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Research on the Impact of China S&T Finance on Technology Innovation

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Abstract: This paper studies the impact of S&T finance on technology innovation using a panel model based on the data of China from 2013-2019. S&T innovation is divided into three stages, and S&T finance are divided into public S&T finance and market S&T finance, and the 31 provinces are divided into east, central, west and northeast for analysis. The results show that: in the technological innovation stage, the proportion of listed companies and VC have a positive effect on the number of patents granted, but the ratio of government investment has a negative effect on the number of patents granted. In the stage of technology transformation, different regions have different results, and in most cases, technology finance has no significant effect on technology innovation. At the stage of high-tech industrialization, market-based s S&T finance has a catalytic effect on technology innovation, but the ratio of government investment in S&T has no significant effect on S&T innovation. In different regions and at various stages, S&T finance has different effects on technology innovation.

1. Introduction

In recent years, relying on the investment-driven, resource-driven economic model, China's economy has made world-renowned achievements, but also brought a series of problems, such as high pollution, overcapacity, etc. As the hottest investor and thinker in Silicon Valley, Peter Thiel's binary view of life - the future of humankind, either unique and innovative, or nothing or to decline (0), if only repeat and imitate, from 1 to N, mankind will be faced with a series of problems. China's economy is currently in a 1 - N dilemma, to solve these problems, our country to achieve a breakthrough from 0 to 1, technology innovation is particularly important. Technology innovation needs capital support, and the high risk and high return of Technology innovation can play the function of financial risk diversification, so that the integration of S&T and finance is formed, and S&T finance is created. Some scholars believe that technology finance gives financial support to science and technology innovation and thus improves the ability of technology innovation of enterprises; some scholars believe that the speculative nature of financial capital makes the investment of financial capital less in the early stage of research and development and the investment of large-scale financial capital when the innovation has certain profitability. This may lead to a mismatch between finance and technology innovation, and S&T finance is not conducive to the improvement of technology innovation.

2. Literature Review

Some domestic scholars' research on the impact of S&T finance on science and technology innovation mostly adopts the method of qualitative analysis. For example, Hu Weicheng and Wu Jiangtao (2012), based on the current situation that the synergistic development mechanism between science and technology innovation and S&T finance in China has not yet been formed, proposed to build an operational mechanism for the effective combination of science and technology enterprises and financial capital, create a good docking channel, and improve the financial innovation system at the same time to provide good conditions for the operational mechanism of S&T finance [1]. Duan Shide and Xu Xuan (2011) proposed that the development of S&T finance in China promotes scientific and technological innovation, supports the development of strategic emerging industries in China, and is an important strategic point to accelerate China's economic transformation, so China needs to effectively combine scientific and technological innovation with financial resources, and change from the traditional financial model to the direction of S&T finance [2]. Hong Yinxing (2012) points out that accelerating China's transformation of economic development and building an innovation-driven economy requires not only the support of the government but also the mobilization of the whole society, so it is necessary to promote and cultivate the development of S&T finance and realize the deep integration of science and technology and finance. In terms of empirical analysis, most domestic scholars analyze the impact of finance on enterprises from the perspectives of financial development, most domestic scholars analyze the impact of finance on enterprise innovation from the perspectives of financial development, financial institution system and corporate finance [3]. For example, Xu, Yulian and Wang, Hongqi (2011), based on the time series of financial development and technological innovation in China from 1994 to 2008, analyze the impact of finance on enterprise innovation [4] Zhu (2010), based on the data of 31 provinces in China from 2000 to 2007, analyzed the impact of financial development on technological innovation from the perspective of financial market structure[5].

