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SCIENCE-TECHNOLOGY FUNDING AND URBAN INNOVATION LEVEL: BASED ON THE REGULATORY ROLE OF SCIENCE-TECHNOLOGY POLICY IMPLEMENTATION AUDIT

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Abstract. *This paper selects 37 representative cities in China from 2017 to 2019 as samples, tries to explore the relationship between sci-tech funding and the level of urban innovation, and introduces the audit of sci-tech policy implementation as a regulatory variable to explore the role of sci-tech policy implementation audit in sci-tech funding and the level of urban innovation. The empirical test shows that sci-tech funding has a positive effect on the level of urban innovation. It also finds out that the effectiveness of sci-tech policy implementation audit can regulate the relationship between sci-tech funding and the level of urban innovation. In regional effect test, sci-tech policy implementation audit shows a differential order pattern in the eastern, central and western regions.*
Keywords: Sci-tech funding, Audit of sci-tech policy implementation, Urban innovation level, Urban sci-tech policy of China, National audit

1. Introduction.

Innovation is the lifeblood of national development that is carried out under the support of sci-tech funding. Sufficient funding is the guarantee of continuous innovation. However, good allocation of sci-tech funding needs to be guided by policies. Policy plays a role of coordination and control in the whole innovation activities. Since 2006, China has introduced more and more sci-tech policies, which reflects that the country attaches great importance to innovation.

Some studies show that sci-tech innovation policy can hinder enterprises from improving their innovation performance [1]. Other studies discuss the spatial spillover effects of it [2]. Furthermore, from what aspects can sci-tech policies affect the level of innovation? At present, researches on sci-tech policy and innovation level are mostly limited to the linear influence or take enterprises as subject. There are few researches on the effect of the implementation of sci-tech policy on the relationship between them.

The rest of the paper is organized as follows. Section 2 reviews the literature on sci-tech funding, innovation and audit of sci-tech policy implementation. In Section 3 we propose our hypotheses. Section 4 presents study design and sample selection. Section 5 analyzes the empirical results. Section 6 carries out the robust test. Conclusions and suggestions are summarized in Section 7.

2. Literature Review.

2.1. Science and technology funding and innovation level.

The relationship between sci-tech funding and innovation level can be discussed from two aspects. When the subject is enterprise, some scholars believe that sci-tech funding is positively related to innovation. Bianchi et al. [3] regarded R&D subsidies as dual signals in technological

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collaborations. However, due to industry, ownership and other factors, scholars find a complex nonlinear relationship between them. Szücs [4] explored publicly-funded R&D grants increased own R&D for smaller firms and projects as well as more R&D-intensive firms. Wei and Zuo [5] found that R&D subsidies from the central government worsen the access of subsidized firms to external capital. In contrast, subsidies from local governments serve as a positive signal.

When taking provinces, regions as the research subjects, some scholars directly discuss the impact of sci-tech funding as resources on innovation. Chen et al. [6] believed that there is a strong synchronicity of sci-tech innovation and resources in various regions of China. Min et al. [7] found that technology development efficiency is higher in regions where R&D is more public-focused than average. Other scholars introduce new variables to conduct empirical research. He and Chen [8] built a multi-level linear model to explore the moderating effect of the intensity of sci-tech policy at the provincial level on the relationship between regional innovation resources and performance.

2.2. **Audit of science technology policy implementation.** Different periods and different national conditions give different definitions of sci-tech policy. The connotation of early sci-tech policy always revolved around politics which was classy. With the development of the times, the goals of sci-tech policy should consider economic and social development goals as well as political goals. As an important part of public policy, sci-tech policy plays a coordinating and leading role in the whole scientific activities. Yigitcanlar et al. [9] estimated a multivariate probit model to find that funds policies were more likely to become nationally competitive. Ivus et al. [10] evaluated the impact of India's tax credit scheme and found a sharp increase in firm R&D expenditures and R&D intensity.

The audit of sci-tech policy implementation belongs to the follow-up audit of major national policies and measures implementation. Since 2015, China has carried out follow-up audit and started to issue reports on a quarterly basis in 2016. Zhou and Han [11] found that national audit can improve the value of the enterprise having a certain substitution effect on internal control.

