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Research Article

Evaluation of County Economic Resilience in Henan Province Based on the Entropy Weight-Normal Cloud Model

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As new urbanization constantly develops, the county economy plays a vital role between country and city, and high economic resilience is necessary to support and safeguard for smooth functioning of the county development. The paper constructs the index system of county economic resilience in Henan Province from three dimensions: risk resistance ability, self-stability, and sustainable development ability, and to empirically analyze the economic resilience of 104 counties and cities in the province from 2013 to 2020 using the entropy weight-normal cloud model. The results show that Henan counties' economic resilience increases slowly over time and decreases spatially from the center to the surrounding region, with Zhengzhou as the main center and Luoyang and Sanmenxia as the subcenter; risk resistance ability and self-stabilization are more influential than the sustainable development ability; the key indicators affecting economic resilience are GDP per capita, retail sales of social consumer goods per capita, financial self-sufficiency rate, education expenditure per capita, and population mobility. Therefore, the counties in Henan should find the right positioning to improve economic resilience; central cities such as Zhengzhou and Luoyang should play their strong functions, while strengthening support for peripheral counties.

1. Introduction

Since the rural revitalization strategy was first proposed by President Xi Jinping in the report of the 19th National CPC Congress, a series of policies has been issued to put forward the general requirements, development goals, and visionary plans of the strategy. In 2022, Central Document No. 1 [1] was issued. As the first policy statement issued annually by the Chinese central government, it is regarded as an indicator of policy priorities. The document emphasized the need to vigorously develop county industries to enrich the people and strengthen the construction of county business systems, once again regarding the development of county economy as a crucial step toward rural revitalization. County economy refers to the regional economy with county cities as the center, small towns as the link and the vast rural areas as the hinterland. On the whole, county economy is still an economy with agriculture and rural economy as the mainstay, which determines that the focus of rural revitalization is mainly in the county. From the practice of the economic development, one of the key factors why eastern rural revitalization is at the forefront of the country lies in the good economic development of eastern counties. It can be said that without the development of the county economy, the development of rural economy would be impossible and rural revitalization would lose its material basis. However, with the rapid advancement of urbanization and the accelerated flow of urban and rural population, the instability, uncertainty, and vulnerability of counties and villages have begun to emerge in the face of internal and external impacts. The high-quality economic development in the new era has put forward new requirements for the integration of urban and rural areas, and the stability and sustainability of county economy become particularly important. Rural areas provide resources for the development of the county economy, which is not only beneficial to the stability of its system but also to the transformation and upgrading of the county economy. The resilience of the county economy reflects the sustainability of integrated urban-rural development, and enhancing county economic resilience plays an important role in resisting risks and ensuring comprehensive rural revitalization. In this context, improving economic resilience with the goal of risk management and sustainable development becomes increasingly important for the revitalization and development of counties and villages. Exploring the strengths and weaknesses of county economic resilience and identifying important factors affecting it can help achieve rapid county economic development and provide strong impetus for rural revitalization.

Henan is a typical inland province located in the hinterland of China. Since Premier Wen Jiabao first proposed to promote the rise of the central region in 2004, Henan has responded to the national call to accelerate the economic development, and it has successfully achieved the transformation from a traditional agricultural province to a nationally important economic province, a major emerging industrial province as well as an influential cultural province. Despite the fact that Henan has a large economic volume, with GDP raking 5th in China and a large number of counties and cities, the number of top 100 counties and cities is extremely small, with only 7 counties and cities on the list in the 2021 evaluation, accounting for less than 7%. However, the problem of unbalanced and insufficient economic development of counties is very prominent. Yangsheng Lou, in the Eleventh Party Congress of Henan Province [2], proposed that the whole economy will be vigorous when the county economy is vigorous and the province will be strong when all the counties are strong, which means the high-quality development of counties should be strengthened. Therefore, exploring the economic resilience of Henan counties is conducive to summarizing the development strengths and weaknesses of counties and cities, finding the right positioning, and constantly seeking new development opportunities. At present, most of the domestic studies on regional economic resilience have been conducted focusing on large and medium-sized cities, with little attention paid to county economic resilience. So this paper takes 104 counties and cities in Henan Province as research objects, building an entropy-normal cloud model to explore economic resilience and analyze essential factors that have affected economic resilience. It is hoped that the research content and findings can provide certain theoretical support and policy suggestions for improving economic resilience of counties.

