

Environmental Effects and Sustainability Evaluation of China's Digital Finance Development

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Abstract: China has a huge demographic advantage and a relatively well-designed infrastructure, which is why digital finance is developing relatively well in China. A statistical analysis of the data relating to the development of digital finance provides insight into the regional differences in current development and the main factors contributing to such differences. At the same time, it also has important guiding significance for China to promote the development of small, medium and micro enterprises, narrow the gap between the rich and the poor, eliminate poverty and promote the better development of inclusive finance. Therefore, the aim of this paper was to investigate the environmental effects and sustainable development strategies of digital finance development in China based on Gaussian Mixture Model (GMM). This paper proposed an improved GMM algorithm for accurate assessment and calculation of the current development of China's digital economy. In the analysis of environmental effects, this paper selected SO₂ and wastewater as explained variables; in the evaluation of the sustainability of the financial environment, this paper selected the scale of digital finance as the explained variable, and selected overseas investment and per capita GDP as the explanatory variables. The system GMM fitting results in this paper showed that the correlation coefficients for SO₂ and wastewater were -0.256 and -0.235, respectively. This showed that the development of digital finance in China could significantly reduce the discharge of SO₂ and wastewater, and had a good effect on improving the environment.

1. Introduction

Since the "18th National Congress of the Communist Party of China" in 2012, socialism with Chinese characteristics has entered a new era. The Party Central Committee has unswervingly followed the path of green development, changed the previous policy of "focusing on economic construction" and accelerated the pace of economic transformation. In the early stage of reform and opening up, local governments placed too much emphasis on GDP growth, adopted economic policies that were too lenient and preferential for overseas businessmen to "attract investment", and even lowered environmental regulatory standards for overseas businessmen, in exchange for a short-term rapid growth of economic indicators at the cost of serious damage to the ecological

environment. The extensive development model poses a huge threat to the living environment and life and health of residents. Smog, water pollution, soil pollution and other issues have been hot environmental issues that people have paid attention to in the past decade. These pollutions seriously reduce people's quality of life. Over the years, overseas direct investment has indeed injected strong capital and technical support into economic development. Scholars are very concerned about the various impacts of overseas direct investment on the economy and society of the host country. In this paper, hypotheses are made based on the literature on digital finance development and theoretical analysis, and it is constructed that empirical test models including dynamic panel models and their robustness tests and difference in differences models (DID) to test the hypotheses.

Due to online processing and online transactions, digital finance has strong convenience and mobility. Since entering the 21st century, digital finance has been studied by scholars. Chen S used the data of listed companies from 2011 to 2018 and the digital finance index of Peking University to study the causal effect of digital finance on the servitization of manufacturing [1]. Reshetnikova N used digital technology in complex field finance as research material to analyze and consider the financial development issues of digital technology and human interaction [2]. Fan L proposed a non-local image denoising method based on edge similarity measure and adaptive parameter selection, and used it to analyze panel data of digital finance [3]. In order to improve the efficiency of financial support for China's new generation of high-tech industries, Zhang M selected 192 listed companies in China's quantum communication and artificial intelligence concept sectors from the perspective of financial resource input entities (enterprises) as samples. Research on the development of digital finance was carried out [4]. Liu S aimed to analyze the application of digital agricultural technology in the development of agricultural economy and provide reference for related research [5]. However, their analysis of digital finance is limited to economic development in terms of economics, and does not analyze environmental effects.

The analysis of environmental effects has always been the focus of research in engineering and geography. Yu S systematically reviewed the interaction between dissolved organic matter and quiet particles, and discussed the impact of dissolved organic matter on environmental behavior [6]. Huang C conducted research on the environmental effects of solid emissions on urban development [7]. Kristina K analyzed the distribution of plankton in the ocean and the situation of marine pollution by the biological species and density of plankton. His research identified how climate-driven changes in the physical and biological environment affected the seasonal and vertical distribution of zooplankton, which had a significant impact on the flow of energy and nutrients in Marine ecosystems [8]. Janicke T conducted research on the environmental effects caused by human activities, especially focusing on the positive impact of waste utilization on the environment [9]. Wang J studied the environmental impact of pavement construction in China, and he believed that the impact of pavement construction on the environment was particularly huge [10]. However, their research on environmental effects does not take into account the current developments in digital finance, and rarely combines economic and environmental effects.

