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"Competition for Innovation": Research on the Strategic Competition of Local Governments' Science and Technology Expenditure in China

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Abstract

By constructing a yardstick competition model of the performance equation, this paper analyzes the internal mechanism of local governments' competition of science and technology (S&T) expenditure in China. By using the Dynamic Spatial Panel Model, we analyze the competition empirically from five dimensions: geographical adjacency, geographical distance, administrative adjacency, administrative grade and economic distance. According to the results, the local governments' S&T expenditure showed a significant strategic competition phenomenon, that is, there is a "competition for innovation", and the competition is more obvious between regions with close geographical proximity and administrative relations. "Competition for innovation" will be affected by political exogenous shocks such as those from the National People's Congress (NPC) of China; There is a "father-son competition" relationship between the superior and inferior governments. At last, the competition can promote the regional innovation significantly, which shows that "competition for innovation" is a kind of top-by-top competition. The conclusions may provide some useful suggestions for optimizing the relationship between local governments and promoting the construction of an innovative country.

Key words

"competition for innovation"; science and technology expenditure; the Dynamic Spatial Panel Model

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1.Introduction

In order to accelerate the transformation and upgrading of economic development, Chinese government attached great importance to the role of science and technology (S&T), putting forward the goal of building an innovative country and placing the innovation-driven nature at the core of the national development strategy. The report of the CPC's 19th National Congress also pointed out that "innovation is the first driving force to lead development and the strategic support to build a modern economic system". For a multi-level government administration structure, local governments are the "testing ground" for implementing the innovation-driven strategy, and how to bring their enthusiasm into the innovative country construction becomes a crucial issue.

Especially in recent years, the incentive distortion of local governments brought by the traditional "competition for growth" have gradually emerged (Jia *et al.*, 2013). In order to better motivate local governments to implement the innovation-driven strategies, many superiors have started to strengthen the assessment of S&T, and put the S&T expenditure of inferiors into the assessment system. The changes in the assessment method profoundly affects the incentive and promotion mechanism of local government officials in the pyramidal administrative hierarchy. Local governments are increasingly enthusiastic about innovation, competing to launch a variety of innovation projects, put forward various types of S&T innovation policies and slogans, and continue to increase fiscal support for them. Local governments seem to have fallen into an unusual "R&D worship" (Yu and Zhang, 2015) and have engaged in strategic competition behaviors: each region will consider the behaviors of others when making fiscal expenditure decisions of S&T and then determine its own response function. In this paper, we call this phenomenon as "competition for innovation".

Therefore, during the economic transition, the traditional "competition for growth" can no longer fully characterize the relationship among local governments, and it has gradually evolved into a "competition for innovation" concerning S&T expenditures. As Zhou *et al.* (2012) pointed out, when the traditional economic growth mode can no longer support future economic growth, it is especially important to focus on innovation competition, which also determines the effect and path of economic transformation. In the case of factor mobility, the innovation environment will be optimized and the marginal returns of production factors will be further enhanced if other regions increase the fiscal S&T expenditures. While if the region does not adopt corresponding strategies, it will lead to the high-quality factors' loss and the deterioration of the economic development environment. Thus, local governments will strategically respond in a similar way if other regions increase the fiscal S&T expenditures, and this leads to "competition for innovation". In essence, "competition for innovation" is a vital shift and "new normal" of local governments' relationship in China during the economic transition.

In the context of the fiscal decentralization and the implementation of the innovation-driven strategy in China, this paper focuses on the "competition for innovation" concerning local governments' S&T expenditure, explores the motives, mechanisms, and empirical evidence behind the phenomenon, and then provides insights for optimizing the relationship between local governments and promoting the construction of an innovative country. This paper may enrich existing studies in the following three aspects: First, from the perspective of the competitive behavior of S&T expenditure among local governments, we analyze the internal causes, main manifestations and influence effects of this competition. This is conducive to understanding local government competition more comprehensively. Second, this paper constructs a yardstick competition model based on the performance equation concerning local governments' S&T

expenditure to analyze the decision-making mechanism of "competition for innovation", so as to provide a theoretical basis for evaluating the competition in S&T expenditure among local governments. Third, this paper systematically constructs five competition dimensions based on geographical adjacency, geographical distance, administrative adjacency, administrative grade and economic distance, and empirically analyzes the "competition for innovation" by using dynamic spatial panel econometric model. In this way it may provide more detailed evidence for understanding the "competition for innovation".

2. Literature Review

Institutional factors have been a breakthrough for scholars to solve the puzzle of China's economic growth. Since the 1980s, the fiscal decentralization and tax-sharing reform have gradually given local governments the power to control local fiscal revenues guaranteed by the system, which highlighted the role of local government in the vertical administrative structure and fundamentally changed the way they engage in socioeconomic activities. Meanwhile, the fiscal expenditure pressure derived from the reform has made it necessary for local governments to continuously expand their sources of fiscal revenue and give them sufficient incentives to develop regional economies. More than the fiscal decentralization reform, scholars have focused on the incentive structure changes of local governments and the resulting direct or indirect competition among local governments under the performance yardstick (Maskin *et al.*, 2000), *i.e.*, "competition for growth" (Xu, 2011). More importantly, the Chinese large state governance structure constituted by economic decentralization and administrative centralization, provides effective incentives for competition among local governments (Blanchard and Shleifer, 2001). The second generation of fiscal federalism theory, represented by Qian and Weingast (1997), argued that fiscal decentralization can improve the incentives of local government and increase the efficiency of resource allocation through local government competition. This also formed a typical competition mode with economic performance as the main goal and fiscal expenditure as the main method[1].

