial infrastructure, promote the balanced development of digital finance and to narrow regional differences. The Chinese government could set up more outlets in the central and western regions to expand the coverage of digital finance. In addition, the government also needs to constantly promote the reform of the financial system and improve the financial system reform. Moreover, it is essential to combine digital finance with traditional financial institutions to expand coverage and help more innovative SMEs to access capital. For example, local digital finance organizations could be set up to cooperate with banks,

enterprises and research institutes to promote the implementation of digital finance projects as soon as possible.

Second, as government subsidies play an intermediary role between digital finance and enterprises' innovation performance, the Chinese government should establish a sound tracking and monitoring mechanism. On the one hand, according to the actual demand of enterprises for digital finance, enterprises who really need funds and have noteworthy potential will be identified and targeted subsidies will be provided to them accordingly, leading to greater improvement in innovation performance. On the other hand, the use of subsidy funds should be further clarified and supervision should be implemented to reduce the occurrence of fraud, so that government subsidies can effectively promote the development of local digital finance and boost the innovation performance of enterprises.

Third, due to the negative moderating effect of financial constraints, enterprises with greater financial constraints will record less improvement in innovation performance after receiving the same government subsidies. However, SMEs have greater financial constraints than large-scale enterprises. Therefore, SMEs should first improve their own financial system first, achieve scientific management and boost their market competitiveness by improving the core competitiveness of products, so as to be able to obtain a higher bank credit line and reduce their financial constraints of enterprises. In addition, in view of the common characteristics of SMEs, the government needs to appropriately increase the intensity of its subsidies and determine a reasonable scale for them. Compared with developed countries in Europe and the United States, China's government subsidies are still at a relatively low level. To do so, the Chinese government should take comprehensive account of the financial capacity, industrial characteristics and technological capabilities of the relevant enterprises.

Fourthly, according to the positive moderating effect of asset-liability ratio, enterprises with a higher asset-liability ratio have more urgent demand for government subsidies and these enterprises tend to record a more obvious improvement in innovation performance after receiving government subsidies. Therefore, targeted subsidies should also be administered through information-based means to assist enterprises who can really benefit from them. However, it should be noted that although the innovation performance of enterprises with a high asset-liability ratio improves more obviously after receiving government subsidies, they also have higher financial risks. Therefore, the government should also take appropriate risk audit measures before providing subsidies to these enterprises to reduce systemic risks.

Finally, considering the negative moderating effect of the shareholding ratio of the largest shareholder, dominant shareholders may be shortsighted and behave irrationally, so enterprises should also establish a moderate supervision mechanism, equity concentration, appropriate supervision of funds for government subsidies, prevent substantial shareholders from using their control to "occupy" government subsidies and ensure the reasonable use of government subsidies to promote enterprises' innovation in practice.

### *6.2 Limitations and suggestions for future research*

Our research has some potential and limitations that cannot be ignored. First, this research has used the number of invention patent applications of enterprises to measure enterprises' innovation performance. However, more and more researchers are beginning to question whether the innovation performance can accurately be measured solely through the number of patents. Thus, future research should adopt more comprehensive measurement methods, including taking R&D intensity and efficiency into account. Second, due to the limited availability of data, this research does not differentiate between types of government subsidies. Therefore, future research could explore the influence of different types of government subsidies on innovation performance, such as R&D subsidies and non-R&D subsidies, national subsidies and provincial and municipal subsidies, pre-subsidy and

post-subsidy, direct cash subsidy and tax rebates subsidy. Meanwhile, the existing research about digital finance is already deep at city level but when we study innovation performance, we examine it at group level and have not subdivided patents into different categories as well as corresponding to city level. Thus, future research could deliver a more detailed examination of heterogeneity here and reach city-specific conclusions.

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