The main innovations of this paper are as follows: In this paper, combined with the transaction mode and transaction amount of digital finance, GMM regression is used to analyze the environmental effect, and the economic sustainable development of dynamic panel and static panel is also studied.

2. GMM Model

The government's environmental policy can directly act on the source of pollution discharge and play a crucial role in the improvement of environmental quality [11-12]. The positive effect of

economic scale growth on environmental quality depends on whether the income effect caused by scale expansion can promote the government to have more resources and be willing to pay higher costs to formulate strict environmental regulations [13-14].

In the process of GMM regression, due to the multi-dimensional data, the accurate model cannot be well calculated in the Stata software, so this paper optimizes it [15].

Assuming that the GMM consists of K Gaussian models, the probability density function of the GMM is as follows [16]:

$$p(x) = \sum_{k=1}^K p(k)p(x|k) = \sum_{k=1}^K \pi_k N(x|\mu_k, \Sigma_k) \quad (1)$$

σ and the CV calculation formulas are as follows:

$$\delta_i = \sqrt{\frac{\sum_{i=1}^n (DIFII_i - \frac{1}{n} \sum_{i=1}^n DIFII_i)^2}{n}} \quad (2)$$

$$CV = \frac{\delta_i}{\frac{1}{n} \sum_{i=1}^n DIFII} \quad (3)$$

$DIFII_i$ is the digital financial index of i prefecture-level city, \overline{DIFII} is the average value of the province's digital financial index, CV is the coefficient of variation, and n is the number of prefecture-level cities in Anhui Province.

This paper uses β convergence test to study the convergence of digital finance development. According to β convergence, areas with a low level of digital finance development in the initial stage will experience a relatively faster growth rate than areas with a high level of digital finance development. According to different convergence conditions, β convergence is divided into absolute β and conditional β convergence [17-18]. The absolute β convergence test mainly studies whether the backward regions can catch up with the developed regions and eventually tend to the same growth rate. Conditional β convergence test mainly studies whether the development level of each region finally converges to its own equilibrium level.

$$\ln\left(\frac{DIFII_{i,t+1}}{DIFII_{i,t}}\right) = \alpha + \beta \ln DIFII_{i,t} + \varepsilon_{i,t} \quad (4)$$

In the formula, $DIFII_{i,t+1}$, $DIFII_{i,t}$, $DIFII_{i,0}$ represent t+1, t and the 2011 digital financial index of the prefecture-level cities in Anhui Province; α is a constant term; β is a convergence coefficient; $\varepsilon_{i,t}$ is a random disturbance term. If $\beta < 0$, it indicates that there is convergence [19].

To investigate the spatial relevance of digital financial development, this paper uses the Moran and Geary indices to detect it. Before calculating these two indices, a weight matrix needs to be constructed. The setting of the weight matrix is:

$$e_{ij} = \begin{cases} \frac{1}{|\bar{Y}_i - \bar{Y}_j|}, i \neq j \\ 0, i = j \end{cases} \quad (5)$$

$$\bar{Y} = \frac{1}{T_1 - T_0 + 1} \sum_{T=T_0}^{T=T_1} Y_{i,T} \quad (6)$$

T_0 and T_1 are the beginning and end of the sample studied in this paper, that is, in 2011 and 2018, respectively, and $Y_{i,T}$ is the per capita GNP of prefecture-level city i in year T . In order to reduce the error, the weight matrix is normalized, and after normalization, the weight matrix is W_{ij} [20].

