

Research on the Linkage Effect and Coordinated Development Between Public Libraries Construction and Innovation Efficiency: Theoretical and Empirical Evidence from China

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Abstract Based on the panel data of 29 provincial administrative regions in China from 2011 to 2022, this study uses the entropy weighting method and the global super-efficiency SBM model to evaluate and measure the public libraries construction level and innovation efficiency in China, uses the vector autoregression model, the α convergence model and the β convergence model to evaluate and test whether there is a positive linkage effect between public libraries construction and innovation efficiency, and uses the coupling coordination model to calculate and analyze the coupling coordination degree between public libraries construction and innovation efficiency. The results show that China's public libraries construction and innovation efficiency are generally in a good development trend, but there is still a large gap from reaching a high level. There is a positive linkage effect between China's public libraries construction and innovation efficiency, which can not only promote each other's development, but also drive each other to achieve regional balanced development. The coupling coordination degree between China's public libraries construction and innovation efficiency is showing a steady upward trend, but it is still on the verge of imbalance as a whole, and the eastern region is significantly better than the central region and western region. The results reveal the positive linkage effect between public libraries construction and innovation efficiency, which has enlightenment significance for building a strong country in culture and innovation. Based on this, this study puts forward suggestions on increasing investment in public libraries construction, optimizing the configuration structure of innovation factors, and strengthening the deep integration of public libraries construction and innovation activities, so as to give full play to the positive linkage effect between public libraries construction and innovation efficiency.

Keywords public libraries; innovation efficiency; linkage effect; convergence test; coordinated development

1 Introduction

In the background of the knowledge economy, the comprehensive development of innovation is not only the fundamental driving force for the transformation of economic and social struc-

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tures, but also an important engine for promoting sustainable and high-quality economic and social development. As an important manifestation of the core competitiveness of innovation, innovation efficiency not only measures the quantitative ratio between innovation resources input and output in a certain period of time, reflects the operation and innovation capabilities of innovation resources, but also directly determines the transformation success rate and high-quality transformation rate of innovation activities^[1]. How to effectively improve innovation efficiency has become a hot topic in academia. A large number of scholars have actively engaged in the research of measuring innovation efficiency and have conducted in-depth discussions on various influencing factors and their mechanisms of innovation efficiency in terms of economic development, economic resilience, government support, government intervention, industrial structure adjustment, infrastructure construction environment, human capital accumulation and digital green business model^[2-7]. These studies found that the higher the level of economic development, the stronger the economic resilience, the more policy support from the government, the higher the proportion of the tertiary industry, the higher the level of human capital accumulation, the more complete the infrastructure construction and the more promoted the digital business model, the higher the regional innovation efficiency.

But in essence, innovation is actually an integrative process of absorbing and reprocessing knowledge and information. Therefore, sufficient knowledge and information is a prerequisite for achieving efficient innovation. As a social knowledge and information resources center, public libraries should play an invaluable and irreplaceable role in promoting innovation efficiency. First, as a distribution center with massive knowledge and information resources, public libraries can provide solid knowledge and information support for innovation activities^[8], which will directly promote the flow of explicit knowledge among innovation subjects and enhance their knowledge and information acquisition capabilities^[9]. Second, as a public cultural venue, public libraries can also provide a communication space for innovation subjects and even assume the role of “innovation incubator”^[10], which will effectively promote the flow of implicit knowledge among innovation subjects and reduce the decision-making risk cost of innovation subjects. Finally, as a cultural infrastructure, public libraries can also provide informal learning venues for the public, promote the public to read popular science knowledge, accelerate knowledge dissemination^[11], promote the development of innovation culture, and provide external environment support for innovation activities.

However, it should be noted that existing research still mainly studies the innovation efficiency issues from the perspective of macroeconomic development, regional innovation policies and micro-enterprise models. It rarely studies innovation efficiency from the perspective of public library construction, a public cultural infrastructure, and related research mainly focuses on qualitative theoretical analysis^[12-15]. Only a small number of studies have examined the specific impact of public libraries construction on innovation efficiency from the perspective of quantitative empirical analysis^[16-18], but these studies have ignored the importance of qualitative theoretical analysis. In addition, it is worth noting that existing research has rarely examined whether innovation efficiency will have a feedback effect on the impact of public libraries construction, which means that research on whether there is a linkage effect between public libraries construction and innovation efficiency is still relatively lacking.

So, can public libraries really have a positive impact on innovation, a knowledge-intensive activity? Will innovation efficiency have a feedback effect on the construction of public libraries? It will be positive feedback or negative feedback? In view of this, on the basis of completing qualitative theoretical analysis, based on the panel data of 29 provincial administrative regions in China from 2011 to 2022, this study attempts to establish a quantitative evaluation system for public libraries construction and innovation efficiency that conforms to China's national conditions, and uses the entropy weighted model and the global super-efficiency SBM model to evaluate and measure China's public libraries construction level and innovation efficiency. On this basis, the α convergence model, the β convergence model, the vector autoregression model and the coupling coordination model are constructed to quantitative empirical test whether there is a positive linkage effect between public libraries construction and innovation efficiency, so as to drive them to achieve balanced development among regions and measure the coordinated development level between public libraries construction and innovation efficiency.

2 Theoretical Analysis and Research Hypotheses

Innovation is essentially the re-creation of existing knowledge and technology, so fully mastering knowledge and technology is the basic condition for achieving innovation. As an important part of the cultural service system, public libraries not only have obvious advantages in knowledge and information resources, thus providing a channel for scientific and technological innovation activities to obtain knowledge, but also provide a place for knowledge exchange for innovation activities by building a reading room with a good atmosphere. This will effectively improve the efficiency of the dissemination and utilization of knowledge and information in innovation activities, thereby having a positive impact on regional innovation efficiency^[19]. In theory, public libraries construction should be able to provide support for innovation activities from the following three aspects, thereby effectively improving regional innovation efficiency and narrowing the innovation efficiency gap among regions.

On the one hand, as a social memory center for knowledge and information, public libraries can provide explicit knowledge and information for innovation activities^[13]. As a knowledge and information service center that integrates collection, analysis, processing and dissemination, public libraries not only have rich collections, but also directly include a large number of primary, secondary and tertiary documents such as books, journals, conference proceedings, scientific reports, patents, citations, abstracts and manuals and yearbooks. They can also expand and integrate scientific and technological literature resources, thereby strengthening the construction of literature resources such as patents, processes and scientific and technological reports, and strive to achieve the complementarity of paper printed and online electronic literature resources, while opening up various channels for obtaining international scientific and technological literature resources^[20], thereby promoting the innovation subject to obtain sufficient explicit knowledge and information, and ultimately effectively improving the regional innovation efficiency.

