Textile & Leather Review

ISSN 2623-6281 | www.tlr-journal.com | 10.31881/TLR

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How to cite: REN Y, WANG N, XIAO K, LIU M, WANG J. Research on the Impact of Low-Altitude Economy on High-Quality Development. Textile & Leather Review. 2026; 9:3989-4011. https://doi.org/10.31881/TLR.2026.3989

How to link: https://doi.org/10.31881/TLR.2026.3989

Published: 25 April 2026

Research on the Impact of Low-Altitude Economy on High-Quality Development

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Article
https://doi.org/10.31881/TLR.2026.3989
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ABSTRACT

This study draws upon provincial-level panel data for China spanning 2013 to 2022. Employing both OLS and spatial econometric models, it examines how the low-altitude economy influences regional high-quality development and generates spillover effects on adjacent areas. The findings are as follows: ①Both the low-altitude economy and high-quality development exhibit a sustained upward trajectory over the study period, with low-level regions declining markedly and high-level regions increasing substantially. Both dimensions demonstrate pronounced spatial agglomeration. ②The low-altitude economy exerts a statistically significant positive impact on high-quality development, accompanied by notable spatial spillover effects. The indirect effect coefficient substantially exceeds the direct effect coefficient. The direct effects in the eastern and central regions surpass those in the western and northeastern regions, with significant polarization evident. Notably, the spatial spillover effect in the central region fails to reach statistical significance. ③Each tier of the low-altitude industry generates a significant positive local effect on high-quality development. In terms of the total effect, a clear hierarchical structure emerges: the midstream manufacturing tier outperforms the upstream foundational tier, which in turn exceeds the downstream application tier. Significant spatial spillover effects are observed between the upstream foundational tier and the midstream manufacturing tier, whereas the spatial influence of the downstream application tier remains statistically insignificant.

KEYWORDS
low altitude economy, high quality development, spatial durbin model, spatial heterogeneity analysis, hierarchical spatial effect decomposition

INTRODUCTION

The report of the 20th National Congress of the Communist Party of China clearly states that high-quality development is the primary task for the comprehensive construction of a socialist modernized country. Currently, our country is at a crucial stage of rapid economic development. To break through development bottlenecks and build a new domestic and international dual circulation development pattern, high-quality development urgently needs to open up new growth lanes as an engine. The low-altitude economy, by its efficient utilization of airspace resources and innovative empowerment of the aviation industry, is gradually becoming a strategic breakthrough point for driving regional industrial upgrading and smart city construction. The low-altitude economy refers to an economy that utilizes low-altitude airspace resources as its carrier, covering various consumption and production scenarios such as unmanned aerial vehicle delivery, air taxis, emergency rescue, aerial photography, geological surveying, meteorological detection, low-altitude tourism, and low-altitude logistics. As an emerging form of productive force, it holds significant strategic importance and great potential for development. As an important part of the national strategy, low-altitude economy not only plays a significant role in promoting national development and the strategy of science and education revitalization, but also aligns perfectly with the concept of high-quality development in our country. By integrating new technologies with traditional industries and leveraging its own spatial attributes to enhance the utilization rate of actual spatial resources, it injects new impetus into high-quality development through innovation-driven and industrial upgrading [1]. Currently, low-altitude economy is in the ascendant, with broad market prospects. From the central government to local authorities, low-altitude economy is regarded as an important driving force for economic transformation and growth. Therefore, delving into the impact of low-altitude economy on high-quality development and maximizing its effectiveness, opening up new horizons and patterns for high-quality development, and enabling it to contribute new impetus to economic growth, is both an urgent theoretical issue and an important guiding principle for practical activities.

Currently, academic research on the low-altitude economy [2] primarily focuses on two directions: theoretical topics and empirical analysis. In terms of theoretical topics, scholars have delved into the role of the low-altitude economy in industrial integration and scenario innovation, its impact on regional development, as well as legal regulation and infrastructure construction. Based on the field of remote sensing, some scholars [3] have applied low-altitude industry to urban planning and mapping, agriculture and other directions, and found that the cost can be greatly reduced by using smaller and lighter spacecraft than traditional remote sensing satellites. Meanwhile, Cruzan, M.B. scholarsp [4] integrated UAV technology into plant ecology and found that the use of micro-drones can provide sufficient image detail to estimate the distribution of a single plant species or vegetation type over several hectares at relatively low cost. Zhou (2025) [5], from a full life-cycle perspective, conducted a techno-economic-environmental analysis, demonstrating the significant value of the low-altitude economy in building sustainable smart cities. In research on the integration of the low-altitude economy with regional development. Regarding legal regulation, multiple scholars have explored the importance of the rule of law from different angles; constructing a legal and governance system adapted to the development of the low-altitude economy has become an urgent consensus in academia. In AP Cracknell [6] study, the jurisprudence logic and institutional system of the Low-altitude Economy Industry Promotion Law were systematically expounded; Rey Koslowski [7] thinks border drones could save the lives of migrants crossing deserts and rough seas, while also eroding privacy and undermining geo-security. Furthermore, Alena Otto studies [8] optimization methods for civil UAV applications to provide a new reference path for operation planning experts. Similarly, scholars have focused on low-altitude architecture and infrastructure construction; Montemanni R studied [9] multiple vehicles and drones in parallel to complete tasks, and found that drones could process tasks at a faster speed., Celia Seguin’s research [10] shows that drones can be used as basic rescue facilities to safely and quickly deliver buoyancy devices to swimmers. The inclusion of drones in rescue operations will improve the quality and speed of first aid, while keeping lifeguards away from dangerous sea conditions. Furthermore, Recent scholarship by Liao Xiaohan [11] highlights that the burgeoning low-altitude economy presents both novel opportunities and hurdles for geographic information technology. Specifically, the availability of high-precision geographic data is now a prerequisite for ensuring the safety of low-altitude navigation. In terms of empirical quantitative analysis, Li Xiaojin [12] utilized input-output models and the income approach to advocate for the prioritization of “low-altitude advantageous industries.” Li’s findings stress the necessity of fostering talent and technological innovation, bolstering infrastructure, and enforcing rigorous safety supervision and policy support to maximize the sector’s contribution to regional economies. Despite these insights, a standardized framework for evaluating the low-altitude economy remains elusive within the academic community. Conversely, methodologies for assessing high-quality development have matured significantly. Researchers have established comprehensive index systems grounded in the five pillars of the new development philosophy: innovation, coordination, green development, openness, and sharing. These studies frequently employ measurement techniques such as the entropy method, TOPSIS, and Data Envelopment Analysis (DEA) to explore influencing factors and spatial effects [13]. Currently, existing studies on the impact of the low-altitude economy on high-quality development indicate a positive effect between the two. On one hand, the low-altitude economy promotes the development of low-altitude industries and drives high-quality regional economic development by integrating resources and optimizing related configurations