3. Environmental Effects of China's Digital Finance Development

3.1 Model Setting

This paper uses the panel data of 30 provinces and cities in China from 2004 to 2017, with a long time span, which meets the needs of using dynamic panel data models. Therefore, a dynamic panel data model will be used to test the problem in this paper, in order to make the estimates more reasonable and valid [21].

In general, the model for studying the relationship between trade and the environment is:

$$\ln P_{i,t} = \alpha + \beta \ln P_{i,t-1} + \gamma E_{i,t} + X'_{it} \varphi + \mu_i + \varepsilon_{it} \quad (7)$$

Formula 7 is the basic formula. All variables except trade openness are in logarithmic form, and the coefficient of the variable represents the elasticity of the explained variable to the explanatory variable. In the formula, $P_{i,t}$ represents the pollutant emission of the i -th province in the t -th year; $P_{i,t-1}$ is the first-period lag term of the explained variable; $E_{i,t}$ is the main explanatory variable of this paper, representing the digital financial trade volume; X'_{it} is other control variables.

3.2 Variable Selection and Data Description

According to the model, the data are processed on the original basis (except for the export trade openness data). Table 1 shows the main variables and their meanings in the environmental effect model.

Table 1: Variable meaning and sample size

variable name	Variable meaning	Number of samples
E	Digital financial trade volume	400
lnFDI	foreign direct investment	400
lnGDP	GDP per capita	400
ln(K/L)	capital-labor ratio	400
ln(INVEST)	pollution control investment	400
ln(DENSITY)	Population density	400
ln(SO ₂)	SO ₂ emissions	400
ln(WATER)	Wastewater discharge	400
ln(COD)	Biochemical Oxygen Demand Emissions	400

3.3 Evidence and Results

In order to confirm the dynamic impact of pollution emissions and address the model's endogenous issue, this paper uses the commands in Stata 14.0 to perform systematic GMM regression on the dynamic panel, and also shows the results of the other two regression methods to compare the advantages of GMM. The overall fitting results of the model are shown in Table 2.

Table 2: Model fitting effect

	OLS		FE		GMM	
	SO ₂	waste water	SO ₂	waste water	SO ₂	waste water
number of provinces	30	30	30	30	30	30
R ² /Sargan test	0.964	0.992	0.845	0.795	0.678	0.758

On the whole, export trade has significantly suppressed sulfur dioxide emissions. This is mainly attributable to the scale effect brought about by the rapid growth of export scale, which exceeds the improvement effect brought by the structural effect; for wastewater indicators, the scale effect is small, and the impact of the lag term on the current discharge is smaller than that of sulfur dioxide. This also reflects that the pollution period of wastewater is shorter than that of sulfur dioxide, so in the long run, the export is still promoting the emission of sulfur dioxide, while the wastewater is already in an improved state with the improvement of the structural effect.

The robustness of the benchmark regression results in Table 2 will be tested by adding control variables and transforming dependent variables.

Table 3: Robustness tests

	SO ₂		waste water		biochemical oxygen demand
	1	2	3	4	
E	-0.225***	-0.106**	-0.306***	-0.256***	-0.459***
Sargan test	0.715	0.678	0.779	0.751	0.683

*** means significant at 1% significance level, ** means significant at 5% significance level, 1 and 3 are the results after increasing population density and pollution control investment.

As shown in Table 3, from the perspective of the two indicators of sulfur dioxide and wastewater, adding the two control variables of population density and pollution control did not have much impact on the sign and significance of the export trade openness coefficient. The absolute value of the economic elasticity of pollution emissions to trade openness is between 0.106 and 0.306, which indicates that the benchmark regression results are robust. The increase in population density will significantly reduce sulfur dioxide emissions, which may be because there are fewer heavily polluting enterprises in densely populated areas, and industrial sulfur dioxide emissions will naturally decline; the increase in population density will lead to a significant increase in wastewater discharge. This is because the population increase brings a large amount of life wastewater. It is seen that the addition of pollution control investment does not work for the reduction of the two pollutants, which reflects from the side that there are obvious problems in environmental governance in China's provinces, and the input-output efficiency is low. As far as China's current situation is concerned, it is often the provinces that do not carry out treatment and investment according to their actual pollution conditions, but are passively driven by policies. For example, when the province is going to hold large-scale events, such as the Olympic Games and the SCO Summit, the local government will increase investment in pollution control in the current period or even in the early stage.