In terms of research on local government fiscal expenditure competition, a growing body of literature has begun to study the competition concerning the structure of fiscal expenditure, which better reflects the incentive mechanism and its distortion of local governments under the decentralization: *i.e.*, the dysfunctions in the fiscal expenditure structure of local governments and the insufficient supply of public goods. However, the conclusions have not formed a complete consensus. On the one hand, some studies have found that the competition is detrimental to the supply of public goods, for example, fiscal decentralization brings about the insufficient supply of local public goods and leads to the loss of supply efficiency (Keen and Marchand, 1997; Brehm, 2013; Jia *et al.*, 2014). Fu and Zhang (2007) have found that the structure of public expenditure in China under the fiscal decentralization shows a heavy emphasis on infrastructure construction, but not on human capital investment and public services. On the other hand, some scholars have argued that local government competition can promote the efficiency of public goods supply. Among them, Tiebout (1956), an early researcher on the efficiency of fiscal expenditure under local government competition, argued that it can bring about economic efficiency improvement because local government competition can achieve efficient supply of public goods, which got the support of Faguet (2004). The study of Adam *et al.* (2014) for OECD countries further found that

[1] Generally, local government's fiscal competition consists revenue competition and expenditure competition. However, the strict restrictions on tax types and tax rates leave relatively little room for local governments to compete on the revenue in China.

fiscal decentralization has a significant inverted U-shaped characteristic in affecting the efficiency of public goods expenditure. Finally, Fernando *et al.* (2017) conducted studies on competition within the fiscal expenditure structure of local governments. Yin and Xu (2011) and Zhou *et al.* (2013) also studied expenditure competition of infrastructure public and education respectively, and their findings further validated the local governments' competition of fiscal expenditure.

Along with the implementation of China's innovation-driven strategy, some scholars have analyzed the impact of local government competition on technological innovation activities under the fiscal decentralization. Most of these studies were made from the perspective of fiscal decentralization, examining whether and how local government competition caused by decentralization affects technological innovation. Taylor (2007) found that although decentralized governments have a more flexible internal structure that can adapt to the "disruptive currents" of technological innovation, his empirical study using data of international patents, scientific publications, and high-tech exports have not found reliable evidence of relationship between government structure and technological innovation. Wu (2017) believed that under Chinese decentralization, the self-interested investment preferences of officials can act on the investment behavior of various market participants through the "visible hand" of local government, so that the whole society shows a production-oriented investment bias. The result shown that the higher the degree of fiscal decentralization, the lower the innovative expenditures of local governments and enterprises.

However, these studies have neglected the change of competition among local governments and the "competition for innovation" during the economic transition. They still haven't comprehensively analyzed the internal logic of local governments' competition for innovation around fiscal technology expenditure, and where the reason for competition for innovation has come from. Nor have they explained how it is related to traditional "competition for growth", or what kind of local governments may compete for innovation. These issues remain unresolved. This situation is not conducive to a more comprehensive understanding of the competitive behavior of local governments, nor is it conducive to a better analysis of the institutional incentives.

3. Research Hypothesis and Empirical Facts

3.1. Research Hypothesis

Previous studies on local government competition were mainly carried out within the framework of Besley and Case (1995), assuming that the superior government is a kind "social planner", whose goal is to maximize the welfare of residents in the jurisdiction. However, this assumption may not accurately describe the current situation of China: the optimal goal of local governments might also include supporting the officials' political promotion. Therefore, this paper attempts to construct a theoretical model that can comprehensively and accurately describe a neglected side of the current reality in China, so as to analyze the internal logic of "competition for innovation".

First, we consider a vertical structure containing superior and inferior government, and a simple horizontal structure with only two homogeneous regions, i and j (which differ only in terms of fiscal S&T expenditure). The appraise standard of the superior government to the inferior government's official is the economic performance, *i.e.* superior governments always favor the inferior government officials in areas with better economic performance. The utility function U for local government officials in region i is assumed to be:

$$U=\mathrm{Ln}y_i+\mu_i \tag{1}$$

In Eq. (1), y_i denotes the performance of local governments in region i; μ_i denotes other factors that may affect the satisfaction of superiors with inferiors. We assume that the economic performance of local government is mainly reflected in GDP, so according to the Cobb-Douglas production function, economic output can be expressed as:

$$y_i=A_iK_i^aL_i^\beta \tag{2}$$

In Eq. (2), K_i and L_i denote the capital and labor input of region i, a and β denote the output elasticities of capital and labor respectively, with $a+\beta=1$ under the assumption of constant returns to scale. We are more interested in A_i in Eq. (2), which denotes the Solow residual and reflects the technological progress of region i according to traditional economic growth theory. We further assume that A is an increasing function of the local government's S&T expenditure (labeled as e), the higher e is, the larger A_i is and the higher the economic performance is, *i.e.*,

$$\frac{\partial A_i(e_i)}{\partial e_i}>0 \tag{3}$$

In these two homogeneous regions, only officials in one region can be promoted, so the promotion probability of local government officials in region i is affected not only by the economic performance of this region, but also by other regions. Therefore, according to the discrete choice model proposed by McFadden (1974), the degree of preference of superiors for local government officials in region i, *i.e.*, the probability of being promoted, can be expressed as:

$$P_i(lny_i, lny_j)=\frac{\exp(lny_i)}{\exp(lny_i)+\exp(lny_j)}=\frac{y_i=A_i(e_i)K_i^aL_i^\beta}{Y} \tag{4}$$

The P_i in Eq. (4) represents the probability of promotion in region i, which can also be considered as the performance equation of local government. Then, the popularity equation constructed by Revelli (2005) is replaced by a similar performance equation that also motivates government officials: greater performance means higher probability of promotion. But the incentive comes from the superior government's preference for performance. Y denotes the sum of economic output of all regions.

If local government officials in region i choose to increase e, this will directly increase A, and promote the economic output. Therefore, the marginal promotion probability it receives is,

$$\frac{\partial P_i(lny_i, lny_j)}{\partial e_i}=\frac{K_i^aL_i^\beta Y-A_i(e_i)K_i^aL_i^\beta}{Y^2}\frac{\partial A_i(e_i)}{\partial e_i}=\frac{Y-y_i}{Y^2}K_i^aL_i^\beta\frac{\partial A_i(e_i)}{\partial e_i}>0 \tag{5}$$

And each unit increase in e by local government j reduces the marginal probability of official's promotion in local government i. That is:

$$\frac{\partial P_i(lny_i, lny_j)}{\partial e_j}=-\frac{y_i}{Y^2}K_j^aL_j^\beta\frac{\partial A_i(e_j)}{\partial e_j}<0 \tag{6}$$

However, in order to increase their own probability of promotion, local government officials in region i need to meet the following conditions:

$$dP_i(lny_i, lny_j)=\frac{\partial P_i(lny_i, lny_j)}{\partial e_j}\mathrm{d}e_i+\Sigma_{j\neq i}\frac{\partial P_i(lny_i, lny_j)}{\partial e_j}\mathrm{d}e_i\geq 0 \tag{7}$$

From Eq. (7), it can be seen that when there is no change in fiscal S&T expenditure in other regions, an increase in local will increase the probability of local government official's promotion. Of course, we also need to consider the scenario that fiscal S&T expenditures in other regions also increase, assuming that only two regions exist, that is

$$\frac{de_i}{de_j}\geq 0 \tag{8}$$

In Eq. (8), when e in one region increases, officials in another region also need to adopt the same strategy to ensure the promotion possibilities do not decrease. Therefore, we propose the following research hypothesis to be tested.