On the other hand, based on the social education function, public libraries can provide knowledge power for innovation activities^[21]. By transmitting and spreading knowledge information to innovation subjects, public libraries can achieve the purpose of imparting and cul-

tivating the knowledge and skills of innovation subjects^[22]. For example, public libraries will not only continuously provide basic document services to the public, but also regularly hold various public welfare lectures and skills training activities with the purpose of disseminating knowledge and skills, providing innovation subjects with a platform and place to accumulate knowledge and supplement skills, thereby promoting the exchange of implicit knowledge and information among innovation subjects, and ultimately effectively improving regional innovation efficiency^[23].

In addition, as a distribution center for systematic knowledge and information, public libraries can also provide systematic knowledge and information support for regional innovation activities. While the regional knowledge and information environment has been significantly improved, the regional knowledge and information absorption capacity can also be significantly improved, which will effectively shorten the distance among regional innovation subjects and knowledge information resources, enhance the diffusion, complementarity and sharing of knowledge and information resources among regional innovation subjects^[24], and reduce the unpredictability and risk of innovative activities. Regional innovation subjects can acquire and use various knowledge resources more accurately and make correct decisions, ultimately narrowing the innovation efficiency gap among regions^[25].

Based on the above analysis, this study proposes the following hypotheses:

Hypothesis 1: Public libraries construction can effectively improve innovation efficiency.

Hypothesis 2: Public libraries construction can effectively narrow the innovation efficiency gap among regions.

It is worth noting that when regional innovation efficiency is effectively improved, it will have a positive interactive effect on public libraries construction. Theoretically, as innovation efficiency improves, innovative results, especially high-level results, emerge one after another. The innovation cycle has been significantly shortened, the speed of updating knowledge and information has also been significantly increased^[19], and the cross-integration of complex knowledge and information across disciplines and cross-professional systems has become more common, which will give rise to a higher level of knowledge and information demands. As a result, government departments will increase their investment in human, material and financial resources in public libraries, and allocate more social resources to the public libraries construction, thereby improving the public libraries construction level. At the same time, in the process of improving regional innovation efficiency, innovation results at different stages also provide solid technical support for promoting the public libraries construction and comprehensively reshape the governance system of public libraries^[22]. While continuing to promote the organizational management reform of public libraries, accelerate the flow and sharing of various library resources among regions, thereby effectively solving the problem of resource islands and promoting the balanced development of public libraries construction among regions.

Based on the above analysis, this study proposes the following hypotheses:

Hypothesis 3: Innovation efficiency can effectively promote public libraries construction.

Hypothesis 4: Innovation efficiency can effectively narrow the public libraries construction gap among regions.

3 Research and Data Methodology

The data in this study are all from the 2012–2023 “China Statistical Yearbook”, “China Cultural Relics and Tourism Statistical Yearbook” and “China Science and Technology Statistical Yearbook”, covering all the data needed to evaluate and measure the public libraries construction level and innovation efficiency. However, given that Qinghai province and Tibet autonomous region lack some of the data needed to measure the innovation efficiency, this study selected 29 provincial administrative regions in China except Qinghai province and Tibet autonomous region as the research objects, and set the research period from 2011 to 2022.

3.1 Research Objects

3.1.1 Public Libraries Construction

The method of existing research for evaluating the public libraries construction level is mainly the single indicator method, that is, using the single indicator such as the total number of public library institutions or the total collection of public libraries or the total number of public libraries circulation visits to be the proxy indicator of the public libraries construction level^[16–18]. However, in terms of the objective reality of current public libraries construction, the single indicator method cannot effectively make a comprehensive evaluation of the public libraries construction level. Therefore, this study adopts the comprehensive indicators method based on the entropy weighting model to make a comprehensive evaluation of the public libraries construction level in China by constructing an indicators evaluation system. The advantage of the entropy weighting model is that it not only avoids the one-sided evaluation defects of the single indicator method, but also does not require subjective setting of the data distribution form, so that the weight of each indicator is directly determined based on the information contained in the data itself^[26].

Specifically, in order to evaluate the public libraries construction level more objectively and comprehensively and avoid subjective and one-sided evaluation like the single indicator method, this study uses the entropy weighting method to make a comprehensive and effective evaluation of China’s public libraries construction level from four dimensions: basic infrastructure, document resources, digital access and service business. In terms of specific indicator selection, based on reference to the existing researches^[18, 27], taking the representativeness and accessibility of data into account, this study selected the number of public libraries, the number of employees and the number of seats in the reading room as the proxy indicators for basic infrastructure, the total collection of public libraries as the proxy indicator for document resources, the number of terminals and computers in the electronic reading room of public libraries as the proxy indicators for digital access, and the total number of circulation visitors to public libraries, the cumulative number of valid library cards issued, the number of people borrowing books and periodicals, the number of books and periodicals borrowed, the number of lectures organized, the number of exhibitions held, the number of training courses held, the number of people attending lectures, the number of people visiting exhibitions and the number of people attending training as the proxy indicators for service business. The specific evaluation models are set as follows:

The first step is to standardize the original indicators using the deviation standardization

method^[28]:

$$y_{i,j} = \frac{x_{i,j} - \min(x_j)}{\max(x_j) - \min(x_j)} * 0.99 + 0.01. \quad (1)$$

In the above formula, $y_{i,j}$ and $x_{i,j}$ respectively represent the j -th original indicator of provincial administrative region i after standardization and without standardization. $\max(x_j)$ and $\min(x_j)$ respectively represent the maximum value and minimum value of the j -th unstandardized indicator. The second step is to calculate the entropy value of each indicator:

$$H_j = -\frac{1}{\ln(n)} * \sum_{i=1}^n p_{i,j} \ln p_{i,j}. \quad (2)$$

In the above formula, $p_{i,j} = y_{i,j} / \sum_{i=1}^n y_{i,j}$. When $p_{i,j} = 0$, set $p_{i,j} \ln p_{i,j} = 0$, so as to ensure $0 \leq H_j \leq 1$. The third step is to calculate the weight of each indicator:

$$w_j = \frac{1 - H_j}{\sum_{j=1}^m (1 - H_j)} = \frac{1 - H_j}{m - \sum_{j=1}^m H_j}. \quad (3)$$

In the above formula, $0 \leq w_j \leq 1$, and $\sum_{j=1}^m w_j = 1$. The fourth step is to calculate the comprehensive score of the public libraries construction level of each provincial administrative region:

$$PLC_i = \sum_{j=1}^m w_j y_{i,j}. \quad (4)$$

In the above formula, the larger the value of PLC_i is, the higher the level of public libraries construction in provincial administrative region i is. Based on the entropy weighting method, this study calculated the weights of the four dimensions of basic infrastructure, document resources, digital access, and service business to be 0.0792, 0.0513, 0.0648, and 0.8047, respectively. The weighted calculation was performed with the standardized data to obtain the public libraries construction level in each provincial administrative region in China from 2011 to 2022, on this basis, China's nationwide public libraries construction level is summarized according to the calculation results (see Table 1), and the changing trend of China's nationwide public libraries construction level is plotted accordingly (see Figure 1).

