TEMPORAL AND SPATIAL PATTERNS OF AGRICULTURAL ECONOMIC RESILIENCE IN CHINA

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Yuan Hu*
Nirote Sinnarong**
Ke Nunthasen**
Kittawit Autchariyapanitkul***

ABSTRACT

Agricultural economic resilience is vital for national food security and sustainable agricultural development. Using panel data from 31 Chinese provinces from 2011 to 2022, this study constructs an Agricultural Economic Resilience (AER) evaluation framework based on resistance, adaptability, and transformative capacity. The entropy method was applied to measure provincial AER levels and analyze their temporal evolution, regional disparities, and spatial correlations.

The results indicated that China's agricultural economic resilience generally improved over time, while significant regional differences remained. Central China exhibited relatively high resilience, eastern regions showed steady enhancement, and western regions displayed considerable development potential. Moreover, AER demonstrated significant positive spatial autocorrelation, with "high-high" clusters concentrated in eastern coastal areas and "low-low" clusters mainly located in western regions and parts of Northeast China.

These findings provided empirical evidence for regionally differentiated agricultural policies and the enhancement of agricultural security.

Keywords: Agricultural Economic Resilience, Entropy Method, Spatiotemporal Evolution, Spatial Autocorrelation, China.

* PhD student, Faculty of Economics, Maejo University Academic Year 2025
** Faculty of Economics, Maejo University
*** Corresponding author e-Mail: Kittawit_a@mju.ac.th

INTRODUCTION

Agriculture is the basic sector of China's national economy, and the stability and sustainability of the agricultural economy serve as crucial pillars for China's national food security and social stability. In recent years, the stability of the agricultural economy has been impacted by global climate change, fluctuations in the market economy, and public health events such as the COVID-19 pandemic. This has also made agricultural economic resilience a topical issue of shared concern among scholars and government departments.

Agricultural economic resilience refers to the capacity of an agricultural economic system to effectively withstand external shocks, adapt to changes, and recover swiftly. This concept not only focuses on the short-term stability of agricultural production but also emphasizes its long-term sustainability and flexibility.

China's agricultural development is characterized by vast geographical expanse, significant variations in natural conditions, and uneven developmental foundations. This has resulted in pronounced spatial disparities in the resilience of agricultural economies across different regions.

A systematic analysis of the temporal trends and spatial patterns of agricultural economic resilience can help reveal the underlying patterns of regional disparities, providing empirical evidence for formulating differentiated agricultural development policies tailored to each region.

Despite the growing literature on agricultural economic resilience, several notable gaps remain. First, most existing studies rely on static measurements or single-year analyses, which fail to capture the dynamic evolution of agricultural economic resilience over time. Second, although regional disparities are widely acknowledged, insufficient attention has been paid to spatial dependence and clustering characteristics, limiting the understanding of spatial spillover effects across regions. Third, many studies adopt aggregated regional frameworks, which may obscure substantial inter-provincial heterogeneity and reduce the policy relevance of empirical findings. Addressing these limitations requires a long-term, spatially explicit, and provincial-level analytical framework.

Therefore, this study employs the entropy method to construct an evaluation index system for agricultural economic resilience across China's 31 provinces from 2011 to 2022. It systematically analyzes temporal trends, regional disparities, and spatial correlation characteristics. The main contributions are threefold:

1. Establishing a provincial-level index that comprehensively reflects resilience, adaptability, and transformative capacity in agricultural economies;

2. Revealing the overall changes and regional convergence patterns of China's agricultural economic resilience from a temporal perspective;

3. Identifying the spatial clustering patterns and hotspot distributions of agricultural resilience.

RESEARCH OBJECTIVES

This study aims to examine the temporal and spatial patterns of Agricultural Economic Resilience (AER) across China's provinces during 2011-2022. Based on the research gaps identified in the Introduction, the specific objectives are as follows:

1. To construct a provincial-level Agricultural Economic Resilience (AER) index for China using the entropy weight method, covering the dimensions of resistance capacity, adaptability, and transformation capacity.

2. To analyze the temporal evolution of agricultural economic resilience in China from 2011 to 2022, including overall trends and regional differences among the eastern, central, and western regions.

3. To investigate the distribution dynamics and regional disparities of provincial AER using kernel density estimation and Theil index decomposition.

4. To examine the spatial correlation and clustering characteristics of provincial AER by applying Global Moran's I and Local Indicators of Spatial Association (LISA) analysis.

5. To provide policy recommendations for improving agricultural economic resilience through region-specific and coordinated development strategies.