Hypothesis: There is a strategic competition among local governments in terms of S&T expenditure, i.e., if a region with which they are in competition increases its fiscal S&T expenditure, the region will tend to increase it as well.

3.2. Empirical Facts

As discussed, the change of the local government assessment standard and the rapid rise of S&T expenditure vividly illustrate the "competition for innovation": local governments tend to choose the same response strategy if other local governments increase their S&T expenditure. Thus, it is highlighted by the interdependence between local governments in terms of the size of their S&T expenditures. Referring to Long *et al.* (2014), we use the Moran index to initially verify the "competition for innovation". This paper constructs five spatial weight matrixes based on geographical adjacency, geographical distance, administrative adjacency, administrative grade and economic distance (the construction method will be introduced in detail later) and measures the Moran index of the mean of fiscal S&T expenditure among 333 prefecture regions in China from 2007 to 2014, the results of which are shown in Figure 1.

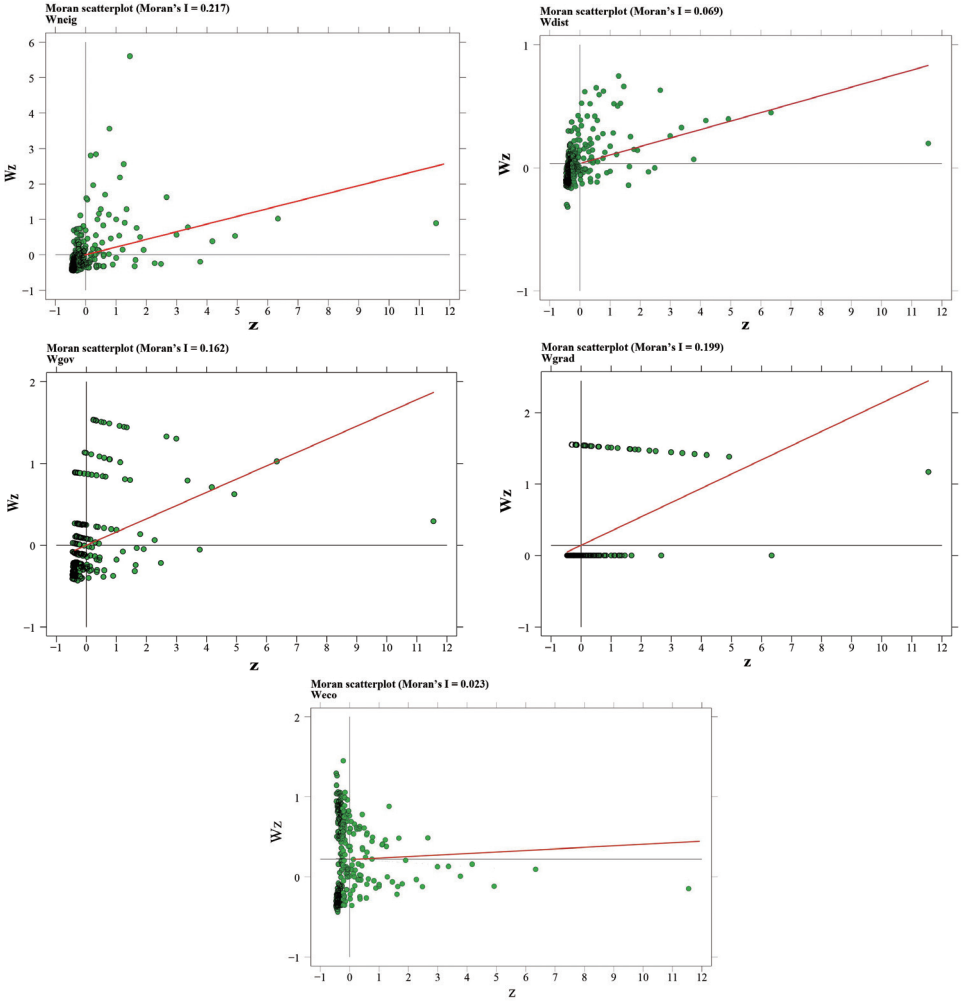

Fig. 1. Moran scatterplot of local government S&T expenditure

In Figure 1, it is clear that the Moran index is significantly positive during the examined period regardless of the competition dimension, indicating that there is a positive autocorrelation effect of fiscal S&T expenditure, *i.e.*, if the scale of fiscal S&T expenditure of this region is higher, the scale of it in other regions with which there is geographical adjacency, geographical distance proximity, administrative adjacency, equal administrative level and similar economic distance, are also higher. Of course, the empirical facts based on the Moran index only show the positive autocorrelation effect and interdependence from an overall perspective, based on which this paper tentatively believes that there is "competition for innovation". However, the question of whether this autocorrelation effect is caused by competition instead of other factors still needs further empirical analysis.