Foreign scholars have not proposed the concept of technology finance but have mainly studied the impact of finance on technological innovation at the national level, i.e., at the macro level, and at the firm level, i.e., at the micro level. At the national level, foreign studies are as follows: Ana Paula Aria, Natal Barbados (2013) used data from 17 EU countries to build a panel data model to study the relationship between VC and innovation, showing that patent applications are actually influenced by VC and that VC is considered as an endogenous variable that promotes firm innovation and can have a significant impact[6]. Po-Susan Hus, Xian Tan, AnAu (2012) used a large dataset including 32 developed and emerging countries to develop a cross-sectional framework panel data structure model and found that at the 5% significance level, based on the number of innovation outputs, the provision of external financing by stock markets, credit markets has a significant impact on innovation outputs - mainly patents[7]. Chang Wei, Din Yugo, and Wang Japing (2014) developed a VAR model and used the data from 1997-2013 to conduct an empirical analysis. According to the empirical analysis using Chinese data from 1997-2013, it is concluded that both VC and bank loans of financial instruments are conducive to innovation in green real industries and VC is more efficient than bank loans [8]. Muriel Cal-ContGrandness, Sophie Pommet (2009) conducted a professional model association and performance comparison based on the financial association model of Huang and Xu, using the aggregation principle to build an analytical model, and the results showed that the level of support from banks and other financial institutions directly affects the innovation projects of enterprises, has a positive impact and has a Kendall correlation [9].

Conclusions can find that: first, most of the current domestic and international literature studies the impact of finance on science and technology innovation at the national level and at the firm level, but not specifically at the regional level. Due to the vast territory of China and the great differences between regions, it is not enough to analyze this issue only from the national perspective. Therefore, this paper divides the 31 provinces into four regions, namely, East, West and Northeast, according to the degree of economic development, regional factors and the distribution of financial institutions, and uses a panel model to study the impact of finance on science and technology innovation in each region. Second, in terms of the selection of variables for science and technology innovation, most of the literature selects patent-related indicators as proxy variables, but patent application only represents the technological innovation stage in science and technology innovation. This paper draws on Xu Yulian et al. Finally, most of the literature at home and abroad stand in the narrow sense of financial market - credit market, capital market, etc. [10]. To study the impact of S&T finance on science and technology innovation, but it ignores the government's developmental finance to support science and technology innovation, S&T finance has market and policy nature [11], so this paper divides S&T finance into public S&T finance and market S&T finance for relevant empirical study.

3. Research Design

3.1. Indicator Selection and Data Description

Since the functions of S&T finance are different in different innovation stages, S&T finance adopts different operation methods in different innovation stages. Refer to the research of Lu Feng et al., innovation of new products can be divided into 3 stages (Table 1): the incubation stage of new technology or new products, the transformation stage of scientific and technological achievements, and the industrialization stage of high technology[12].

Table 1: Indicator selection at various stages

<table>
<tr><td rowspan="4">Dependent variable</td><td rowspan="4">Innovation level</td><td>Phase I</td><td>Technology incubation stage</td><td>Number of patents granted</td></tr>
<tr><td rowspan="2">Phase II</td><td rowspan="2">Science and technology results conversion stage</td><td>Technology market turnover as a proportion of R&D expenditure in science and technology</td></tr>
<tr><td>The proportion of new product revenue to core business revenue of technology-based enterprises</td></tr>
<tr><td>Stage 3</td><td>High-tech industrialization stage</td><td>Revenue of domestic enterprises in high-tech industry</td></tr>
<tr><td rowspan="3">Explanatory variables</td><td rowspan="3">Technology Finance</td><td>Public Finance</td><td>Government investment funding ratio in science and technology</td><td>Investment in R&D in science and technology as a percentage of government expenditure</td></tr>
<tr><td rowspan="2">Market Finance</td><td>The intensity of capital market support for technology-based companies</td><td rowspan="2">Number of VC institutions</td></tr>
<tr><td>Technology financial services provided by VC</td></tr>
</table>

In the innovation incubation stage the stage is usually a new technology or new product discovered by scientific research institutions, R&D teams of technology-based companies, universities or individuals in the research process, which requires a large amount of investment, mainly in the enterprise's own funds, the first round of financing by VC institutions to some enterprises, and also requires government investment funds to support. At this stage, the main measure of the degree of incubation of an innovative technology or new product is the number of patents; at the stage of transformation of scientific and technological achievements, the enterprise transforms the innovative technology into a new product, and at the same time puts the new product into the market. The stage of innovative technology to new product requires the integration of technology, in this stage, the sale and purchase transactions of technology contracts are more active, and the indicators reflecting the scientific and technological achievements in this stage are the turnover of technology market and the income of new products, which are expressed here as relative numbers. At this stage, VC institutions are the main providers of science and technology financial services, and innovation capital is the main body of VC at this stage. The final stage is the gradual development of new products into new industries, which is the stage of high-tech industrialization. This stage reflects the scale production of new products and the formation of related high-tech industries. High-tech output value is used as the indicator to measure the technological innovation in this stage, and the core business income of domestic enterprises in high-tech industry as the proxy variable of technological innovation in this stage.