CONCEPTUAL FRAMEWORK

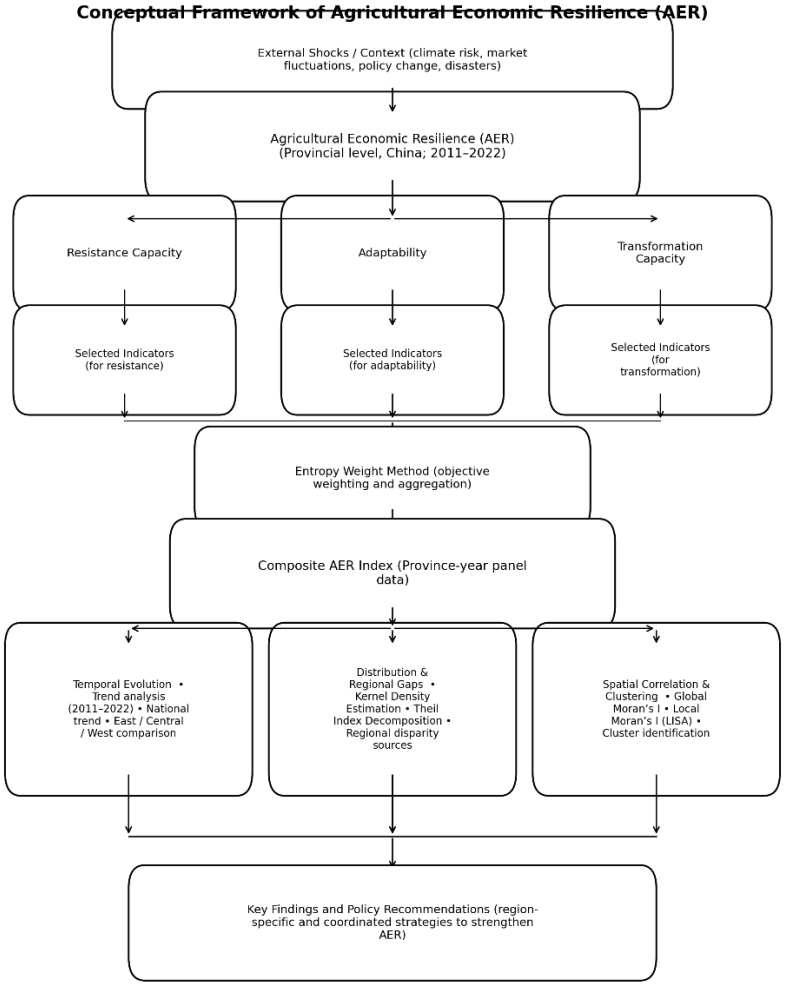


Figure 1 Conceptual diagram linking AER dimensions, index construction, and temporal/spatial analysis

Figure 1shows that agricultural economic resilience (AER) is influenced by external shocks and should be understood through three dimensions: resistance, adaptability, and transformation. The study measures these dimensions using selected indicators and combines them into a composite AER index with the entropy weight method. The index is then analyzed from three perspectives-temporal evolution, regional distribution gaps, and spatial clustering-to generate evidence-based policy recommendations for strengthening agricultural resilience across China's provinces.

LITERATURE REVIEW

The term resilience was first introduced by ecologist Holling (1973, pp. 1-23) who defined it as “the ability of a system to absorb disturbances and still maintain its basic structure and functions.” Subsequently, resilience theory was extended to studies of ecosystems and economic systems, emphasizing a system's resistance, returnability, adaptability, and transformability (Walker, Holling, Carpenter & Kinzig, 2004; Folke, 2006, pp. 253-267). These core dimensions form the theoretical foundation for most subsequent research in constructing indicator systems and analytical frameworks.

Regarding agricultural economic resilience, scholars have primarily focused on conceptual implications, evaluation system development, and influencing factors and operational mechanisms.

Concepts and Theoretical

Martin and Sunley (2015, pp. 1-42) define economic resilience as a region's capacity to withstand, recover from, and reconstruct itself in the face of external shock. Agricultural resilience, meanwhile, emphasizes the ability of agricultural systems to maintain stable production and development amid multiple shocks such as natural disasters, market fluctuations, and policy adjustments (Darnhofer, 2014, pp. 461-484).

Evaluation System and Measurement Methods

Regarding measurement methods, existing studies primarily employ multi-indicator comprehensive evaluation approaches, factor analysis, and analytic hierarchy process to assess and measure agricultural economic resilience. Guo, Chen and Pan (2021, pp. 1-17) constructed an agricultural resilience evaluation indicator system and identified agricultural production efficiency, agricultural input-output ratio, and rural infrastructure as core factors influencing agricultural economic resilience.

Although these multi-indicator evaluation methods provide valuable insights into the level of agricultural economic resilience, most empirical applications are based on cross-sectional data or single-year measurements.

Influencing Factors and Mechanisms

Current research generally holds that the formation of agricultural economic resilience is closely linked to factors such as regional economic foundations, technological innovation capabilities, institutional environments, and digitalization levels. Liu and Xu (2025, pp. 29-39) indicated that financial support, agricultural mechanization, and educational attainment positively influence agricultural resilience, while income disparities may weaken the adaptive capacity

of agricultural systems. Sun, Kan and Chen (2025) further revealed the mediating effect of agricultural technology investment in resilience enhancement.