2. Literature Review

The term “resilience” was first introduced into ecological sciences by Holling [3] in the 1970s, and its connotation has developed through three paradigms: engineering resilience [4], ecological resilience [5], and evolution resilience [6, 7]. Scholars have applied the notion of resilience to many fields, such as ecological system, urban infrastructure system, and economic system [8, 9]. Reggiani et al. [10], a foreign scholar, was the first to introduce resilience research into the field of economic research, which extended the manner and paradigm of regional economic research. However, there is no conclusive research on the connotation of economic resilience [11, 12] and its measurement methods [13]. Regarding the study of the connotation of economic resilience, Hassink [14] and Hill et al. [15] saw economic resilience as the ability of a regional economy to maintain or recover to a preexisting state (usually assumed to be equilibrium states) in the presence of external shocks. Martin [16] viewed regional economic resilience as the ability of a regional economic system to respond to and absorb disturbances or shocks while maintaining the stable development of the system or evolving into a new stable developmental posture. Most domestic scholars on the connotation of economic resilience have followed Martin’s theory and innovated on the basis of it. Zeng and Zhang [17] learned from Martin’s theory to define the concept of regional economic resilience as the ability of a system to resist external shocks and perturbations and retain its functions, the ability to return to a balanced and stable state, the ability to reorganize internal structure and function through active adaptation and transformation, as well as the ability to construct new development models and paths by completely changing the original structure. According to Cai et al. [18], economic resilience was an inherent property of the system, which refers to the ability to maintain its stability after a shock, the resilience to return to its original growth dynamics and evolutionary power to transform and develop by relying on its endowment. In general, research on the measurement of regional economic resilience was broadly divided into two approaches: the comprehensive index method and the core variable method. The comprehensive index method refers to constructing a system of indicators to measure economic resilience. For example, Zhang et al. [19] classified economic resilience into resistance and reconfiguration from the perspective of economy, society, environment, and public policy, and constructed an economic resilience indicator system; Ngouhouo and Nchofoung [20] constructed a resilience index based on three dimensions: macrostability, adjusted market efficiency, and governance; Cai et al. [18] constructed an evaluation system of regional economic resilience indicators based on three dimensions: resistance, resilience, and evolutionary power. In terms of the core variable method, most researchers draw on Martin’s sensitivity index method to select or construct indicators, such as GDP per capita [21] and employment rate [22], which may intuitively reflect economic resilience for measurement and evaluation. The two methods have their advantages and disadvantages. The comprehensive index method could reflect different dimensions of economic resilience, but the selection of indicators was subjective; the core variable method could reflect intuitively, but was not comprehensive enough. However, most of the studies focused on regions above prefecture-level cities, and few studied the level of economic resilience of counties in China. Only Qi et al. [23], Duan and Xuan [24], and Yao et al. [25] explored economic resilience of counties in Zhejiang, Jiangsu, and Hunan provinces, respectively. In general, domestic research on economic resilience is not detailed enough, focusing only on large and medium-sized cities, while ignoring the role of counties in the economic growth. The county is an important link between urban and rural areas; it is both an important vehicle for the comprehensive rural revitalization of rural areas and an important pivot point for the high-level integrated development of metropolitan areas and urban agglomerations. The county economy largely affects the level of China's economic development, so focusing on the county economy and studying the economic resilience of counties can help understand their development status and accelerate the urbanization construction with counties as important carriers.

In summary, based on Sun and Sun's [26] interpretation of the notion of economic resilience and combining the features of the county's economic resilience, this paper defines economic resilience as the ability to resist and absorb shocks, the speed and extent of recovery from shocks and the ability to restructure its own construction to adapt to the new external environment after a shock. Therefore, the entropy weight-normal cloud model is used to assess the economic resilience of 104 counties in Henan Province.

3. Construction of Economic Resilience Evaluation Index System

To construct an evaluation index system of economic resilience, it is important to consider both scientific, systematic, practical and data availability, as well as the region's current status and level of development. There is currently no agreed standard for building the index system, and researchers build appropriate index systems based on different research objects. Therefore, based on the research of scholars such as Qi et al. [23] and Duan and Xuan [24] and taking into account the actual situation of Henan counties, where the level of innovation is generally low, this paper divides Henan counties' economic resilience into three criterion layers: risk resistance ability, self-stability, and sustainable development ability, as outlined in Table 1.

(1) Risk resistance ability: it is the ability of the economic system to resist risks, which depends on the strengths and weaknesses of the economic system itself. The better the endowment of the system's own circumstances, the stronger ability it has to resist risks and the greater economic resilience it has. Per capita GDP, per capita disposable income of residents, retail sales of social consumer goods per capita, the growth rate of value added of industry, and urbanization rate are all strong indicators to assess regional economic conditions for a county.

(2) Self-stability: it reflects the ability of the economic system to stabilize itself in the face of risks. The more diversified an economic system is, the more it can disperse risks to keep itself stable. The diversity of economic system is further divided into economic structure diversity and industrial structure diversity. For county-level regions, industrial structure diversity is especially important, not only to develop agriculture but also to develop primary product processing, manufacturing, and new industries. The more diverse the industrial structure, the stronger the ability to resist shocks. In this paper, we adopt the Herfindahl–Hirschman index (HHI) to measure the concentration of three industrial structures according to the study of Zhang et al. [19]. The higher the concentration degree of the industrial structure, the lower the industrial diversity is. It means that the higher the HHI index, the lower the industrial diversity. This index is a negative indicator. The calculation formula is as follows:

$$
\begin{aligned}
HHI &= \sum_{i=1}^{N}\left(\frac{X_i}{X}\right)^2 \\
&= \sum_{i=1}^{N} S_i^2.
\end{aligned}
\tag{1}
$$

In the formula: $N = 3$, X_i refers to the output value of i industrial, X refers to the gross regional product, and S_i refers to the proportion of output value of i industry in regional GDP.

(3) Sustainable development ability: it is the ability to restructure itself in order to adapt to the new external environment after a shock, or the ability of economic systems to evolve itself after a shock. It is similar to the theory of biological evolution, which can constantly maintain and renew beneficial traits. Counties are generally just followers of innovation and do not contribute much to the innovation aspect, and there are few data statistics on innovation indicators in Henan counties. So, in terms of sustainability, innovation indicators are not selected for the time being. The growth rate of investment is selected to reflect the ability of sustained development; the education expenditure per capita reflects the importance of education; the population mobility reflects the economic vitality of the county, and the industry advancement measures the innovation and transformation ability of the county.

4. Research Methodology

4.1. Calculation of the Weights. There are a variety of methods for assigning weights to indicators in the comprehensive index method, such as the entropy weight method, principal component analysis, and the delphi method. In this paper, we choose the entropy weight method to calculate the weight of index, because it is an objective weighting method, by using the magnitude of the information provided by the entropy value of each indicator to determine the weight of the indicator, analyzed purely from quantitative aspects, thereby avoiding the flaws of subjective attribution factors to some extent.

The entropy method is calculated as follows:

Step one: Standardized processing

Table 1: County economic resilience index system and its weights.

