Efficiency Measurement and Influencing Factors of Chinese Public Libraries from a Spatial Perspective: Post-Print

Authors: Shi Li, Qin Ping

Date: 2023-04-01T16:15:53+00:00

Abstract

[Purpose/Significance] Public libraries constitute an important component of China's public cultural service system. Research on efficiency measurement and influencing factor analysis from a spatial perspective holds practical significance for the construction of the public cultural service system. [Method/Process] Using panel data from China's provinces and municipalities for 2007-2016 as research units, and based on efficiency measurement and analysis of public libraries using the super-efficiency three-stage DEA model and Markov chain model, this study introduces spatial effects into the analysis of factors influencing public library efficiency, constructs a spatial panel econometric model to estimate the degree of impact, and discusses the differential characteristics of influencing factors across regions and time periods. [Results/Conclusions] The study finds that external environmental and random error factors significantly affect the efficiency of public libraries in China. Adjusted efficiency values exhibit significant spatial non-equilibrium characteristics in regional distribution, manifesting as highest in the eastern region, followed by the central region, and lowest in the western region. Public library efficiency demonstrates significant spatial positive correlation and spatial spillover effects. Under conditions accounting for spatial elements, internal factors including expenditures on new collection acquisitions, the quantity and structure of professional technical personnel, per capita library building area, library activity level, and equity index all influence public library efficiency.

Full Text

Spatial Perspective on Measuring and Analyzing Influencing Factors of Public Library Efficiency in China

Shi Li[1],[2], **Qin Ping**[1],[2] [1]Nanjing University of Aeronautics and Astronautics Library, Nanjing 210016 [2]Evaluation Center for Think Tank of Industry and Information Technology, Nanjing University of Aeronautics and Astronautics, Nanjing 210016

Abstract: [Purpose/Significance] Public libraries constitute a vital component of China's public cultural service system. Examining their efficiency from a spatial perspective holds practical significance for constructing an effective public cultural service framework. [Method/Process] Using provincial panel data from China spanning 2007–2016, this study first measures public library efficiency through a super-efficiency three-stage DEA model and Markov chain analysis. It then incorporates spatial effects into the examination of influencing factors, constructing a spatial panel econometric model to estimate impact magnitudes while discussing differentiated characteristics across regions and time periods. [Result/Conclusion] The findings reveal that external environmental and random error factors significantly affect public library efficiency in China. Adjusted efficiency values demonstrate pronounced spatial disequilibrium in regional distribution, with the highest values in eastern regions, followed by central regions, and the lowest in western regions. Public library efficiency exhibits significant positive spatial correlation and spatial spillover effects. Under spatial considerations, internal factors—including new collection acquisition expenditures, quantity and structure of professional technical personnel, per capita library space, library activity levels, and equity indices—all influence public library efficiency.

Keywords: public library; super-efficiency three-stage DEA; spatial econometric model; influencing factors

1 Introduction

The "13th Five-Year Plan for Cultural Development and Reform" issued by the General Office of the CPC Central Committee and the State Council in 2017 explicitly called for accelerating the construction of a modern public cultural service system that is inclusive, basic, equal, and sustainable. The Public Library Law of 2018 reaffirmed from a legal standpoint the fundamental connotation of public libraries and their significance as components of the socialist public cultural service system, emphasizing the need to improve service effectiveness. The Ministry of Culture's "13th Five-Year Plan for National Public Library Development" proposed enhancing service efficiency and promoting equalization of public library services. These policy documents demonstrate that transformation and development focused on improving service effectiveness hold important

practical significance for public library development within the public cultural service system.

In recent years, a "paradox" has emerged as a societal focus: despite continuous increases in public cultural resource inputs, performance continues to decline. As key members of the public cultural service system, libraries have attracted widespread scholarly attention regarding their efficiency issues. P. Miidla et al. employed DEA methods to evaluate the relative efficiency of 20 central public libraries in Estonia, concluding that high redundancy in personnel expenditures was the primary factor causing low public library efficiency. J. Stroobants et al. applied FDH and DEA techniques to public libraries in Flanders, arguing that non-parametric frontier methods hold potential advantages for benchmarking local public service efficiency. J. Simon et al. combined DEA models with Malmquist indices to analyze the efficiency of 34 university libraries in Spain from 2003–2007, identifying technological progress as the main driver of productivity improvement.

