The Interactive Effect of Science and Technology Finance Development and Regional Economic Growth in the Yangtze River Economic Belt: Analysis Based on Panel Vector Autoregressive (PVAR) Model of Interprovincial Data

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Abstract. The interaction effects between science and technology finance development and regional economic growth have received academic and governmental attention in recent years. Based on the data of 11 provinces and cities in the Yangtze River Economic Belt from 2008 to 2017, this paper constructs a panel vector autoregressive (PVAR) model, and analyzes the direct and indirect relationship between Sci-tech finance input, Sci-tech finance output and regional economic growth through Gaussian Mixed Model (GMM) estimation and impulse response function. The study finds that: (1) The regional economic development level has a fluctuant effect on the support of science and technology finance development. (2) The enhancement mechanism of Sci-tech finance output is autonomous. (3) Sci-tech finance output and economic development level have a positive impact on each other. (4) Sci-tech finance output contributes more to economic development than Sci-tech finance input, and its effect is sustainable in the long run. Some practical proposals are put forward on the basis of the conclusions above.

Keywords: Science and technology finance; Regional economic growth; PVAR model.

1. Introduction
China's economy has entered a period of new normal, and highly calls for mid-speed growth with higher efficiency and lower costs. Under the new normal state, technological innovation becomes the motive force and source of regional economic development. However, since innovation activities are always characterized with high risk and high input, it is a challenge for high-tech enterprises to get sufficient fund from traditional financing channels. Science and technology finance (Sci-tech finance) is considered as a financial instrument or policy, which aims to establish an efficient and economical financing environment for technological innovation activities. It can guide financial institutions, such as the banking, securities and insurance industries, to provide comprehensive financial support and services. The Yangtze river economic belt is an important fiscal support zone in China, which can be described as the epitome of China's overall economy. The development path of Sci-tech finance along the Yangtze river economic belt has reference significance for other regions of China. Therefore, at a time of economic transition in China, it is of great value to use 11 provinces’ and cities’ panel data of the Yangtze river economic zone to do further research on the dynamic relationships between Sci-tech finance input, Sci-tech finance output and regional economic growth. We will then give advice on a more reasonable system of science and technology finance on the basis of the empirical conclusions.
2. Literature Review
The academic circle has accumulated a certain amount of research results on the interaction effect between regional Sci-tech finance and economic growth. From the perspective of time dimension, Gu (2018) proved that the influence coefficient of China's Sci-tech finance investment on the quality of economic growth took on the nonlinearly increasing trend, and he also pointed out the temporal heterogeneity between China's Sci-tech finance investment and economic quality. View from space dimension, the development of regional Sci-tech finance is extremely unbalanced, indicating the polarization state of a high level in the eastern coastal areas and a low level in the central and western regions (Huo 2018; Yi et al 2019). Zhang (2018) believed that no matter how different the Sci-tech financial service level is, it could benefit regional economic growth. But Zhang (2019) proposed that Sci-tech finance in the central and western regions had no significant effect on the quality of economic growth, so he recommends to adjust the developing mode according to local conditions. Existing literature mainly focuses on the unidirectional relationship of Sci-tech finance to regional economic growth, ignoring the dynamic interaction between two variables. Therefore, by considering all variables as endogenous, this paper establishes a panel vector autoregressive model to analyze the dynamic interaction effect of Sci-tech finance input, Sci-tech finance output and economic growth through GMM estimation and impulse response function, hoping to provide suggestions for the sustainable economic enhancement pattern of the Yangtze river economic belt.

3. Methodology and Data

3.1. Model Specification
The panel vector autoregression (Panel VAR) model was first proposed by Holtz-Eakin (Eakin,1988) and then refined by Inessa Love (Love,2006). Combining the advantages of the VAR method and panel data analysis, this model is not only fit for studying complex the relationships between variables, but also suited to investigate the impact of one variable to affect other variables brought. This paper aims to carry out multi-regression analysis and obtain the result of mutual effects between Sci-tech finance input, Sci-tech finance output and economic growth of all provinces and cities of the Yangtze river economic belt, so panel vector autoregressive model is set as follows:

$$y_{it} = \beta_0 + \sum_{j=1}^{k} \beta_j y_{i,t-j} + \varphi_{i_t} + \mu_{t} + \epsilon_{i,t}$$  \hspace{1cm} (1)

In the Equation(1), $i$ represents 11 provinces and cities of the Yangtze river economic belt; $t$ represents the year,$k$ represents the lag order;$y_{i,t}$ contains three variables, Sci-tech finance input($\ln OFT$), Sci-tech finance output($\ln IFT$) and the economic development level of provinces and cities along the Yangtze river economic belt($\ln PGDP$) respectively;$\varphi_{i}$ is a spatial effect vector;$\mu_{t}$ is a time effect vector;$\epsilon_{i,t}$ is a random perturbed variable.