[14]. On the other hand, some scholars have noted issues in the integration of the low-altitude economy and high-quality development, such as imperfect top-level design, a lack of relevant talent, and the failure of industrial policies to form a synergy [15]. Currently, the measurement of indicators for the low-altitude economy in academia is still in an exploratory stage; particularly, research on the direct and indirect driving factors of the low-altitude economy for high-quality development from a spatial perspective is insufficient, and related empirical analyses are even scarcer.

Building upon the existing academic framework, this study establishes a comprehensive indicator system rooted in the fundamental definition of the low-altitude economy. Utilizing panel data spanning 2013 to 2022 across 31 Chinese provinces, the research analyzes the determinants driving the low-altitude economy's influence on high-quality development. The study maps the spatiotemporal evolution of both the low-altitude economy and development quality. Methodologically, it applies Ordinary Least Squares (OLS) and Spatial Durbin Models (SDM) to scrutinize these impacts through both linear and spatial lenses. Furthermore, the paper validates the heterogeneity of these effects across different tiers of the low-altitude economy. The marginal contributions of this research are threefold: ① Addressing the lack of measurement standards for the low-altitude economy, this paper constructs an indicator system by dividing the low-altitude economy into upstream infrastructure, midstream manufacturing, and downstream application layers based on related concepts and existing research, thereby filling gaps in current studies. ② Spatial Empirical Analysis: Responding to the lack of spatial investigations, this study employs the Spatial Durbin Model and heterogeneity tests. This approach elucidates the spatial spillover effects and associations, offering robust empirical evidence that was previously unavailable. ③ Industrial Chain Decomposition: The research delves deeper by dissecting the spatial effects of the industry's upstream, midstream, and downstream segments. By analyzing the direct and spillover impacts of each specific layer, the study offers actionable insights for optimizing industrial structures and enriches the theoretical understanding of the sector's role in high-quality development.

RESEARCH DESIGN

Research Methods

OLS Regression Model

The Ordinary Least Squares (OLS) method calculates the sum of the squared residuals between the predicted values and the actual values to find the optimal regression parameters and establish the best-fitting model. It is widely used to estimate the linear relationship between explanatory variables and the dependent variable.

To observe the actual impact of the low-altitude economy on high-quality development, this paper formulates the following benchmark model [16]:

$$hqd_{it} = \alpha_0 + \alpha lae_{it} + \alpha_i X_{it} + \mu_i + \varphi_i + \varepsilon_{it} \tag{1}$$

in the formula: where i represents the province and t (t =1,2,…,10) denotes the year, hqd_{it} denotes the level of high-quality development , lae_{it} stands for level of low-altitude economy, X_{it} stands for the remaining control variables, α_0 is constant term, α and α_i is coefficients of each variable, μ_i represents the individual fixed effects, φ_i denotes the time fixed effects, ε_{it} is a random error term.

Spatial Econometric Models

This paper constructs a spatial econometric model to further explore the impact of low-altitude economic levels on high-quality development from a spatial perspective. The standard spatial econometric models include the spatial error model (SEM), the spatial autoregressive model (SAR), and the spatial Durbin model (SDM). Compared to SAR, which only includes the spatial lag term of the dependent variable, SEM only reflects spatial correlation through the error term, while SDM, by introducing the spatial lag terms of the dependent variable and the independent variable, provides a more comprehensive and reliable reflection of the spatial spillover effects between the two. In this paper, SDM is selected [17] in this paper:

$$hqd_{it} = \delta \sum_{i=1}^{n} W hqd_{it} + \beta_1 lae_{it} + \beta_2 X_{it} + \theta_1 \sum_{i=1}^{n} W lae_{it} + \theta_2 \sum_{i=1}^{n} W X_{it} + \mu_i + \varphi_i + \varepsilon_{it} \tag{2}$$

Where W is spatial weight matrix. This paper selects the geographic adjacency matrix for testing, δ 、 β_1 、 β_2 、 θ_1 、 θ_2 is coefficients of each variable, n is sample size, The sample size in this paper is 31, and the final estimation model is determined using spatial effect tests.

Variable Selection

(1) Dependent Variable. This paper selects the level of high-quality development as the dependent variable. Considering the interpretation of high-quality development as “adhering to the people-centered development philosophy and upholding innovative, coordinated, green, open, and shared development,” and based on research by relevant scholars, a development index system comprising 5 secondary indicators

and 15 tertiary indicators is constructed to comprehensively calculate the provincial-level high-quality development level from 2013 to 2022 using the entropy weight method, see Table 1.

Table 1. High-Quality Development Level Evaluation Index System

first-level indicator	secondary indicator	third-level indicator	Definition of Indicators
High-quality development	innovative development	technology transaction activity	Ratio of technical transaction volume to regional GDP
		degree of marketization	Regional Marketization Index
		R&D intensity	Ratio of R&D expenditure of industrial enterprises above designated size to regional GDP
	coordinated development	demand structure	Ratio of total retail sales of consumer goods to regional GDP
		industrial structure	The rate of increase in the proportion of the tertiary industry in regional GDP
		urban-rural structure	urbanization rate
	Green development	wastewater generated by units	Total industrial wastewater discharge compared with regional GDP
		industrial waste gas emission ratio	Ratio of industrial sulfur oxide emissions to regional GDP
		industrial waste utilization rate	Ratio of comprehensive utilization of industrial solid waste to generation
	open development	share of foreign investment	Foreign investment as a percentage of regional GDP
		foreign trade dependence degree	Total imports and exports as a percentage of regional GDP
		investment efficiency	incremental capital-output ratio
	shared development	GDP growth rate	Regional GDP growth rate
		elasticity of residents’ income	Ratio of the growth rate of per capita disposable income of residents to the regional GDP growth rate
		proportion of livelihood-related fiscal expenditure	Ratio of the growth rate of per capita disposable income of residents to the regional GDP growth rate