4. Sustainability Evaluation of China's Digital Finance Development

4.1 Regional Convergence of Digital Finance Development

The digital finance global index is shown in Figure 1.

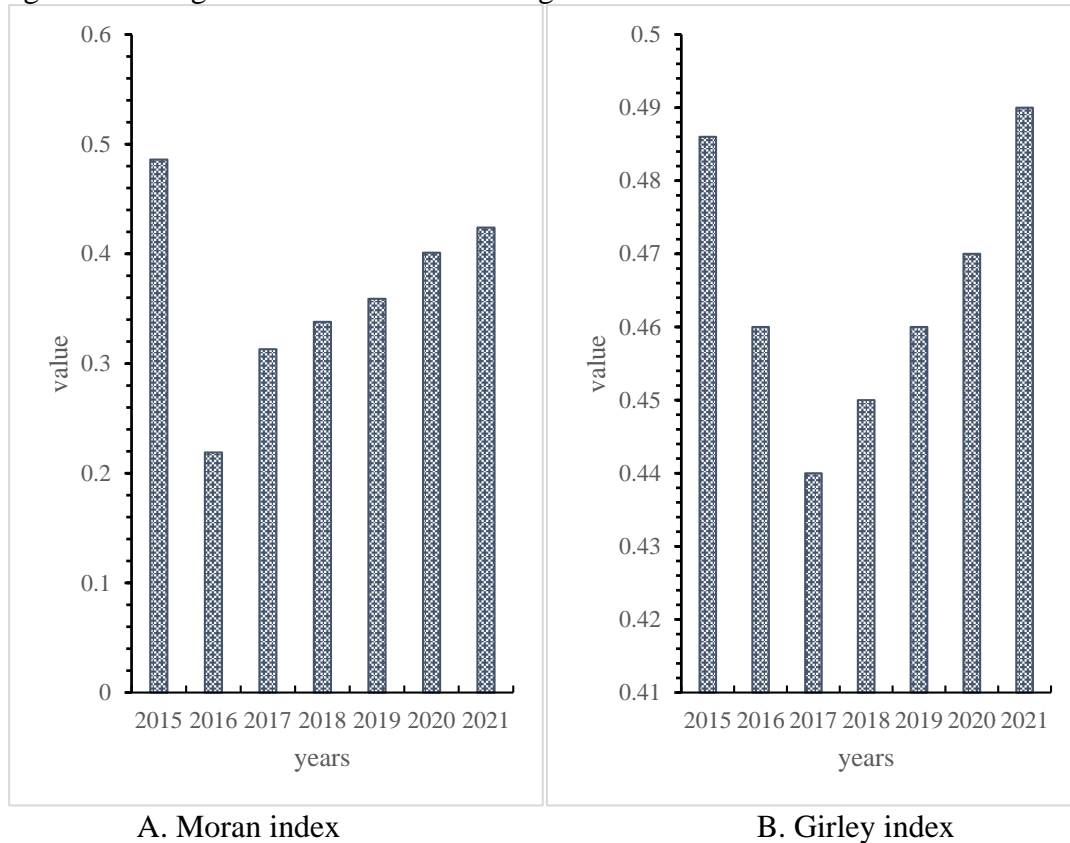


Figure 1: Digital finance value global index

It can be seen from Figure 1(A) and Figure 1(B) that from 2015 to 2021, the global Moran index of digital finance is greater than 0, and the Girley index is less than 1. This indicates a positive spatial correlation; in terms of the significance of the results, except for the 2018 Moran index which was significant at the 5% level, all other years were significant at the 1% level. This shows that the development of digital finance among provinces presents a highly significant positive spatial autocorrelation clustering phenomenon of “high-high” or “low-low” type.