However, most existing studies implicitly treat regions as independent observational units, paying limited attention to spatial dependence and interregional spillover effects.

Review of Existing Research and Limitations

In summary, existing studies have established a relatively mature framework for defining the concept and measuring methods of agricultural economic resilience. However, current research still exhibits the following limitations: On one hand, most existing studies focus on static measurements or single-year comparisons, lacking systematic analysis of the temporal dynamics of agricultural resilience; On the other hand, existing studies pay insufficient attention to spatial correlations and clustering characteristics, failing to fully reveal the patterns of spatial evolution. Therefore, building upon prior research, this paper proposes to measure the agricultural economic resilience of China's provinces using the entropy method. Combined with kernel density analysis and spatial autocorrelation models, it systematically explores the temporal evolution trends and spatial distribution patterns of agricultural resilience, aiming to provide empirical evidence for enhancing regional agricultural sustainability.

DATA AND RESEARCH METHODS

Data Sources This study utilizes data from 2011 to 2022 across China's 31 provinces (including autonomous regions and municipalities directly under the central government). The study period is selected to align with China’s 12th, 13th, and early stage of the 14th FiveYear Plans, during which agricultural modernization, rural revitalization, and food security strategies were successively advanced, providing an appropriate policy context for examining the evolution of agricultural economic resilience.

The primary sources are the China Statistical Yearbook, the China Rural Statistical Yearbook, and provincial statistical yearbooks.

Agricultural Economic Resilience Evaluation System This study constructs the Agricultural Economic Resilience (AER) Index based on the indicator system developed by Chinese scholar Zhao and Xu (2023, pp. 87-96). Zhao’s framework, widely recognized in academic research, provides a systematic and comprehensive approach to measuring agricultural resilience.

Table 1 The Agricultural Economic Resilience Measurement Index System

Primary Indicator	Secondary Indicator	Tertiary Indicator	Unit
Resistance Capacity	Intrinsic Stability	Cultivated Land Area	1,000 hectares
		Effective Irrigated Area	1,000 hectares
		Rural Primary Industry Workforce	10,000 people
		Per Capita Grain Output	kg
	Supply Robustness	Agricultural Price Index	%
		Grain Production per Sown Area	%
		Pesticide Usage	10,000 tons
		Disaster-Affected Area Ratio	%
		Agricultural Plastic Film Usage	tons
Adaptability	Recoverability	Multiple Cropping Index	%
		Agricultural GDP Growth Rate	%
		Rural Electricity Consumption	billion kWh
		Total Agricultural Machinery Power	10,000 kW
Capacity	Diversity & Collaboration Technological Progress	Crop Diversity Index	%
		R&D Expenditure	10,000 yuan
		Agricultural Fixed Asset Investment	billion yuan
		Agricultural Workforce in Urban Employment	10,000 people

Note: This framework assesses agricultural economic resilience across three core dimensions.

Weighting and Comprehensive Calculation of Indicators The Entropy Weight Method (EWM) is applied to determine indicator weights in an objective manner. Indicators with greater variability receive higher weights, while those with lower variability are assigned smaller weights.

First, the Min-Max normalization method is used to standardize all indicators:

$$X_{ij}^{*} = \frac{X_{ij} - X_{\min j}}{X_{\max j} - X_{\min j}}, X_{ij}^{*} = \frac{X_{\max j} - X_{ij}}{X_{\max j} - X_{\min j}}$$

Second, the entropy value of each indicator is calculated as:

$$E_j = -k \sum_{i=1}^{n} P_{ij} \ln P_{ij}, k = \frac{1}{\ln n}$$

where P_{ij} denotes the proportion of province i under indicator j.

Based on the entropy values, indicator weights are determined as:

$$W_j = \frac{1 - E_j}{\sum_{j=1}^{m}(1 - E_j)}$$

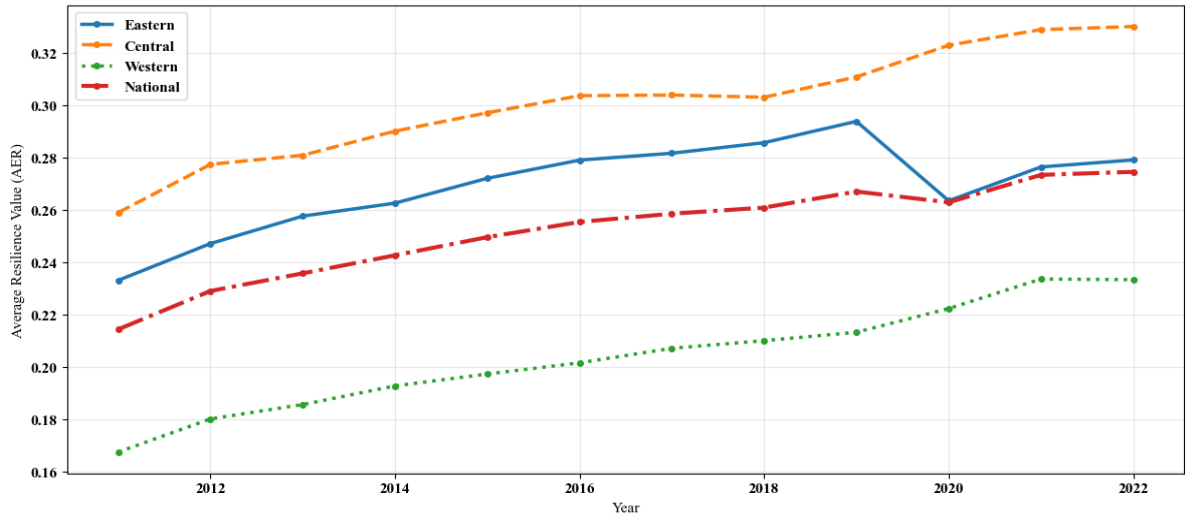
Finally, the composite index is calculated using a weighted summation of normalized

