Hindawi
Mobile Information Systems
Volume 2022, Article ID 6230817, 13 pages
https://doi.org/10.1155/2022/6230817

Research Article

Convergence Spatial Measurement of Economic Growth Based on Big Data

Jianglei Jin,[1,2,3] Haowen Yan ,[1,2,3] and Qianqian Zhao[4,5]

[1]*Faculty of Geomatics, Lanzhou Jiaotong University, Lanzhou 730070, Gansu, China*
[2]*Gansu Provincial Engineering Laboratory for National Geographic State Monitoring, Lanzhou 730070, Gansu, China*
[3]*National-local Joint Engineering Research Center of Technologies and Applications for National Geographic State Monitoring, Lanzhou 730070, Gansu, China*
[4]*School of Economics, Lanzhou University, Lanzhou 730000, Gansu, China*
[5]*Party School of Gansu Provincial Party Committee of the CPC (Gansu Institute of Public Administration), Lanzhou 730000, Gansu, China*

Correspondence should be addressed to Haowen Yan; yanhw@lzjtu.edu.cn

Received 25 April 2022; Revised 16 May 2022; Accepted 21 July 2022; Published 7 September 2022

Academic Editor: Mian Ahmad Jan

Economic growth has always been one of the hottest topics in economic research. Behind the rapid economic growth, the economic gap between regions is gradually widening, and the internal gap will have an impact on the overall coordination of economic growth. Research on the convergence of economic development and its causes has great strategic significance for narrowing the differences in raising economy among regions. In recent years, the impact of big data on economic analysis has become more and more obvious, and this fact has attracted the attention of the academic community. Big data are a new strategic resource and a tool for assessing economic trends. Adding big data technology to the research on the convergence raise of economics can predict the law of data changes, reduce data errors, optimize research results, and provide a more scientific basis for the coordinated development of regional economies. Based on big data theory and technology, this paper uses a spatial econometric model to empirically analyze the convergence of regional economic growth and its influencing factors. The experimental results show that the research on the convergence mechanism and spatial relationship of economic growth in the context of big data can improve the accuracy of the convergence analysis of economic growth to a certain extent. Through modeling analysis, the accuracy of economic convergence is improved by 4.1%. The utilization of big data in a trend of economic development makes the analysis results more reasonable and has greater reference value.

1. Introduction

At the same time as rapid economic growth, and the economic development of various regions also show the obvious difference. In theory, the study of the convergence of economic growth can provide practical knowledge of economic development theory and development economics, helping to identify differences between economies. From the actual point of view, it is of great significance to implement practical and effective macroeconomic development policies, recognize the current situation of regional economic inequality, and find out the main reasons for the inequality problems in the region. Big data allow the collection, integration, classification, and processing of information on factors such as GDP, price levels, employment rates, household income, money, and the amount of credit. It can then provide strategic and economic means on the basis of certain development and regulation, which is of great significance to the study of economic convergence problems.

Recently, technology has been improving, making the application of big data technology more and more widespread. A number of scientists have researched and analyzed big data technology and obtained good results. Zhang analyzed the concept and value orientation of the college education quality management system from the aspects of the establishment of a quality management system and the

improvement of the service process, and constructed a college education quality management system based on big data. Finally, a systematic study is carried out on the evaluation of the quality management system of college education, which provides a certain reference for the development of college education [1]. Ni et al. used big data technology to carry out process optimization using case-based reasoning (CBR) approach. The results show that optimization results with different optimization objectives can be obtained using the CBR method and the solution time is less than 1 second [2]. The Pingping team proposed an employee incentive management model based on the background of big data [3]. Wang et al. proposed a new grid fault tracing method based on a big data platform [4]. Du and Zhao propose a mathematics web-based teaching technology, that is, based on the fusion of big data to build a teaching model that enables the adaptive allocation and integration of teaching resources [5]. Guo et al.'s team designed an EME portrait model based on big data. Studies have shown that portrait models are not only convenient for storage and retrieval, but also for transmission and expansion [6]. Yan and Wang propose an intelligent command system for road traffic through big data mining, which offers great practical value in addressing the complexity of transport systems [7]. The analysis of big data in these studies is more specific but does not involve the convergence of economic growth.