In order to reflect the capital market's support for technology innovation, this paper would like to use the relative number of technology-based listed companies (LTCR) to represent the science and technology financial services provided by the capital market, but since it is too late to get the data, there are too many of them, so for the time being, VC is used to measure the market S&T finance. The reason for using relative numbers in the article is: Technology-based listed companies are the carriers of science and technology innovation, which reflect the level of science and technology innovation at the same time as S&T finance, while using relative numbers can better reflect the strength of capital market support for technology-based enterprises, reflecting the S&T finance part. The proportion of technology-based listed companies is the number of technology-based listed companies divided by the number of all technology-based companies. This paper draws on Li Xiyi et al.'s (2008) criteria for defining technology-based listed companies to identify all listed companies in Shanghai and Shenzhen stock exchanges, to obtain the number of technology-based listed companies by region and year. In addition, the amount of VC investment should theoretically be used to indicate the technology finance provided by VC. Due to the availability of data, this paper uses the number of VC institutions (VCI) to reflect VC investment.

The government is the main provider of public S&T finance, and because of the strong externalities of most science and technology innovation in the early stage of R&D, the government is the main investment body at this stage, and the ratio of the government's investment in science and technology R&D is used to the government's fiscal expenditure to represent the government science and technology investment ratio (GSIR).

From the above, it is clear that the transmission mechanism of S&T finance on innovation, the effect is different in various innovation stages, so when choosing the proxy variables of regional innovation, different innovation variables are chosen in different innovation stages. In the first stage, the incubation stage of new technologies, the number of granted patents in different provinces within one year is selected as the proxy variable of regional innovation in this stage; in the second stage, the transformation stage of scientific and technological achievements, since the main feature of this stage is the application of new technologies to new products, the main measurement indicators are the ratio of technology market turnover and the ratio of new product revenue to reflect; in the third stage, the industrialization stage of high-tech, the measurement indicators are The income of domestic enterprises in high-tech industry.

3.2. Data selection

Due to the vast territory of China, the level of science and technology innovation is uneven among regions, and the level of science and technology innovation in the central and eastern parts of each region is significantly higher than that in other regions. To compare the regions, this study divides China into four regions: East, Central, West and Northeast according to the caliber of National Bureau of Statistics of China, and four panel data models: National, East, West and Central for comparative analysis (Table2). The division of East, Central and West is based on the regional division criteria of China's National Bureau of Statistics, and the western province of Tibet is excluded due to incomplete data on Tibet. The research of this paper spans from 2013 to 2019, and the data are obtained from China Statistical Yearbook, China Science and Technology Statistical Yearbook, High-tech Industry Statistical Yearbook and Securities and Futures Statistical Yearbook, CSMAR database and EPS database from 2013-2019.

Table 2: Regional Classification

Regional Classification	Number of Provinces	Provinces included
National	30	/
East	10	Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Hainan
Middle	6	Shanxi, Anhui, Jiangxi, Henan, Hubei and Hunan
West	11	Inner Mongplia, Guangxi, Chongg ing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ninexia and Xinjiang
Northeast	3	Liaoning, Jilin and Heilongjiang

3.3. Model Construction

According to the above theoretical basis it is known that the impact of S&T finance on science and technology innovation is different in various stages of science and technology innovation, so the proxy variables of science and technology innovation in the model are in stages, and it contains 4 variables. At the same time, due to the different development levels of S&T finance in each region, its impact on science and technology innovation is also different. In this paper, panel models are established for the whole country (30 provinces), the east (11 provinces), the central (8 provinces) and the west (11 provinces), and the Tibetan region is excluded because of incomplete data, and the model is as follows.

$$LNSIit = \alpha i + \beta 1it\ LNGLSRit + \beta 2it\ VCTit + uit,\ i = 1, 2, 3..., 30 \quad (1)$$