Table 1 Evaluation results of public libraries construction and innovation efficiency

Series	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
PLC	0.0854	0.0981	0.1082	0.1184	0.1297	0.1424	0.1578	0.1703	0.1853	0.1634	0.1891	0.2034
IE	0.0854	0.0981	0.1082	0.1184	0.1297	0.1424	0.1578	0.1703	0.1853	0.1634	0.1891	0.2034

The results show that the public libraries construction level in China has generally shown a relatively stable and steady upward trend from 2011 to 2022. Although its construction level has briefly declined in 2020, it has resumed a stable growth trend in 2021. The value has increased from 0.0854 in 2011 to 0.2034 in 2022, an increase of 138.17%, with an average annual growth of 8.21%. However, it should be noted that the average public libraries construction level in China during this period was only 0.1460, and there is still a lot of room for improvement to reach a high construction level.

3.1.2 Innovation Efficiency

The existing research methods for measuring innovation efficiency are mainly the Stochastic Frontier Analysis (SFA) model and the Data Envelopment Analysis (DEA) model. The advantage of the SFA model is that its efficiency results has taken the random errors caused by external factors into account, but it requires artificially setting the form of the production function and must be limited to a single target output^[29]. The advantage of the DEA model is that it does not require artificially setting a production function, but can directly calculate the efficiency value of the decision-making unit based on mathematical programming, effectively avoiding biased measurement results caused by subjective weighting, and the DEA model does not restrict the output structure which means that the DEA model do not need to meet the single target output structure. It can measure the efficiency value more comprehensively based on the input-output structure of multiple input indicators and multiple output indicators^[30]. Therefore, this study selects the DEA model to measure China's innovation efficiency.

Specifically, in order to measure innovation efficiency more objectively and accurately, avoid the evaluation bias of a large number of pseudo-efficient units with an efficiency value of 1 that is prone to appear in the measurement results of the traditional DEA model, and make the measurement results comparable across periods^[31], this study uses the non-angle global super-efficiency SBM model with variable returns to scale to measure China's innovation efficiency. In terms of specific indicator selection, based on reference to the existing researches^[32-34], taking the representativeness and accessibility of data into account, this study selected R&D funds, new product development funds, local fiscal science and technology expenditures and the number of R&D personnel as labor and capital input indicators, and selected the number of patent applications accepted, the number of patent applications granted, technology market turnover, new product sales revenue and new product export sales revenue as patent application and technology transfer output indicators. The specific measurement models are set as follows:

$$\theta^* = \min \frac{1 + \frac{1}{m} \sum_{i=1}^m \frac{S_i^{-t}}{x_{i,o}^t}}{1 - \frac{1}{q} \sum_{\tau} \frac{S_{\tau}^{+t}}{y_{\tau,o}^t}} \quad (5)$$

$$\text{s.t. } x_{i,o}^t \geq \sum_{t=1}^T \sum_{j=1}^n \lambda_j^t x_{i,j}^t - S_i^{-}, \quad i = 1, 2, \dots, m, \quad (6)$$

$$y_{\tau,o}^t \leq \sum_{t=1}^T \sum_{j=1}^n \lambda_j^t y_{\tau,j}^t + S_{\tau}^{+}, \quad \tau = 1, 2, \dots, q, \quad (7)$$

$$\lambda_j^t \geq 0, S_i^{-} \geq 0, S_{\tau}^{+} \geq 0. \quad (8)$$

In the above formula, θ^* represents the innovation efficiency value. $y_{\tau,o}^t$ and $x_{i,o}^t$ respectively represent the τ -th output indicator and the i -th input indicator of provincial administrative region o in period t . λ_j^t , S_i^{-} and S_{τ}^{+} respectively represent the weight vector, slack vector and residual vector.

Based on the non-angle global super-efficiency SBM model with variable returns to scale, this study measures the innovation efficiency of each provincial administrative region in China from 2011 to 2022, on this basis, China's nationwide innovation efficiency is summarized according to the measurement results (see Table 1), and the changing trend of China's nationwide innovation efficiency is plotted accordingly (see Figure 1). The results show that China's innovation efficiency has generally shown a relatively unstable fluctuating upward trend from 2011 to 2022. Although the efficiency value has increased from 0.4221 in 2011 to 0.6356 in 2022, an increase of 50.58%, the average annual growth rate is only 3.79%, and the average efficiency during this period is only 0.4688, indicating that China's innovation activities are still inefficient overall. However, it is worth noting that the changing trend of China's innovation efficiency has obvious two-stage characteristics. The first stage is from 2011 to 2019. Although China's innovation efficiency value has increased from 0.4221 in 2011 to 0.4595 in 2019 during this period, the increase is only 8.86%, and the average annual growth rate is only 1.07%. The second stage is from 2019 to 2022. During this period, China's innovation efficiency value has increased from 0.4595 in 2019 to 0.6356 in 2022, an increase of 38.32%, with an average annual growth of 11.42%.

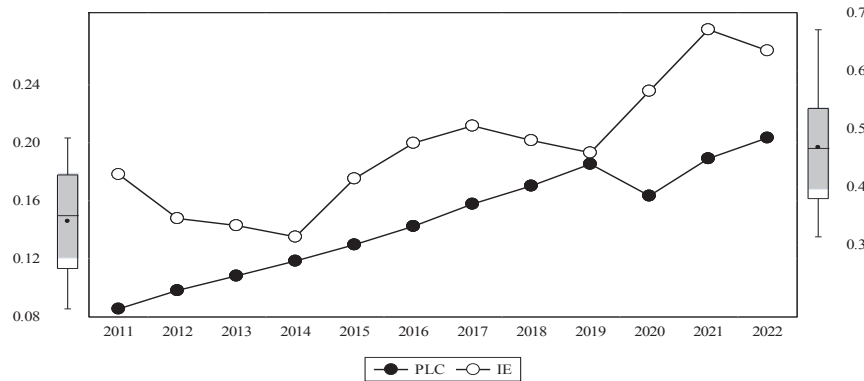


Figure 1 Changing trends of public libraries construction and innovation efficiency

3.2 Empirical Model

3.2.1 Vector Autoregression Model

In order to dynamically evaluate the impact of public libraries construction and innovation efficiency on each other, this study constructs the vector autoregression (VAR) model to test whether the two can effectively promote each other's development. To ensure the stability of the data, this study logarithmized the time series of public libraries construction and the time series of innovation efficiency. The results of ADF, PP and DF unit root tests all show that the logarithmic series have reached a stable status and can be directly used to establish the model. In addition, the AIC, HQ and SC information criteria and stability test results show that the optimal lag order of the model is the second lag. The specific models are set as follows:

$$\ln PLC_t = \gamma_1 + \sum_{j=1}^2 A_j \ln IE_{t-j} + \sum_{j=1}^2 B_j \ln PLC_{t-j} + \epsilon_t, \quad (9)$$

$$\ln IE_t = \gamma_2 + \sum_{j=1}^2 C_j \ln IE_{t-j} + \sum_{j=1}^2 D_j \ln PLC_{t-j} + \mu_t. \quad (10)$$

In the above formula, $\ln PLC_t$ and $\ln IE_t$ respectively represent the natural logarithms of the public libraries construction and innovation efficiency in year t . A_j , B_j , C_j and D_j respectively represent the estimated coefficients before several lagged variables. γ_1 and γ_2 represent the constant terms. ϵ_t and μ_t represent the random disturbance terms.