Domestic research on public library efficiency has concentrated in three areas: First, measurement of public library efficiency in China, evolving from traditional non-parametric DEA models to three-stage DEA methods that account for external environments, and further to Super-SBM models that strip away environmental slack effects. Research has also progressed from static efficiency measurement to dynamic efficiency analysis using DEA-Malmquist productivity indices and examinations of efficiency convergence. Second, studies on influencing factors of public library efficiency in China. For instance, Chu Jiewang et al. analyzed 2012 provincial cross-sectional data using Tobit models, while Wang Wei et al. examined regional panel data from 2011–2013, finding that influencing factors include both external elements like per capita disposable income and average education levels, and internal factors such as professional technical personnel and electronic book investments. Fu Caiwu analyzed scale returns and "congestion" phenomena in public libraries, concluding that inadequate technical management and resource allocation congestion were primary reasons for declining efficiency. Third, research on the relationship between efficiency and equity in Chinese public libraries. Scholars including Chen Lin, Guo Zhengwu, Xu Xiangwang, and Zhou Di have examined efficiency-equity issues within unified frameworks from perspectives of institutional differences, disciplinary variations, resource scarcity, and coordinated development, arguing that public library development in China should follow a principle of "balancing equity and efficiency."

In summary, existing research has yielded rich findings on public library efficiency in China. However, it is noteworthy that current literature contains relatively few studies on spatiotemporal differences in public library efficiency, with most treating regions as independent entities without considering inter-regional flows of library resource elements. This oversight of spatial factors such as spatial heterogeneity and dependence makes it difficult to reveal the true dynamics of spatiotemporal evolution in public library efficiency. In reality, as China's

public libraries have accelerated their socialization, resource elements increasingly flow across regions, inevitably creating connections and diffusion effects among neighboring areas. This raises important questions: What spatial characteristics will emerge in public library efficiency under these circumstances? Will spatial agglomeration effects exist? If so, what are the influencing factors of public library efficiency under spatial effects, and how do they operate? Addressing these questions, this study employs provincial panel data from 2007–2016, measures public library efficiency using a super-efficiency three-stage DEA model, introduces spatial effects into the analysis of influencing factors, establishes a spatial panel econometric model to estimate impact magnitudes, and discusses differentiated characteristics across regions and time periods to deepen understanding of spatial influences on public library efficiency changes and identify key factors and pathways for improvement.

2 Research Methods

2.1 Public Library Efficiency Measurement: Super-Efficiency Three-Stage DEA Model and Markov Chain Model

2.1.1 Super-Efficiency Three-Stage DEA Model Current public library efficiency measurement methods primarily include DEA, SFA, and SBM approaches. This study employs a super-efficiency three-stage DEA model, which combines H. Fried et al.'s three-stage DEA model with P. Andersen et al.'s super-efficiency DEA model. This hybrid approach effectively eliminates environmental and random error impacts, providing a true reflection of decision-making unit efficiency while enabling further comparison among efficient units.

The operational procedure involves three stages: First, initial efficiency measurement using the super-efficiency DEA model, which yields efficiency values affected by external environments and random errors. Second, adjustment of input variables through Stochastic Frontier Analysis (SFA). Using an input-oriented approach, SFA regression analysis is applied to input variable slack values across regions, with input indicators adjusted based on regression results to exclude environmental and random error influences. Specific calculation formulas follow Jiang Ping et al. and Guo Sidai et al. Third, re-calculation of public library efficiency using the super-efficiency DEA model with adjusted input data and original output data to obtain super-efficiency values purged of environmental and random error effects.

2.1.2 Markov Chain Model Named after Russian mathematician Markov's 1906 research, the Markov chain is a random process discrete in both time and state. Following Zhou Di et al., this study discretizes efficiency values into four types—low, medium-low, medium-high, and high—using 50%, 100%, and 150% of the annual average public library efficiency as cutoff points. By calculating transition probabilities among these four types, the model assesses the persistence of different efficiency levels over time and tests for "Matthew effects." The

transition probability matrix for a d-year period is given by: P_{t,t+d}^{ij} = {X_{t+d} = j | X_t = i}.