SIit represents the panel data of proxy variables of science and technology innovation, which contains 4 indicators, i.e., *SIit = (SI1it, SI2it, SI3it, SI4it). SI1it refers to the* number of patents granted in a year in a specific region; SI2it refers to the panel data of the share of technology market turnover in the R&D expenditure of science and technology in a year in a specific region, i.e. the panel data of the share of technology market *SI3it refers to the panel data of the* share of new product revenue in the main business revenue of technology-based enterprises; *SI4it refers to the panel data of the* revenue of domestic enterprises in high-tech industry, representing the industrialization degree of high-tech industry. *glsrit* refers to the panel data of the ratio of government investment in science and technology, representing the public finance component of S&T finance. *vciit* refers to the number of the number of VC institutions, representing the technology financial services provided by VC, and this indicator represents the market finance component of technology finance. The *i in the* national panel data model represents the 29 provinces in the country, and the *i in the* eastern, central, and western panel data models represent the corresponding provinces in the above-mentioned regions; *t* represents the time dimension. To reduce the effect of heteroskedasticity, all indicators are taken as logarithms, i.e., *LNSIit, LNGLSRit, and LNLTCRit*, but the corresponding logarithms cannot be taken because the number of VCs in some provinces is zero in some years.

3.4. Establishment of the Panel Data Model

The main commonly used panel models are mixed-effects, fixed-effects, and random-effects models. The mixed regression model is characterized by the fact that the regression coefficients α and β are the same for any individual and cross-section. In the fixed-effects model, α_i is a random variable and its variation is related to Xit. In the random effects model, α_i is a random variable and its variation is independent of Xit. The establishment of the model was determined by testing.

The model was first tested for the joint significance of individual and random effects to determine whether it used a mixed-effects model, a fixed-effects model, or a random-effects model. The national panel as well as the sub-regional panel were tested by selecting a non-mixed effects model. Due to word limit, results can be requested by email inquiry

The above results illustrate the need to consider both individual and random effects, and the next step is to use Hausman commands for the selection of fixed-effects and random-effects models.

The types of models set according to Hausman test at 10% significance level have been given in the table 3, while the corresponding panel data models are set according to the above results.

4. Empirical Results and Analysis

The regression results are shown in Table 4. From the perspective of the national panel model, the first stage - the technology incubation stage, the proxy variable for technology innovation in this stage is the number of patents granted, and only the number of VC institutions has a significant and positive impact on technology innovation at the 5% and 10% significance levels, indicating that the capital market plays a strong role in promoting the creation of new technology. This indicates that the capital market plays a strong role in promoting the emergence of innovative technologies.

In the second stage - the conversion of scientific and technological achievements, from the perspective of technology market turnover, the S&T finance provided by each entity has a significant impact on scientific and technological innovation. Among them, the proportion of government investment in science and technology plays a negative role in the conversion of scientific and technological achievements, which may be due to the non-structural problems of government research funding or the lag of funding. In terms of the new product revenue ratio, only the number of VC institutions has a significant positive effect at this stage, which may be due to the fact that VC institutions hope to get a faster return on the investment in the first stage and thus have an incentive to promote the transformation of scientific and technological achievements. The lack of significant impact of government funding may be due to the fact that there is no strong externality at this stage and the capital market can instinctively promote the transformation of scientific and technological achievements.

The third stage - high-tech industrialization stage. Government funds and capital market funds both play a significant positive influence, indicating that both the government and the market have incentives to promote high-tech industrialization. The government hopes to promote the benign development of technology through high-tech industrialization, improve technical standards and create more employment and tax revenue through this; the capital market hopes to achieve large-scale production, gradually reduce technology costs and promote technology coverage through industrialization.