3.2. Variable Description
For the dependent variable, taking the heterogeneity of population density and economic structure in different provinces and cities into consideration, it would be biased to use the index of gross domestic product (GDP). Therefore, this paper uses the per capita gross domestic product (PGDP) to objectively evaluate the economic development level of 11 provinces and cities in the Yangtze river economic belt. Sci-tech finance input ($\ln IFT$) and Sci-tech finance output ($\ln OFT$) are two core variables. In order to construct the index system of Sci-tech finance input, based on other scholars' research (Jie 2020), this paper chooses the main data which can reflect investment efficiency from the perspectives of governments, enterprises and financial institutions. Since scientific and technological innovation is a long process, to a certain extent, the achievements of different stages from beginning to the end all reflect scientific and technological innovation ability. Therefore, this paper constructs the index system of Sci-tech finance output from four aspects: research and development capacity, achievement transformation capability, industrialization capability and technology diffusion capability. To avoid arbitrariness of subjective weight, a feasible entropy-weighing method is employed in this paper. The explicit construction system of each indicator is illustrated in the table 1 below.
Table 1. A comprehensive evaluation system for the input and output levels of science and technology.

| Grade I Indexes                  | Grade II indexes                             | Grade III indexes                                      |
|---------------------------------|----------------------------------------------|--------------------------------------------------------|
| Sci-tech Finance input (IFT)    | Government input level                       | Local financial expenditure for science and technology (ten thousand yuan) |
|                                 | Enterprise input level                       | Enterprise R&D investment (ten thousand yuan)          |
|                                 | Financial institution input level            | Loan amount for science and technology (ten thousand yuan) |
|                                 | R&D capacity                                 | Number of domestic authorized patents (Piece)          |
| Sci-tech Finance output (OFT)   | Achievement transformation capability        | Sales revenue of new products (ten thousand yuan)      |
|                                 | Industrialization capability                 | Prime operating revenue of high-tech industries (ten thousand yuan) |
|                                 | Technology diffusion capability              | Technology transaction contract amount (ten thousand yuan) |

3.3. Data Description
Considering the availability of data, the main research object of this study is the sample of 11 provinces and cities along the Yangtze river economic belt from 2008 to 2017. All the raw data is from the official website of China's National Bureau of Statistics, the Annual China Science and Technology Statistical Yearbook, China Financial Statistics Yearbook etc. In addition, all the raw data carries on a logarithm analysis to steady the wave of variance, expressed as $\ln PGDP$, $\ln IFT$, $\ln OFT$. The descriptive statistics of the adjusted variables are shown in Table 2.

Table 2. Descriptive Statistics Variables.

| Variables | Sample Size | Mean     | Std. Dev. | Min    | Max    |
|-----------|-------------|----------|-----------|--------|--------|
| $\ln PGDP$ | 110         | 1.3061   | 0.5838    | -0.1251| 2.5387 |
| $\ln IFT$  | 110         | 16.47219 | 0.9120    | 14.2669| 18.5370| |
| $\ln OFT$  | 110         | 15.7225  | 1.5655    | 11.5843| 18.4772| |

4. Empirical Analysis
According to the general processing steps of the Panel VAR model, the paper processes the data by statistical software STATA 14.0 as follows: (1) Stationarity test of panel data;(2) Lag length selection; (3) GMM estimation;(4) Impulse response function. After these scientific test procedures and methods, we can comprehend the significance of the variables related to themselves and other variables.