Indicators: $Index_i = \sum_{j=1}^{m} W_j X_{ij}^{*}$

Following these steps, annual agricultural economic resilience indices for each province are obtained for subsequent analysis.

Analysis of Temporal Evolution and Regional Differences

1. Temporal Trend Analysis First, this study analyzed the temporal variation characteristics of China's AER from 2011 to 2022. The results are shown in Figure 2.



Note: This figure presents provincial agricultural economic resilience indicators calculated using the dataset employed in this study, with regional divisions adhering to China's official economic zoning standards.

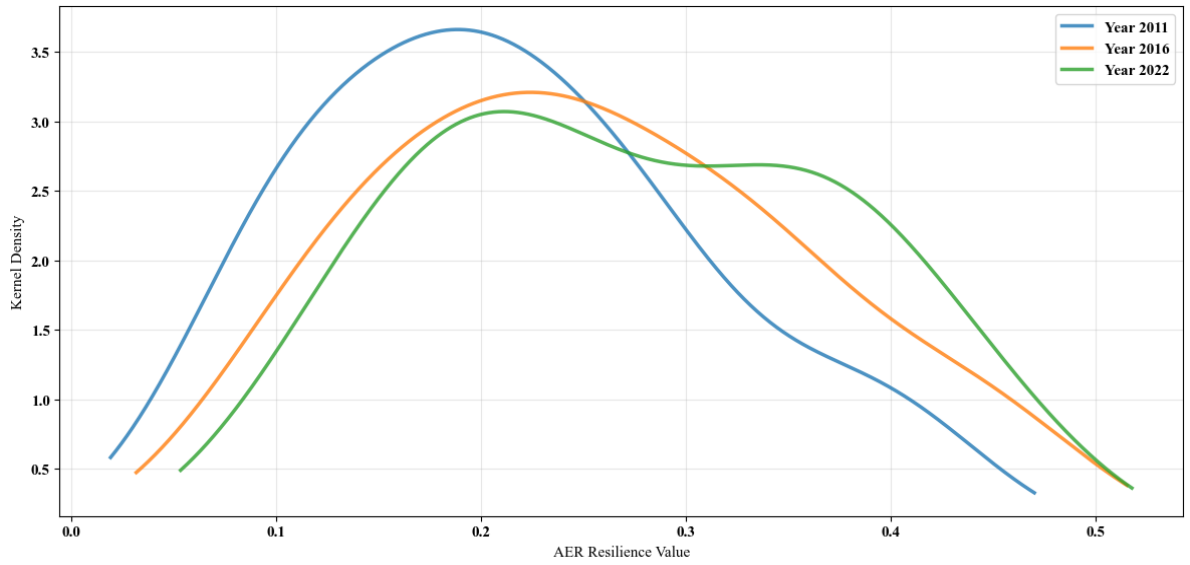
Figure 2 Temporal Trends of Provincial AER in China

From Figure 2 can observe that China's AER exhibited a steady upward trend between 2011 and 2022, indicating the continuous strengthening of the country's agricultural system in withstanding risks and adapting to external shocks.

From a regional perspective, the average AER in the central region is significantly higher than that in the eastern and western regions, while the western region maintains a relatively low average AER. This reveals a distinct regional gradient in China's agricultural economic resilience. Such regional disparities may be closely linked to differences in regional economic development levels, agricultural infrastructure construction, and digitalization.

Overall, China's agricultural economic resilience experienced slight fluctuations in its growth trajectory in 2020 due to external shocks like the COVID-19 pandemic. However, it rebounded rapidly the following year, demonstrating the strong recovery characteristics of China's AER.

2. Kernel Density Estimation Analysis Kernel density estimation analysis of the AER Index reveals the dynamic evolution of the distribution of provincial resilience levels over time. This method visually depicts the changing distribution patterns of provincial AER across different years.



Note: This figure is generated based on the calculation of provincial agricultural economic resilience indicators from the dataset used in this study, depicting the distribution characteristics of provincial AER in 2011, 2016, and 2022.