4. Model Construction and Variable Selection

4.1. Model Construction

The spatial econometric model provides a better identification strategy for this paper to examine "competition for innovation" (Revelli, 2005). If there is a strategy competition among local governments around S&T expenditure, then the intensity of competition will decay as the competition relationship decreases. In particular, those regions where there is geographical adjacency, administrative adjacency, equal administrative level and similar economic development level are more likely to compete and the intensity is higher. Therefore, if the empirical results support that the dependency relationship of fiscal S&T expenditure with geographical adjacency, administrative adjacency, equal administrative level and similar economic development level is higher than that among other regions, it can be believed that the dependency relationship is indeed caused by competition, but not others. In terms of the spatial econometric model, this paper focuses on the competitive relationship of the dependent variable of local government, so the spatial autoregressive panel model (SAR) is chosen. It can be expressed as follows.

$$e_{it}=\rho\omega\times e_{it}+X'\gamma+\varepsilon_{it} \tag{9}$$

In Eq. (9), the dependent variable e_{it} denotes the fiscal S&T expenditure in year t of region i (i=1, 2, ……, n; t=1, 2, ……, T). The ω is a standardized spatial weight matrix with diagonal elements of zero, and its element ω_{ij} denotes the spatial dependence of local government i and j on fiscal S&T expenditure, which we adopt to define and describe the competitive relationship between them. The ρ, as the core coefficient in this paper, denotes the spatial autoregressive coefficient, if ρ is significantly not equal to 0, it means that there is a significant strategic behavior among local governments in S&T expenditure, and if is significantly greater than 0, it means that there is "competition for innovation"; and if ρ is significantly less than 0, it means that it is a mutual substitution type of behavior among local governments. The independent variable X' denotes a set of control variables, and γ is the corresponding coefficient to be estimated. ε is the random error term.

According to Elhorst (2012), the spatial dependence among regions is not only reflected in the current period, but also may be influenced by the inter-period behavioral decisions. In practice, the S&T expenditure of a local government in the current is most likely to be influenced by the decisions of other regions in the previous, which means that there is also a dynamic competition over time. Therefore, we attempt to construct a dynamic spatial autoregressive panel model (DSAR) that includes the spatio-temporal lag terms of fiscal S&T expenditure, which can be expressed as:

$$e_{it}=\tau e_{i,t-1}+\rho\omega\times e_{it}+X'\gamma+\varepsilon_{it} \tag{10}$$

In Eq. (10), τ is the time lag coefficient, and the meanings of other variables are the same as Eq. (9). From Eq. (10), it can be seen that the DSAR model can examine the competitive relationship of e from multiple dimensions such as spatial and temporal dimension, which can obtain more robust estimation results.

4.2. Dimensions of Local Government Competition

In this paper, it is a key point that how to define the competitive relationship between local governments, that is, what kind of regions are likely to have competition? Referring to Elhorst and Fréret (2009), this paper constructs a spatial weight matrix to measure the relationship between local governments from the following aspects.

(1) the competition based on geographic adjacency (W-neig). In terms of the most basic spatial relationship, spatial dependencies are more likely to arise between regions that are geographically contiguous, and these local governments, which may often be exposed to more serious competitive behavior in fiscal S&T expenditure, are also more closely related to each other. Therefore, this paper constructs a binary spatial weight matrix based on geographic adjacency to measure the governmental competition. If there is a geographical adjacency relationship between two regions, the value of ω_{ij} is 1, otherwise it is 0.

(2) the competition based on geographical distance (W-dist). Those regions that are close in geographic distance but not adjacent may also have some competitive relationship with each other, so geographic distance is an important form to describe the competitive relationship of local governments. This paper constructs a weight matrix based on geographic distance to measure the governmental competition in the following form: if i is not equal to j, then element $\omega_{ij}=1/d_{ij}^2$, otherwise it is 0. Here d denotes the geographical distance between regions i and j measured by longitude and latitude data of prefecture-level cities according to the National Basic Geographic Information System.

(3) the competition based on administrative adjacency (W-gov). Local government competition is still a political phenomenon. Under Chinese administrative system, prefecture local government officials within the same provincial region share a common superior, forming direct rivals. These officials often attend meetings together and have a deeper understanding of the fiscal expenditure on S&T of others, which also constitutes the direct competition. Therefore, we construct a binary administrative adjacency weight matrix in the form of element $\omega_{ij}=1$ if regions i and j are located in the same province, and 0 otherwise.

(4) the competition based on administrative grade (W-grad). In China, provincial capitals and sub-provincial cities tend to have higher status compared to others, and these cities are more similar in terms of economic and social development. The administrative grade of their officials is also higher, and they have more room for future promotion. Therefore, we construct a binary administrative grade weight matrix as a measure of competition among those regions at the same administrative grade in the form of element $\omega_{ij}=1$ if both regions i and j are provincial capitals or sub-provincial cities, and 0 otherwise.

(5) the competition based on economic distance (W-eco). According to the yardstick competition theory, an important condition for neighboring regions to engage in strategic behavior is that they share similar economic and social characteristics. Those regions with more similar economic and social characteristics tend to have more similar development paths and popularity, resulting in direct competition around fiscal expenditure on S&T. We will construct an economic distance weight matrix of the following form: if i is not equal to j, element $\omega_{ij}=\omega_{dist}diag(\frac{\overline{eco}_1}{\overline{eco}}, \frac{\overline{eco}_2}{\overline{eco}}, ..., \frac{\overline{eco}_n}{\overline{eco}})$, where $\overline{eco}_i$ denotes the

average value of GDP of region i during the investigation period, and $\overline{eco}$ is the average value of GDP of all regions during the period.

4.3. Data Description and Variable Selection

This paper selects the panel data of 333 prefecture regions in China during the time span from 2007 to 2014, with a total sample size of 3338=2664. the Ministry of Finance promulgated the Government Revenue and Expenditure Classification Reform Program and formally implemented it on January 1, 2007; this program has adjusted the classification subjects of government expenditure functions. Therefore, this paper chooses 2007 as the initial year to ensure the consistency of statistical caliber. The data used in this paper are mainly from the *China Regional Economic Statistical Yearbook, China City Statistical Yearbook*, and *China Statistical Yearbook*. For the missing samples, such as Qinghai, Tibet, Ningxia, *etc*., we make up for them by manually searching the annual reports of national economy statistics of the region. Finally, in consideration of comparability, Beijing, Tianjin, Shanghai, and Chongqing municipalities are excluded, so as Taiwan province, and Hong Kong and Macao Special Administrative Regions because of the lack of data.

As the core variable, we choose S&T expenditure in the public fiscal expenditure column of local governments in each year to measure the local government's fiscal expenditure on S&T (recorded as e), which covers S&T management affairs, basic research, applied research, technical R&D, S&T conditions and services, social science, S&T popularization, S&T communication and cooperation, etc. We adopt the ratio e to the real GDP of the region as the final measurement index, the real GDP is calculated by using the GDP index reduction of province based on 2007.