(2) Explanatory Variable. To evaluate the low-altitude industry, this study adopts its development level as the explanatory variable. Given the current scarcity of empirical literature on the low-altitude economy, the measurement framework is constructed by synthesizing core concepts and building upon the work of scholars like Shen Yingchun [18]. This approach involves segmenting the industrial chain into three distinct tiers: the upstream foundation layer, the midstream manufacturing layer, and the downstream application layer. Among them, the upstream foundational layer is the core foundation of the low-altitude industry, consisting of low-altitude technology patents and the number of low-altitude-related enterprises. The

output of low-altitude technology patents is expressed by the number of aircraft, unmanned aircraft and aircraft patents. The number of low-altitude-related enterprises is indicated by the number of newly established unmanned aircraft enterprises. The midstream manufacturing layer, which is the manufacturing sector for low-altitude supporting products, is an important link connecting the upstream and downstream industries. It is divided into two indicators: the output of low-altitude-related equipment and the level of low-altitude-related industries. Among them, the output of integrated circuits for unmanned aircraft represents the output of low-altitude-related equipment, and the unmanned aircraft bidding announcements describe the level of low-altitude-related industries. The downstream application layer serves applications for the deep integration of the low-altitude economy and industries. It focuses on the achievements of the low-altitude industry, as well as public attention and participation enthusiasm. The actual application results of low-altitude and the related popularity of low-altitude are selected as the variable indicators. The aerial photography results describe the practical application outcomes at low altitudes. Based on the existing literature [19], the public attention level is measured through Baidu search index. Therefore, the Baidu search index of unmanned aerial vehicles is used to represent the popularity of low-altitude related topics. The entropy method is used to measure the level of low-altitude economy, and the comprehensive evaluation index is obtained, see Table 2.

Table 2. Low-altitude Economic Level Evaluation Index System

	Hierarchical division	variable name	Metric Description
Low-altitude Economic	Upstream foundational layer	Low-altitude technology patent output	Number of patents for aircraft, drones, and aviation vehicles
		Number of low-altitude related enterprises	Number of newly added drone enterprises
	Midstream manufacturing layer	Low-altitude related equipment production volume	Unmanned aerial vehicle integrated circuit production volume
		level of low-altitude related industries	Unmanned Aerial Vehicle Tender Announcement
	Downstream application layer	Low-altitude practical application achievements	aerial survey results
		Low-altitude related popularity	Drone Baidu Search Index

(3) Control Variables. Considering the potential impact of other factors on the robustness of the empirical results, this paper selects the following indicators as control variables. ①Communication level, represented by the capacity of mobile phone switching stations. Information infrastructure is the underlying support for high-quality development in the digital economy era and the core carrier for cultivating new productive

forces and promoting economic transformation and upgrading. ②Network level, described by the length of optical cable lines. Network services are the nerve hub of digital transformation, and the quality of network services directly affects the depth and breadth of the digital economy. ③Freight level, represented by the total freight volume. Efficient connectivity of transportation infrastructure is the guarantee for the flow of economic factors and the physical framework for regional coordinated development, and directly affects the efficiency of factor circulation. ④Human resources, described by the level of human capital. Labor force is the core element of innovation-driven development, and the quality and allocation efficiency of labor force directly affects economic vitality.

Research Period and Data Sources

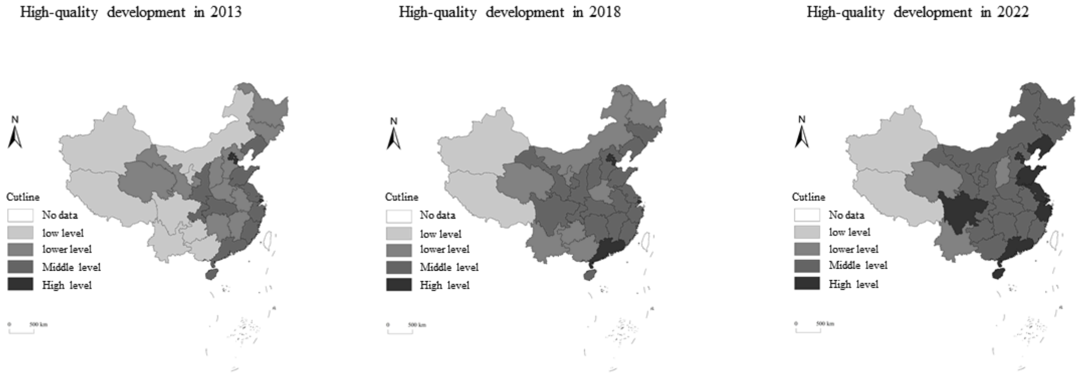
In 2013, the General Staff Department of the People's Liberation Army of China and the Civil Aviation Administration of China jointly issued the "Regulations on the Approval and Management of General Aviation Flight Tasks", which was regarded as the first year of the low-altitude economy development. In 2018, the Civil Aviation Administration of China released the "Interim Regulations on the Flight Management of Unmanned Aircraft", which implemented the first classification management of drones and clearly stipulated the regulatory requirements for different types of drones, providing policy guarantees for the standardized development of the drone industry. In 2023, the Central Economic Work Conference explicitly identified the low-altitude economy as a national strategic emerging industry, further enhancing the strategic position of the low-altitude economy. At the same time, the "Regulations on the Flight Management of Unmanned Aircraft" was officially implemented, implementing full life cycle management for drones, providing a more complete legal framework for the standardized development of the drone industry. Therefore, this study takes 2013 as the starting point and covers the 31 provinces of China (excluding Hong Kong, Macao and Taiwan regions) as the research objects. Based on the validity and availability of the data, an index system was constructed to comprehensively calculate the level of the low-altitude economy and its high-quality development. The initial data of the indicators came from the "China Statistical Yearbook", "National Intellectual Property Administration", "National Bureau of Statistics", Qichacha and the Ministry of Industry and Information Technology. Missing values in some panel data were replaced using the linear interpolation method. According to the zoning standards of the seventh national population census, the provinces were divided into eastern provinces, central provinces, western provinces and northeastern provinces.