3.2.2 Convergence Test Model

α Convergence Test Model. If the standard deviation of a region's innovation efficiency from the mean decreases over time, it is considered that the region's innovation efficiency has the α convergence property. The formula for measuring the α coefficient of innovation efficiency is set as follows:

$$\alpha IE_t = \sqrt{\frac{1}{N} \sum_{i=1}^N \left(\ln IE_{i,t} - \frac{1}{N} \sum_{i=1}^N \ln IE_{i,t} \right)^2}. \quad (11)$$

In the above formula, αIE_t represents the natural logarithm of the innovation efficiency of provincial administrative region i in year t . If $\alpha IE_t < \alpha IE_{t+1}$, it means that over time, the innovation efficiency gap among provincial administrative regions in the region is narrowing, and there is the α convergence property.

If the standard deviation of a region's public libraries construction from the mean decreases over time, it is considered that the region's public libraries construction has the α convergence property. The formula for measuring the α coefficient of public libraries construction is set as follows:

$$\alpha PLC_t = \sqrt{\frac{1}{N} \sum_{i=1}^N \left(\ln PLC_{i,t} - \frac{1}{N} \sum_{i=1}^N \ln PLC_{i,t} \right)^2}. \quad (12)$$

In the above formula, αPLC_t represents the natural logarithm of the public libraries construction of provincial administrative region i in year t . If $\alpha PLC_t < \alpha PLC_{t+1}$, it means that over time, the public libraries construction gap among provincial administrative regions in the region is narrowing, and there is the α convergence property.

β Convergence Test Model. Without considering any other factors, if the provincial administrative regions with low innovation efficiency in a region gradually converge to the provincial administrative regions with high efficiency at a faster growth rate, it is believed that the innovation efficiency of the region has the absolute β convergence property. On this basis, if the convergence speed is further improved after the introduction of the public libraries construction variable, it is believed that the innovation efficiency of the region has the conditional β convergence property, and the construction of public libraries can effectively accelerate the convergence of provincial administrative regions with low innovation efficiency to provincial administrative regions with high efficiency. Referring to the approach of Liu, Zhao and Ma^[35], the measurement models of the absolute β coefficient and conditional β coefficient of innovation

efficiency are set as follows:

$$(\ln IE_{i,0+T} - \ln IE_{i,0})/T = F_1 + \beta_1 * \ln IE_{i,0} + \sigma_{i,t}, \quad (13)$$

$$(\ln IE_{i,0+T} - \ln IE_{i,0})/T = F_2 + \beta_2 * \ln IE_{i,0} + \theta_1 * \ln PLC_{i,t} + \varphi_{i,t}. \quad (14)$$

In the above formula, $\ln IE_{i,0}$ and $\ln IE_{i,0+T}$ respectively represent the natural logarithm of the innovation efficiency of provincial administrative region i in 2011 and T years from 2011. $\ln PLC_{i,t}$ represents the natural logarithms of the public libraries construction level of provincial administrative region i in year t . β_1 and β_2 respectively represent the absolute β coefficient value and the conditional β coefficient value of the innovation efficiency to be measured. If $\beta_1 < 0$ is significant, it indicates that the innovation efficiency in the region has the absolute β convergence property. Even if other factors are not considered, as time goes by, the innovation efficiency gap among provincial administrative regions in the region will gradually narrow, and the convergence rate is $v_1 = -\ln(1 + \beta_1)/T$. If $\beta_2 < 0$ is significant and numerically $< \beta_1$, it indicates that the innovation efficiency of the region has the conditional β convergence property, that is, with the improvement of the public libraries construction level, the innovation efficiency gap of the region is accelerating and narrowing, and can converge to consistency at a faster speed, the convergence speed is $v_2 = -\ln(1 + \beta_2)/T$. T represents the length of time. F_1 and F_2 represent the constant terms. $\sigma_{i,t}$ and $\varphi_{i,t}$ represent the random error terms.

Without considering any other factors, if the provincial administrative regions with low public libraries construction levels in a certain region gradually converge to the provincial administrative regions with high construction levels at a faster growth rate, it is believed that the public libraries construction in this region has the absolute β convergence property. On this basis, if the convergence speed is further improved after the introduction of the innovation efficiency variable, it is believed that the public libraries construction in this region has the conditional β convergence property, and innovation efficiency can effectively accelerate the convergence of provincial administrative regions with low public libraries construction levels to provincial administrative regions with high construction levels. Referring to the approach of Liu, Zhao and Ma^[35], the measurement models of the absolute β coefficient and conditional β coefficient of public libraries construction are set as follows:

$$(\ln PLC_{i,0+T} - \ln PLC_{i,0})/T = F_3 + \beta_3 * \ln PLC_{i,0} + \delta_{i,t}, \quad (15)$$

$$(\ln PLC_{i,0+T} - \ln PLC_{i,0})/T = F_4 + \beta_4 * \ln PLC_{i,0} + \theta_2 * \ln IE_{i,t} + \omega_{i,t}. \quad (16)$$

In the above formula, $\ln PLC_{i,0}$ and $\ln PLC_{i,0+T}$ respectively represent the natural logarithm value of the public libraries construction level of provincial administrative region i in 2011 and T years from 2011. $\ln IE_{i,t}$ represents the natural logarithms of the innovation efficiency of provincial administrative region i in year t . β_3 and β_4 respectively represent the absolute β coefficient value and conditional β coefficient value of the public libraries construction to be measured. If $\beta_3 < 0$ is significant, it indicates that the public libraries construction in the area has the absolute β convergence property, even if other factors are not considered, as time goes

by, the public libraries construction gap among provincial administrative regions in the region will gradually narrow, and the convergence rate is $v_3 = -\ln(1 + \beta_3)/T$. If $\beta_4 < 0$ is significant and numerically $< \beta_3$, it indicates that the construction of public libraries in this region has the conditional β convergence property, that is, with the improvement of innovation efficiency, the public libraries construction gap among provincial administrative regions in this region is accelerating and narrowing, and can converge to consistency at a faster speed, the convergence speed is $v_4 = -\ln(1 + \beta_4)/T$. T represents the length of time. F_3 and F_4 represent the constant terms. $\delta_{i,t}$ and $\omega_{i,t}$ represent the random error terms.

3.2.3 Coupling Coordination Model

Figure 2 shows that, the vast majority of provincial administrative regions in China are located in the second and fourth quadrants in 2011–2022, showing the characteristics of higher public libraries construction and higher innovation efficiency, but most of them are located in the second quadrant, and their public libraries construction and innovation efficiency are at a relatively low level. Of course, there are also quite a few provincial administrative regions located in the first quadrant, showing the characteristics of a low level of public libraries construction and a high innovation efficiency.