The convergence of economic growth is an important part of regional economic development. The analysis and research on the convergence of economic growth being beneficial to the healthy development of the regional economy. Many teams have joined this research. Song et al. studied the "club convergence" of economic growth and used a dynamic panel threshold model to derive the nonlinear relationship between financial development and economic growth. The results show that the probability of convergence increases greatly. When the level is higher than the higher threshold, the positive effect of the level on the steady-state relative output will gradually weaken, and the marginal utility will decrease significantly [8]. Chakraborty calculated that public capital expenditure is positively related to economic growth through fiscal asymmetry based on the GMM model [9]. The Mei team modeled the variability of GDP per capita in each emerging and developing region, and then developed a combined energy efficiency and GDP per capita model. The study found that the growth of local per capita GDP reflects the trend of economic convergence, and the convergence degree of energy consumption is slightly lower than that of per capita GDP [10]. Ibrahim et al. performed regression analysis on regional economic growth convergence using a panel of fixed effects models (REM). The estimation results show that the analysis and management of the convergence of economic growth are beneficial to the rapid growth of the regional economy [11]. Godowsky applied descriptive statistics and multiple regression methods to study economic growth and business environment in EU countries in the context of economic convergence processes. Experiments show that the changes and upward trend of the entire EU business environment are gradually approaching the development of member economies [12]. The research on the convergence of economic growth has an important impact on regional economic development, but the traditional research methods can no longer meet the specific analysis requirements of economic convergence.

The economic convergence index is used to construct a spatial weight table, and domain and regional factors are introduced into the economic growth convergence model. The real per capita GDP is used as the benchmark for measuring economic growth, and the per capita income and expenditure share are used as the benchmark for economic integration analysis. Through big data technology, the model of economic growth convergence mechanism and spatial correlation is constructed, and finally, the simulation model is concluded to improve the accuracy of economic growth convergence analysis to a certain extent. This also shows the convergence of economic growth makes the analysis results more accurate and reasonable and has greater reference value.

2. Statistical Analysis Based on Big Data

2.1. Big Data Technology. The network big data can be automatically recorded when the event occurs, and the investigation and collection of the data can be extracted directly through engineering methods [13]. Figure 1 is a diagram of a big data statistical model. It includes parallel processing techniques, database sharing, storage and programming, data mining, and cloud computing.

2.2. Statistical Analysis Framework of Big Data. Statistics is an important part of data processing. Due to the large statistical sample and the complex nature of the data, the statistical work is relatively heavy. Data mining is a kind of statistical model that processes, analyzes, and organically combines the relevant data by accurately processing the data in the state of big data, and then introducing the idea of statistics into data mining [14]. As shown in Figure 2, Hadoop provided a powerful and reliable analysis engine and shared memory for statistical tasks, including two key technologies, MapReduce and HDFS. MapReduce is responsible for data processing and analysis, and HDFS is responsible for shared data storage.

2.3. Construction of Big Data Statistical Analysis Model. The statistical analysis system in the big data environment is based on batch data mining and adopts the method of regular data processing and analysis to update the model [15]. The key to system design is real-time retrieval, statistical analysis, data processing, and mass storage, and distribution of statistical data sources. The data collection, aggregation, and movement of Hadoop clusters, as well as the distributed storage of data, meet the demand for the diversity of statistical analysis, and task scheduling can manage and schedule jobs submitted by all users in a unified manner. The Hadoop-based computing model is shown in Figure 3,