At the same time, in order to improve the national innovation system and speed up efforts to build the country into a scientific and technological powerhouse, the National Audit Office has been paying close attention to the innovation-driven development strategy. In terms of theoretical research, Wang et al. [12] used the method of combining semantic network analysis with social network analysis to analyze the focus and trend of sci-tech policy audit.

To sum up, scholars analyze the relationship between sci-tech funding and innovation levels from macro and micro perspectives. However, there exist some shortcomings: 1) most of the research subjects of sci-tech funding and innovation level are enterprises, and there are few researches on provinces and regions; 2) few factors are considered in the relationship, so new perspectives are needed for further research; 3) the theory and practice of audit sci-tech policy implementation are infancy, and in-depth research is needed. Based on this, we take 37 representative cities in China as subjects to explore the relationship between sci-tech funding, sci-tech policy audit and urban innovation, in order to provide useful suggestions for building an innovation-oriented country.

3. **Theoretical Analysis and Hypotheses.** Sci-tech funding can improve the level of urban innovation. The 14th Five-Year Plan proposes that in the next five years, China will strengthen basic research, strengthen the construction of state key laboratories and improve the level of sci-tech innovation. Based on this, we propose the following hypothesis.

Hypothesis 1: Sci-tech funding is positively correlated with the level of urban innovation.

Audit supervision can be used as a way to strengthen the implementation of policies and help the efficiency of government service. Shi [13] believed that policy audit should focus on the coordination and application of policies economic laws, coordinate policies issued by government, and dynamically track policies. With the continuous expansion of audit scope, some scholars focus on various problems in policy implementation, such as targeted poverty alleviation, revitalization of Northeast China and control of COVID-19. Fan [14] believed that the implementation and release of policy can effectively promote the transformation of achievements in colleges and stimulate innovation vitality. Therefore, audit institutions should carry out the audit of sci-tech policy implementation and play an important role in innovation activities. Based on the preceding discussion, we propose the following hypothesis.

Hypothesis 2: The audit of sci-tech policy implementation has a moderating effect on the relationship between sci-tech funding and urban innovation level.

Innovation activities and processes are affected by regional factors. Innate differences in location conditions make different regions often have huge gap in resources, administration and other aspects. The eastern region has obvious advantages in industrial agglomeration, government scale, human capital, policy update, implementation speed, etc. In the central and western regions, there are few high-tech industries, and the policy support for innovation activities is relatively weak. Thus, we propose the following hypothesis.

Hypothesis 3: The regulating effect of audit on the implementation of sci-tech policy shows regional differences in the central, eastern and western regions.

4. **Study Design.**

4.1. **Samples and data sources.** Our study selects 37 representative cities from 2017 to 2019 as research samples. The explained variable, *innov*, is provided by Capital Academy of Science and Technology Development Strategy that considers not only innovation performance, but also other factors. The explanatory variable, *sci_tech*, is represented by R&D internal expenditure. The regulatory variable, *audit*, is a dummy variable. We use key words to search on the websites of governments or audit institutions. If the information about the above keywords is retrieved, 1 will be assigned; otherwise, the value is 0.

According to the existing research, we select human capital, financial development, foreign investment, average GDP, government scale as control variables. All continuous variables are winsorized at the top and bottom 1 percent to avoid the impact of outliers.

4.2. **Model construction.** In order to verify H1, H2 and H3, we build models as follows and the variables in the equations are specified in Table 1.

$$\begin{aligned} innov_t = {} & \alpha_0 + \alpha_1 sci\_tech + \alpha_2 edu + \alpha_3 finance + \alpha_4 open + \alpha_5 aveGDP \\ & + \alpha_6 gov + \delta \end{aligned} \tag{1}$$

$$\begin{aligned} innov_t = {} & \alpha_0 + \alpha_1 sci\_tech + \alpha_2 audit + \alpha_3 sci\_tech \times audit + \alpha_4 edu + \alpha_5 finance \\ & + \alpha_6 open + \alpha_7 aveGDP + \alpha_8 gov + \delta \end{aligned} \tag{2}$$

4.3. **Method.** Our samples are randomly selected from China and we want to provide reference for others through these 37 cities in microcosm. Therefore, we use random effect model which is a group concept and represents the information or characteristics of a distribution. First, we use Stata15.0 to analyze the panel data from 2017-2019. Then, we examine the impact of sci-tech funding on the level of urban innovation, and the regulatory effect of sci-tech policy implementation audit. After these, we further discuss the space-time factor.