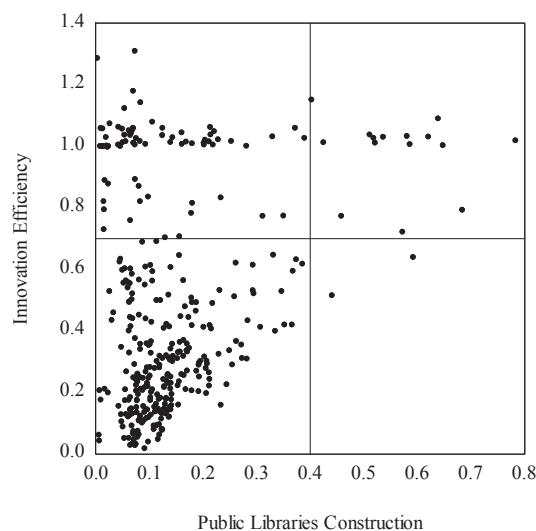


Figure 2 Two-dimensional matrix of public libraries construction and innovation efficiency

In order to further test the development consistency between public libraries construction and innovation efficiency, this study constructs the coupling coordination model to measure the coordinated development of public libraries construction and innovation efficiency, drawing on the concept of coupling in physics. The specific models are set as follows:

$$D = \sqrt{CT}, \quad (17)$$

$$C = 2\sqrt{G_1G_2}/(G_1 + G_2), \quad (18)$$

$$T = w_1G_1 + w_2G_2. \quad (19)$$

In the above formula, D represents the coupling coordination degree between public libraries construction and innovation efficiency, reflecting their development consistency. The higher the D value, the higher the coordinated development level between public libraries construction and innovation efficiency. C and T represent respectively the coordination degree and comprehensive development level between public libraries construction and innovation efficiency. G_1 and G_2 respectively represent public libraries construction and innovation efficiency. w_1 and w_2 represent respectively the weights of public libraries construction and innovation efficiency, and satisfy $w_1 + w_2 = 1$. This study believes that both are equally important, so this study assigns w_1 and w_2 a value of 0.5. The specific coupling coordination judgment criteria are shown in Table 2.

Table 2 Judgment criteria for coupling coordination

Coupling level	Coupling grade	Coupling value	Coupling coordination degree
Disorder recession	1	(0, 0.1)	Extremely disorder
	2	[0.1, 0.2)	Serious disorder
	3	[0.2, 0.3)	Moderate disorder
Coordination transition	4	[0.3, 0.4)	Mild disorder
	5	[0.4, 0.5)	On the verge of disorder
	6	[0.5, 0.6)	Barely coordinated
Coupled coordination	7	[0.6, 0.7)	Primary coordination
	8	[0.7, 0.8)	Intermediate coordination
	9	[0.8, 0.9)	Good coordination
	10	[0.9, 1.0)	High-quality coordination

4 Empirical Analysis

4.1 Impulse Response Analysis

Figure 3 reports the response feedback of public libraries construction and innovation efficiency to each other's impact in China nationwide. The results show that after being impacted by each other, both public libraries construction and innovation efficiency experienced a relatively weak short-term negative response, but the responses of both to each other's impact quickly turned to positive feedback and reached peaks in the second and third periods respectively. Although the responses between public libraries construction and innovation efficiency have since turned into varying degrees of fluctuation and weakening trends, from high to low, gradually converging to 0, they have always shown positive responses, indicating that public libraries construction and innovation efficiency can effectively promote each other's development, which verifies Hypothesis 1 and Hypothesis 3.

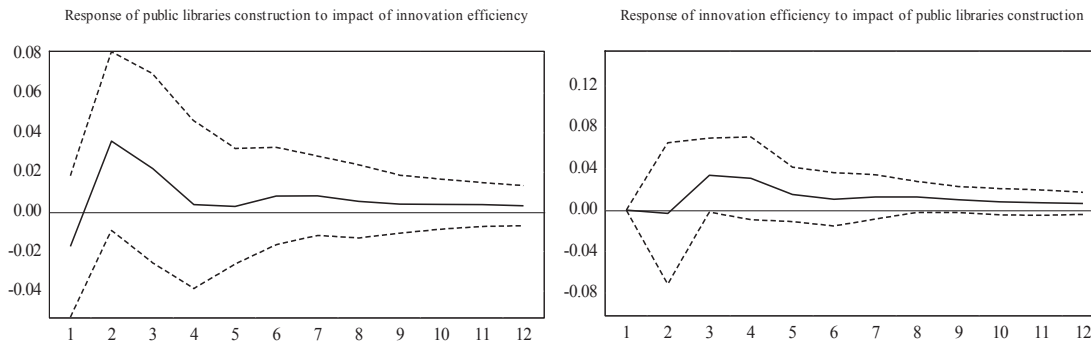


Figure 3 Impulse response between public libraries construction and innovation efficiency

4.2 Variance Decomposition Analysis

Based on the above verification that there is a positive interactive effect between public libraries construction and innovation efficiency, this study conducted the variance decomposition on the impulse response results to specifically measure the contribution of public libraries construction and innovation efficiency to each other's development (see Tables 3 and 4).

Table 3 Variance decomposition results of public libraries construction (%)

Series	1	2	3	4	5	6	7	8	9	10	11	12
PLC	90.89	67.46	63.56	66.40	68.42	68.85	68.89	69.21	69.53	69.72	69.82	69.91
IE	9.11	32.54	36.44	33.60	31.58	31.15	31.11	30.79	30.47	30.28	30.28	30.09

Table 4 Variance decomposition results of innovation efficiency (%)

Series	1	2	3	4	5	6	7	8	9	10	11	12
PLC	100.00	99.93	93.15	88.33	87.33	87.00	86.28	85.55	85.11	84.85	84.63	84.63
IE	0.00	0.07	6.85	11.67	12.67	13.00	13.72	14.45	14.89	15.15	15.37	15.55

The results show that in the process of constructing public libraries, the contribution of innovation efficiency can reach about 30%, and in the process of improving innovation efficiency, the contribution of public libraries construction even can exceed 80%. Public libraries construction and innovation efficiency can not only effectively promote each other's development, but also had a relatively large promotion intensity.

4.3 Convergence Test Analysis

4.3.1 α Convergence Test Analysis

Table 5 and Figure 4 reports the measurement results and change trends of China's nationwide α coefficient of public libraries construction and the α coefficient of innovation efficiency.