Target layers	Criterion layers	Indicator layers	Symbols	Meaning of indicators	Weights
Economic resilience	Risk resistance ability	GDP per capita	A_{11}	Reflects the economic level of the region (+)	0.1758
		Per capita disposable income of residents	A_{12}	Reflects the material living standard of the region (+)	0.0038
		Retail sales of social consumer goods per capita	A_{13}	Reflects the level of regional consumer demand and economic prosperity (+)	0.0994
		Growth rate of value added of industry	A_{14}	Reflects the level of the regional industrial development (+)	0.1243
		Urbanization rate	A_{15}	Reflects the level of urbanization of the region (+)	0.0969
	Self-stability	Financial self-sufficiency rate	A_{21}	Reflects the degree of regional financial self-sufficiency and dependence on central payments (+)	0.209
		Share of tertiary sector in GDP	A_{22}	Reflects the development of the tertiary sector (+)	0.0403
		Industrial Structure HHI	A_{23}	Reflects the level of diversification of regional industrial structure (−)	0.017
		Loans of financial institutions	A_{24}	Reflects corporate borrowing from banks and financial institutions (−)	0.0082
	Sustainable development	Growth rate of investment	A_{31}	Reflects the growth of fixed asset investment (+)	0.0152
		Education expenditure of per capita	A_{32}	Reflects regional educational development (+)	0.0988
		Population mobility	A_{33}	Reflects regional economic vitality (+)	0.0644
		Industry advancement	A_{34}	Percentage of output value of primary industry × 1 + percentage of output value of secondary industry × 2 + percentage of output value of tertiary industry × 3 (+)	0.0467

Data source: 2013–2020 <Statistical Yearbook of Henan province>, <Statistical Yearbook of China counties>, and < county and city statistical bulletins >.

$$\lambda_{ij} = \frac{x_{ij} - x_{\min}}{x_{\max} - x_{\min}} + 0.01,$$
$$\lambda_{ij} = \frac{x_{\max} - x_{ij}}{x_{\max} - x_{\min}} + 0.01, \quad (2)$$

x_{ij} is the value of the index j of the county i, $x_{\min}$ is the minimum value of the index j of 104 counties, $x_{\max}$ is the maximum value of index j of 104 counties, and λ_{ij} is the value of the standardized index. To ensure that the entropy value calculation is meaningful for digitization, 0.01 is added in the data normalization stage. However, if an index is positive, the front formula is chosen and else for the after formula.

Step two: Calculating the contribution of the object:

$$R_{ij} = \frac{\lambda_{ij}}{\sum_{i=1}^{104} \lambda_{ij}}. \quad (3)$$

Step three: Calculating the entropy values of indexes:

$$e_j = -\frac{1}{\ln 104} \sum_{j=1}^{104} R_{ij} \ln R_{ij}. \quad (4)$$

Step four: Calculating the weight of indexes:

$$\omega_j = \frac{(1 - e_j)}{\sum_{j=1}^{n} (1 - e_j)}. \quad (5)$$

4.2. Cloud Model. Li et al. [27], a member of the Chinese Academy of Engineering, proposed the concept of the cloud model in 1995; it was used to realize qualitative and quantitative transformation of uncertainty concepts and solve ambiguity and randomness problems. Cloud models have broad universal applicability and had been widely used in data mining [28], decision analysis [29], and system assessment (such as urban security resilience assessment [30], evaluation of water resources sustainability [31], and ecological environment security evaluation [32]).

Cloud Model Definition: It is supposed that U be a quantitative domain of values, C is the qualitative concept of the domain of argument, x is the quantitative value, $x \in U$, and x is a random realization of C, μ is degree of membership of x to C, $\mu: U \longrightarrow [0,1]$, $\forall x \in U$, $x \longrightarrow \mu(x), \mu(x) \in [0,1]$, then x on domain U distribution is called the cloud, each x is called a cloud droplet. A large number of cloud drops form a cloud, and there is no temporal relationship between cloud drops; if it has significant probability to appear cloud drops, the degree of certainty is large, and has significant contribution to the concept.

4.3. Establishment of the Evaluation Model

Step one: The entropy weight method is used to calculate the weight of each indicator and get the weight matrix $\omega = \{\omega_1, \omega_2, \ldots, \omega_j\}$.

Step two: first of all, we divide minimum and maximum value of each level about economic resilience and calculate the three cloud characteristic values (Ex, En, He) of each evaluation index according to its corresponding level. The three eigenvalue parameters (Ex, En, He) of each level of the evaluation index are determined by the upper and lower boundary values of each evaluation index corresponding to its level, which can be found by the corresponding eigenvalue parameter value formula. With the data x_{ij}, where i refers to the evaluation index, j refers to the evaluation level corresponding to data x. There are data x_{ij} with upper and lower boundary values of x_{ij}^1 and x_{ij}^2; the qualitative concept of indicator i in data x_{ij} corresponding to its rank j can be represented by a cloud model, which is able to obtain a $i \times j$ cloud model.

Since the central value of each rank is the most typical sample of the qualitative concept, so the expected value is expressed as follows: $Ex_{ij} = (x_{ij}^1 + x_{ij}^2)/2$; x_{ij} as the boundary of each level, which belongs to both the upper and lower levels, so the affiliation of this boundary value to the upper and lower classes is equal, and thus: $\exp(-(x_{ij}^1 - x_{ij}^2)^2/(8(En_{ij})^2)) \approx o.5$; the final entropy values are obtained: $En_{ij} = |x_{ij}^1 - x_{ij}^2|/2.355$.

Step three: according to the three digital characteristic parameters for each level and actual evaluation index data, and using the X-conditioned cloud generator algorithm, we obtain the affiliation degree of each index corresponding to each rank, the obtained affiliation of each indicator is used to form an affiliation matrix $U = [\mu_{ij}]_m$; among them, i refers to evaluation indicators, j refers to the evaluation level, and m refers to the evaluation object. Then, the affiliation of the actual index data belonging to each level of the cloud: $\mu_0 = \exp[-(x_0 - Ex)^2/2(Enn)^2]$, where Enn is a normal random distribution with En as the expectation, and He as the standard deviation in the equation, the specific formula is $Enn = \mathrm{rand}n(1) * He + En$.