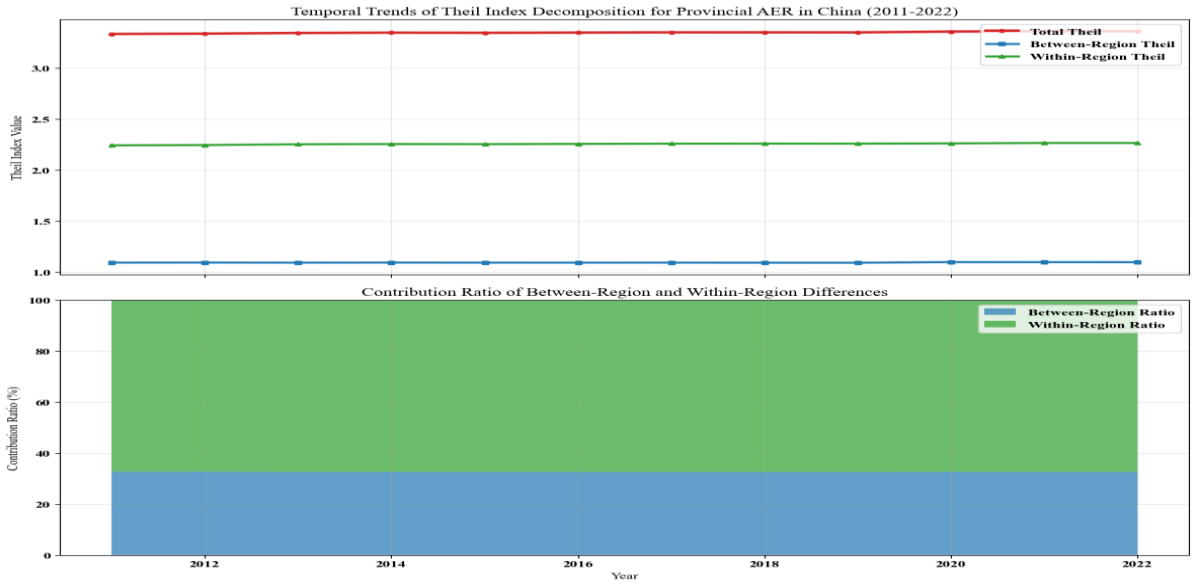
Figure 3 Kernel Density Estimation of Provincial AER in China

From Figure 3, can observe that the overall distribution curves of AER in 2011, 2016, and 2022 exhibit a gradual shift to the right. This indicates that the resilience level of China's provincial agricultural economies has shown an overall upward trend.

Simultaneously, the distribution peaks have gradually decreased and slightly broadened, reflecting an expanding gap between provinces that is, a certain "differentiation effect" exists. In 2011, AER values were concentrated in the lower range with a pronounced single peak distribution. By 2022, the proportion of provinces with high values increased, the distribution tail extended to the right, and a slight multi-peak characteristic emerged. This indicates that high-resilience regions are gradually forming clusters, while low-resilience provinces are improving at a slower pace.

This "the rich get richer" divergence pattern in China's AER may be linked to regional disparities in digital agriculture, infrastructure investment, and technology dissemination capabilities.

3. Theil Index Decomposition Analysis To further uncover the sources and evolution of spatial variations in China's agricultural economic resilience, this study conducted a Theil index decomposition analysis of China's agricultural economic resilience index from 2011 to 2022.



Note: This figure is generated based on the calculation of provincial agricultural economic resilience indicators from the dataset used in this study, illustrating the temporal trends of total Theil index, between-region Theil index, within-region Theil index, and their contribution ratios to spatial differences in provincial AER from 2011 to 2022.

Figure 4 Temporal Trends of Theil Index Decomposition and Contribution Ratio for Provincial AER in China (2011-2022)

As shown in Figure 4, the overall Theil index of national agricultural resilience remained relatively stable throughout the study period, indicating that interprovincial disparities did not undergo significant changes overall.

The analysis results in Figure 3 also reveal that the contribution rate of intra-group variation consistently exceeded that of inter-group variation, accounting for approximately 70%, while the inter-group variation contribution rate was about 30%. This suggests that internal regional imbalances are the primary source of variations in national agricultural resilience.