Table 3: Results of the Hausman test

	Regional Innovation Proxy Variables	χ Statistics	P-value	Test results
National Panel	Number of patents granted	75.26	0	Fixed effects model
	Technology Market Turnover Share	13.12	0.0014	Fixed effects model
	New product revenue ratio	12.38	0.002	Fixed effects model
	Domestic enterprises high-tech industry income	45.81	0	Fixed effects model
East Panel	Number of patents granted	-41.36	/	Random effects model
	Technology Market Turnover Share	25.85	0	Fixed effects model
	New product revenue ratio	2.47	0.2907	Random effects model
	Domestic enterprises high-tech industry income	4.8	0.0908	Fixed effects model
Middle panel	Number of patents granted	1.03	0.5984	Random effects model
	Technology Market Turnover Share	1.38	0.5014	Random effects model
	New product revenue ratio	3.28	0.1939	Random effects model
	Domestic enterprises high-tech industry income	-3.85	/	Random effects model
Western Panel	Number of patents granted	0.64	0.7246	Random effects model
	Technology Market Turnover Share	3.16	0.2061	Random effects model
	New product revenue ratio	2.8	0.2466	Random effects model
	Domestic enterprises high-tech industry income	5.12	0.0772	Random effects model
Northeast Panel	Number of patents granted	12.76	0.0017	Fixed effects model
	Technology Market Turnover Share	0.15	0.9284	Random effects model
	New product revenue ratio	1.15	0.5637	Random effects model
	Domestic enterprises high-tech industry income	1.44	0.4863	Random effects model

Table 4: Results of Regression

Regional Innovation Proxy Variables		R-side	Government investment funding ratio in science and technology			Number of VC institutions		
			Estimated coefficient	T-statistic	P-value	Estimated coefficient	T-statistic	P-value
National Panel	Number of patents granted	0.4189	0.0142295	0.29	0.775	0.0016449***	2.73	0.007
	Technology Market Turnover Share	0.013	-0.1586137**	-2.25	0.026	0.0028389***	3.31	0.001
	New product revenue ratio	0.2514	0.0069381	0.05	0.961	0.0063656***	3.69	0
	Domestic enterprises high-tech industry income	0.4353	0.083531*	1.73	0.085	0.0017068***	2.91	0.004
East Panel	Number of patents granted	0.2124	-0.0538896	-0.54	0.591	0.0014491***	2.65	0.008
	Technology Market Turnover Share	0.0081	-0.315296**	-2.06	0.043	0.0023544***	2.8	0.007
	New product revenue ratio	0.0732	-0.2003758	-1.16	0.245	0.0018439**	2.07	0.039
	Domestic enterprises high-tech industry income	0.2064	-0.010649	-0.11	0.912	0.0012526**	2.38	0.021
Middle panel	Number of patents granted	0.37	0.0777897	0.66	0.51	0.0115014***	3.44	0.001
	Technology Market Turnover Share	0.0419	-0.0851652	-0.96	0.338	0.0098304***	4.31	0
	New product revenue ratio	0.1805	0.1491488	1.06	0.288	0.0107165**	2.06	0.04
	Domestic enterprises high-tech industry income	0.3127	0.1590535	1.54	0.123	0.008284***	3.07	0.002
Western Panel	Number of patents granted	0.596	0.3094936***	3.91	0	0.0123386***	2.69	0.007
	Technology Market Turnover Share	0.0819	0.0926658	0.76	0.444	0.0065239	0.96	0.335
	New product revenue ratio	0.0016	-0.0203855	-0.19	0.846	0.0029449	0.37	0.712
	Domestic enterprises high-tech industry income	0.5688	0.015589	2.83	0.005	0.2534307***	3.09	0.002
Northeast Panel	Number of patents granted	0.0335	-0.0558125	-0.96	0.351	0.0039373	0.61	0.553
	Technology Market Turnover Share	0.123	-0.1950045	-1.46	0.145	0.0115294	0.98	0.327
	New product revenue ratio	0.2474	-0.3071768	-2.37	0.018	0.0130442	1.14	0.253
	Domestic enterprises high-tech industry income	0.0726	0.0538846	0.46	0.648	-0.0122127	-1.18	0.24

Note: ***, **, * denote the coefficients are significant at 1%, 5%, and 10% level of significance, respectively.

For the East, West and Central Asia, as well as parts of the Northeast, the number of VC institutions all play a significant positive impact on STI in the first stage, with the western panel having the largest impact coefficient, followed by the central, northeastern and eastern regions. This may be due to the great gap between the number of patents granted in the central and western regions themselves and the east, but the gap in the number of VC institutions is relatively small, as shown in the figure 1 below. In addition, government funding in the west also plays a positive role in technology incubation, while government funding for science and technology investment in the rest of the regions does not play a significant role, which may be due to the more developed economies in the east and other regions, where the level of science and technology innovation is higher and the operation of VC institutions is more standardized making the influence of government funding relatively weak.