EMPIRICAL ANALYSIS

High-Quality Development and Low-Altitude Economy in Space and Time

The Spatiotemporal Pattern of High-Quality Development

Using the ArcGIS software, the high-quality development index was divided into four levels: high level, medium level, lower level, and extremely low level by the natural discontinuity classification method. The visualization display was made for the years 2013, 2018, and 2022 (Figure 1): Overall, the level of high-quality development across the country has significantly improved. The number of low-level areas decreased from 8 in 2013 to 2 in 2022, the number of lower-level areas decreased from 10 in 2013 to 1 in 2022, the number of medium-level areas increased from 9 in 2013 to 17 in 2022, while the number of high-level areas increased from 3 in 2013 to 10 in 2022. Liaoning Province, Sichuan Province, Hainan Province, Shandong Province, Jiangsu Province, Zhejiang Province, and Guangdong Province showed the most significant improvement. Liaoning Province has abundant port resources, possesses superior opening-up conditions and maritime transportation advantages, and is located at the core of the Northeast Asian economic circle. Its southern part is adjacent to the Beijing-Tianjin-Hebei urban agglomeration. In addition, it has received support from relevant policies such as “Several Opinions on Comprehensively Revitalizing the Old Industrial Bases in Northeast China” and others. The overall high-quality development level of Liaoning Province has improved rapidly. Sichuan Province, leveraging major regional development strategies such as the Chengdu-Chongqing Twin-City Economic Circle and the Western Development Initiative, provides crucial impetus for its high-quality economic development in the western region. Hainan Province takes advantage of the policy advantages such as the “Overall Plan for the Construction of Hainan Free Trade Port”, as well as its abundant tourism resources, actively promotes industrial structure optimization and improvement of the business environment, and has rapidly improved its high-quality development level. The four eastern coastal provinces including Shandong Province, with their outstanding geographical location advantages, have significantly improved their high-quality development levels.


High-quality development in 2013

High-quality development in 2018

High-quality development in 2022

Figure 1. Spatiotemporal Distribution Characteristics of High-Quality Development

The Spatiotemporal Patterns of the Low-Altitude Industry Layers

Overall, the low-altitude economy has gradually improved from 2013 to 2022, with the eastern coastal areas remaining the core of development and showing a spatial distribution pattern of “high in the south and low in the north”. With the upgrading of industries and technological progress, the medium and high-level regions have continued to expand. Layered analysis shows: ① The development of upstream basic layer patents has shown an evolution trajectory of diffusion from east to west. In 2013, patents were concentrated in the eastern, southern regions and Sichuan, while the central and western regions showed a low level, reflecting insufficient technological reserves. By 2018, the number of medium-level regions continued to increase, indicating the successful effect of the national laboratory layout. However, there was still a technological gap in the western region. In 2022, high-level regions showed a continuous growth in clusters, presenting a spatial agglomeration effect. The eastern, central regions and Sichuan have long been at the forefront of the level, benefiting from the country’s continuous strengthening of research and development investment and promotion of scientific and technological innovation, such as the support for scientific and technological innovation in the “14th Five-Year Plan”, as well as the emphasis and policy support for low-altitude economy in various regions. ② The midstream manufacturing layer has transformed from “high-end concentration along the coast” to “coordinated upgrading nationwide”, through technology transfer and policy-driven measures, achieving a transition from low-level dominance to widespread adoption in the medium-level regions. In 2013, the low-level regions had the largest distribution, while high-end manufacturing was concentrated in places like Beijing, Jiangsu, and Guangdong, relying on the advantages of industrial chain complementarity. In 2018, the overall trend was a transition from low levels to even lower levels, with Xi’an and Chengdu forming regional manufacturing centers by absorbing technologies from the eastern regions. In 2022, the country showed a characteristic of aggregating from the coast to overall coordination, with the medium-level regions replacing the lower-level regions. This was due to economic development and the country’s emphasis on technological innovation and talent cultivation. ③ The development situation in the northern part of the downstream application layer is very good. Xinjiang, Gansu and Inner Mongolia have increased from a low level in 2013 to a medium level in 2018, and have maintained at a medium level in 2022. Qinghai has increased from a low level in 2013 to a high level in 2018, but then dropped to a low level in 2022. The development level of low-altitude applications in the Beijing-Tianjin-Hebei region has always been at the forefront of the country. Guizhou and Hunan have moved from a low level in 2013 to a high level in 2022. It is worth noting that Sichuan has dropped from a high level in 2013 to a low level in 2018, and still remains at a low level in 2022, see Figure 2.

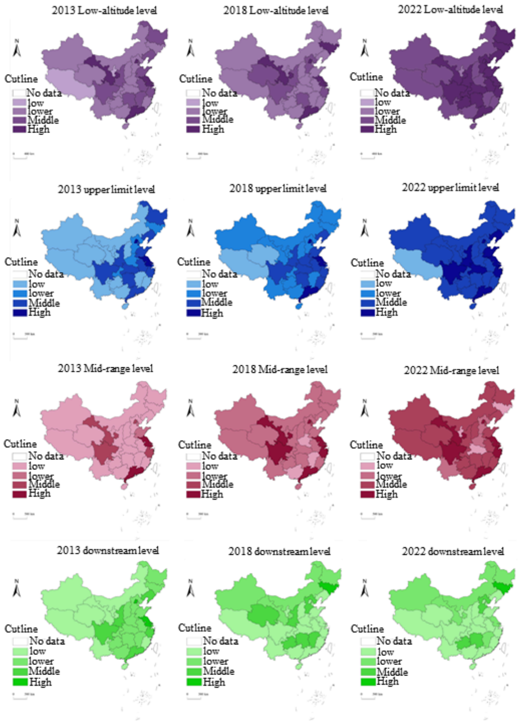


Figure 2. National Low-Altitude Economy and Stratified Spatiotemporal Distribution Characteristics

The Effects of Low-Altitude Economy on High-Quality Development

OLS Regression Analysis

First, a multicollinearity test was conducted on the explanatory variables and control variables. The variance inflation factors of each variable were all less than 5, indicating that there was no multicollinearity among the variables.

Table 3, Column (1) displays the baseline regression outcomes, which indicate that the low-altitude economy exerts a statistically significant positive influence on high-quality development. Specifically, a one standard deviation rise in the low-altitude economic level corresponds to a 0.720 standard deviation increase in high-quality development. Columns (2) through (5) illustrate the results following the sequential inclusion of control variables. While the coefficient for the low-altitude economy exhibits minor fluctuations, both its sign and statistical significance remain consistent with the baseline model. Furthermore, the progressive increase in the R^2 value alongside the addition of control variables underscores the robustness of the low-altitude economy's promotional effect. This positive impact is primarily driven by agglomeration effects and technology spillovers, where the expansion of emerging sectors—such as UAV logistics and low-altitude transport—substantially enhances regional economic efficiency.