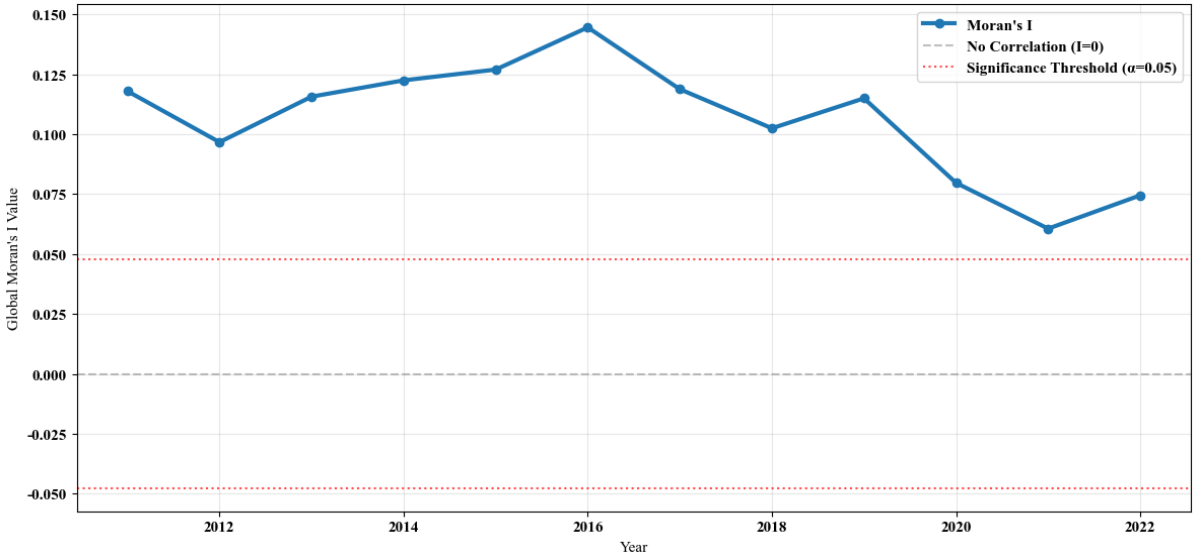
Intra-regional disparities in the eastern region may stem from gaps between coastal and inland provinces in digital agriculture adoption, agricultural technology investment, and ecological governance capabilities. Although the central region exhibits a relatively high overall level, significant variations exist among its provinces in terms of fiscal support for agriculture and the pace of agricultural product restructuring. Constrained by natural conditions and industrial foundations, the western region also exhibits pronounced internal disparities.

Spatial Correlation Analysis To further reveal the spatial distribution characteristics and regional clustering patterns of AER *at the provincial level in China*, this study employs the Queen adjacency criterion to construct a spatial weight matrix W based on inter-provincial panel data, thereby examining the spatial dependency of agricultural economic resilience. This criterion is particularly suitable for China's provincial context, as it captures both edge- and vertex-based contiguity among adjacent provinces and better reflects administrative and geographical adjacency than distance-based or k-nearest neighbor weighting schemes.

1. Global Spatial Autocorrelation (Moran's I) First, this study employ the Global Moran's I index to measure the overall spatial clustering characteristics of China's provincial agricultural economic resilience from 2011 to 2022. The Moran's I statistic is calculated as follows:

$$I = \frac{n}{S_0} \cdot \frac{\sum_i \sum_j w_{ij}(x_i - \bar{x})(x_j - \bar{x})}{\sum_i (x_i - \bar{x})^2}$$

Where: n denotes the number of spatial units;
x_i and x_j represent the AER values for regions i and j, respectively;
$\bar{x}$ is the mean value;
w_{ij} is the element of the spatial weight matrix,$S_0 = \sum_i \sum_j w_{ij}$.
When $I > 0$, it indicates positive spatial correlation;
when $I < 0$ it indicates negative correlation;
and when $I = 0$, it indicates spatial random distribution.



Note: This figure is generated based on the calculation of provincial agricultural economic resilience indicators from the dataset used in this study, depicting the temporal changes of Global Moran's I, the no-correlation baseline (I=0), and the significance threshold (α=0.05) for provincial AER resilience in China from 2011 to 2022.

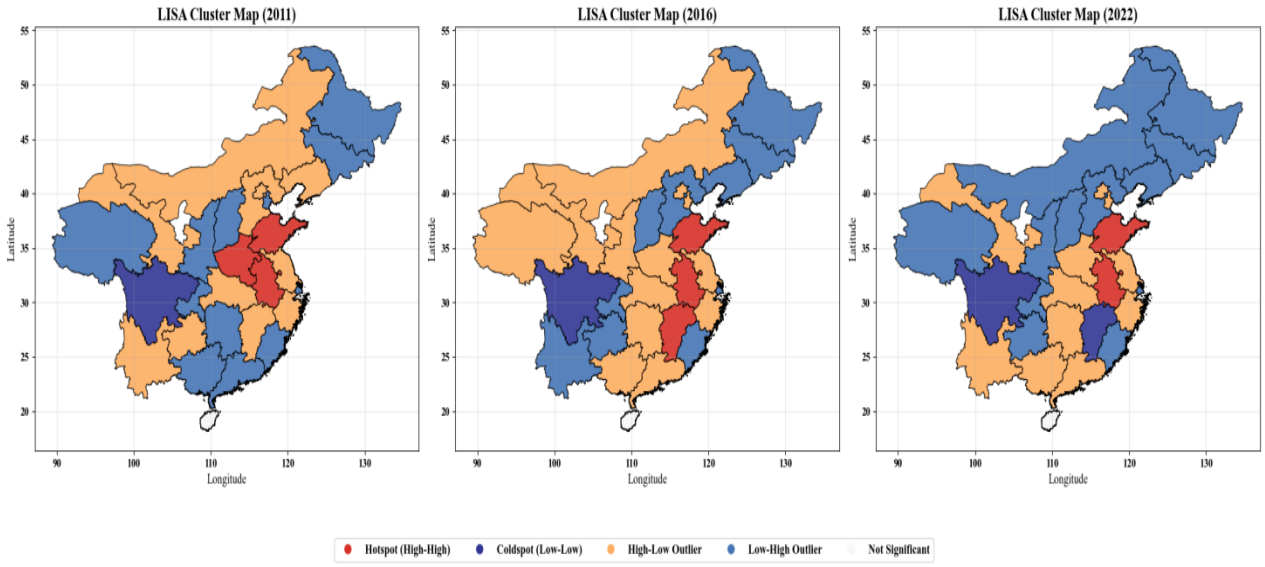
Figure 5 Temporal Trends of Global Moran's I for Provincial AER in China (2011-2022)