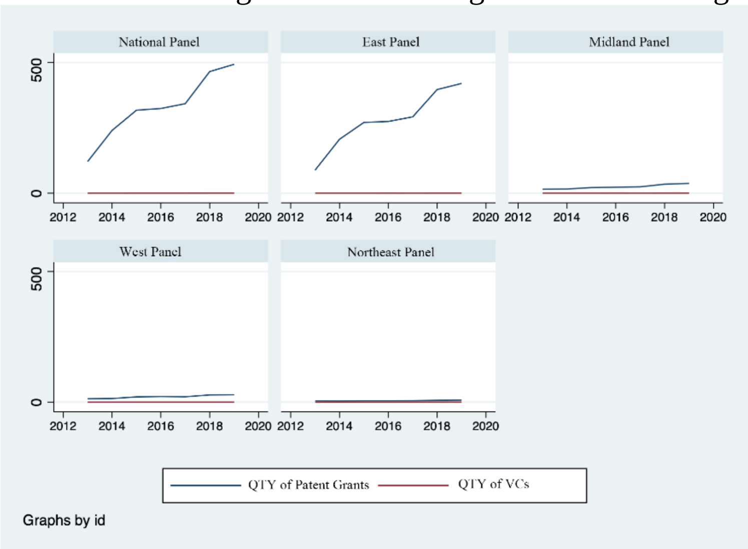

Figure 1: Number of VC and number of granted patents

In the second stage, the number of VC institutions has a significant positive effect on the eastern and central parts of the science and technology market transactions, but the effect of the western and northeastern parts is not significant, which may be due to the higher level of science and technology innovation in the eastern and central regions, and the division of labor of VC institutions in each stage is clearer, so there will be no absence in the link, so it will have a significant effect. In addition, government funds in the eastern region also play a positive and significant role in the transformation of scientific and technological achievements. From the perspective of new product revenue, the results are consistent with the technology market turnover, and only the VC institutions in the east-central region have a positive and significant effect. The low coefficient of decidability of government funding in each region indicates that government funding does not play a more significant role in the second stage, i.e., in the transformation of research results.

In the third stage of high technology production value stage, firstly, VC has a positive contribution to science and technology innovation in this stage in all northeastern regions, from the coefficient is the highest in the central region, followed by the western region, while the lowest in the eastern region, this may be due to the same reason as the first stage. Finally, government capital investment in science and technology has no significant effect on the regions in this stage, this point may be due to the higher incentive of capital market to raise high-tech output value and significantly higher than the government, to which the government has a lower degree of influence in this stage.

In general, public capital and market capital play distinct roles in the three stages of technological innovation, and their roles are different in the four regions of East, West, and Northeast, so specific analysis should be done for each region and specific innovation stage.

5. Conclusions

This paper mainly explores the influence of S&T finance on science and technology innovation, divides science and technology innovation into three stages, and specifically analyzes the mechanism and influence of S&T finance in each stage of science and technology innovation nationwide. However, this paper has come to some opposite conclusions, while on this basis, this paper further divides the country into four regions and studies the influence of S&T finance on science and technology innovation in each region. Through the conclusions obtained at the end of the study, the author believes that, first of all, because of the different levels of economic development from region to region, the government investment funds should be specifically analyzed in science and technology for specific regions. For example, the economic development of the western region is slower and the market capital is weaker, so the government should support the development of such companies more in the western region, while in the eastern region there is no such problem. Second, since the mechanism of the role of S&T finance is different in each stage of science and technology innovation, the impact of S&T finance on science and technology innovation in each stage should be analyzed specifically. In the first and second stages, the government should increase the funding of science and technology investment, while in the third stage, it should increase the number of technology-based listed companies or support the establishment and development of technology-based companies. Finally, from the empirical results, in the second stage of science and technology innovation, most of the regional S&T finance has no significant impact on science and technology innovation, which may be due to the lack of services caused by the unclear positioning of two financial services in this stage. Therefore, science and technology innovation in this stage needs financial services between market-based S&T finance and public S&T finance, such as policy-based finance.

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