Table 3. benchmark regression result

variables	(1)	(2)	(3)	(4)	(5)
lae	0.720***	0.728***	0.553***	0.488***	0.529***
	(9.629)	(9.551)	(8.545)	(6.484)	(7.143)
C1		−0.015	−0.001	−0.042	0.005
		(−0.577)	(−0.055)	(−1.304)	(0.139)
C2			0.356***	0.364***	0.387***
			(11.947)	(12.102)	(12.965)
C3				0.067*	0.154***
				(1.698)	(3.511)
C4					−0.162***
					(−4.109)
Constant	0.251***	0.255***	0.133***	0.127***	0.118***
	(34.857)	(23.639)	(9.829)	(9.081)	(8.529)
Observations	310	310	310	310	310
R-squared	0.231	0.232	0.476	0.481	0.509

Robust t-statistics in parentheses

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

Spatial Durbin Model Analysis

The classical ordinary least squares estimation method neglects the spatial correlation characteristics and has model specification errors, which in turn leads to insufficient overall explanatory power. Therefore, in order to alleviate the limitations of traditional econometric models, this paper further constructs a spatial econometric model for empirical testing.

According to Elhorst’s theory, the optimal model is selected through LM, LR and Wald tests (Table 4). The results show that there are spatial lag and error effects, and the SDM model does not degenerate into SLM or SAR. The Hausman test supports the use of fixed effects, and the fit of the time fixed effects is the best. In conclusion, the final selected model is the time-fixed effects spatial Durbin model.

Table 4. The test results of the spatial econometric model

test	statistic
LM-spatial lag	70.432***
Robust LM-spatial lag	73.045***
LM-spatial error	19.590***
Robust LM-spatial error	22.203***
LR-spatial lag	35.33***
LR-spatial error	37.10***
Wald_Spatial lag	37.10***
Wald_Spatial error	39.52***
Hausman test	9.67*
LR-ind fixed	16.78
LR-time fixed	673.42***

The low-altitude economy exhibits significant spatial dependence on high-quality development, with a linkage intensity of approximately 0.262; specific marginal effects are shown in Table 5 regarding impact decomposition.

Table 5. Spatial Durbin Model Effect Decomposition

variables	(1) Main	(2) WX	(3) Direct	(4) Indirect	(5) Total
lae	0.505***	0.676***	0.560***	1.044***	1.604***
	(9.86)	(6.87)	(0.0551)	(0.153)	(0.184)

variables	(1) Main	(2) WX	(3) Direct	(4) Indirect	(5) Total
C1	−0.041	−0.582***	−0.0807***	−0.763***	−0.844***
	(−1.62)	(−10.94)	(0.0258)	(0.0913)	(0.104)
C2	0.196***	0.543***	0.237***	0.761***	0.997***
	(6.96)	(9.23)	(0.0266)	(0.0793)	(0.0816)
C3	0.143***	0.436***	0.174***	0.610***	0.785***
	(4.45)	(6.94)	(0.0331)	(0.0810)	(0.0948)
C4	−0.011	0.211***	0.00345	0.267***	0.271***
	(−0.30)	(4.10)	(0.0338)	(0.0719)	(0.0858)
Observations	310	310	310	310	310
rho	0.262***	0.262***	0.262***	0.262***	0.262***
	(0.0707)	(0.0707)	(0.0707)	(0.0707)	(0.0707)
R-squared	0.729	0.729	0.729	0.729	0.729

Because the variable estimated parameters of the spatial Durbin model (SDM) can only reflect the direct direction of the impact of low-altitude economy on high-quality development, and the true partial regression coefficient or marginal effect cannot be obtained, this paper uses the partial differential method to decompose the SDM results under fixed effects into direct effect, indirect effect and total effect. Among them, the direct effect coefficient is 0.560 and significant at the level of 1%, indicating that for every standard deviation increase in the local low-level economic development level, the high-quality development level will increase by 56.0% accordingly. This means that the local low-altitude economy-related industries directly promote regional high-quality development through technological upgrading and the increase of low-altitude patent R&D investment, which is consistent with the results of the benchmark regression model. The estimated parameter of the indirect effect is 1.044, which also passes the significance test of 1%, indicating that the low-altitude economy has a significant spatial effect on high-quality development. Specifically, the local low-altitude industry level has a positive spatial spillover effect on the high-quality development of neighboring areas through technology spillover and inter-regional industrial chain synergy. To a certain extent, low-altitude economy breaks down the development barriers caused by geographical differences. In addition, affected by industrial agglomeration, the local low-altitude manufacturing industry has a “trickle-down effect” on the surrounding areas, promoting the development of low-altitude related industries in the adjacent areas. Under the guidance and implementation of favorable policies such as common prosperity, inter-regional policy support, mutual benefit and win-win principle and regional inclusive development, the development of local low-altitude industry also forms a radiation and driving effect on the high-quality economic development of adjacent areas.

Robustness Check

To further verify the reliability of the experimental results, a robustness check was conducted by replacing the spatial weight matrix. This paper introduced economic geography and spatial geography matrices to separately verify the spatial spillover effects of low-altitude industry levels on high-quality development The results show that compared with the spatial adjacency matrix, the signs and significance levels of the coefficients of the core variables remained highly consistent, and the explanatory power of the SDM m not undergo any substantial change, fully demonstrating the robustness of the research conclusions, see Table 6.