Step four: Fuzzy transformation of the obtained weight vector and the affiliation matrix of each evaluation object is $R = \omega * U$; among them, $R = \{r_1, r_2, \ldots, r_k\}$, let r_i denote the degree that the evaluation object i belongs to each level, and according to the principle of maximum affiliation, the level of the object to be evaluated can be obtained, as shown in the Figure 1.

5. Empirical Analysis

5.1. Normal Cloud Model Interval Determination. Our data were derived from the Henan Statistical Yearbook for 2013–2020, the Statistical Yearbook of China Counties, as well as county and city statistical bulletins; 104 counties and cities are selected at the county level of Henan Province as study area, taking into account the policy of removing counties and designating them as urban areas in Henan Province; it is based on the administrative plan of 2020 to exclude the data of removing counties and designating them as urban areas between 2013 and 2020. Some of the detailed

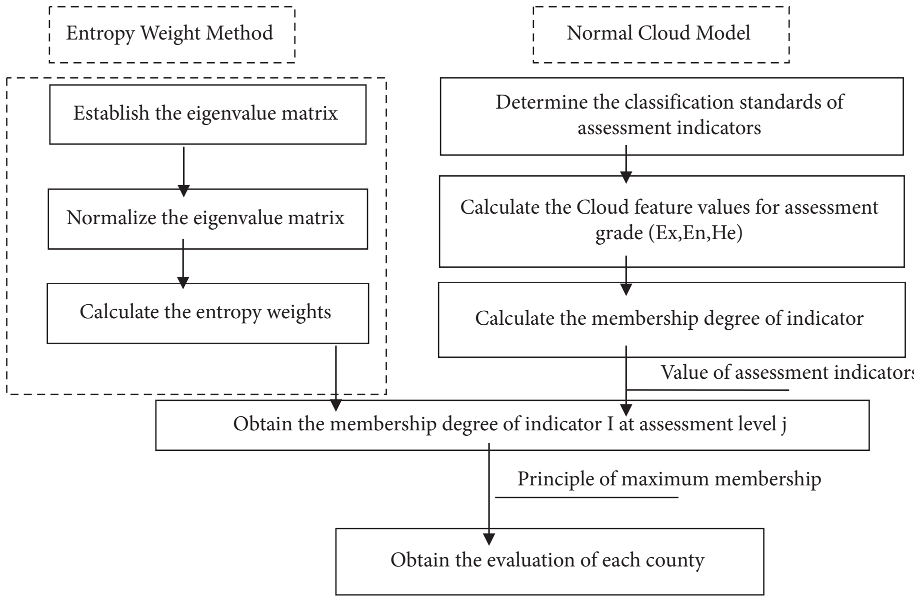

Figure 1: The flow diagram of the entropy weight-cloud mode.

underlying data are subject to preliminary statistical, computational, and other related processing in this article to aid in the empirical analysis.

In the study of regional economic resilience, county is a relatively small study area. Given the current situation of its low level of development and low capacity of innovation, in this article, with reference to the normal cloud model and related literature on economic resilience assessment, and taking into account the actual situation of county economic development, the level of county economic resilience is classified into four levels I, II, III, and IV, which indicate strongest, stronger, medium, and low county economic resilience, respectively. The classification standards are shown in Table 2.

5.2. Numerical Characteristics of Normal Cloud. The maximum and minimum values are the extremes of the mathematical calculation and best reflect the evaluation level, which should be at the location of the densest cloud drops with the largest affiliation; therefore, for positive indicators, the maximum value is taken as Ex of level I and the minimum value is taken as Ex of level IV, while the opposite is true for negative indicators. Applying the formula to calculate the mathematical expectation Ex and entropy En of the index at each level, He is a constant number; when $He = 0$, the cloud droplets are strictly Gaussian distributed, clouds will fog up when He is too large and the consensus will be reduced; in this paper, we finally determine the value of $He = 0.001$ by experiment, and get three numerical features (Ex, En, He) to construct the normal cloud model. The numerical characteristics of the cloud model are shown in Table 3

5.3. Classification of Economic Resilience Levels. The numerical features (Ex, En, He) calculated from the original index data are used as parameters, using the X-conditional cloud generator in the cloud mode to calculate the affiliation degree of each index corresponding to each rank in each sample city, and construct the affiliation matrix; this algorithm is based on python + pandas implementation. Subsequently, the weight ω vector, which has been calculated using the entropy weight method, is fuzzed with the affiliation matrix U_{ij}; in order to avoid randomness, the number of cloud drops is set to 1,000 in this paper, and the final affiliation degree is taken as its average to get the affiliation degree of each city corresponding to the four evaluation levels; according to the maximum membership degree principle, the rank corresponding to the maximum value of affiliation is the evaluation rank of each city. The distribution statistics of the resilience level of each county from 2013 to 2018 are shown in Table 4. Due to the large sample size of counties for space reasons, the annual resilience level of each county is not shown in detail, and this paper only shows the counties with economic resilience level in I and IV.

5.3.1. Analysis of Time Series. In terms of time series, the level of economic resilience for all counties in Henan Province is slowly increasing from 2013 to 2020. The percentage of counties with medium resilience and above is increased from 47% in 2013 to 94% in 2020, and the percentage of counties with stronger resilience and above is increased from 1.9% in 2013 to 12.5% in 2020. The economic resilience level of counties in Henan Province in 2020 is mostly distributed in stronger and medium levels, and the areas of low resilience decreased from 55 in 2013 to 6 in 2020. Lushan county, Taiqian county, and Shangcai county are always at the low economic resilience level from 2013 to 2020. Taiqian county and Shangcai county are located at the edge of the Henan Province in terms of the geographical location. From Table 4, it can be seen that the economic resilience of Yima is different from others, falling first and then rising, as it is a typical resource-based city that once

Table 2: Classification of indexes for Henan county economic resilience.