4.1. Stationarity Test of Panel Data
Before using the Panel VAR model to measure the dynamic interaction effect between Sci-tech finance input, Sci-tech finance output and regional economic growth, unit root test is a necessarily initial validation method. Non-stationary variables will cause a spurious regression problem. In this study, we implement two common panel unit root tests (LLC and IPS criterion) proposed by Levin (2002) and Kyung (2003) et al. respectively. The testing result shows that under the 1% significant level, after the first difference transformation to the three variables, $d_1 \ln PGDP$, $d_1 \ln IFT$, $d_1 \ln OFT$ all becomes stationary series, which also indicates all three variables are first-order integral sequences. The unit root test results of the three original variables and three processed variables can be found in Table 3.
Table 3. Test Result of Panel Unit Root.

| Variables      | LLC Test | IPS Test |
|----------------|----------|----------|
|                | T Value  | P Value  | W-t-bar Value | P Value |
| ln PGDP        | 1.5486   | 0.9393   | -0.1553       | 0.4383  |
| ln IFT         | -3.4447  | 0.0003***| 0.2526        | 0.5997  |
| ln OFT         | -3.4832  | 0.0002***| -2.0642       | 0.0195**|
| d_{ln}PGDP     | -6.6858  | 0.0000***| -5.0034       | 0.0000***|
| d_{ln}IFT      | -5.6978  | 0.0000***| -2.4846       | 0.0065***|
| d_{ln}OFT      | -8.3722  | 0.0000***| -2.1806       | 0.0146**|

* *** indicates passing the significance test at 1% and 5% levels.

4.2. Lag Length Selection
After confirming the stationary of the data, lag order selection is also of great importance in the process of constructing the Panel VAR model. Too short lag order will reduce the effectiveness of the results, while too long lag order may lead to distortion of sample data. In our study, there are three means simultaneously selected as the criterion of the lag order selection for three adjusted variables, Akaike information criterion (AIC), Schwarze information criterion (BIC) and Hannan-Quinn information criterion (HQIC) as well. The appropriate lag length for this Panel VAR model is presented in Table 4.

Table 4. Selection Order Criterion.

| Lag Periods | AIC       | BIC       | HQIC      |
|-------------|-----------|-----------|-----------|
| 1           | -3.62709  | -2.44472  | -3.15074  |
| 2           | -3.46649  | -1.91410  | -2.84555  |
| 3           | -6.03568* | -4.04509* | -5.24911* |
| 4           | -5.83449  | -3.3162   | -4.86065  |

* * indicates lag order selected by the criterion

With the information given above, we can find that when the lag period is 3, AIC, BIC and HQIC results turn out to be the smallest, so the PVAR (3) model is chosen to explore the dynamic relationship between Sci-tech finance input, Sci-tech finance output and economic growth.

4.3. GMM Estimation
To avoid coefficient estimation bias, “Helmert Procedure” (Arellano and Bover, 1995) is adopted to eliminate the individual fixed effect. Mean-differencing procedure is also utilized to eliminate the time fixed effect at the same time. When the optimal lag order is determined to be 3, we estimate the parameters by GMM method to improve the effectiveness of the coefficient estimation. \( h_{ln}PGDP, h_{ln}IFT, h_{ln}OFT \) respectively represents the variables without individual fixed effect through helmert transformation. \( L_{h_{ln}PGDP}, L_{2 h_{ln}PGDP}, L_{3 h_{ln}PGDP} \) represents the first-order lag, second-order lag and third-order lag of \( h_{ln}PGDP \) respectively. The other two variables are processed in the same way. \( b_{GMM} \) represents estimated coefficient by means of GMM estimation, and \( SE_{GMM} \) is the standard error by way of GMM. The detailed results of this model’s GMM estimation are presented in Table 5.
Table 5. Results of GMM Estimation.

| Variables | $h_{\ln \text{PGDP}}$ | $h_{\ln \text{IFT}}$ | $h_{\ln \text{OFT}}$ |
|-----------|------------------------|------------------------|------------------------|
| $L. h_{\ln \text{PGDP}}$ | 0.948*** (0.145) | 1.475 (1.061) | -1.695 (1.459) |
| $L. h_{\ln \text{IFT}}$ | 0.050 (0.176) | 1.209 (0.885) | 1.648 (1.398) |
| $L. h_{\ln \text{OFT}}$ | -0.031 (0.073) | 0.174 (0.391) | 1.044* (0.633) |
| $L2. h_{\ln \text{PGDP}}$ | -0.172 (0.388) | -3.653* (1.937) | -1.871 (3.305) |
| $L2. h_{\ln \text{IFT}}$ | -0.096*** (0.025) | -0.362** (0.164) | -0.575* (0.294) |
| $L2. h_{\ln \text{OFT}}$ | 0.022** (0.008) | -0.0889 (0.061) | -0.182** (0.089) |
| $L3. h_{\ln \text{PGDP}}$ | 0.057 (0.111) | 1.905*** (0.571) | 1.286 (0.965) |
| $L3. h_{\ln \text{IFT}}$ | -0.042 (0.095) | -0.196 (0.483) | -0.876 (0.786) |
| $L3. h_{\ln \text{OFT}}$ | 0.013 (0.032) | 0.110 (0.162) | 0.356 (0.236) |