Table 6. robustness check

variables	Economic Geography Main	Economic Geography WX	Geographical distance Main	Geographical distance WX
lae	0.578***	1.919***	0.559***	0.773**
	(0.0619)	(0.356)	(0.0668)	(0.376)
C1	−0.0270	0.121	−0.136***	−0.240
	(0.0302)	(0.106)	(0.0358)	(0.239)
C2	0.197***	1.064***	0.238***	0.954***
	(0.0305)	(0.149)	(0.0316)	(0.184)
C3	0.0947**	0.0420	0.251***	1.105***
	(0.0405)	(0.166)	(0.0441)	(0.355)
C4	−0.177***	0.106	−0.160***	0.257
	(0.0404)	(0.155)	(0.0445)	(0.269)
Observations	310	310	310	310

Heterogeneity Analysis

This article divides the 31 provincial administrative regions across the country into four major regions: the eastern region, the central region, the western region, and the northeastern region. It also decomposes the spatial effect results to further explore the spatial impact of the low-altitude economy on the high-quality development of different regions. The specific regression results are shown in Table 7. The analysis indicates that the direct promoting effect of the low-altitude economy on high-quality development is as follows: the eastern region > the central region > the western region > the northeastern region. ① The leading role of the eastern region is the most significant. Its local effect parameter is 0.892, ranking first. This is mainly due to the higher degree of marketization, complete industrial chain, and vigorous economic vitality in this region. City clusters such as the Yangtze River Delta and the Pearl River Delta have formed a full-chain collaboration of “research and development - manufacturing - service”, and the agglomeration effect, multiplier effect, and redistribution effect of the low-altitude industry have been fully released to promote high-quality development. ② The spatial spillover effect of the central region is not significant, Similar to the research conclusions of scholars on regional economic disparities [20], the main reasons lie in the relatively insufficient overall economic development level, industrial synergy, and policy support in the central region. ③ The spatial spillover coefficient of the western region is 1.218, far exceeding the local coefficient of 0.427, indicating frequent element flow. Under the “drop-by-drop effect”, it benefits the surrounding provinces and cities, fully confirming the hub role of “Belt and Road” nodes. ④ The local effect and spatial spillover effect of the northeastern region are both smaller than those of the other three regions. The reason is that the low-altitude industry in the northeastern region started relatively late. Many old cities mainly relied on resource-based economies, which made economic transformation difficult and the development of the low-altitude industry lagging behind.

Table 7. heterogeneity test

variables	Eastern Main	Eastern WX	Central Main	Central WX	Western Main	Western WX	Northeast Main	Northeast WX
lae	0.892***	0.611***	0.685**	0.472	0.427***	1.218***	0.328***	0.321*
	(12.96)	(3.97)	(2.78)	(0.90)	(0.073)	(0.203)	(0.083)	(0.170)
C1	−0.218***	−0.473***	0.0739***	−0.0373	0.122**	−0.137	0.395***	1.267***
	(−4.13)	(−5.21)	(4.58)	(−0.80)	(0.048)	(0.103)	(0.039)	(0.190)
C2	0.095**	0.099	0.556***	0.543***	0.078**	0.263***	−0.523***	−1.757***
	(2.90)	(1.87)	(5.85)	(3.41)	(0.034)	(0.073)	(0.166)	(0.409)
C3	−0.144*	−0.018	0.076	0.141	−0.072**	0.077	−0.110**	−0.250*
	(−1.48)	(−0.21)	(1.87)	(1.67)	(0.034)	(0.089)	(0.048)	(0.128)
C4	−0.124***	0.077	0.254***	0.356***	0.138***	0.166**	0.074	−0.685**
	(−3.88)	(1.53)	(4.85)	(3.48)	(0.032)	(0.080)	(0.120)	(0.325)
Observations	100	100	60	60	110	110	40	40
R-squared	0.949	0.949	0.861	0.861	0.647	0.647	0.667	0.667

DECOMPOSITION OF HIERARCHICAL SPATIAL EFFECTS IN THE INDUSTRIAL CHAIN

To further verify the differences in the impact effects of various levels of the low-altitude economy on high-quality development, this paper first eliminates the influence of data unit differences by using a dimensionless method for all data levels. Then, it decomposes the spatial effects of each level of data. The results are shown in Table 8. In terms of direct effects, the upstream basic layer, midstream manufacturing layer, and downstream application layer of the low-altitude industry all have significant positive direct impacts on high-quality development. Among them, the upstream basic layer has the most obvious impact, with a coefficient of 0.427, indicating that the upstream basic layer, midstream manufacturing layer, and downstream application layer of the low-altitude economy can all promote local high-quality development. Among them, the upstream basic layer performs particularly well. In terms of indirect effects, the upstream basic layer and midstream manufacturing layer have significant impacts on high-quality development with a 1% significance level, while the downstream application layer has not passed the significance test. The direct effect of the upstream basic layer is higher than the indirect effect, indicating that there is a geographical boundary for the technology spillover of the upstream basic layer, midstream manufacturing layer, and downstream application layer. This "knowledge stickiness" stems from the complexity characteristics of aviation technology. The high-precision and advanced technology barriers not only exist among enterprises but also between regions, and there is a potential risk of "patent pool lock-in effect". The midstream manufacturing layer shows the strongest spatial indirect effect, with its indirect effect being 2.06 times that of the direct effect, revealing the promoting effect of the regional transmission network of the manufacturing flow on the high-quality development of adjacent regions. The downstream application layer has a significant direct effect but an insignificant indirect effect, indicating that the current localization service characteristics of low-altitude achievements are relatively prominent, and the achievements cannot be diffused and spread between adjacent regions, with a strong geographical boundary effect.

From the perspective of the total effect, all industry tiers demonstrate statistical significance. Specifically, the upstream foundational tier and the midstream manufacturing tier pass the 1% significance threshold, whereas the downstream application tier meets the 10% confidence level. Regarding the influence on high-quality development, the low-altitude industry exhibits a hierarchical structure: the midstream manufacturing tier exerts the strongest effect, followed by the upstream foundational tier, with the downstream application tier ranking lowest. ① The midstream manufacturing tier generates the most pronounced impact on high-quality development, a pattern consistent with China's status as a global manufacturing powerhouse. Industries within this tier are highly concentrated regionally, attracting substantial specialized talent, and their rapid expansion propels regional economic advancement while bolstering the manufacturing sector. The materials and equipment required for precision avionics systems are sourced from multiple regional cities, constituting an integrated modular supply chain network that fosters close inter-regional linkages. Through a "trickle-down" mechanism, manufacturing facilitates the diffusion of talent, technology, and capital to neighboring regions, thereby influencing their high-quality economic development. ② The upstream foundational tier spearheads the development of the low-altitude industry, functioning as its core component with a robust driving effect on high-quality development. As an emerging sector, the low-altitude economy tends to generate considerable employment opportunities. Nascent industries demonstrate a particularly strong appetite for talent influx, securing additional benefits through policy subsidies targeting enterprises, which in turn attracts technical professionals. Simultaneously, regions with vigorous technological innovation are more prone to draw capital investment. Patent-driven technological progress stimulates regional development, which subsequently fuels economic growth. ③ The downstream application tier exerts a comparatively weaker influence on high-quality development. Given that the low-altitude economy remains an emerging industry, sectoral maturity has yet to be achieved, underlying application deployment remains incomplete, and the implementation of industry standards has not been fully executed. These constraints prevent the low-altitude economy from realizing its full efficiency potential.