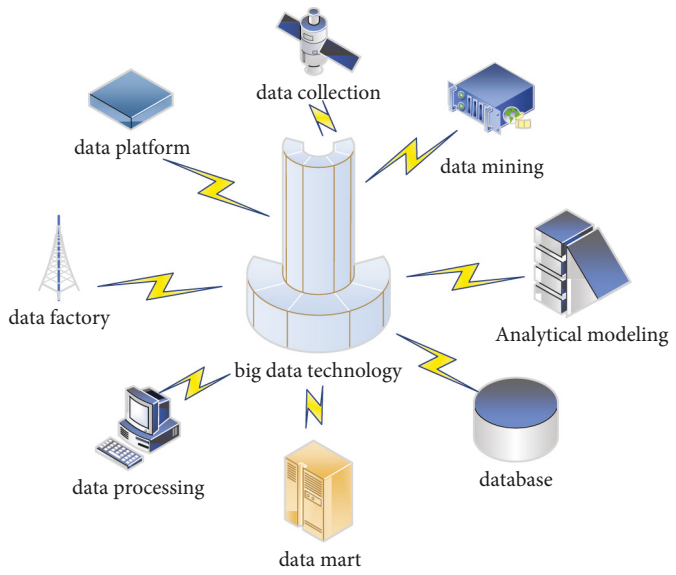

Figure 1: Big data statistical model.

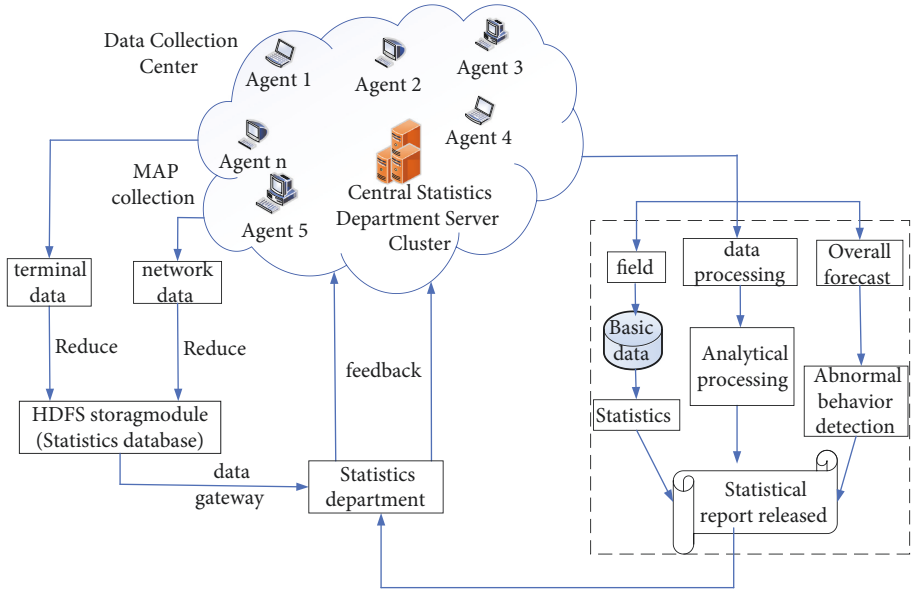

Figure 2: The basic structure of data statistics.

including cloud platform application layer, technology and interface layer, computer layer, file management layer, and physical top-level source code.

3. Construction of a Spatial Econometric Model of Economic Growth Convergence

The theory of economic development is an important subject of economic research. The gap in economic development between countries or regions and its changing trend (the convergence of economic development) is one of the focuses that has received much attention [16]. Economic growth convergence refers to a state in which a country's growth rate or per capita output is negatively correlated with its baseline level. That is, backward regions have higher economic growth rates than developed regions, which leads to a process in which the differences in the static indicators of each economic unit at the beginning of the period gradually disappear. The method of the spatial econometric model has been used in many fields, and the convergence of economic growth in different areas can be studied and analyzed by the method of spatial econometric model [17].