The calculation process is: P_d^{ij} = Σ_t n_{t,t+d}^{ij} / Σ_t n_{t,t+d}^i, where n_{t,t+d}^{ij} represents the total number of regions transitioning from type i in year t to type j in year t+d, and n_t^i denotes the number of regions belonging to type i in year t.

2.2 Analysis of Public Library Efficiency Influencing Factors: Spatial Correlation and Spatial Econometric Models

2.2.1 Spatial Correlation Analysis Due to differences in geographic location, economic development, and regional culture, public library efficiency exhibits spatial variation, potentially leading to spatial autocorrelation in regional distribution—where changes in one region's public library efficiency affect neighboring regions through knowledge spillovers and factor flows. To detect spatial correlation, exploratory spatial data analysis is required, typically including global and local spatial autocorrelation analysis. This study employs Moran's I to measure spatial association and differentiation in regional public library efficiency:

$$I = (\Sigma_i \Sigma_j w_{ij}(x_i - \bar{x})(x_j - \bar{x})) / (\Sigma_i \Sigma_j w_{ij} \Sigma_i (x_i - \bar{x})^2)$$

where x_i and x_j represent public library efficiency values in regions i and j, $\bar{x}$ is the mean efficiency across regions, and n is the total number of spatial units. Moran's I ranges from -1 to 1, with positive values indicating positive spatial correlation, negative values indicating negative correlation, and zero indicating no correlation. w_{ij} is an element of the spatial weight matrix, which this study constructs using the inverse distance squared method proposed by L. Anselin and R. Florax, reflecting that inter-regional influence decays with distance: $w_{ij} = 1/d_{ij}^2$ for $i \neq j$, and 0 for $i = j$, where d_{ij} represents Euclidean distance between provincial capitals.

2.2.2 Spatial Econometric Models Existing research demonstrates that spatial factors play non-negligible roles in regional analysis. Spatial econometric models primarily include two types: When spatial dependence among variables is crucial and causes spatial autocorrelation, this constitutes a Spatial Autoregressive Model (SAR); when spatial correlation exists in the model's error term, this forms a Spatial Error Model (SEM). This study constructs spatial econometric models to estimate public library efficiency influencing factors.

The SAR model is specified as: $Y_{it} = \Sigma_j W_{ij}Y_{it} + \beta X_{it} + \_{it}$

where subscripts i and t denote regions and years; Y_{it} represents public library efficiency in region i at time t; X_{it} is a vector of explanatory variables including new collection acquisition expenditures and professional technical personnel; W_{ij} is the spatial weight matrix using inverse distance weights;

W_{ij}Y_{it} captures spatially weighted efficiency in neighboring regions; is the spatial autoregressive coefficient measuring the impact of neighboring regions' efficiency on local efficiency; and _{it} is the random disturbance term.

The corresponding SEM model is: Y_{it} = βX_{it} + ϕ{it} ϕ{it} = λ Σ_j W_{ij}ϕ{it} + {it}

where λ is the spatial error coefficient measuring spatial dependence in the disturbance term, and ϕ is a normally distributed random error vector.

Model selection typically involves testing two Lagrange Multipliers (LM-lag and LM-error) and their robust forms (Robust LM-lag and Robust LM-error). The procedure compares the significance of LM-lag and LM-error, selecting the significant one. If both are significant, Robust LM-lag and Robust LM-error are compared, choosing the more significant. Additional criteria include goodness-of-fit (R^2), log-likelihood function value (LogL), and $Sigma^2$—higher R^2 and LogL with lower $Sigma^2$ indicate better model fit.

3 Indicator Selection and Data Sources

Public library efficiency essentially involves maximizing output benefits with minimal resource inputs. Drawing on relevant studies and considering public library characteristics, data availability, and statistical consistency, this study constructs an input-output indicator system. Input indicators include total collections, staff numbers, reading room seats, and total public library expenditures (4 indicators). Output indicators include total circulation, book loans, and valid library cards (3 indicators).