However, judging from the temporal and spatial trends of financial development in Figure 1(B), before 2021, the overall Moran index showed a first decline (2015-2017) and then an increase (2018-2021). But the overall remained between 0.43-0.49. In 2017, however, the Moran index fell sharply to 0.44, a drop of nearly 55% year-over-year. It shows that the development of e-finance in prefecture-level cities in 2017 showed the characteristics of decentralization in space. Since then, the Moran Index has risen but is still nowhere near its 2021 average.

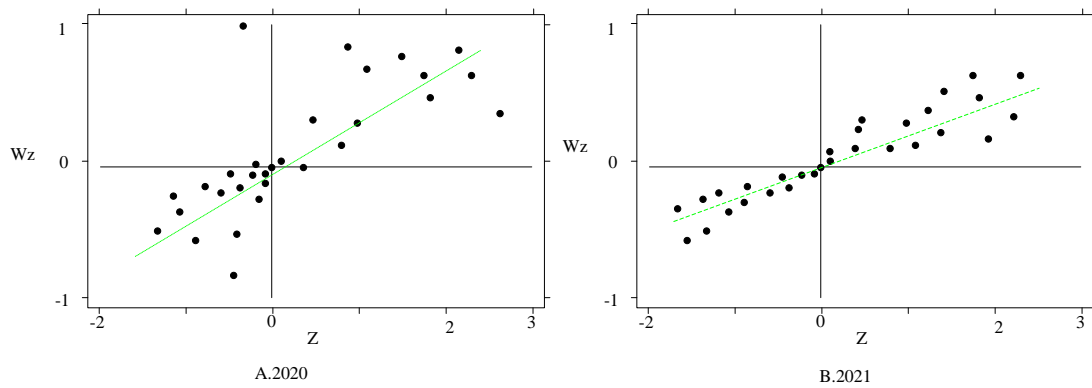


Figure 2: Moran's scatter plot of digital financial index in various cities in Anhui from 2011 to 2018

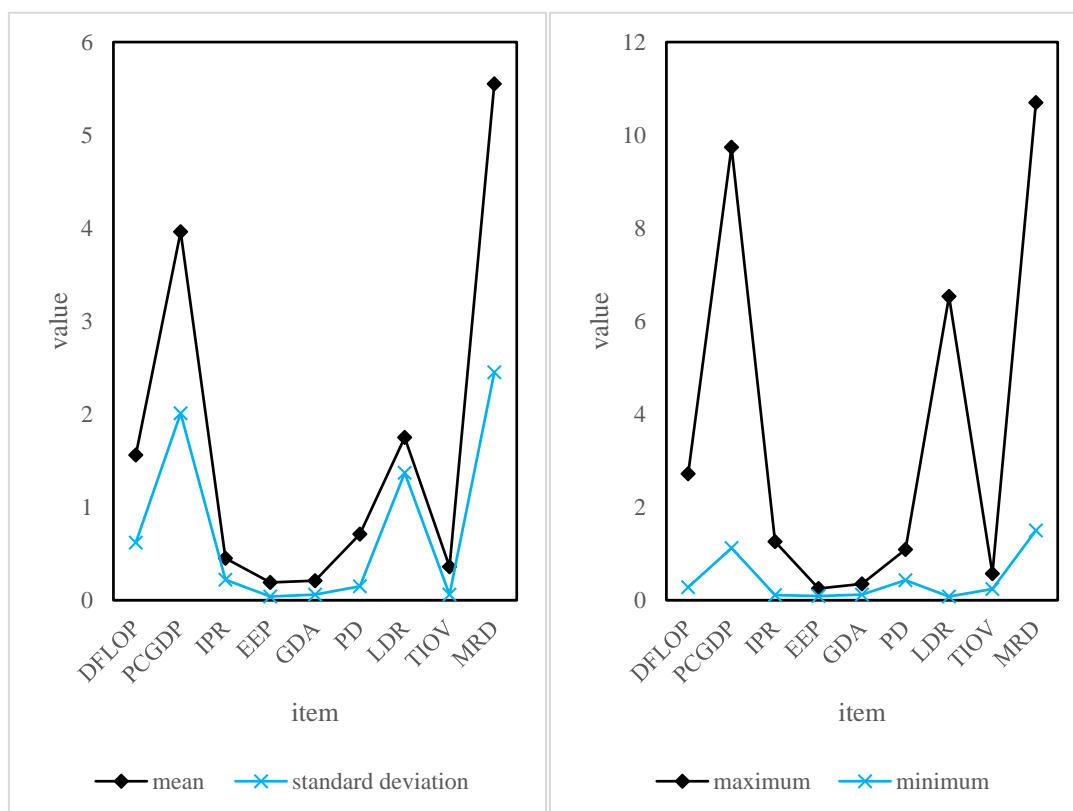
The global Moran index can only reflect the overall spatial correlation, but cannot reflect the spatial correlation of individuals. Therefore, in order to facilitate a more intuitive analysis of the individual spatiality of e-finance development, this paper draws the Moran scatter plot of the e-finance index based on the economic distance weight matrix in 2020 and 2021, as shown in Figure 2(A) and Figure 2(B). As can be seen from Figure 2, the vast majority of Chinese provinces fall into the positive correlation areas of the first and third quadrants. A smaller number of cities are located in the negatively correlated regions of the second and fourth quadrants.