Table 1. Variables in archival analyses

Variable	Code	Definition	
Urban innovation level	*innov*	Innovation index	Actual value
Sci-tech funding	*sci_tech*	Urban R&D internal expenditure	Natural logarithm
Audit of sci-tech policy implementation	*audit*	Whether the website of government or audit institution can retrieve relevant information by keywords	1 – yes 0 – no
Human capital	*edu*	Number of students in colleges/ permanent resident population	Actual value
Financial development	*finance*	Balance of financial institution loan/GDP	
Foreign investment	*open*	Actual foreign capital	Natural logarithm
Average GDP	*aveGDP*	Average GDP	
Government scale	*gov*	Government expenditure	

5. Empirical Results and Analysis.

5.1. Descriptive statistics.

Table 2 lists the mean, standard deviation, minimum and maximum values of the variables. The results show that 64.9% of the 37 cities have carried out the audit of sci-tech policy implementation, and the preliminary conclusion is that some cities have begun to pay attention to the audit. From the perspective of sd, there is a big gap in *sci_tech*, *audit*, *finance* and *gov* in different cities. In terms of max and min values, there are great discrepancies in these 37 cities, such as the capacity of innovation, education and finance, which is largely related to geographical location.

Table 2. Descriptive statistics

Variables	N	mean	sd	min	max
innov	111	0.366	0.0806	0.249	0.613
sci_tech	111	14.60	0.904	12.74	16.74
audit	111	0.649	0.480	0	1
edu	111	0.0525	0.0328	0.00797	0.126
gov	111	7.098	0.785	5.877	9.009
open	111	3.391	1.111	0.00349	5.250
finance	111	1.826	0.663	0.724	4.139
aveGDP	111	11.64	0.273	10.92	12.15

5.2. Regressive analysis.

5.2.1. *Sci_tech funding and urban innovation level.* Table 3 lists the multiple regression analysis of each variable. The results show that *sci_tech* is positively correlated with $innov_1$, and the regression coefficient is 0.055, which is consistent with Hypothesis 1. *edu* was negatively correlated with $innov_1$, but not significantly. Their regression coefficient is -0.124. One cause may be that some cities with high level of innovation, such as Shenzhen, have a small number of collages but a large number of permanent residents. Both *finance* and *aveGDP* are positively correlated with $innov_1$, and the regression coefficients are 0.031 and 0.034. This shows that financial development and *aveGDP* play a significant role in promoting the level of urban innovation.

The middle part of Table 3 discusses the hysteresis effect of sci-tech funding, we see *sci_tech-1* as sci-tech funding lag one period. The results show that *sci_tech-1* is positively correlated with $innov_2$, and the regression coefficient is 0.087. This finding suggests that

TABLE 3. Sci-tech funding and urban innovation level

	Hysteresis		Robustness
Variables	$Innov_1$	$Innov_2$	Rank_1
sci_tech	0.055***		−1.551***
	(2.97)		(−4.77)
sci_tech-1		0.087***	
		(4.08)	
edu	−0.124	0.026	0.126
	(−0.44)	(0.08)	(0.03)
gov	0.006	−0.033	0.348
	(0.25)	(−1.24)	(0.92)
open	0.001	0.007	0.073
	(0.09)	(0.63)	(0.41)
finance	0.031**	0.040**	−0.891***
	(2.17)	(2.40)	(−3.43)
aveGDP	0.034*	0.032	−1.850***
	(1.76)	(1.61)	(−4.06)
Constant	−0.914***	−1.136***	
	(−3.99)	(−4.78)	
Observations	111	74	111
Number of codes	37	37	37

Robust z-statistics in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

sci-tech funding in the last period has a positive impact on the level of innovation in this period, and the effect of *sci_tech-1* is greater than *sci_tech*.