Environmental variables are selected based on factors that influence public library efficiency but cannot be subjectively controlled. Regional economic development level, population density, urbanization, education level, and regional culture may all affect efficiency. Due to data availability constraints, three variables are selected: (1) Education level, calculated from statistical yearbook survey data using the formula: (illiterate/semi-illiterate × 0 + primary school × 6 + junior high × 9 + senior high × 12 + college and above × 16) / population aged 6 and above. (2) Regional economic development level, measured by real per capita GDP using 2007 as the base year. (3) Urbanization rate, measured by urban population as a proportion of total population.

Additionally, based on the "13th Five-Year Plan" indicators and existing research, this study analyzes influencing factors from five dimensions: facility networks, literature resources, service effectiveness, workforce development, and equity indices. Specific variables include: (1) New collection acquisition expenditures, reflecting fiscal allocation utilization; (2) Library activity level, measured by cumulative counts of lectures, exhibitions, and training events; (3) Human capital factors, using the quantity and structure of intermediate-level and above professional technical personnel; (4) Per capita library space, reflecting facility network support; (5) Equity index, as the "Matthew effect" in public library

equity remains severe in China. Whether this equity issue causes efficiency decline requires further quantitative evidence. Following Zhou Di's approach, this study measures equity using standardized per capita fiscal allocations.

The research sample comprises 30 provinces, municipalities, and autonomous regions in mainland China. Tibet, Hong Kong, Macao, and Taiwan are excluded due to data availability and completeness. The time span covers 2007–2016. Original data are sourced from the China Library Yearbook (2008–2017), China Statistical Yearbook (2008–2017), China Labor Statistical Yearbook (2008–2017), and various provincial statistical yearbooks, yielding a 10-year panel dataset. To examine regional differences, China is divided into eastern, central, and western regions (eastern: Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Hainan; central: Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, Hunan; western: Sichuan, Chongqing, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang, Guangxi, Inner Mongolia).

4 Empirical Research and Results Analysis

4.1 Public Library Efficiency Measurement and Evaluation

4.1.1 Super-Efficiency Three-Stage Model Results Tests confirm that provincial public library input-output data satisfy DEA model requirements of "isotonicity" and "correlation." Using EMS 1.3 + Frontier 4.1 software, efficiency is calculated for 30 regions. Wilcoxon signed-rank tests reveal significant differences between pre- and post-adjustment efficiency values (test statistic = -13.045, significant at 1%), indicating that removing environmental variables and random errors yields more accurate efficiency measures.

Comparing first-stage and third-stage mean efficiency values shows: (1) After eliminating environmental and random interference, regional efficiency values change, with the overall mean decreasing from 0.82 to 0.76, suggesting that initial high efficiency values partly reflect advantageous external environments. (2) Regionally, Shanghai, Jiangsu, Zhejiang, and Guangdong consistently operate on the DEA efficient frontier, reflecting rational input-output ratios. Fujian, Hunan, and Guangxi shift from DEA efficient to inefficient, indicating that pre-adjustment high efficiency did not reflect true input-output conditions and that environmental factors significantly impact their efficiency. Other regions remain DEA inefficient, suggesting that irrational input-output ratios are the primary cause of low efficiency.

Regional comparisons reveal clear spatial disparities: efficiency values rank as eastern > central > western, with means of 0.990, 0.710, and 0.575 respectively. The top three regions are Shanghai, Zhejiang, and Jiangsu in the east, while the bottom three are Shanxi, Qinghai, and Guizhou in central/western regions [Figure 1: see original paper].

Kernel density estimation using a Gaussian normal distribution for the years

2007, 2010, 2012, 2014, and 2016 shows an evolution from right-skewed to left-skewed distributions, with peaks shifting from low to high [Figure 2: see original paper]. Public library efficiency exhibits a declining trend over time, with most regions converging toward low efficiency levels. The 2007 distribution shows a wide, low "single peak" around 0.80 with a right tail indicating multiple high-efficiency regions. By 2016, the curve becomes narrow and high, with the peak dropping to around 0.50, indicating more significant convergence toward low efficiency. This suggests that public library development lags behind economic and social development, failing to meet growing public cultural needs.