Indicators	I	II	III	IV
A_{11}	[12.72, 9.84]	(9.84, 6.96]	(6.96,4.08]	(4.08,1.20]
A_{12}	[27, −0.19]	(-0.19, −27.39]	(-27.39, −54.58]	(-54.58, −81.77]
A_{13}	[3.20, 2.60]	(2.60, 2.00]	(2.00, 1.40]	(1.40, 0.80]
A_{14}	[4.74, 3.65]	(3.65, 2.55]	(2.55, 1.46]	(1.46, 0.36]
A_{15}	[97.00, 78.50]	(78.50, 60.00]	(60.00, 41.50]	(41.50, 23.00]
A_{21}	[89.75, 69.66]	(69.66, 49.58]	(49.58, 29.50]	(29.50, 9.42]
A_{22}	[60.75, 47.64]	(47.64, 34.54]	(34.54, 21.43]	(21.43, 8.33]
A_{23}	[0.33, 0.44]	(0.44, 0.55]	(0.55, 0.65]	(0.65, 0.76]
A_{24}	[20.22, 197.92]	(197.92, 375.62]	(375.62, 553.32]	(553.32, 731.02]
A_{31}	[207.98, 141.96]	(141.96, 75.94]	(75.94, 9.92]	(9.92, −56.10]
A_{32}	[2,541.25, 2,027.88]	(2,027.88, 1,514.51]	(1,514.51, 1,001.14]	(1,001.14, 487.76]
A_{33}	[1.69, 1.41]	(1.41,1.13]	(1.13, 0.85]	(0.85, 0.57]
A_{34}	[2.48, 2.32]	(2.32, 2.16]	(2.16, 2.00]	(2.00, 1.84]

Table 3: Numerical characteristics of a normal cloud model of county economic resilience in Henan.

Indicators	I	II	III	IV
A_{11}	(12.72, 1.83, 0.001)	(8.40, 1.83, 0.001)	(5.52, 1.83, 0.001)	(1.20, 1.83, 0.001)
A_{12}	(27.00, 17.32, 0.001)	(-13.79, 17.32, 0.001)	(-40.99, 17.32, 0.001)	(−81.77, 17.32, 0.001)
A_{13}	(3.20, 0.38, 0.001)	(2.30, 0.38, 0.001)	(1.70, 0.38, 0.001)	(0.80, 0.38, 0.001)
A_{14}	(4.74, 0.70, 0.001)	(3.10, 0.70, 0.001)	(2.00, 0.70, 0.001)	(0.36, 0.70, 0.001)
A_{15}	(97.00, 11.78, 0.001)	(69.25, 11.78, 0.001)	(50.75, 11.78, 0.001)	(23.00, 11.78, 0.001)
A_{21}	(89.75, 12.79, 0.001)	(59.62, 12.79, 0.001)	(39.54, 12.79, 0.001)	(9.42, 12.79, 0.001)
A_{22}	(60.75, 8.35, 0.001)	(41.09, 8.35, 0.001)	(27.99, 8.35, 0.001)	(8.33, 8.35, 0.001)
A_{23}	(0.33, 0.07, 0.001)	(0.50, 0.07, 0.001)	(0.60, 0.07, 0.001)	(0.76, 0.07, 0.001)
A_{24}	(20.22, 113.19, 0.001)	(286.77, 113.19, 0.001)	(464.47, 113.19, 0.001)	(731.02, 113.19, 0.001)
A_{31}	(207.98, 42.05, 0.001)	(108.95, 42.05, 0.001)	(42.93, 42.05, 0.001)	(-56.10, 42.05, 0.001)
A_{32}	(2541.25, 326.99, 0.001)	(1771.20, 326.99, 0.001)	1257.83, (326.99, 0.001)	(487.76, 326.99, 0.001)
A_{33}	(1.69, 0.18, 0.001)	(1.27, 0.18, 0.001)	(0.99, 0.18, 0.001)	(0.57, 0.18, 0.001)
A_{34}	(2.48, 0.1, 0.001)	(2.24, 0.1, 0.001)	(2.08, 0.1, 0.001)	(1.84, 0.1, 0.001)

Table 4: 2013–2020 Henan county economic resilience rating.

Years	*Quantity*				*County*	
	I	II	III	IV	I	IV
2013	1	1	47	55	Yima city	Qi county, Tongxu county, Ye county, Lushan county, Jia county, Hua county, Neihuang county, Xun county, Huojia county, Yuanyang county, Yanjin county, Fengqiu county, Qingfeng county, Nanle county, Fan county, Taiqian county, Puyang county, Wuyang county, Lushi county, Nanzhao county, Fangcheng county, Zhenping county, Neixiang county, Sheqi county, Tanghe county, Dengzhou city, Minquan county, Sui county, Ningling county, Zhecheng county, Yucheng county, Xiayi county, Luoshan county, Guangshan County,Shangcheng county, Gushi county, Huangchuan county, Huaibin county, Xi county, Fugou county, Xihua county, Shangshui county, Shenqiu county, Dancheng county, Taikang county, Luyi county, Xiangcheng city, Xiping county, Shangcai county, Pingyu county, Zhengyang county, Queshan county, Biyang county, Runan county, and Xincai county
2014	1	3	58	42	Yima city	Qi county, Song county, Ye county, Lushan county, Hua county, Neihuang county, Xun county, Yuanyang county, Fengqiu county, Qingfeng county, Nanle county, Fan county, Taiqian county, Fangcheng county, Sheqi county, Tanghe county, Dengzhou city, Minquan county, Sui county, Ningling county, Zhecheng county, Yucheng county, Xiayi county, Luoshan county, Guangshan county, Shangcheng county, Gushi county, Huaibin county, Xi county, Fugou county, Xihua county, Shangshui county, Shenqiu county, Dancheng county, Taikang county, Xiping county, Shangcai county, Pingyu county, Zhengyang county, Biyang county, Runan county, and Xincai county

Table 4: Continued.