Table 5 α coefficient measurement results of public libraries construction and innovation efficiency

Series	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
PLC	0.0568	0.0608	0.0661	0.0760	0.0917	0.1010	0.1149	0.1302	0.1523	0.1472	0.1605	0.1879
IE	0.3852	0.3076	0.2915	0.2650	0.3342	0.3372	0.3336	0.3084	0.2952	0.3602	0.3675	0.3489

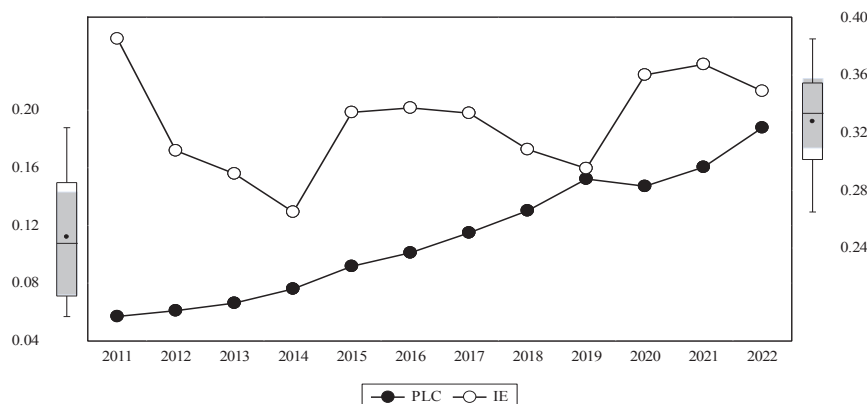


Figure 4 α coefficient changing trends of public libraries construction and innovation efficiency

The results show that: Although there was no strict α convergence property for innovation efficiency, the α coefficient of innovation efficiency generally showed a fluctuating downward trend over time. However, the α coefficient of public libraries construction showed a rapid upward trend during this period. Specifically, the α coefficient of innovation efficiency has dropped from 0.3852 in 2011 to 0.3489 in 2022, a decrease of 9.42%, while the α coefficient of public libraries construction has increased from 0.0568 in 2011 to 0.1879 in 2022, an increase of 230.81%, indicating that the innovation efficiency gaps among provincial administrative regions in China were likely to be gradually narrowing, while the public libraries construction gaps among provincial administrative regions were expanding. So, can public libraries construction accelerate the convergence speed of the innovation efficiency gaps among provincial administrative regions in China? Can innovation efficiency inhibit the widening trend of the public libraries construction gaps among provincial administrative regions in China? This needs to be further measured and judged through the β convergence test results.

4.3.2 β Convergence Test Analysis

Table 6 reports China's nationwide β convergence test results of innovation efficiency. The results show that: In terms of innovation efficiency, its absolute β coefficient value is significantly less than 0, indicating that China's innovation efficiency has the absolute β convergence property, even if no other factors are considered, the innovation efficiency gap among provincial administrative regions will also tend to be eliminated at a convergence rate of 0.59%. After introducing the variable of public libraries construction, compared with the absolute β coefficient value, the conditional β coefficient value of innovation efficiency is further reduced, indicating that China's innovation efficiency has the conditional β convergence property, and public libraries construction can significantly increase the convergence speed of the innovation efficiency gap among provincial administrative regions from 0.59% to 0.64%, an increase of 8.47%. This shows that as an important convergence mechanism for the efficient and balanced development of regional innovative activities, the public libraries construction can not only directly empower innovative activities and effectively improve their operational efficiency, but can also significantly drive the efficient and balanced development of regional innovative activities, ac-

celerates the convergence of regional innovation efficiency and narrows the innovation efficiency gap among regions, which verifies Hypothesis 3.

Table 6 Results of the β convergence test on innovation efficiency

Innovation efficiency	β coefficient	Public libraries construction	Constant term	Convergence status	Convergence speed	N
Absolute convergence	-0.0632*** (0.0057)	Uncontrolled	-0.0768*** (0.0091)	Convergent	0.59%	319
Conditional convergence	-0.0675*** (0.0062)	Controlled	-0.0955*** (0.0122)	Convergent	0.64%	319

Note: *** represents $P < 0.1\%$, ** represents $P < 1\%$, * represents $P < 5\%$. Numbers in parentheses are standard errors. Same below.

Table 7 reports China's nationwide β convergence test results of public libraries construction. The results show that: in terms of public libraries construction, the absolute β coefficient value is significantly greater than 0, indicating that China's public libraries construction is in a divergent status. If other factors are not taken into account, the public libraries construction gap among provincial administrative regions will gradually expand. After introducing the innovation efficiency variable, although the conditional β coefficient value of public libraries construction is still significantly greater than 0, compared with the absolute β coefficient value, it has been controlled, indicating that innovation efficiency can, to a certain extent, promote the balanced development of regional public libraries construction and narrow the public libraries construction gap among provincial administrative regions, which verifies Hypothesis 4.

Table 7 Results of the β convergence test on public libraries construction

Public libraries construction	β coefficient	Innovation efficiency	Constant term	Convergence status	Convergence speed	N
Absolute convergence	0.0092** (0.0028)	Uncontrolled	0.1204*** (0.0074)	Divergent	-	319
Conditional convergence	0.0087** (0.0029)	Controlled	0.1178*** (0.0088)	Divergent	-	319

4.4 Coupling Effect Analysis

Table 8 and Figure 5 reports the results of China's coupling coordination measurement between public libraries construction and innovation efficiency.

Table 8 Coupling coordination degree measurement results

Region	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Nationwide	0.3822	0.3874	0.3939	0.3979	0.4346	0.4669	0.4842	0.4911	0.4912	0.4956	0.5452	0.5464
Eastern	0.4473	0.4533	0.4559	0.4526	0.4825	0.5306	0.5320	0.5727	0.5815	0.5895	0.6405	0.6451
Central & Western	0.3424	0.3472	0.3560	0.3645	0.4053	0.4280	0.4551	0.4412	0.4360	0.4382	0.4869	0.4861

The results show that: The coordinated development level between public libraries construction and innovation efficiency in nationwide China showed a steady upward trend from 2011 to

2022. The coupling value between public libraries construction and innovation efficiency has increased from 0.3822 in 2011 to 0.5464 in 2022, an increase of 42.96%. The coupling coordination degree has also increased from mild imbalance to barely coordinated. However, it should be noted that from the perspective of the development stage, although the coupling grade level of China's public libraries construction and innovation efficiency has jumped from level 4 to level 6 from 2011 to 2022, the average coupling coordination between public libraries construction and innovation efficiency during this period was still only 0.4598, and overall it was still on the verge of disorder, and the coupling coordination between public libraries construction and innovation efficiency still needs to be further improved.

In addition, there are obvious regional differences in the coupling coordination degree between China's public libraries construction and innovation efficiency. Specifically, in the eastern region, not only has the coupling value between public libraries construction and innovation efficiency increased steadily from 0.4473 in 2011 to 0.6451 in 2022, which is much higher than the nationwide average, but the average coupling value between public libraries construction and innovation efficiency has also reached 0.5320 during this period, and the coupling grade level has reached level 6, which is in a barely coordinated stage. In particular, in 2021 and 2022, the coupling value exceeded 0.6, and there is a trend of entering the primary coordination stage. In contrast, the coupling value between public libraries construction and innovation efficiency in the central region and western region has only fluctuated from 0.3424 in 2011 to 0.4861 in 2022, which is significantly lower than the nationwide average. The average coupling value between public libraries construction and innovation efficiency during this period is only 0.4156, and the coupling grade level is level 5, which is on the verge of disorder.