5.2.2. *Regulating effect.* Table 4 presents the regulatory effect of sci-tech policy implementation audit on the relationship between sci-tech funding and urban innovation level. The results show that *audit* plays a positive regulatory role and the regression coefficient is 0.017. This finding is consistent with Hypothesis 2. Meanwhile, *audit* was negatively correlated with $innov_3$, and their coefficient is −0.232. It shows that the audit of sci-tech policy implementation has a certain constraint on the level of urban innovation, which makes the innovation activities develop cautiously.

$Innov_4$ and $Innov_5$ reveal the results of the *audit* and *sci_tech* lag. *audit-1* means the audit of sci-tech policy implementation falls behind one period. In the second column, *audit-1* has a negative impact on $innov_4$, and the regression coefficient is −0.278 which is similar to the left-hand side and opposites to the coefficient of *audit* and $innov_4$. The results show that the previous audit will affect the effect of current audit on innovation, and it can bring long-term advantages. *audit-1*×*sci_tech* has a positive impact on $innov_4$, which shows that the regulatory effect of *audit* is more significant.

The third column of Table 4 presents the result of both *audit* and *sci_tech* lag. *audit-1*×*sci_tech-1* positively affects $innov_5$, and the regression coefficient is 0.021. With the coefficient increasing, it suggests that the impact of sci-tech funding and the regulatory effect of audit on innovation are stronger and stronger.

5.2.3. *Regional effect.* Table 5 shows the differences in the effects of sci-tech policy implementation audit in three regions. Obviously, the effect in the eastern is the strongest, followed by the central and western. The regression coefficients of these regions are 0.032, −0.007 and −0.015. The results are consistent with Hypothesis 3. On the one hand, it may be due to the location advantage of the eastern region. On the other hand, in the face of resource constraints, the central and western regions are more inclined to traditional industries than innovation.

TABLE 4. Regulating effect

	Hysteresis			Robustness
Variables	$Innov_3$	$Innov_4$	$Innov_5$	$Rank_2$
audit×sci_tech	0.017*			−0.664**
	(1.77)			(−2.48)
audit-1×sci_tech		0.020*		
		(1.77)		
audit-1×sci_tech-1			0.021*	
			(1.87)	
audit	−0.232*	0.010	0.010	10.134***
	(−1.71)	(0.95)	(0.90)	(2.61)
audit-1		−0.278*	−0.303*	
		(−1.73)	(−1.84)	
sci_tech	0.036*	0.052**		−1.254***
	(1.83)	(2.20)		(−3.36)
sci_tech-1			0.060**	
			(2.48)	
edu	−0.026	0.139	0.147	−3.822
	(−0.08)	(0.36)	(0.40)	(−0.73)
gov	0.012	−0.011	−0.022	0.167
	(0.54)	(−0.39)	(−0.79)	(0.43)
open	−0.000	0.004	0.006	0.156
	(−0.00)	(0.31)	(0.58)	(0.82)
finance	0.037**	0.031	0.039**	−0.857***
	(2.49)	(1.62)	(2.07)	(−3.02)
aveGDP	0.027	0.029	0.029	−1.344***
	(1.36)	(1.45)	(1.41)	(−2.72)
Constant	−0.612**	−0.748***	−0.790***	
	(−2.30)	(−2.66)	(−2.84)	
Observations	111	74	74	111
Number of codes	37	37	37	37

Robust z-statistics in parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

TABLE 5. Regional effect

	Eastern	Central	Western
Variables	y	y	y
audit×sci_tech	0.032**	−0.007	−0.015
	(2.11)	(−0.55)	(−0.79)
Control variable	YES	YES	YES
Constant	−0.447	−0.391	−1.516
	(−1.33)	(−1.54)	(−1.02)
Observations	72	21	18
Number of codes	24	7	6

Robust z-statistics in parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

6. **Robustness Test.** Our study selects innovation index to represent the level of urban innovation. In order to better guarantee the reliability and robustness of empirical results, we choose the ranking of urban innovation capacity, *rank*, as a new explained variable, and use Oprobit regression model to test the above results. The results are shown on the right-hand side of Table 3 and Table 4. Due to the characteristics of the ranking, values of the regression coefficients will be completely reversed. After inspection, the results are basically consistent with the above, and the conclusion is still valid.