Years	Quantity				County	
	I	II	III	IV	I	IV
2015		9	57	38		Ye county, Lushan county, Hua county, Neihuang county, Xun county, Yuanyang county, Fengqiu county, Qingfeng county, Nanle county, Fan county, Taiqhan county, Fangcheng county, Sheqi county, Tanghe county, Dengzhou city, Minquan county, Sui county, Ningling county, Zhecheng county, Yucheng county, Xiayi county, Guangshan county, Shangcheng county, Gushi county, Huaibin county, Xi county, Fugou county, Xihua county, Shangshui county, Dancheng county, Taikang county, Xiping county, Shangcai county, Pingyu county, Zhengyang county, Biyang county, Runan county, and Xincai county
2016		12	68	24		Ye county, Lushan county, Hua county, Neihuang county, Xun county, Yuanyang county, Fengqiu county, Taiqian county, Tanghe county, Minquan county, Sui county, Ningling county, Zhecheng county, Yucheng county, Xiayi county, Huaibin county, Xi county, Xihua county, Shangshui county, Dancheng county, Taikang county, Shangcai county, Zhengyang county, and Xincai county
2017		13	74	17		Ye county, Lushan county, Hua county, Yuanyang county, Fengqiu county, Taiqian county, Sui county, Ningling county, Zhecheng county, Xiayi county, Huaibin county, Xi county, Shangshui county, Taikang county, Shangcai county, Zhengyang county, and Xincai county
2018		12	81	11		Ye county, Lushan county, Hua county, Fengqiu county, Taiqian county, Ningling county, Xiayi county, Xi county, Shangshui county, Shangcai county, and Xincai county
2019	1	12	87	4	Yima city	Lushan county, Anyang county, Taiqian county, and Shangcai county
2020		13	85	6		Lushan county, Anyang county, Neihuang county, Taiqian county, Xi county, and Shangcai county

relied on coal resources for the rapid development. Yet the depletion of coal resources makes Yima always seek other development opportunities.

5.3.2. Analysis of Spatial Distribution. In general, as shown in Figure 2, the level of economic resilience of Henan counties shows a decreasing distribution from the center to the surrounding area, and the economic resilience level of the central counties is higher than that of the surrounding area. For ease of spatial analysis, we divide Henan into Central Henan, East Henan, West Henan, South Henan, and North Henan based on the geographic location (as illustrated in Table 5). As of 2020, counties in Central Henan with stronger economic resilience and above account for 50% of the region and 50% have medium resilience level. The spatial distribution is uneven; the surrounding counties centered on Zhengzhou, the provincial capital, are generally higher than the counties in the other areas of Central Henan. The counties in East Henan of medium economic resilience account for 100%, and the level of resilience of the counties generally increases by only one grade from 2013 to 2020, with slow development. The counties in South Henan are all in the medium resilience level except Xixian and Shangcai counties, and the distribution and development rate are similar to those in East Henan, with the problem of slow development rate. In North Henan, the counties with medium and stronger economic resilience accounted for 88.5%, and only Mengzhou City achieved a stronger level of economic resilience. West Henan has 31.6% counties with stronger resilience and 63.2% with medium resilience. It can be seen from the analysis that most of the areas with economic resilience at the stronger level and above are located in Central and West Henan, such as Zhongmou, Gongyi, Xingyang, Xinmi, Xinzheng, and other cities around Zhengzhou, which have higher economic resilience levels than other areas. Then, some counties in Luoyang and Sanmenxia areas of West Henan have economic resilience at stronger level and above, such as Mengjin, Xin'an, Luanchuan, Mianchi, and Yima. Most of the other areas are at the medium resilience level and the development rate is much slower.

5.3.3. Analysis of Influencing Factors. In order to further analyze which indicators of economic resilience have a more significant impact, in this paper, we conduct a detailed comparative analysis indicator of county economic resilience and find that factors that play an important role in economic resilience are basically stable across years. This paper has a large sample size, and only four counties in East, West, South, North, and Central Henan are randomly selected to show the statistical results in 2020. Each level of the resilience is assigned a corresponding score (as in Table 6) for the sake of comparison, and an arithmetic weighted average method is used to calculate the criterion level score and the composite score for each respondent, and then, ranked according to the scores, the formula for calculation is as follows:

$$T_m = \sum_{i=1}^{p} z_k r'_{jk}, \tag{6}$$

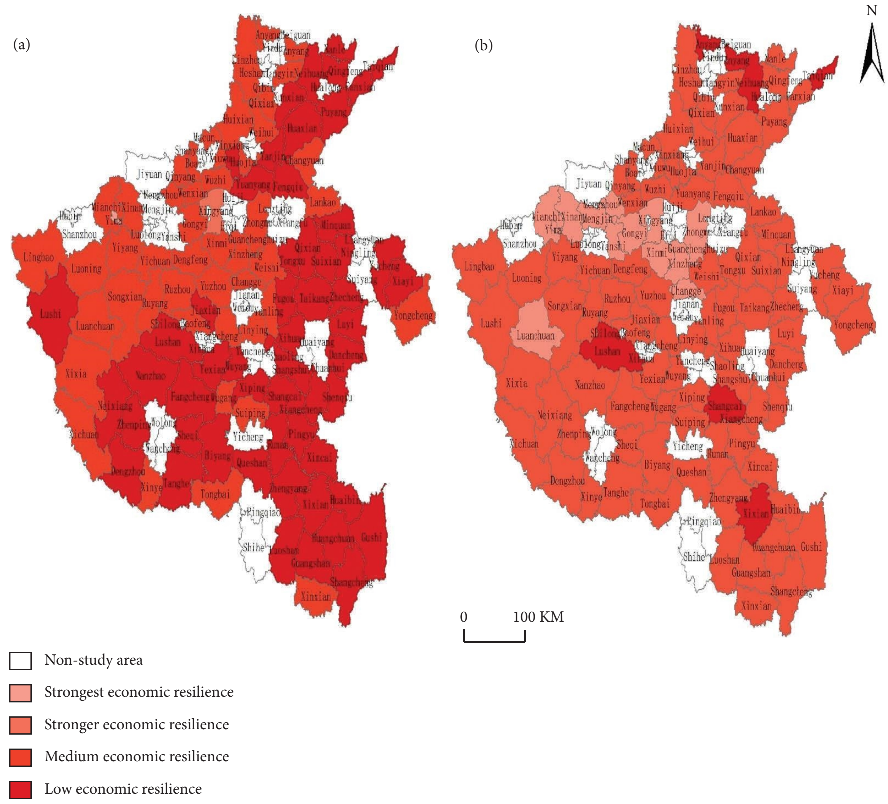

Figure 2: Spatial distribution of county economic resilience in Henan Province. (a) 2013. (b) 2020.