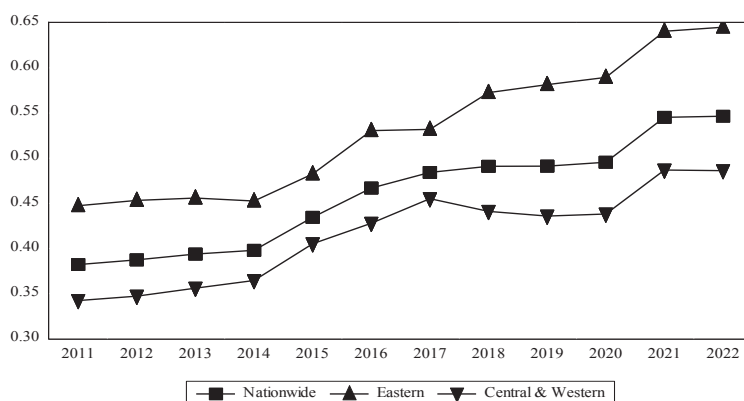


Figure 5 Changing trend of coupling coordination degree

5 Discussion

This study not only qualitatively discusses the relationship between public libraries construction and innovation efficiency from the perspective of theoretical analysis, but also quantitatively tests the relationship between the two from the perspective of empirical analysis based on scientific evaluation and measurement of the China's public libraries construction level and innovation efficiency. Consistent with the research conclusions of Xu^[16], Zhang and Tan^[17], the public libraries construction can effectively promote innovation efficiency. But different from

the research conclusion of Wang and Zhou^[18], public libraries construction can also significantly narrow the innovation efficiency gap between regions and accelerate the convergence of provincial administrative regions with low innovation efficiency to provincial administrative regions with high innovation efficiency.

In addition, the biggest difference between this study and existing studies is that this study also analyzes and examines the reaction force of innovation efficiency on public libraries construction from both theoretical qualitative and empirical quantitative perspectives, and measures the coordinated development level between public libraries construction and innovation efficiency. The study found that innovation efficiency can effectively promote the high-level balanced development of regional public libraries construction, thereby confirming that there is indeed a positive linkage effect between public libraries construction and innovation efficiency, and the coupling coordination degree between public libraries construction and innovation efficiency is on a steady upward trend, further enriching and expanding the existing theories and research results on public libraries construction and innovation efficiency, and making up for the lack of relevant research on the linkage effect between public libraries construction and innovation efficiency.

However, this study also has shortcomings. It should be noted that under the background of global digital transformation, it is worth pondering how digital technology will affect the linkage effect between public libraries construction and innovation efficiency. Existing studies have pointed out that digital technology can not only break through the limitations of physical platforms, time and space, and promote the high-speed circulation of massive innovative knowledge and information in all aspects of innovation activities, thereby promoting the improvement of innovation efficiency^[33], but also provide important technical support for public libraries to upgrade their software and hardware, and optimize and expand their service processes and models, thereby improving the public libraries construction level^[36]. Therefore, in future research, we will also focus on the role of digital technology in the coordinated development of public libraries construction and innovation efficiency.

6 Conclusion

This study uses the entropy weighting method and the global super-efficiency SBM model to evaluate and measure China's public libraries construction and innovation efficiency from 2011 to 2022, uses the VAR model to evaluate the impact of the public libraries construction and the innovation efficiency on each other, and constructs the α convergence model and the β convergence model to test whether public libraries construction and the innovation efficiency can effectively drive each other's balanced development. On this basis, this study also uses the coupling coordination model to measure the coordinated development level between public libraries construction and innovation efficiency. The research conclusions are as follows:

The level of public libraries construction in China has not only achieved steady growth from 2011 to 2022, but also can effectively promote the improvement of innovation efficiency and accelerate the narrowing of regional innovation efficiency gap. However, the overall level of public libraries construction in China is still at a relatively low level, and there is still much room for improvement to reach a high level of construction.

Although China's innovation efficiency has fluctuated in its growth trend from 2011 to 2022, it has also achieved a significant improvement, and can effectively promote the improvement of the level of public libraries construction and curb the widening of regional public libraries construction gaps. However, China's innovation efficiency is still in an inefficient status overall, and there is still much room for improvement before achieving high-efficiency operation.

The level of coordinated development between China's public libraries construction and innovation efficiency has achieved steady growth from 2011 to 2022, and the coupling coordination degree has improved from mild imbalance to barely coordinated, but there are obvious regional gaps. The coupling coordination degree between public libraries construction and innovation efficiency in the eastern region is significantly better than that in the central region and western region.

7 Managerial Implication

When purchasing document resources, especially those related to scientific and technological innovation, public libraries should fully consider the local city's positioning, industrial advantages, and innovation needs, and, in combination with the expansion and deepening of their own functions, focus on collecting document resources that are consistent with local development plans to form a rich collection with local characteristics.

Public libraries should strengthen their ability to develop and utilize knowledge and information resources, especially to train a team of librarians who are specialized in innovation services. This team should not only be good at collecting and collating cutting-edge innovation information at home and abroad, but also be good at mastering the information on the innovation market, innovation subjects and related innovation policies, and be able to make in-depth analysis and evaluation of this information, so as to provide more comprehensive and efficient advice and guidance for innovation subjects.

When formulating innovation strategies, government departments should adapt to local conditions. They should not only fully consider the actual local innovation capabilities, but also strengthen the supervision of innovation resources, make reasonable resource investment in innovation activities, avoid blindly reducing investment and excessive redundant investment, and establish a scientific and effective innovation achievement evaluation mechanism to accelerate the transformation rate of innovation achievements while improving the quality of innovation achievement transformation.

8 Social Implications

The coordinated development level between China's public libraries construction and innovation efficiency is showing a steady growth trend, which mainly depends on the continuous improvement of the public libraries construction level and the innovation efficiency value, but the coupling coordination between public libraries construction and innovation efficiency still has a lot of room for improvement. Therefore, government departments should actively guide and continuously promote the coordinated development of public libraries and innovation activities, and create a good policy environment for the efficient integration of the two.

On the one hand, government departments should increase the publicity and promotion of the integrated development concept of public libraries and innovation activities, and strengthen

the social cognition of this integrated development concept. On the other hand, government departments should strengthen the team of compound talents construction who have proficient library and information skills and good at knowledge innovation, so as to lay a solid intellectual guarantee for the integrated development of public libraries construction and innovation activities.

In addition, government departments should also give full play to the coordination and promotion role of industries and associations, actively organize seminars and exchanges between library associations, innovation associations and innovation industry entities, and jointly carry out seminars on the integrated development of public libraries and innovation activities, so as to promote each other's in-depth understanding of the functional positioning and advantageous resources of both parties, form interactive and complementary forces, and thus promote the efficient integration of public libraries construction and innovation efficiency.