Since the "11th Five-Year Plan," central and local governments have increased support for public library construction, with steady growth in fiscal investment and accelerated legal and institutional development. However, the output growth rate has consistently remained below the input growth rate. Therefore, public library development should shift from scale expansion (increasing fiscal allocations and building space) to intensive development focused on enriching service content, strengthening resource integration, and improving service effectiveness, thereby enhancing management levels and maximizing input utilization through modern technology.

4.1.2 Markov Chain Analysis Results Based on super-efficiency three-stage DEA results, variable-duration (1–5 year) Markov chain models examine transitions among efficiency levels. Concurrently, equity is measured using standardized per capita fiscal allocations to analyze internal transfer characteristics of efficiency and equity .

The transition probability matrix shows diagonal elements representing the probability of efficiency levels remaining unchanged, reflecting persistence within each category, while off-diagonal elements show upward or downward transition probabilities. Overall, medium-low and medium-high efficiency regions demonstrate relative stability and convergence. Regions at medium-low and medium-high levels have 80.6% and 67.3% probabilities of remaining in the same category after one year, declining to 71.1% and 55.5% after five years. However, this persistence is not observed at low and high efficiency extremes. Low-efficiency regions show only 57.9% persistence after one year, dropping to 41.2%, 14.3%, 7.7%, and 8.3% over 2–5 years. High-efficiency regions show 55.0% persistence after one year, declining to 47.4%, 30.6%, 38.6%, and 21.2%. Thus, the "Matthew effect" in public library efficiency is not significant.

By contrast, the equity index of public library fiscal investment shows a pronounced Matthew effect. Persistence probabilities for the four equity categories after one year are 87.8%, 83.4%, 68.9%, and 89.7%, remaining as high as 71.7%, 75.2%, 65.0%, and 87.8% after five years. This indicates severe regional inequality in per capita fiscal allocations for public libraries, with a long-standing "the rich get richer" pattern. Whether this equity issue negatively impacts efficiency and to what extent requires further investigation.

4.2 Spatial Effect Analysis of Influencing Factors

Moran's I tests across all years show positive values (0.091–0.334), significant in most years , indicating significant positive spatial clustering in public library efficiency distribution and spatial dependence among neighboring regions. This confirms that spatial effects must be considered when analyzing influencing factors.

Using Matlab to estimate spatial econometric models and following model identification principles, the fixed-effects SAR model is selected as the final specification based on Hausman test results . The spatial effect coefficient is positive and significant at 1%, confirming significant spatial spillover effects—improvements in one region's public library efficiency boost neighboring regions' efficiency.

Key findings from the national sample: (1) Increased new collection acquisition expenditures fail to improve efficiency, likely due to quality issues unmet diverse reader needs and potential time lags in impact. (2) Professional technical personnel expansion significantly enhances efficiency, but talent structure hinders improvement. From 2007–2016, the proportion of intermediate-level and above librarians averaged less than 40%, far from the 45.7% target in the "13th Five-Year Plan." As library services shift toward smart models, diverse user needs, upgraded technologies, and expanded knowledge services demand more specialized expertise, making professional training crucial for efficiency gains. (3) Library activity frequency aligns positively with efficiency but lacks statistical significance, suggesting low activity levels. In 2016, the average province held approximately 4,500 events annually—requiring about 10,000 participants per event to provide each citizen with one annual opportunity—far from national reading promotion goals. Insufficient reader engagement may further dampen libraries' activity enthusiasm. (4) Increased library space negatively impacts efficiency. From 2007–2016, library space grew 71% while overall efficiency declined, as space expansion accompanied increased staff and funding while reader numbers remained relatively stable, reducing utilization efficiency. (5) The equity index shows significant negative correlation with efficiency, indicating that long-standing equity issues and regional inequality hinder efficiency improvement, reflecting inadequate government macro-regulation of inter-regional library transfer payments.