Table 5: Counties included in the five major regions.

	The county areas included
Eastern Henan	Qi county, Tongxu county, Weishi county, Lankao county, Minquan county, Sui county, Ningling county, Zhecheng county, Yucheng county, Xiayi county, Yongcheng city, Fugou county, Xihua county, Shangshui county, Shenqiu county, Dancheng county, Taikang county, Luyi county, and Xiangcheng city
Western Henan	Mengjin county, Xin'an county, Luanchuan county, Song county, Ruyang county, Yiyang county, Luoning county, Yichuan county, Yanshi city, Mianchi county, Lushi county, Yima city, Lingbao city, BaoFeng county, Ye county, Lushan county, Jia county, Wugang city, and Ruzhou city
Southern Henan	Nanzhao county, Fangcheng county, Xixia county, Zhenping county, Neixiang county, Xichuan county, Sheqi county, Tanghe county, XinYe county, Tongbai county, Dengzhou city, Xiping county, Shangcai county, Pingyu county, Zhengyang county, Queshan county, Biyang county, Runan county, Suiping county, Xincai county, Luoshan county, Guangshan county, Xin county, Shangcheng county, Gushi county, Huangchuan county, Huaibin county, and Xi county
Northern Henan	Anyang county, Tangyin county, Hua county, Neihuang county, Linzhou city, Xinxiang county, Huojia county, Yuanyang county, Yanjin county, Fengqiu county, Changyuan city, Weihui city, Huixian city, Xiuwu county, Boai county, Wuzhi county, Wen county, Qinyang city, Mengzhou city, Qingfeng county, Nanle county, Fan county, Taiqian county, Puyang county, Xun county, and Qi county
Central Henan	Zhongmou county, Gongyi city, Xingyang city, Xinmi city, Xinzheng city, Dengfeng city, Yanling county, Xiangcheng county, Yuzhou city, Changge city, Wuyang county, and Linying county

Table 6: Economic resilience evaluation level assignment score.

Level	I	II	III	IV
Score	100	85	75	60

Table 7: Ranking of some counties and their guideline tiers.

County	Ranking	*Risk resistance ability* Index (≥II)	Index (=IV)	Ranking	*Self-stability* Index (≥II)	Index (=IV)	Ranking	*Sustainable development* Index (≥II)	Index (=IV)	Ranking
Zhongou county	3	A_{11}, A_{12}, A_{13}, A_{15}		3	A_{21}, A_{22}, A_{23}		2	A_{33}, A_{34}		2
Gongyi city	2	A_{11}, A_{12}, A_{13}, A_{14}, A_{15}		2	A_{21}, A_{22}, A_{23}, A_{24}		3	A_{32}, A_{34}		4
Tong Xu county	10	A_{12},		9	A_{22}, A_{23}, A_{24}		10	A_{34}		20
Mengjin county	5	A_{11}, A_{12}, A_{13}		5	A_{21}, A_{22}, A_{23}, A_{24}		5	A_{32}, A_{34}		6
Luoning county	7	A_{12}		7	A_{22}, A_{23}, A_{24}		6	A_{32}, A_{34}	A_{33}	5
Lushan county	19	A_{12}	A_{11}, A_{14}, A_{15}	20	A_{22}, A_{23}, A_{24}	A_{21}	16	A_{34}		11
Anyang county	20	A_{12}, A_{13}	A_{11}, A_{14}	19	A_{22}, A_{23}, A_{24}	A_{21}	13	A_{34}	A_{32}	19
Xun county	14	A_{12}, A_{13}		10	A_{22}, A_{23}, A_{24}	A_{21}	17	A_{34}		18
Weihui city	9	A_{12}, A_{13}	A_{14}	15	A_{22}, A_{23}, A_{24}		7	A_{34}		10
Qinyang city	4	A_{13}, A_{15}		4	A_{21}, A_{22}, A_{23}, A_{24}		4	A_{34}		7
Wuyang county	8	A_{12}		8	A_{22}, A_{23}, A_{24}		9	A_{34}	A_{33}	12
Linying county	6	A_{12}, A_{13}		6	A_{22}, A_{23}, A_{24}		8	A_{32}, A_{34}		9
Yima city	1	A_{11}, A_{12}, A_{13}, A_{14}, A_{15}		1	A_{21}, A_{22}, A_{23}, A_{24}		1	A_{32}, A_{34}		1
Nanzhao county	13	A_{12}	A_{11}	14	A_{22}, A_{23}, A_{24}	A_{21}	19	A_{32}, A_{34}		8
Dengzhou city	11	A_{12}, A_{13}		11	A_{22}, A_{23}, A_{24}	A_{21}	12	A_{34}	A_{31}, A_{33}	13
Minquan county	15			16	A_{22}, A_{23}, A_{24}	A_{21}	11	A_{34}	A_{33}	16
Sui county	18	A_{12}	A_{11}	17	A_{22}, A_{23}, A_{24}	A_{21}	15		A_{33}	17
Xi county	12	A_{12}		13	A_{22}, A_{23}, A_{24}	A_{21}	20	A_{32}, A_{34}	A_{33}	3
Taikang county	16	A_{12}		12	A_{22}, A_{23}, A_{24}	A_{21}	18	A_{34}	A_{33}	15
Runan county	17	A_{12}	A_{14}, A_{15}	18	A_{22}, A_{23}, A_{24}	A_{21}	14		A_{33}	14

where r_{jk}' is the arithmetic mean of the affiliation of each criterion layer, $p = 4$:

$$Q = \sum_{i=1}^{p} z_k d_k, \tag{7}$$

where d_k refers to the arithmetic mean of the affiliation of each county.