This paper controls some factors that may affect the fiscal expenditure on S&T. (1) Regional economic development (Economy). We select the regional gross regional product per capita (GRP) of each region to measure it, using the GDP index with 2007 as the base period to de-price. (2) Regional openness degree (Open). This paper selects the amount of actual utilized foreign capital as a share of GDP in each region for measurement. The amount of actual utilized foreign capital is accounted for in RMB units based on the actual exchange rate of RMB to USD in that year, and we use the GDP index with 2008 as the base period to de-price. (3) Infrastructure construction (Facility). In this paper, the length of road miles per square kilometer in each region is used as its measurement index. (4) Regional human capital (Human). We select the number of college students per 10,000 people in each region to measure it. (5) Regional institutional environment (Market). Considering the availability of data, this paper adopts the total assets of state-owned and state-controlled enterprises in the province over the total assets of industrial enterprises above the scale to measure the regional institutional environment. Table 1 gives the results of descriptive statistics for each variable.

Table 1
Results of descriptive statistics of variables.

Variable	Obs.	Mean	SD	Max	Min
e	2664	0.004	0.009	0.240	0.000
Economy	2664	21195.406	14579.799	98398.000	3207.480
Open	2664	0.026	0.146	5.188	0.000
Facility	2664	1.178	5.555	131.462	0.019
Human	2664	147.360	222.212	3351.700	0.506
Market	2664	0.188	0.244	2.098	0.000

5. Analysis and Discussion

5.1. Model Identification and Testing

It is necessary to test and verify the rationality of the DSAR model we used before the regression analysis. In this paper, the residual-based Lagrangian multiplier statistics (LM) and its robust form (Robust LM) are used for validation. According to LeSage and Pace (2009), the more significant the LM statistic is, the better the model is fitted. Not only that, we also analyze the joint significance likelihood ratio LR test based on time and spatial fixed effects to determine the rationality. We use Table 2 to report the results of five types of spatial weight matrix mentioned above of LM statistics and their robust forms (Robust LM), as shown in (1) to (5), respectively.

Table 2
Spatial panel model LM test.

	(1)	(2)	(3)	(4)	(5)
No lag	48.6723*** (0.0000)	454.8771*** (0.0000)	112.7756*** (0.0000)	163.0362*** (0.0000)	2228.4357*** (0.0000)
Robust no lag	115.2936*** (0.0000)	1119.8600*** (0.0000)	247.1468*** (0.0000)	163.6108*** (0.0000)	2270.7808*** (0.0000)
LR-test joint significance spatial fixed effects			2036.2112(0.0000)		
LR-test joint significance time-period fixed effects			252.2654(0.0000)		

*Note: The symbols ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively; chi-squared distribution values are put outside parentheses, and corresponding probability P values in parentheses.*

As can be seen from Table 2, the LM statistics and its robust form statistics are highly significant at the 1% level regardless of the spatial weight matrix used, indicating that the SAR has a good fit. The joint significance likelihood ratio LR test based on the fixed effects model rejects the original hypothesis that the joint time and spatial fixed effects are not significant at the 1% level, indicating that the model should include both time and spatial fixed effects. In summary, the choice of DASR model in this paper has good reasonableness.

5.2. Results of Benchmark Regression Model

The estimation method of DSAR model mainly consists of Maximum Likelihood Estimation (ML), quasi-maximum likelihood estimation (QML), instrumental variables (IV) and generalized method of moments (SGMM) (Elhorst, 2012). Although the ML or QML can obtain consistent estimates of model parameters (Yu *et al.*, 2008), they cannot solve the problem of constructing valid test statistics to ensure the validity of the inferential process by calculating robust variance covariance matrices of the relevant estimators. And the data structure of this paper has "large N and small T" characteristics, which is hard to satisfy the QML. Based on this, we choose the SGMM, which is still able to select appropriate instrumental variables without introducing external instrumental variables (Elhorst, 2012). For comparison, we report the estimation results based on both QML and SGMM, as shown in Panel A and Panel B in Table 3, respectively, where (6) to (10) and (11) to (15) correspond to the estimation results of the above five dimensions respectively.

Table 3
Baseline regression model estimation results

Panel A					
	(6)	**(7)**	**(8)**	**(9)**	**(10)**
τ	0.7447*** (0.0167)	-1.7340*** (0.0411)	0.5874*** (0.0173)	0.9189*** (0.0133)	0.5698*** (0.0187)
ρ	0.0299*** (0.0034)	0.0979*** (0.0001)	0.3739*** (0.0201)	0.0585 (0.0469)	0.3871*** (0.0253)
Economy	0.2593*** (0.0629)	-1.3418*** (0.2031)	0.1677*** (0.0597)	0.2336*** (0.0654)	0.2782*** (0.0614)
Open	-0.0034 (0.0084)	-0.0002 (0.0276)	-0.0019 (0.0079)	-0.0025 (0.0089)	-0.0091 (0.0082)
Facility	0.0121 (0.0351)	-0.7475*** (0.1146)	-0.0143 (0.0332)	-0.0220 (0.0369)	-0.0278 (0.0349)
Human	-0.0275 (0.0202)	-0.3759*** (0.0659)	-0.0354* (0.0191)	-0.0403* (0.0213)	-0.0489** (0.0199)
Market	-0.0985 (0.0870)	-2.4689*** (0.2850)	-0.1706** (0.0825)	-0.2438** (0.0970)	-0.0315 (0.0848)
Observations	2664	2664	2664	2664	2664
R-sq Adjusted	0.7486	0.7725	0.7691	0.7254	0.7675
Panel B					
	(11)	**(12)**	**(13)**	**(14)**	**(15)**
τ	1.1571*** (0.1525)	0.5804*** (0.1195)	0.7149*** (0.1329)	1.2345*** (0.1543)	1.1888*** (0.1536)
ρ	0.0165*** (0.0031)	0.0199*** (0.0021)	0.0447*** (0.0035)	0.0028*** (0.0005)	0.0011*** (0.0002)
Economy	0.8781*** (0.0591)	0.3133*** (0.0804)	0.2776*** (0.0798)	0.8922*** (0.0573)	0.8381*** (0.0597)
Open	0.0234*** (0.0088)	0.0236*** (0.0084)	0.0227*** (0.0083)	0.0292*** (0.0089)	0.0232*** (0.0088)
Facility	0.1791*** (0.0385)	0.0623* (0.0376)	0.0793** (0.0370)	0.2802*** (0.0372)	0.2413*** (0.0373)
Human	0.1197*** (0.0181)	0.1123*** (0.0196)	0.1269*** (0.0196)	0.1376*** (0.0184)	0.1249*** (0.0182)
Market	-0.1329 (0.1115)	0.0202 (01063)	-0.1211 (0.0985)	-0.1935 (0.1354)	-0.0809 (0.1128)
Observations	2664	2664	2664	2664	2664
R-sq. Adjusted	0.9985	0.9988	0.9990	0.9984	0.9984
Wald test	509.9718 (0.0000)	188.1006 (0.0000)	247.6526 (0.0000)	721.3465 (0.0000)	592.1475 (0.0000)