Table 8. Decomposition Results of Spatial Effects in Multi-tiered Low-altitude Economy

variables	Upstream foundation layer	Midstream Manufacturing Layer	Downstream application layer
Direct	0.427***	0.318***	0.0740***
	(0.02)	(0.03)	(0.012)
Indirect	0.397***	0.656***	0.0383
	(0.06)	(0.08)	(0.05)
Total	0.824***	0.974***	0.112*
	(0.08)	(0.09)	(0.06)
Control	yes	yes	yes
time	yes	yes	yes
ind	yes	yes	yes
Observations	310	310	310
rho	0.315***	0.150**	0.451***
	(0.07)	(0.07)	(0.06)
R-squared	0.770	0.688	0.749

CONCLUSIONS AND DISCUSSION

Conclusions

Based on the above research, the following conclusions can be drawn:

First, the low-altitude economic level and the high-quality development level have been increasing year by year. The low-level areas have significantly decreased, while the high-level areas have significantly increased. However, the regional differences have been increasing year by year. Some regions have weak infrastructure and limited economic belt radiation range, which hinders development. This indicates that there is still considerable potential for development. Both the low-altitude economy and high-quality development exhibit pronounced spatial agglomeration. The Beijing-Tianjin-Hebei region, the Yangtze River Delta, and the Pearl River Delta function as core growth poles, spearheading the advancement of the low-altitude economy. Spatially, the low-altitude economy displays a north-south disparity, with higher levels concentrated in the south; conversely, high-quality development manifests an east-west gradient, characterized by higher performance in the east and lower performance in the west.

Second, the benchmark regression model demonstrates that the low-altitude economy exerts a significant positive impact on high-quality development. The spatial Durbin model further corroborates this finding, revealing both a significant promotional effect and spatial spillover effect of the low-altitude economy on high-quality development. Notably, the indirect effect coefficient substantially exceeds the direct effect coefficient. During the study period, high-quality development exhibits pronounced spatial heterogeneity. The direct effects in the eastern and central regions outperform those in the western and northeastern regions, with the overall developmental trajectory characterized as “eastern and central regions taking the lead, while western and northeastern regions follow.” In particular, the spatial spillover effect in the central region remains statistically insignificant.

Third, each tier of the low-altitude economy exerts a significant positive impact on local high-quality development. In terms of the total effect, a hierarchical structure emerges, with the midstream manufacturing tier outperforming both the upstream foundational tier and the downstream application tier. Significant spatial spillover effects are observed between the upstream foundational tier and the midstream manufacturing tier, whereas the spatial influence of the downstream application tier fails to reach statistical significance.

Discussion

As low-altitude economy plays a key role in technological innovation, maintenance cycles, and the implementation of expanding domestic demand, it is of great significance for promoting innovative, green, and shared development. This study explores the impact effects of different levels of the low-altitude economy on high-quality development, contributing to the theoretical exploration and empirical analysis of related fields. To a certain extent, it fills the research gap regarding the stratified analysis of the low-altitude economy, possessing not only important theoretical value but also practical guiding significance.

Based on the research conclusions of this paper, the following suggestions and implications are proposed:

First, improve the supporting facilities for the low-altitude economy, popularize knowledge related to the low-altitude sector, and innovate products and supply-side services related to the low-altitude industry. Ensure the connectivity of upstream, midstream, and downstream industrial chains, achieving the synergy of "demand from below and creation from above, innovation from above and supporting facilities from below," and realizing a virtuous mutual transformation between outcomes and demands. Organize science, education, and trade fairs for the low-altitude industry, establish pilot projects to promote high-quality sharing of construction outcomes, and build demonstrative low-altitude industry cities and bases. Enhance the radiating effect of knowledge aggregation in the low-altitude industry from high to low levels, facilitate the steady flow of technology and low-altitude standards across regions, and utilize government and market platforms to publicize relevant knowledge to the public, establishing the benefits of low-altitude-related concepts.

Second, given the differentiated development among regions, local governments are required to formulate targeted policies and measures based on local conditions. Eastern regions should fully leverage their leading role in the low-altitude economy and high-quality development, further strengthening technological innovation and industrial upgrading. Central regions need to break through geographical constraints and strengthen the flow of factors between regions. Through policy formulation, encourage enterprises to engage in cross-regional cooperation and establish industrial alliances; strengthen infrastructure construction such as transportation and communication to reduce logistics and information exchange costs between regions, and promote the free flow of factors like technology and talent. Western regions should fully utilize their spatial spillover advantages and strengthen the hub construction of "Belt and Road" node cities; utilize policy support to attract more low-altitude economy-related enterprises to invest and build factories in the western region. Northeastern regions need to accelerate the start and development of the low-altitude industry and optimize resource allocation. The government should introduce special policies to support the construction of low-altitude economy industrial parks, providing support such as tax incentives and land policies.

Thirdly, the research on the impact of the low-altitude economy at different levels on high-quality development reveals that technological innovation at the upstream basic layer is the key to the development of the low-altitude economy. Continuing to expand the influence of the upstream basic layer and increasing investment in basic research, as well as encouraging universities, research institutions, and enterprises to carry out cooperative research and development, are necessary. The middle manufacturing layer should fully leverage its network effect advantages and enhance the collaboration among enterprises at all links of the industrial chain. Through establishing industrial alliances and conducting research and development cooperation, resource sharing and technological collaboration can be achieved. The downstream application layer should break through geographical boundaries and strengthen the expansion and innovation of application scenarios. Policy guidance can be used to encourage enterprises to carry out pilot projects in different regions, and explore suitable low-altitude economic application models for local development.

This article still has some shortcomings. The research perspective of this article starts from the provincial level, which is relatively macroscopic. In the future, when exploring the impact of the low-altitude economy on high-quality development, it is advisable to focus on prefecture-level cities and combine industry research data to further refine the indicators and lower the scale to facilitate more concrete analysis of the influencing factors and causes.