Given spatial and temporal heterogeneity, further regional and temporal disaggregation reveals: All three regions show positive, significant spatial spillover effects. The equity index negatively affects all regions, most strongly in central China. New acquisition expenditures negatively impact all regions. Talent structure and space indicators show particularly negative effects in eastern regions. Temporal analysis shows stable spatial spillover effects across 2007–2011 and 2012–2016 periods. The negative equity effect weakened over time, though the problem persists. Library activity impact shifted from significantly positive in 2007–2011 to weakly negative in 2012–2016, indicating declining activity

quality.

5 Conclusions and Recommendations

This study measures provincial public library efficiency in China from 2007–2016 using super-efficiency three-stage DEA and Markov chain models, estimates influencing factors through spatial econometric models, and conducts regional and temporal disaggregation. Key conclusions:

(1) External environment and random errors significantly affect public library efficiency. Adjusted efficiency values show pronounced spatial disequilibrium, ranking eastern > central > western. Wilcoxon tests confirm significant differences between adjusted and unadjusted values, validating the three-stage DEA approach. The national mean efficiency of approximately 0.85 indicates substantial room for improvement. Kernel density analysis reveals convergence toward low efficiency, with declining peak values over time, demonstrating that scale expansion alone cannot sustain performance growth.

(2) Significant positive spatial correlation and spillover effects exist. Moran's I values (0.091–0.334) are positive and significant, confirming spatial clustering. The SAR model's positive spatial autoregressive coefficient indicates strong spillover effects that intensify with proximity, suggesting effective inter-regional resource flows.

(3) Internal influencing factors are diverse. Declining efficiency reflects negative impacts from new acquisition expenditures, talent structure, and space expansion, while activity levels show positive but insignificant effects. The equity index's significant negative impact highlights urgent need to address fiscal inequality. Traditional scale-expansion management models are losing effectiveness, indicating that fundamental efficiency improvements require institutional innovation and market integration.

Policy recommendations: (1) Strengthen performance evaluation of public library resource inputs with binding constraints and penalty mechanisms to escape the "Matthew effect trap" in equity issues. (2) Recognize that regional development patterns constrain public library efficiency. Local governments should formulate differentiated policies based on regional characteristics, while central authorities should enhance macro-regulation and increase resource allocation to central and western regions. (3) Leverage spatial spillover effects by promoting market mechanisms in resource allocation, removing institutional barriers to factor mobility, and encouraging national/provincial libraries to break resource barriers and cooperate with top-tier institutions domestically and internationally. (4) Optimize talent structure, enhance library activity levels, and rationally allocate physical and financial resources. Implement full-process talent management (recruitment, training, utilization, retention), build sustainable age-professional-knowledge structures, and match facility expansion with regional population, education levels, and user needs. Develop regular, branded,

diversified reader activities (lectures, book reviews, debates, reading clubs, essay contests) through online and offline channels to boost activity levels and service effectiveness. (5) Introduce social forces into public library services to create internal and external competition. The "13th Five-Year Plan" explicitly calls for improving government procurement of public cultural services and exploring delegated management by professional social institutions. Market-based resource allocation under competitive pressure can stimulate libraries' initiative and enhance management and service effectiveness.

References

[1] Fu Caiwu, Xu Qitong. Efficiency Dilemma of Grassroots Cultural Units: Supply-Side Structural Issues or Management Technical Problems—Observations Centered on 10 Cultural Stations in 5 Provinces[J]. Journal of Shandong University (Philosophy and Social Sciences), 2017(1): 55-64.

[2] Miidla P, Kikas K. The Efficiency of Estonian Central Public Libraries[J]. Performance Measurement and Metrics, 2009, 10(1): 49-58.

[3] Stroobants J, Bouckaert G. Benchmarking Local Public Libraries Using Non-Parametric Frontier Methods: A Case Study of Flanders[J]. Library & Information Science Research, 2014, 36(3/4): 211-224.

[4] Simon J, Simon C, Arias A. Changes in Productivity of Spanish University Libraries[J]. Omega, 2011, 39(5): 578-588.

[5] Guo Junhua. Regional Public Library Efficiency Measurement and Environmental Impact Factor Analysis—An Empirical Study Based on DEA-Tobit Two-Step Method[J]. Library and Information Service, 2010, 54(13): 87-90.