As shown in Figure 5, the Moran's I value for provincial agricultural economic resilience in China remained consistently positive between 2011 and 2022, all passing the 5% significance level test. This indicates that AER exhibits significant positive spatial autocorrelation, reflecting pronounced regional clustering characteristics.

Overall, the Moran's I value showed an upward trend from 2011 to 2016, peaking at approximately 0.145, indicating enhanced spatial clustering of agricultural resilience during this period. After 2017, it fluctuated slightly and trended downward, dropping to approximately 0.06 in 2020. This suggests that while regional disparities in agricultural resilience have narrowed in recent years, a certain degree of spatial dependence persists overall. This result indicates that China's agricultural economic resilience exhibits significant spatial spillover effects, with resilience improvements in one region potentially driving or diffusing to others.

2. Local Spatial Autocorrelation (LISA) Building upon the foundation of overall spatial clustering, this study further employs the Local Spatial Autocorrelation (LISA) method to characterize the spatial distribution patterns of interprovincial agricultural resilience across different years. Figure 5 presents the LISA clustering maps for 2011, 2016, and 2022, visually

illustrating the spatial positions and evolutionary trajectories of provinces within the clustering framework.



Note: This figure is generated based on the calculation of provincial agricultural economic resilience indicators from the dataset used in this study, depicting the local spatial autocorrelation clustering patterns of provincial AER in China for 2011, 2016, and 2022.

Figure 6 LISA Clustering Maps of Provincial AER in China (2011, 2016, 2022)

As shown in Figure 6, the LISA results reveal pronounced spatial clustering in China's agricultural economic resilience. In 2011, a clear high–high (hotspot) cluster was observed in the eastern coastal regions, particularly Jiangsu and Shandong, indicating strong resilience spillovers among neighboring provinces, while low–low (cold spot) clusters were mainly concentrated in the southwestern region and parts of Northeast China.

By 2016, the eastern hotspot expanded to include Anhui and Zhejiang, suggesting the growing influence of technological investment and agricultural digitalization, although low-low clustering persisted in some central and western provinces. By 2022, the eastern high-high pattern remained generally stable, while several inland provinces, such as Hubei and Hunan, exhibited noticeable improvements in agricultural economic resilience. Overall, the spatial pattern evolved from a traditional "east–west divide" toward a more multi-centered diffusion structure.

These results indicate significant positive spatial autocorrelation in agricultural economic resilience, with high-resilience areas concentrated in economically developed and digitally advanced eastern provinces. With the advancement of digital transformation and regional coordinated development, the spatial agglomeration pattern is gradually shifting from unipolar concentration toward multipolar differentiation, highlighting the role of spatial spillover effects in enhancing regional agricultural resilience.

CONCLUSIONS

Through analyzing the temporal evolution, spatial distribution, and spatial correlation of provincial AER in China from 2010 to 2022, this study draws the following key conclusions:

First, overall trends indicate a sustained upward trajectory in China's agricultural economic resilience during the study period, reflecting the agricultural system's growing capacity to withstand risks and recover from setbacks. Particularly against the backdrop of external shocks like the COVID-19 pandemic, China's agricultural system has demonstrated strong resilience and adaptability.

However, significant regional disparities persist. Central China maintains a consistently high AER level due to its solid agricultural foundation and substantial policy support. Eastern China exhibits steady improvement in agricultural economic resilience, influenced by industrial restructuring and urbanization. Western China, despite weaker foundations, shows considerable growth potential, reflecting a late-mover advantage. Overall, China’s agricultural economic resilience exhibits a pattern of general improvement coupled with regional divergence.

Second, from the perspective of distribution evolution, kernel density estimation reveals that while China's agricultural economic resilience has improved overall, it also shows a certain trend of polarization. This divergence pattern reflects, to some extent, regional gaps in agricultural technology application, digitalization levels, infrastructure investment, and ecological governance capabilities.