*Note: The symbols ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Values in parentheses of each variable are robust standard errors. Values outside parentheses in the Wald test statistic are their chi-square distribution values, and values inside parentheses are the corresponding probability p-values.*

From Table 3 we can see that the fitness of the Panel A is significantly lower than that of the Panel B. And the results of time or spatial lagged variables and control variables are extremely unstable or

anomalous among the five dimensions in Panel A. Therefore, the results based on the SGMM method shown in Panel B will be used for analysis in this paper.

Regardless of the competition dimension, the variable e shows a significant "lock-in" feature in time, that is, e in the early stage influence the later. Because of the strong continuity and long cycle of S&T activities, the government needs to continuously invest in fiscal expenditure to maintain the needs of S&T activities, rather than "explosive" rise or "precipitous" fall.

As the results show, ρ is significantly positive at the 1% level, which indicates that local governments exhibit a strategic complementary behavior of yardstick competition among themselves in S&T expenditure decision, that is, if the fiscal expenditure on S&T of the region with which they are spatially related increases, the government of this region will also increase it accordingly, which verifies our hypothesis. As mentioned above, the driving significance of innovation for economic development also makes the increasing support for S&T, which will promote the sustainable and rapid development of economy. While the flow of innovation factors and the "voting with feet" make the competition become more urgent, especially in recent years, the scale of S&T expenditure has gradually become an important standard for local government assessment; this directly motivates the increase of S&T expenditure.

In terms of the comparison of the competition dimensions, the competition degree in administrative grade and economic distance is significantly lower than that of the others, which indicates that the competition is stronger among those regions that are more geographically close and have more frequent administrative exchanges. Firstly, fiscal S&T expenditures have strong administrative characteristics, and government officials' decisions are largely influenced by others within the same administrative range, which also indicates the role of political factors such as promotions in the competition. Secondly, although the boundaries of knowledge spillover have been gradually expanded along with the development of transportation infrastructure and information technology, geospatial factors are still the main reason affecting the flow of factors, so the competition shows the characteristics of "close geographical relationship".

5.3. Results of Sensitivity Analysis

In order to exclude that the above findings are influenced by other factors or omitted variables, the following two sensitivity analyses are done to verify the robustness of this study.

(1) There are significant differences in fiscal expenditure capacity among local governments due to various factors. Although the differences in the absolute size of fiscal expenditure may still be significant for those regions with direct competitive relationships, the competition is likely to revolve around the relative growth rate of fiscal S&T expenditure. Therefore, this paper further adopts the growth rate of e as the dependent variable as the first sensitivity analysis. The results based on the SGMM are shown in Panel A in Table 4, and (16) to (20) correspond to the results of the five competition dimensions respectively.

(2) In China's regional economic growth pattern, the development differences among the eastern, central and western areas are very obvious, which also creates a significant gradient pattern in the process of economic development. For fiscal expenditures, the eastern area has a higher level of economic and social development than the central and western areas, and its fiscal expenditure capacity and the demand for fiscal expenditures for S&T are higher than the other two areas. Therefore, this paper adds the influence of regional factors such as central and western areas to the model shown in Eq. (2) to further control the problem of possible omitted variables as the second sensitivity analysis. And the results are shown in Panel B in Table 4, and (21) to (25) correspond to the results of the five competition dimensions respectively.

Table 4
Sensitivity analysis estimation results.

Panel A					
	(16)	**(17)**	**(18)**	**(19)**	**(20)**
τ	0.0149*** (0.0040)	0.0155*** (0.0056)	0.0085** (0.0041)	0.0231*** (0.0044)	0.0207*** (0.0041)
ρ	0.1606*** (0.0043)	0.0447*** (0.0012)	0.0789*** (0.0018)	0.0053** (0.0024)	0.0192*** (0.0009)
R-sq Adjusted	0.4818	0.4771	0.5386	0.1517	0.2864
Wald test	1565.6644 (0.0000)	1575.3244 (0.0000)	2045.7938 (0.0000)	116.5711 (0.0000)	520.8561 (0.0000)
Panel B					
	(21)	**(22)**	**(23)**	**(24)**	**(25)**
τ	1.1728*** (0.1546)	0.9347*** (0.1374)	1.1119*** (0.1559)	1.2582*** (0.1572)	1.1975*** (0.1554)
ρ	0.0166*** (0.0029)	0.0060*** (0.0004)	0.0129*** (0.0017)	0.0031*** (0.0005)	0.0012*** (0.0002)
Middle	-0.7335*** (0.1254)	-0.5780*** (0.0999)	-0.5256*** (0.1590)	-0.6065*** (0.1061)	-0.7789*** (0.1209)
West	-0.7081*** (0.1294)	-0.1648 (0.1083)	-0.4945*** (0.1643)	-0.7355*** (0.1120)	-0.5224*** (0.1259)
R-sq Adjusted	0.9985	0.9988	0.9986	0.9983	0.9984
Wald test	613.4453 (0.0000)	1199.6060 (0.0000)	451.5751 (0.0000)	860.3931 (0.0000)	686.4937 (0.0000)

*Note: The symbols ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Values in parentheses are robust standard errors. Values outside parentheses in the Wald test statistic are their chi-square distribution values, and values in parentheses are the corresponding probability P values. Estimates of the control variables are not reported here due to space limitations.*

From Table 4, we can see that the variable e has a significant "lock-in" feature in time and significant correlation effects in the spatial dimension. That is, there is a strategic interaction between local governments in terms of fiscal S&T expenditures. And if the expenditures of other regions are higher, the local regions tend to increase it, too. And this competition mainly manifests among regions that are geographically adjacent or close to each other and have the same administrative scope. Moreover, after adding the dummy variables of central and western areas, the "competition for innovation" still exists. In summary, the sensitivity analysis supports the previous findings, which also verifies the good robustness.