7. **Conclusion and Enlightenment.** This paper first studies the impact of sci-tech funding on the level of urban innovation, and then introduces the regulatory variable to explore its effect between the two. The main conclusions are as follows: sci-tech funding is positively correlated with the level of urban innovation. The greater the investment in sci-tech, the more positive urban innovation activities will be. The hysteresis effect of sci-tech funding shows that there is a time cycle for sci-tech funding to improve innovation level. When introducing the audit of sci-tech policy implementation as a moderating variable, it can effectively adjust the relationship. Moreover, its effect is hysteretic and regional. To a certain extent, our study enriches the research results of sci-tech policy implementation audit and expands the situational factors of sci-tech funding affecting the level of urban innovation.

The 14th Five-Year Plan proposes to grasp the new situation and new mission of sci-tech work in the new stage and accelerate the realization of sci-tech independence. Government should strengthen the institutional foundation, the top-level design of innovation and establish a sound and efficient policy system. Sci-tech management department should establish organization leadership and responsibility mechanism, track the implementation of policy and improve the efficiency. Audit institutions need to make efforts to improve the supervision mechanism, strengthen technical support and the use of reports, so as to meet the needs of audit of sci-tech policy implementation and improve the efficiency during this process.

REFERENCES

[1] C.-Y. Lee, The differential effects of public R&D support on firm R&D: Theory and evidence from multi-country data, *Technovation*, vol.31, nos.5-6, pp.256-269, 2011.
[2] M. Ugur, S. A. Churchill and H. M. Luong, What do we know about R&D spillovers and productivity? Meta-analysis evidence on heterogeneity and statistical power, *Research Policy*, vol.49, no.1, 103866, 2020.
[3] M. Bianchi, S. Murtinu and V. G. Scalera, R&D subsidies as dual signals in technological collaborations, *Research Policy*, vol.48, no.9, 103821, 2019.
[4] F. Szücs, Do research subsidies crowd out private R&D of large firms? Evidence from European framework programmes, *Research Policy*, vol.49, no.3, 103923, 2020.
[5] J. Wei and Y. Zuo, The certification effect of R&D subsidies from the central and local governments: Evidence from China, *R&D Management*, vol.48, no.5, pp.615-626, 2018.
[6] Z. Chen, F. Meng and H. Wang, The research on the impact of government support on innovation efficiency of high-technological industries, *Studies in Science of Science*, vol.10, pp.1782-1790, 2020.
[7] S. Min, J. Kim and Y.-W. Sawng, The effect of innovation network size and public R&D investment on regional innovation efficiency, *Technological Forecasting & Social Change*, vol.155, 119998, 2020.
[8] Z. He and S. Chen, The cross-level adjustment influencing mechanism of science and technology innovation policies on innovation resources performance, *Science of Science and Management of S.&T.*, vol.4, pp.19-33, 2020.
[9] T. Yigitcanlar, J. Sabatini-Marques, Md. Kamruzzaman et al., Impact of funding sources on innovation: Evidence from Brazilian software companies, *R&D Management*, vol.48, no.4, pp.460-484, 2018.
[10] O. Ivus, M. Jose and R. Sharma, R&D tax credit and innovation: Evidence from private firms in India, *Research Policy*, vol.50, no.1, 104128, 2021.

[11] S. Zhou and Y. Han, Could internal control quality and national audit improve the stated-owned enterprises value?, *International Journal of Innovative Computing, Information and Control*, vol.17, no.4, pp.1475-1482, 2021.

[12] Q. Wang, F. Li and Q. Li, Semantic network analysis of science and technology policy audit, *Finance and Accounting Monthly*, vol.7, pp.97-102, 2019.

[13] J. Shi, Priorities and methods of auditing the implementation of policy measures, *Auditing Research*, vol.1, pp.17-21, 2016.

[14] R. Fan, Implementing and distributing benefits of scientific and technological achievements transformation policies, effectively promoting transformation of scientific and technological achievements in universities, *Science and Technology Management Research*, vol.40, no.15, pp.145-149, 2020.