4.2 Data Sources and Descriptive Variable Statistics

Table 4 shows the meaning of the variables and sample size selected for the sustainable GMM regression model of digital finance development in China.

Table 4: Variable meaning and sample size

variable name	Variable meaning	Number of samples	Coefficient of variation
DFLOP	Digital Finance lag one period	150	0.41
PCGDP	Per capita GDP	150	0.53
IPR	Internet penetration rate	150	0.49
EEP	Education expenditure proportion	150	0.20
GDA	Government's degree of anticipation	150	0.29
PD	Population density	150	0.22
LDR	Loan-to-deposit ratio	150	0.80
TIOV	Tertiary industry output value	150	0.19
MRD	Mean road density	150	0.46



A. The case of the sample mean

B. The case of the extreme value of the sample

Figure 3: Descriptive statistics of development variables

As shown in Figure 3, Figure 3(A) represents the sample mean value, Figure 3(B) represents the sample extreme value situation), the average value of the digital financial index is 1.56, the minimum value is 0.27, the maximum value is 2.75, and the coefficient of variation is 0.4. This shows that the digital financial index from 2015 to 2021 is quite different. The average per capita GDP (PGDP) is 39,620 yuan, the minimum value is 11,200 yuan, the maximum value is 97,470 yuan. This shows that the per capita GDP of the samples varies greatly; the Internet penetration rate (Int) has a mean value of 0.452, a minimum value of 0.106, a maximum value of 1.260. It shows that the Internet development level of the sample regions varies greatly; the share of education expenditure indicates that there is little variation in the share of education expenditure in the sample, and also indicates that there is not much variation in education expenditure between prefectures and municipalities overall across years; the average value of the proportion of government expenditure (Gov) is 0.214, the minimum value is 0.118, the maximum value is 0.356, and the coefficient of variation is 0.28. This shows that the proportion of government fiscal expenditure in the sample is not very different; the loan-to-deposit ratio (Loan) of financial institutions has an average value of 0.693, a minimum value of 0.428, a maximum value of 1.08, and a coefficient of variation of 0.21; the mean road density (Road) is 1.567, the minimum value is 0.0832, the maximum value is 6.528, and the coefficient of variation is 0.79. This indicates that the sample grade road density varies widely; the average value of the proportion of tertiary industry output value (ThR) is 0.367, the minimum value is 0.234, the maximum value is 0.567, and the coefficient of variation is 0.18.

4.3 GMM Model Regression Results

As can be seen from Figure 4, factors influencing the development of e-finance, in descending order of influence, i.e. the absolute value of the regression result coefficients, are ranked as follows.