5.4. Results of Further Research

(1) Impact of political exogenous shocks. In fact, the promotion of local government officials is itself a political phenomenon, and it is bound to be influenced by policy factors. Thus, local government officials may change their promotion decisions to provide more leverage for promotion. In the current Chinese political system, political events that have an impact on promotion mainly manifest as a political cycle. Local government's officials may increase their fiscal expenditure on S&T during certain key years of the political cycle. Thus, exogenous shocks from political events which are highlighted by the convening

of the National Congress of the CPC (the Congress) may also have an important effect on the fiscal S&T expenditure. In the years when the Congress is held, there is an intensive change of local government officials, and most of them achieve political promotion around the session of the Congress. The growth rate of fiscal S&T expenditure exceeded 30% in the years when the Congress was held (31.65% in 2007 and 30.04% in 2012), while that of the rest years were maintained at about 20%.

We adopt two approaches to examine this effect. First, this paper adds a dummy variable for the year of the Congress to the model shown in Eq. (2), and the results are shown in (26) ~ (30) of Table 5. Second, based on the cross-sectional SAR model, we conduct a regression in each year to verify the differences of local government S&T expenditure competition in different years. Due to the limitation of space, we only report the results of ρ in the cross-sectional SAR model by year. The results based on five dimensions are shown in (31) ~ (35) of Table 5, respectively.

Table 5
Estimation results of the impact of political exogenous shocks

Panel A					
	(26)	**(27)**	**(28)**	**(29)**	**(30)**
ρ	0.0165*** (0.0031)	0.0056*** (0.0003)	0.0219*** (0.0022)	0.0028*** (0.0005)	0.0011*** (0.0002)
Congress	0.0133*** (0.0010)	0.0571*** (0.0121)	0.0065*** (0.0009)	0.0222*** (0.0103)	0.0170* (0.0100)
Panel B					
	(31)	**(32)**	**(33)**	**(34)**	**(35)**
2007	0.0174*** (0.0026)	0.0029*** (0.0005)	0.0050*** (0.0011)	0.0009* (0.0005)	0.0022* (0.0012)
2008	0.0032 (0.0025)	0.0014*** (0.0004)	0.0041*** (0.0011)	0.0005 (0.0005)	0.0003*** (0.0001)
2009	0.0025 (0.0024)	0.0015*** (0.0004)	0.0044*** (0.0010)	0.0003 (0.0005)	0.0002** (0.0001)
2010	0.0036 (0.0023)	0.0017*** (0.0004)	0.0039*** (0.0010)	0.0001 (0.0005)	0.0003*** (0.0001)
2011	0.0046** (0.0023)	0.0017*** (0.0004)	0.0042*** (0.0010)	-0.0001 (0.0005)	0.0003*** (0.0001)
2012	0.0098*** (0.0022)	0.0022*** (0.0004)	0.0055*** (0.0009)	0.0005*** (0.0001)	0.00013*** (0.0001)
2013	0.0068*** (0.0022)	0.0025*** (0.0004)	0.0042*** (0.0009)	-0.0007 (0.0005)	0.0004*** (0.0001)
2014	0.0087*** (0.0023)	0.0020*** (0.0004)	0.0041*** (0.0010)	-0.0008 (0.0005)	0.0001 (0.0001)

*Note: The symbols ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Values in parentheses are robust standard errors. Estimates of control variables are not reported here due to space limitations.*

In Table 5, after adding the new dummy variable, coefficients of ρ are still significant positive regardless of the dimension, and coefficients of the Congress have significant positive impact on e, which is consistent with our expectations. In the cross-sectional regression model by year, the results of all dimensions show that the significance and the coefficients of ρ in 2007 and 2012 are higher than those of

other years. This indicates that around the session of the Congress, local governments' competition in S&T expenditure is more obvious and intensive, which further verifies the effect of political exogenous shocks on local governments' competition in S&T expenditure.

(2) "Father-son competition": vertical co-response between superior and inferior. In a multi-level government structure, there is a vertical joint reaction between the upper and lower levels of government, and the decisions of the upper-level government will have a potentially significant impact on the lower-level government. On the one hand, as mentioned earlier, the innovation driven strategy proposed by the higher-level government may be warmly welcomed by the lower-level government, which also arranges fiscal funds to support technological innovation activities through various means. There is a positive vertical strategic response between the higher- and lower-level governments; On the other hand, support for technological innovation activities may not achieve significant economic growth performance in the short term, which also leads to a lack of enthusiasm from lower-level governments towards the innovation policies of higher-level governments, resulting in negative vertical strategic reactions between upper and lower level governments. The vertical strategic response between upper and lower levels of government can also be vividly referred to as "father-son competition", while the competition for fiscal S&T expenditures between lower level governments can be referred to as "sibling competition". The current Chinese fiscal governance system also provides institutional feasibility for the "father-son competition" between upper and lower level governments.

In this paper, we also examine the vertical strategic responses to verify the relationship between "father-son competition". Since all prefectural administrative regions within the same jurisdiction face a common provincial leader, the identification of the "father-son competition" relationship is done by constructing an observable common factor that does not vary with individuals but only with time. And we select the interaction term, which will be brought into the regression model for testing, using dummy variables of the provincial government and the year to measure the policy variables of the superiors. The results are shown in Table 6.

Table 6
The results of the "father-son competition" test

type	Father-son competition (provincial - prefecture level)
W-neig	Hebei, Shanxi, Inner Mongolia, Liaoning, Jilin, Heilongjiang, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Shandong, Henan, Hubei, Hunan, Guangdong, Guangxi, Hainan, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Ningxia, Xinjiang
W-dist	Hebei, Shanxi, Inner Mongolia, Liaoning, Jilin, Heilongjiang, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Shandong, Henan, Hubei, Hunan, Guangdong, Guangxi, Hainan, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Ningxia, Xinjiang
W-gov	Hebei, Shanxi, Inner Mongolia, Liaoning, Jilin, Heilongjiang, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Shandong, Henan, Hubei, Hunan, Guangdong, Guangxi, Hainan, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Qinghai, Ningxia, Xinjiang
W-grad	Hebei, Shanxi, Inner Mongolia, Liaoning, Jilin, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Shandong, Henan, Hubei, Hunan, Guangdong, Guangxi, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Qinghai, Xinjiang
W-eco	Hebei, Shanxi, Inner Mongolia, Liaoning, Jilin, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Shandong, Henan, Hubei, Hunan, Guangdong, Guangxi, Hainan, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Qinghai, Xinjiang

Note: Due to space constraints, only the names of provincial governments with significant "father-son competition" at the 10% level are reported here, and no specific estimates are reported.