a ***, **, * respectively means passing the significance test at 1%, 5% and 10% levels

The two years lagged expenditure of Sci-tech finance input has negative effect on economic growth at the significant level of 1%, while at the significant level of 5%, it plays an active role in economic growth, which indicates how Sci-tech finance benefit the regional economic growth is determined by the efficiency of Sci-tech finance investment and output. The economic development level has a fluctuant influence on the support of Sci-tech finance development, because the two years lagged expenditure of economic growth level has a negative effect on Sci-tech finance input, and the three years lagged expenditure of economic growth level’s effect on the Sci-tech finance input take on the opposite trend instead. One year lagged expenditure of Sci-tech finance input will increase the output in an insignificant way, showing that apart from Sci-tech finance input, the improvement of Sci-tech finance output level of the Yangtze river economic belt may rely on other factors. For example, Jie(2020) pointed out in developed areas, such as Shanghai, human capital can greatly promote Sci-tech finance output. She also discovered that urbanization level is a leading factor for less developed areas.

4.4. Impulse Response Function

Impulse response function is an effective instrument to describe the long-term dynamic impact effects and trajectories among economic variables. Figure 1 shows the corresponding impact-response model for 1 lag VAR of $\ln \text{PGDP}, \ln \text{IFT}, \ln \text{OFT}$ under 95% confidence interval condition, generated by Monte-Carlo with 1000 reps. The test period is fixed for 5 years. The middle solid line of each graph in Figure 1 represents the IRF point estimate sequence, and the other two lines represent the 95% line range. As is demonstrated in Figure 1, the impulse responses value between the economic growth level and Sci-tech finance input is less than zero, which illustrates the tendency of mutual restrain existed between economic growth and Sci-tech finance input in the long run. In addition, technology finance output has a positive influence on the economic growth. Its promoting effect will be sustainable in the long run. The adverse impact of Sci-tech finance input on Sci-tech finance output is volatile. Furthermore, the lower right corner graph of Figure 1 indicates Sci-tech finance output itself has a significant enhancement mechanism in the long term. This conclusion is also supported by Zhang’s (2019) research.
Figure 1. Impulse-responses for 1 lag VAR of $\ln PGDP, \ln IFT, \ln OFT$.

5. Conclusion and Recommendations
Over the use of the panel vector auto regression (Panel VAR) method, this paper performs a research on the dynamic interaction effect between Sci-tech finance and regional economic growth based the data of 11 provinces and cities in the Yangtze economic belt from 2008 to 2017. The study finds that:(1) The economic development level has a fluctuant effect on the support of Sci-tech finance development. (2) The enhancement mechanism of Sci-tech finance output is autonomous and durable. (3) Sci-tech finance output and economic development level have a positive impact on each other. (4) Sci-tech finance output contributes more to economic development than Sci-tech finance output, and its effect is sustainable in the long run. However, it should be noted that our study has several limitations. On one hand, owing to lack of the latest two years’ data on achievement transformation capability, the results may be skewed in some way. On the other hand, control variables should be introduced to improve the model accuracy. According to the present research conclusions, some proposals based on the current economic situation are put forward, in the hope to advance Sci-tech finance evolution and economic development quality of the Yangtze river economic belt. First of all, corresponding policies and regulations should be studied and evolved by provincial governments to pilot and promote a conducive macro environment for Sci-tech finance development of in the Yangtze river economic belt. Second, the government and financial institutions should seriously evaluate the potential of innovative projects, rationally control the scale of investment in Sci-tech finance, and efficiently allocate social advantageous resources to priority areas when encouraging enterprises to participate in innovation activities. Moreover, an integrated and whole-process electronic service system for Sci-tech finance output is quite essential to overcome the information asymmetry and market inefficiency.

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