3.1. Economic Convergence. The concept of economic convergence comes from the concept of sequence convergence in mathematics. When $\forall \varepsilon > 0$, when n is large enough, if there are $|X_n - X_{n-1}| < \varepsilon$, the sequence $\{X_n\}$ is said to be a convergent sequence. Eventually, it will converge and become constant over time, and the gaps between the different regions will shrink. Convergence is a data-related

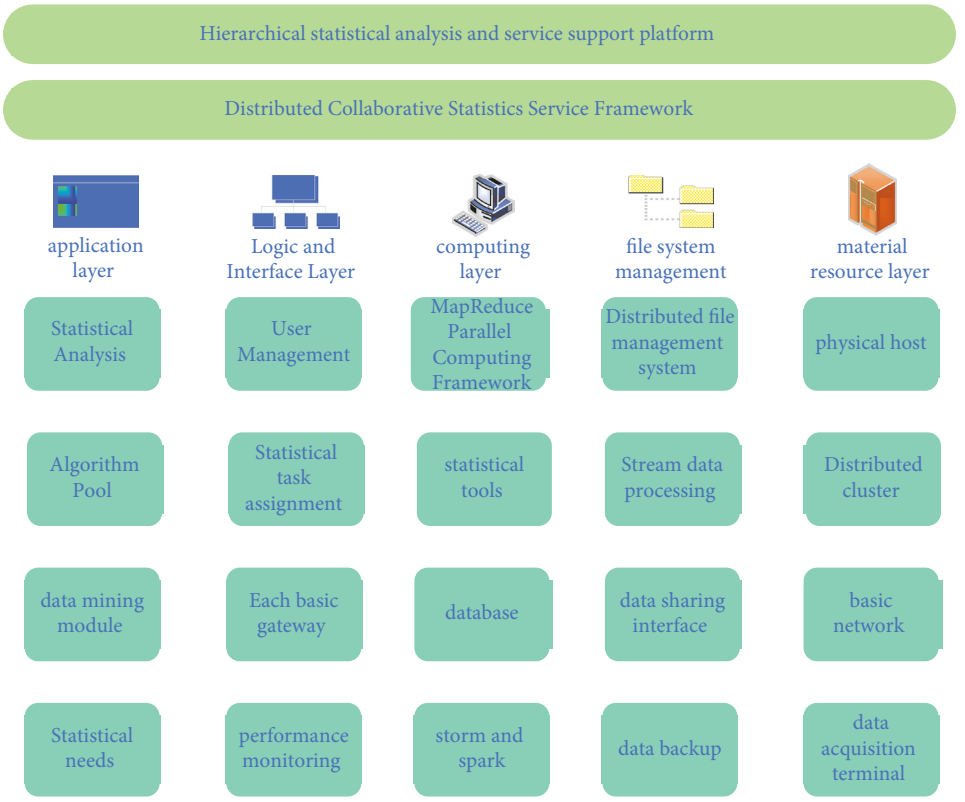

Figure 3: A hierarchical statistical analysis model based on Hadoop.

assumption that refers to the tendency of the standard deviation of real output per capita in different economies to decrease over time. When considering convergence phenomena, convergence can provide the most intuitive convergence information, mainly measured by the non-discriminatory standard deviation [18]. The convergence type is as follows:

$$\sigma_t = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}\left(\log Y_{it} - \frac{1}{N}\sum_{i=1}^{N}\log Y_{it}\right)^2}, \quad i = 1, 2, \cdots, N; t = 1, 2, \cdots, T, \tag{1}$$

i represents the region, t represents the period. Y_{it} represents the per capita output of the ith region in period t, σ_t. If there are $\sigma_{t+k} = C\sigma_t$ (C is a constant, and $C < 1$) in epoch $t + k$, and then this region is said to have a k-order σ convergence [19].

β convergence is a time series assumption that all regions will eventually reach the same per capita income or output over time [20]. β convergence is divided into two forms: absolute convergence β and conditional convergence β. The so-called absolute β convergence means that regions with similar basic characteristics such as technology, system, and culture have the same economic growth path and equilibrium state, and the regional economic growth rate is negatively correlated with the distance from the steady state. The so-called condition β convergence means that different economic regions have different technical, institutional, cultural, and other characteristics, and thus have different economic conditions, so there is no absolute convergence.