From Table 6, it is clear that although the results in a few provinces such as Qinghai, Heilongjiang, and Hainan are insignificant at the 10% level in some weight types, on the whole, there is a phenomenon of vertical strategic responses around S&T expenditure between superior and inferior governments, that is, the existence of "father-son competition". In "competition for innovation", local governments also pay attention to following the policies of superiors, and this co-response between vertical levels is an important source of horizontal competition.

(3) The effect of "competition for innovation". On the one hand, the "competition for innovation" will inevitably change the scale of funding for regional S&T activities, especially when local governments adopt a positive competition strategy, which will continuously motivate the increase of S&T expenditures and thus promote the development of regional S&T activities. On the other hand, the positive competition may also further optimize the regional innovation environment, which promotes the flow of R&D factors and knowledge spillover. This will also have a favorable impact on the development of S&T activities. However, if it evolves into a vicious competitive behavior, such as blindly increasing fiscal S&T investment by ignoring the absorption capacity, or using overdraft or debt regardless of the fiscal expenditure capacity, it may also reduce the macro-control ability of the government and increase the tax burden of enterprises, thus is not conducive to the improvement of S&T.

Specifically, this paper first examines the relationship between "competition for innovation" and the development of regional S&T (measured by the number of regional patent applications granted, labeled as patent). We use the patent as the dependent variable and e as the core independent variable, while controlling for the regional economic development, regional openness, infrastructure construction, regional human capital and regional institutional environment. Since the Dynamic Spatial Durbin Panel model can control the spatial autoregressive effect of independent variables, it helps us to analyze the effect of competition on the dependent variable. The results are shown in Table 7.

Table 7
Estimated results of the effect of "competition for innovation"

	(36)	(37)	(38)	(39)	(40)
L. patent	0.5338*** (0.0571)	0.5524*** (0.0587)	0.5081*** (0.0563)	0.6428*** (0.0598)	0.5772*** (0.0591)
We	0.1613*** (0.0113)	0.0331*** (0.0022)	0.0688*** (0.0052)	0.0251*** (0.0093)	0.0162*** (0.0015)
R-sq. Adjusted	0.9918	0.9893	0.9917	0.9930	0.9907
Wald test	1739.3773 (0.0000)	1786.7944 (0.0000)	2017.8919 (0.0000)	954.8283 (0.0000)	1351.5196 (0.0000)

*Note: The symbols ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Values in parentheses are robust standard errors. Values outside parentheses in the Wald test statistic are their chi-square distribution values, and values in parentheses are the corresponding probability P values. Estimates of the control variables are not reported here due to space limitations.*

As shown in Table 7, the coefficient of the spatial autoregressive term (W×e) is significantly positive at the 1% level regardless of the competition dimension. This indicates that the competition is beneficial to the improvement of regional S&T development, and the "competition for innovation" produces better results. The competition stimulates local governments' support for S&T innovation activities, and further optimizes the regional innovation environment, and thus is conducive to the development of S&T activities and the improvement of innovation.

6. Summary and Implications

In the context of accelerating the transformation of the economic development mode and implementing the innovation-driven strategy, the competition among local governments in China has shown a trend of "competition for innovation". By constructing a theoretical model and a five-dimensional competition matrix, we empirically analyze the "competition for innovation" and its effects by using DSAR model. Based on the above analysis, we draw the following conclusions and implications.

It is found that, regardless of the competition dimensions, there is a significant positive competition of local government S&T expenditure in China, that is, there is a "competition for innovation" phenomenon. This competition is more obvious among regions that are geographically close to each other, and have the same administrative scope. In the further study, the political exogenous shocks marked by the Congress have a significant effect on the competition. In the critical years such as the holding of the Congress, the competition is more obvious. There is also a "father-son competition" between the superior and inferior government in the competition, *i.e.*, there is a vertical common response between them. In addition, "competition for innovation" achieves good results, as it can significantly promote the improvement of regional S&T development.

Based on the above conclusions, on the one hand, the "competition for innovation" among local governments is effective, and it is necessary to continuously optimize and improve the assessment mechanism and system of local governments. The central government needs to build a diversified local government assessment index system, increase the weight and proportion of indicators such as S&T expenditure and S&T tendency in the official assessment process, and encourage local governments to increase fiscal support for activities such as technological innovation, and create a competitive atmosphere around technological innovation among local governments; On the other hand, if "competition for innovation" is not effectively regulated and guided, it may lead to disorderly competition among local governments in terms of fiscal S&T expenditures. In this case, local governments might blindly increase fiscal expenditure while ignoring their own absorption and expenditure capabilities. This not only could increase the fiscal burden and unsustainable development of local governments, but also lead to the waste of S&T resources and the loss of their allocation efficiency. In order to avoid possible disorderly competition, blind competition, and vicious competition, the central government also needs to guide the activities of "competition for innovation" among local governments, by improving institutional design, encouraging local governments to engage in independent innovation behavior, regulating vicious "competition for talent" among local governments, and promoting coordinated, orderly, and healthy development of regional innovation.

This study focuses on the phenomenon of "competition for innovation" carried out by local governments around fiscal S&T expenditures. A benchmark competition model based on the performance equation is constructed to identify the "competition for innovation" of local governments from multiple dimensions. This not only consolidates the theoretical foundation of local government S&T competition, but also provides more methods for related empirical identification, reflecting the theoretical and empirical significance of this study. However, there are also some limitations to the research in this study. For example, due to limited data availability, the research sample in this study mainly focuses on prefecture level administrative governments. As the foundation of the national economy and fiscal system, the fiscal issues of county-level governments and the phenomenon of fiscal competition between county-level governments are also very prominent. We will continue to pay attention to them in future research.

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