[6] Chen Ying, Hong Yuan. Measuring and Optimizing Provincial Public Library Efficiency Considering Environmental Factors—Based on Three-Stage DEA Method[J]. Library Science Research, 2015(11): 17-25.

[7] Chu Jiewang, Chu Yili. Provincial Public Library Efficiency Evaluation and Influencing Factor Analysis in China—An Empirical Study Based on Super-SBM and Tobit Models[J]. Library and Information Service, 2015, 59(22): 33-38.

[8] Wang Hui. Static and Dynamic Efficiency Evaluation of Public Libraries in China[J]. Library Tribune, 2015(1): 30-36.

[9] Zhou Na. Optimal Allocation of Provincial Public Library Resources in China—An Empirical Analysis Based on Development Efficiency Differences and Convergence[J]. Library and Information Service, 2019, 63(2): 68-76.

[10] Wang Wei, Yan Shuai. Measurement and Influencing Factor Analysis of Regional Public Library Malmquist Index[J]. Library Theory and Practice, 2017(1): 79-84.

[11] Fu Caiwu, Zhang Weifeng. Research on Provincial Public Library Efficiency, Scale Returns and "Congestion" Phenomenon in China[J]. China Soft Science, 2017(10): 72-81.

[12] Chen Lin. Research on Equity and Efficiency Issues of Public Library System[J]. Library and Information Service, 2010, 54(7): 26-29.

[13] Guo Zhengwu. Library Service Sharing for All from Equity and Efficiency Perspectives[J]. Library and Information Service, 2009, 53(13): 54-57.

[14] Xu Xiangwang. Strategic Orientation for Improving Library Service Capacity Based on "Efficiency" and "Equity" Symbiosis[J]. Library and Information Service, 2010, 54(7): 108-110.

[15] Zhou Di. Research on Matthew Effect of Equity and Efficiency in Regional Public Libraries in China[J]. Library and Information Service, 2017, 61(2): 67-73.

[16] Fried HO, Lovell CAK, Schmidt SS, et al. Accounting for Environmental Effects and Statistical Noise in Data Envelopment Analysis[J]. Journal of Productivity Analysis, 2002, 17(1/2): 157-174.

[17] Andersen P, Petersen NC. A Procedure for Ranking Efficient Units in Data Envelopment Analysis[J]. Management Science, 1993, 39(10): 1261-1264.

[18] Jiang Ping, Wang Yong. Research on Input-Output Efficiency of Full-Caliber Chinese Cultural Industry—Based on Three-Stage DEA and Super-Efficiency DEA Models[J]. Journal of Quantitative & Technical Economics, 2011(12): 69-81.

[19] Guo Sidai, Tong Meng, Guo Jie, et al. Provincial Real Environmental Efficiency Measurement and Influencing Factor Analysis Based on Three-Stage DEA Model[J]. China Population, Resources and Environment, 2018, 28(3): 106-116.

[20] Sun Yudong. Stochastic Processes and Their Applications[M]. Xi'an: Northwestern Polytechnical University Press, 2016: 87.

[21] Zhou Di, Zheng Chupeng, Hua Shirun, et al. Analysis of Agricultural Carbon Emission Reduction Potential in China from Equity and Efficiency Perspectives[J]. Journal of Natural Resources, 2019, 34(1): 80-91.

[22] Anselin L, Florax R. New Directions in Spatial Econometrics[M]. Berlin: Springer-Verlag, 1995: 21-71.

[23] Rodriguez-Pose A, Fratesi U. Between Development and Social Policies: The Impact of European Structural Funds in Objective 1 Regions[J]. Regional Studies, 2004, 38(1): 97-113.

[24] Bai Junhong, Jiang Fuxin. Collaborative Innovation, Spatial Association and Regional Innovation Performance[J]. Economic Research Journal, 2015(7): 174-187.

[25] Anselin L, Bera AK, Florax R, et al. Simple Diagnostic Tests for Spatial Dependence[J]. Regional Science & Urban Economics, 1993, 26(1): 77-104.

Author Contributions: Shi Li proposed the research topic, designed the evaluation model, collected and analyzed data, and wrote the manuscript. Qin Ping guided the writing and revised the paper.

Note: Figure translations are in progress. See original paper for figures.