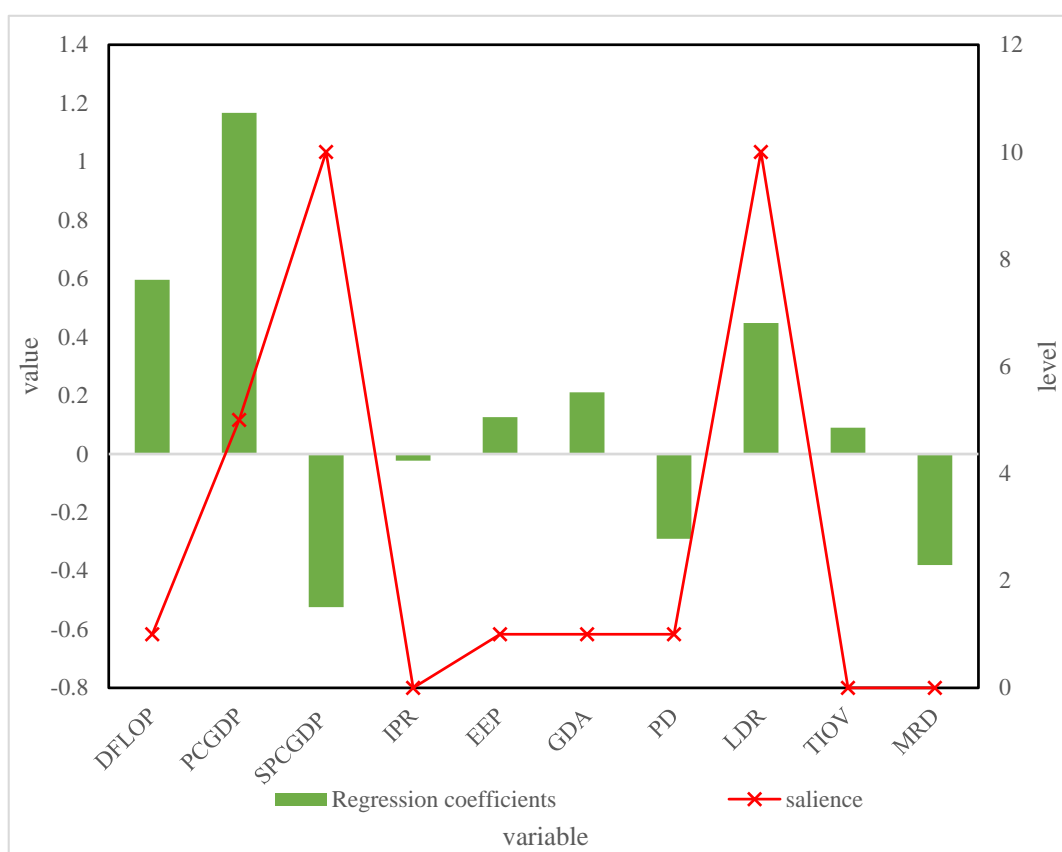


Figure 4: System GMM estimation regression results

5. Conclusions

This study firstly summarized and derived the theory of digital finance and high-quality economic growth on the basis of defining the idea of digital finance and the connotation of such development. This made the fundamental concepts of digital finance and high-quality economic growth clearer and made it easier for relevant academics to do research in related fields. Secondly, it demonstrated the inherent logic of financial progress and superior economic development by beginning with the essence of money. It aided in the objective understanding of the link between digital finance and the high-quality growth of China's economy, supplying relevant ministries with a decision-making framework and financial institutions with a policy framework for conducting digital financial activity. Thirdly, by examining the fundamental mechanisms that underlie digital finance's contribution to high-quality economic growth, pertinent policy departments were able to create frameworks for their respective policies and direct the growth of digital finance in China. Finally, the features of digital finance from many angles, which not only experimentally evaluated the function of digital finance in supporting high-quality economic growth, completely illustrated the influence of digital finance on high-quality economic development.

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