Third, regarding spatial correlation, China's agricultural economic resilience exhibits a pattern of stronger eastern regions, weaker western regions, and improving central regions, with pronounced spatial clustering effects. The global Moran's I indices based on the Queen adjacency matrix are all positive and significant, indicating strong positive spatial correlation in agricultural economic resilience. Localized Inter-area Spatial Autocorrelation (LISA) results further reveal the stability of this clustering pattern.

From an international perspective, the spatial heterogeneity and clustering patterns observed in China are broadly consistent with empirical evidence from other countries with comparable geographical diversity and agricultural structures. Studies from the European Union and the United States show that regions with stronger economic foundations, higher levels of technological adoption, and more complete agricultural infrastructure tend to exhibit higher agricultural resilience, while less-developed or peripheral regions face persistent challenges. In Southeast Asia, evidence from Thailand-a country with pronounced regional differences in agricultural productivity and resource endowments-also reveals significant spatial disparities in agricultural resilience, closely linked to irrigation infrastructure, technological diffusion, and regional policy support.

Compared with these countries, China’s experience underscores the important role of coordinated policy frameworks, long-term planning mechanisms such as the FiveYear Plans, and targeted regional support in mitigating regional disparities and enhancing agricultural resilience in less-developed areas. This suggests that while geographical endowments and market conditions shape agricultural economic resilience globally, institutional capacity and policy intervention can significantly influence its spatial outcomes.

POLICY RECOMMENDATIONS

Based on the above conclusions, to further enhance the resilience of China's agricultural economy and promote coordinated regional development and sustainable growth, government departments should focus on the following areas:

1. Promote coordinated regional development.

Accelerate the establishment of cross-regional agricultural science and technology cooperation and industrial chain collaboration mechanisms. Strengthen knowledge and technology spillovers between eastern, central, and western regions to facilitate the cross-regional flow of agricultural production factors. Establish digital agriculture demonstration zones and regional agricultural innovation alliances to share best practices and achieve synergistic improvements, thereby narrowing resilience gaps between regions. In this process, differentiated digital investment strategies should be designed according to regional development stages and resource endowments.

2. Implement Region-Specific Policy Strategies.

For eastern China, where agricultural economic resilience is relatively high, policy efforts should focus on deepening agricultural digitalization, improving production efficiency,

and strengthening the integration of agriculture with advanced industries. For central China, policies should emphasize coordinated regional development by promoting factor mobility, technology diffusion, and agricultural value chain upgrading. For western and northeastern China, priority should be given to strengthening basic agricultural infrastructure, expanding technology extension services and targeted financial support, and encouraging the development of specialty and environmentally sustainable agricultural products to enhance risk resistance and self-recovery capacity.

3. Strengthen agricultural technological innovation and digital transformation.

Promote agricultural digitization and intelligent development by improving rural information infrastructure and advancing smart agricultural machinery, precision farming, and big data applications. These measures can enhance the policy effectiveness of digital agriculture by aligning technological inputs with region-specific agricultural development needs. Empowered by technological innovation, enhance the agricultural system's resource allocation efficiency and dynamic adaptability to bolster overall resilience.

4. Establish a multi-tiered risk mitigation and protection mechanism.

Refine agricultural insurance systems and disaster risk early warning frameworks to bolster farmers' capacity to respond to natural disasters, market fluctuations, and policy changes. Strengthen agricultural financial support and policy-based insurance offerings, promoting the development of a comprehensive risk prevention and control system covering production, distribution, and sales. This will create a full-cycle agricultural economic resilience mechanism encompassing prevention, emergency response, and recovery.

RESEARCH LIMITATIONS AND FUTURE DIRECTIONS

Although this study explores novel research approaches and methodologies, certain limitations remain. On one hand, the investigation into the impact mechanisms on agricultural economic resilience is insufficiently in-depth. While the study primarily characterizes the evolutionary features of agricultural economic resilience across temporal and spatial dimensions, it has yet to systematically analyze the causal pathways through which potential factors- such as digital economic development, financial support, and agricultural technological innovation- influence agricultural economic resilience.

On the other hand, the scope for model extension in this study is limited. As the focus is on spatial distribution patterns, spatial econometric models like SDM, SEM, or SAR have not been incorporated to identify spatial spillover effects among influencing factors.

Furthermore, the data level and precision require enhancement. While provincial-level panel data form the basis here, future research could extend to prefecture-level cities or counties. Higher granularity would better capture regional variations, improving the specificity and operational feasibility of policy recommendations.

This study identifies correlations and spatial patterns rather than causal relationships. Future research employing advanced econometric models is needed to further examine the causal mechanisms underlying agricultural economic resilience. Build upon this foundation by integrating the interactive mechanisms between the digital economy and agricultural resilience. Constructing a spatial panel econometric model could enable a deeper analysis of how factors such as digital transformation, technological innovation, and institutional support jointly shape pathways for enhancing agricultural economic resilience through both direct and indirect effects. This would provide more empirically grounded decision-making support for achieving high-quality agricultural development.

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