(1) Analysis of Risk Resistance Ability. As shown in Table 7, the overall rankings of county economic resilience and risk resilience ability are in good degrees of agreement, and the weight ratio of risk resistance ability is 0.5, so it can be concluded that the risk resistance ability has a greater impact on economic resilience. In terms of resilience indicators, those lower-ranking counties generally have low GDP per capita, and some counties might be affected by the combination of retail sales of social consumer goods per capita and GDP per capita, such as Lushan county and Runan county. Combined with Table 1, it can be seen that GDP per capita and retail sales of social consumer goods per capita are essential factors affecting risk resilience.

(2) Analysis of Self-Stability. From Table 7, the ranking of self-stability and economic resilience generally match. But some counties have a pretty big gap between the comprehensive ranking and the self-stability ranking. For example, Xixian county has a self-stability ranking of 20 and a comprehensive ranking of 10, which indicates that indicators of self-stability do not have a very big impact on economic resilience. As for the indicators within the criterion layer, the financial self-sufficiency rate has a quite significant impact on the strength of self-stability; almost all the counties with low comprehensive rankings have low level of financial self-sufficiency rate. Its weight ratio is 0.21, which also confirms that it is an important factor affecting self-stability.

(3) Analysis of Sustainable Development Ability. Combined with Tables 1 and 7, sustainable development ability has the least impact on economic resilience, and its ranking coincides poorly with the comprehensive ranking. The difference in the impact degree of each resilience indicator is not noticeable enough. The main reason why sustainable development ability has little impact on economic resilience is that counties are not strong in innovation, and their science and technology innovation systems have not been established, which has been plaguing the sustainable development of county economies. The science and technology innovation in the counties is mainly constrained by four bottleneck factors. First, they have insufficient research and development costs, small and ineffective financial support. Second, there are no effective industry-university-research innovation entities. Third, they have weak science and technology platforms and few scientific and technological achievements. Fourth, insufficient investment, lack of talent, and weak platform make contribution of science and technology bound to be low.

6. Conclusions and Recommendations

The research objects used in this paper are data from 104 counties and cities in Henan Province from 2013 to 2020. The county economic resilience system is constructed and the entropy weight-normal cloud model is used to make a comprehensive measure of the level of economic resilience, and results of the research are as follows: (1) The level of economic resilience of Henan counties is slowly increasing over time, evolving from 53% of counties in low economic resilience level in 2013 to more than 94% of counties in medium economic resilience level and above in 2020. (2) The economic resilience level of Henan counties shows a decreasing distribution from the center to the surrounding area, and the counties in the center are more resilient than the surrounding regions. The counties in the outer circle of the metropolitan area centered on Zhengzhou are rapidly developing, such as Xinzheng, Zhongmou, Gongyi, and other cities, and Luoyang, as the second center city of the Central Plains City Cluster, is developing coordinately with Sanmenxia, which has also driven the development of several nearby counties and cities. In comparison, the more peripheral cities are developing slowly, mostly at medium resilience levels, and even some counties and cities are at low resilience levels, such as Taiqian County and Shangcai County. (3) The economic resilience of Henan counties is influenced more by risk resilience and self-stability than by sustainable development ability. The leading indicators affecting economic resilience are GDP per capita, retail sales of social consumer goods per capita, and fiscal self-sufficiency rate. (4) The sustainable development ability of counties has the least impact on economic resilience. The weak innovation ability and lack of scientific and technological innovation system restrict the sustainable development of the county economy.

In order to improve the economic resilience of Henan counties, this paper makes the following recommendations: (1) According to the distribution of the level of economic resilience, it is important for each county to clarify its current situation, find the correct position for the actual situation, and continually make efforts to increase the regional economic resilience. Thus, East Henan region should seize the policy proposed at Eleventh Party Congress that Shangqiu and Zhoukou should be supported to construct the East Henan industrial transfer demonstration area, not only to undertake the industry but also to promote the industry to take root, and continue to develop and grow. (2) Strengthen the construction of Zhengzhou, Luoyang, and other central cities. From a chronological point of view, Zhengzhou, Luoyang, and other central cities have strong agglomeration, fission, radiation, and driving ability, and should enhance their factor agglomeration, scientific and technological innovation, and service functions in order to continuously inject vitality into the development of the surrounding counties. (3) The support for the development of the peripheral counties of Henan should be strengthened. In order to diversify the industrial composition and levels of county economic structure, it is desirable to increase the degree of primary product processing, the development of manufacturing industries, and the establishment of new industries based on the actual conditions and market needs of the counties. Counties should take into account local conditions to avoid shortcomings and accelerate the adjustment and optimization of the county's economic structure. Products should be developed which meet the county's conditions and the market demand. Advantageous industries should be cultivated, and special economic features should be formed. Ultimately, each county should have an industry and each town a product, and then, related industries can be developed. Thus, the overall competitiveness of the county economy can be enhanced. (4) The county's sustainable economic development of science and technology innovation capacity should be enhanced. First, the financial support for research and development costs should be increased to cover the research and development activities and personnel costs. Effective support should be given to the market to develop its huge potential in order to reflect the county's special economic research projects and enhance the effectiveness of financial support. Second, an effective "industry-university-research" science and technology consortium should be formed. The county's existing scientific and technological achievements should be transformed into products that meet the market demand, and then, the profits brought back can be used to scientific research again so that products of higher technology and better market adaptability can be developed. Finally, a science and technology platform should be created as a base to improve the level of scientific research. Then, technological crossover and integration can be promoted, and the training of innovative personnel should be strengthened in order to break the situation of few scientific and technological achievements.

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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