Author Contributions

Conceptualization – REN Y and WANG N; methodology – REN Y and WANG N; formal analysis – REN Y; investigation – XIAO K and LIU M; resources – XIAO K and WANG J; writing-original draft preparation – REN Y, WANG N and XIAO K; writing-review and editing – LIU M and WANG J; visualization – LIU M and WANG J; supervision – REN Y. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

Funding

This research is supported by the Beijing Social Science Foundation Project "Research on the Synergistic Enhancement Path of Green Innovation Efficiency in the Beijing-Tianjin-Hebei Region from the Perspective of Knowledge Spillover and Environmental Regulation" (20JJC023); the Ministry of Education Humanities and Social Sciences Research Project "Research on the Green Technological Innovation Capacity of Manufacturing Industry Based on Spatial Spillover and Threshold Effects" (20YJC630056); and the Beijing Municipal Education Commission Social Science Project (Approval Number: SM202011232008).

Acknowledgements

Not applicable.

Data Sharing Agreement

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

REFERENCES

[1] Zhou X, Wang X, Zhu M. Theoretical Logic and Practical Pathways for High-Quality Development of Low-Flying Economy under the Context of New Quality Productivity. Commercial Economics. 2026; (08): 128-130 + 142. doi: 10.19905/j.cnki.syjj1982.2026.08.032

[2] Liao W, Cao X, Yuan L, Zhong Z. Context and Progress of Domestic and International Low-Altitude Economic Research Based on the CiteSpace Software. Tropical Geography. 2026; 45(6): 937-953. doi: 10.13284/j.cnki.rddl.20240578

[3] Fearn D G. Economical remote sensing from a low altitude with continuous drag compensation. Acta Astronautica. 2005; 56(5):555-572. doi: 10.1016/j.actaastro.2004.09.052

[4] Cruzan MB, Weinstein BG, Grasty MR, Kohrn BF, Hendrickson EC, Arredondo TM, Thompson PG. Small unmanned aerial vehicles (micro-UAVs, drones) in plant ecology. Applications in Plant Sciences. 2016; 4: 1600041. doi: 10.3732/apps.1600041

[5] Zhou Y. Unmanned aerial vehicles based low-altitude economy with lifecycle techno-economic-environmental analysis for sustainable and smart cities. Journal of Cleaner Production. 2025; 499:145050-145050. doi: 10.1016/J.JCLEPRO.2025.145050

[6] Cracknell A P. UAVs: regulations and law enforcement. International Journal of Remote Sensing. 2017; 38(8-10):3054-3067. doi: 10.1080/01431161.2017.1302115

[7] Koslowski R, Schulzke M. Drones Along Borders: Border Security UAVs in the United States and the European Union. International Studies Perspectives. 2018; 19(4): 305-324. doi: 10.1093/isp/eky002

[8] Otto A, Agatz N, Campbell J, Golden B, Pesch E. Optimization approaches for civil applications of unmanned aerial vehicles (UAVs) or aerial drones: A survey. Networks. 2018;72:411-58. doi: 10.1002/net.21818

[9] Montemanni R, Dell'Amico M, Corsini A. Parallel drone scheduling vehicle routing problems with collective drones. Computers & Operations Research. 2024; 163:106514. doi: 10.1016/j.cor.2023.106514

[10] Seguin C, Blaquière G, Loundou A, Michelet P, Markarian T. Unmanned aerial vehicles (drones) to prevent drowning. Resuscitation. 2018;127:63-67. doi: 10.1016/j.resuscitation.2018.04.005

[11] Liao X, Huang Y, Liu X. Opportunities and Challenges for the Development of Geoinformation Technology in the Era of Low-Altitude Economy. Journal of Geo-Information Science. 2025; 27(01): 1-9.

[12] Li X, Liu S, Diao S, Su M, Hou Y, Bai X, Li Y. Research on the Measurement of Low-Altitude Economy's Contribution to Regional Economy: A Case Study of Jiangs Province. Price Theory & Practice. 2024; (10): 184-190. doi: 10.19851/j.cnki.CN11-1010/F.2024.10.286

[13] Huang C, Pan J, Gao S. Achieving a Virtuous Interaction between High-Quality Development and Ecological Security: Promoting Green Development with Xi Jinping Thought on Economics and Xi Jinping Thought on Ecological Civilization. Econoarch Journal. 2024; 59(10): 4-18.

[14] Ouyang R. Operating Mechanism and Path Selection of Low-Altitude Economy Boosting New Quality Productive Forces. Journal of Xinjiang Normal University (Philosophy and Social Sciences Edition). 2025; 46(01): 11. doi: 10.14100/j.cnki.65-1039/g4.20240716.001

[15] Zhang X. Logic, Obstacles and Suggestions of Low Altitude Economy Enabling New Quality Productive Forces. Contemporary Economic Management. 2025; 47(01): 17-23. doi: 10.13253/j.cnki.ddjjgl.2025.01.003

[16] Zhang F. An EmpiriStudy on the Impact of China's Monopoly Industries on Inflation: Based on Panel Data Analysis from 2004 to 2013. Economic Mnagement. 2014; 36(09): 1-11. doi: 10.19616/j.cnki.bmj.2014.09.003

[17] Li Z, Wang J. The Dynamic Impact of Digital Economy on Carbon Emission Reduction: Evidence City-level Empirical Data in China. Journal of Cleaner Production. 2022; 351:131570-. doi: 10.1016/j.jclepro.2022.131570

[18] Shen Y. Connotation, Characteristics and Operation Mode of Low-altitude Economy. Journal of Xinjiang Normal University (Philosophy and Social Sciences Edition). 2025; 46(01): 108-117. doi: 10.14100/j.cnki.65-1039/g4.20240708.001

[19] Wu L, Luo X, Cheng S. Coupling and Coordination Analysis of Accessibility Improvement and Tourism Network Attention Change in Scenic Areas and Cities Influenced by High-Speed Rail. IET Intelligent Transport Systems. 2025;19(1):e70077-e70077. doi: 10.1049/ITR2.70077

[20] He J, Luo Y. Regional disparities in industry-university-research collaboration and economic impact in China: a spatial econometric analysis. Applied Economics. 2025; 1-14. doi: 10.1080/00036846.2025.2536739