References

- [1] Liu Z H, Xi C J, Yang Y. Research on the measurement method of regional scientific and technological innovation efficiency based on dynamic network SBM model. *Information Science*, 2022, 40(7): 145–153.
- [2] Chen Y E, Li X, L W. Analysis of influencing factors and temporal and spatial heterogeneity of scientific and technological innovation efficiency in China's provincial administrative regions. *Chinese Soft Science*, 2021(4): 137–149.
- [3] Cheng G B, Wu J Q, Sun X Y. Research on the efficiency and influencing factors of scientific and technological innovation in the Yangtze River Economic Belt. *Science and Technology Management Research*, 2022, 42(3): 57–65.
- [4] Wang P, Zhong Y H, Yan Y. Interactive analysis of scientific and technological innovation efficiency and regional economic resilience: Empirical evidence from the Pearl River Delta region. *Scientific & Technological Progress and Countermeasures*, 2022, 39(8): 48–58.
- [5] Yang G M, Yang Y R, Gui Q Q. Analysis on the spatiotemporal evolution characteristics of the coupling coordination between scientific and technological innovation efficiency and economic development level. *Statistics and Decision*, 2023, 39(11): 112–116.
- [6] Yang J, Cheng H D. Analysis on the efficiency and influencing factors of scientific and technological innovation resource allocation in the Yangtze River Delta urban agglomeration from the perspective of government intervention. *Science and Technology Management Research*, 2024, 44(4): 153–158.
- [7] Yin S, Yu Y, Zhang N. The effect of digital green strategic orientation on digital green innovation performance: From the perspective of digital green business model innovation. *SAGE Open*, 2024, 14(2): 21582440241261130.
- [8] Huang L H. How can public libraries serve scientific and technological innovation? *Library Science Research*, 2000(1): 85–86.
- [9] Liu Y P. Research on the countermeasures of regional public libraries serving technology-based small and medium-sized enterprises. *Library Work and Research*, 2016(3): 92–95.
- [10] Zhou L H, Huang R G, Tim Z. The survival and development of British public libraries under the global economic crisis. *Journal of China Library Science*, 2015, 41(1): 16–27.
- [11] Song L Y. An analysis of implicit knowledge management in libraries based on regional innovation. *Library Work and Research*, 2018(3): 64–68.
- [12] Yan W D. Information service practice of public libraries for enterprise technological innovation: Taking Shenzhen Science and Technology Library as an example. *Shandong Library Journal*, 2011(1): 65–68.
- [13] Ma A H. Thinking about public libraries serving regional scientific and technological innovation: Taking Tianjin TEDA Library as an example. *Library Work and Research*, 2014(6): 86–89.
- [14] Liu Y M. Knowledge innovation services and libraries: Thoughts from the “Knowledge Innovation Service Industry Development Strategy Summit Forum”. *Library and Information Guide*, 2020, 5(3): 12–19.
- [15] Hou H. Practice and thinking on innovation in public library service regions: Taking Shenzhen University Town Library as an example. *Library Science Research*, 2022(7): 94–100.

- [16] Xu F. Research on the influence of collection resources, utilization efficiency and urban innovation ability of public libraries in my country. *New Century Library*, 2018(3): 36–41.
- [17] Zhang Y X, Tan Y. Do public libraries promote regional scientific and technological innovation? An empirical study based on dynamic panel and spatial measurement. *New Century Library*, 2021(1): 11–17.
- [18] Wang Z Y, Zhou J. Public libraries, industrial agglomeration and technological innovation: An analysis based on panel data of 278 prefecture-level cities from 2003 to 2016. *Library Research*, 2023, 53(2): 1–10.
- [19] Li W C, Zhu Y P, Zhang X N, et al. Research on the coordinated development of public libraries undertakings and scientific and technological innovation in my country. *Journal of Zhengzhou Institute of Aeronautical Industry Management*, 2022, 40(5): 60–66.
- [20] Wang X L. On the expansion of scientific and technological service functions of public libraries. *Library Forum*, 2008(3): 28–30.
- [21] Xu Z X, Qian M H, Qian J T. A preliminary study on the contribution model of provincial public libraries to regional innovation capabilities. *China Science and Technology Resources Guide*, 2019, 51(2): 48–54.
- [22] Chen Y, Hong Y. An empirical study on the synergistic relationship between the development of public libraries and technological innovation in my country: From the perspective of long-term equilibrium and short-term fluctuations based on the time series model. *Library Work and Research*, 2016(6): 22–29.
- [23] Xu Z X, Qian M H, Qian J T. An empirical study on the impact of public libraries knowledge flow on regional innovation performance. *Library*, 2020(7): 79–86.
- [24] Wei D Y, Peng Z P. Exploration of information service practice for Guangdong regional scientific and technological innovation: Taking Guangdong Science and Technology Library as an example. *Digital Library Forum*, 2016(10): 38–43.
- [25] Cui M. Research on innovative data services provided by libraries to small and medium-sized enterprises under the open data environment. *Journal of Henan Library*, 2019, 39(11): 74–78.
- [26] Cao C, Zhang M. Research on the financial support level and efficiency evaluation of China's new generation of high-tech industries: Evidence from listed companies. *Science and Technology Management Research*, 2021, 41(21): 38–46.
- [27] Han H, Li S H. Study on the temporal and spatial differences and influencing mechanisms of service efficiency of public libraries in my country. *Library Journal*, 2022, 41(2): 24–35.
- [28] Yin S, Zhao Y. An agent-based evolutionary system model of the transformation from building material industry (BMI) to green intelligent BMI under supply chain management. *Humanities and Social Sciences Communications*, 2024, 11(1): 1–15.
- [29] Aigner D, Lovell C A K, Schmidt P. Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics*, 1977, 6(1): 21–37.
- [30] Charnes A, Cooper W, Rhodes E L. Measuring the efficiency of decision making units. *European Journal of Operational Research*, 1978, 2(6): 429–444.
- [31] Liu H J, Qiao L C, Shi Y. Comparative study on ecological efficiency of Yangtze River Economic Belt and Yellow River Basin from the perspective of major national strategic regions. *China Soft Science*, 2021(10): 73–81.
- [32] Yu Y, Yin S. Incentive mechanism for the development of rural new energy industry: New energy enterprise-village collective linkages considering the quantum entanglement and benefit relationship. *International Journal of Energy Research*, 2023, 2023(1): 1675858.
- [33] Gao J C, Liu Y, Wang W. Digital construction and technological innovation efficiency: Empirical analysis based on China's macro data from 2011 to 2021. *Science and Technology Management Research*, 2024(1): 43–50.
- [34] Liu Y, Gao J C. Analysis on the coordinated development of digital construction and scientific and technological innovation efficiency in universities. *Science and Technology Management Research*, 2024, 44(1): 67–76.
- [35] Liu H W, Zhao Z X, Ma J Q. Comprehensive evaluation measurement and trend convergence test of high-quality development of national high-tech zones. *Science of Science and Management of Science and Technology*, 2021, 42(6): 66–80.
- [36] Wang Y, Liu J J. Digital technology empowers library intelligent services: Logic, obstacles and solutions. *Library*, 2024(1): 47–52.