The regression model with absolute convergence β is as follows:

$$\frac{1}{T}\log\left(\frac{Y_{i,t_0+T}}{Y_{i,t_0}}\right) = \alpha + \beta \log Y_{i,t_0} + \varepsilon_{i,t_0,t_0+T}, \quad \varepsilon_{i,t_0,t_0+T} \sim iid, N\left(0, \sigma_t^2\right), \tag{2}$$

i represents the region, t_0 is the beginning, and $t_0 + T$ is the end. Y_{i,t_0} and Y_{i,t_0+T} represent the per capita output at the beginning and end of the i-th region, respectively, $\varepsilon_{i,t_0,t_0+T}$ represents the random error term. The distribution of $\varepsilon_{i,t}$ in t_0 and $t_0 + T$ lags into an independent state distribution, σ changes with the change of technical conditions at the initial time t_0, and β represents the convergence speed to be estimated.

The Condition β convergent regression model is as follows:

$$\frac{1}{T}\log\left(\frac{Y_{i,t_0+T}}{Y_{i,t_0}}\right) = \alpha + \beta \log Y_{i,t_0} + \varphi(X) + \varepsilon_{i,t_0,t_0+T}, \quad \varepsilon_{i,t_0,t_0+T} \sim iid, N\left(0, \sigma_t^2\right). \tag{3}$$

Among them, X is the population growth rate, employment rate, degree of urbanization, degree of industrialization, transparency, government public expenditure, industrial structure, and other control variables, as well as several factors that may affect convergence. β indicates the conditional convergence rate to be measured.

The connotation of club convergence theory is that the level of economic development, that is, countries or regions with similar economic basic conditions, will converge to the same local stable state. Club Convergence examines the convergence that exists between different systems within each economic bloc that has the same structural characteristics as human capital and market opening in its initial stages. For example, there is a phenomenon of club convergence in the three main regions of M country, east, middle, and west. For each prefecture-level city and urban area in area B, the regional dummy variables can be defined according to the city to converge the regression. The convergence model is as follows:

$$\frac{1}{T}\log\left(\frac{Y_{i,t_0+T}}{Y_{i,t_0}}\right) = \alpha + \beta \log Y_{i,t_0} + \gamma D + \varepsilon_{i,t_0,t_0+T}, \quad \varepsilon_{i,t_0,t_0+T} \sim iid, N\left(0, \sigma_t^2\right). \tag{4}$$

The description of each variable is similar to the previous model, γ is the coefficient vector of the dummy peripheral variable to be measured, and D denotes the subregion within the hypothesis domain. If the β value is negative, the area shows club convergence. According to the model comparison between club convergence and β convergence, it can be found that club convergence can be regarded as a form of absolute β convergence, which occurs in subdomains with the same stable state within the region, rather than in the entire economy.

3.2. Model Construction and Data Interpretation. Before the formal modeling, people first have a preliminary understanding of the overall economic operation of the B region of M country. Table 1 gives the descriptive statistical indicator data of the total per capita income of area B. It can be seen from this table that in the past 20 years, the per capita income of district B has been greatly improved, the average value has increased by nearly 2 times, and the average annual growth rate is about 7.6%. From 1998 to the end of 2011, per capita income increased by 0.36 times, noting that the economic growth gap in the region is gradually widening, the standard deviation from 1998 to 2018 increased from 1257.13 to 3065.02.

Table 1: Per capita income.

Years	Maximum value	Minimum	Standard deviation	Mean
1998	15311	10493	1257.13	12819.65
2011	18167	13759	1938.24	15369.29
2012	20966	15781	2134.57	17308.14
2018	28228	21810	3062.02	25387.25

Table 2: Per capita expenditure.

Years	Maximum value	Minimum	Standard deviation	Mean
1998	4985	3096	679.46	3886.13
2011	7655	5378	734.87	6057.48
2012	8939	6347	782.67	7614.31
2018	12371	10358	846.25	11492.5

Table 2 gives the descriptive statistical indicator data of the total per capita expenditure in area B. It can be seen from the table that in the past 20 years, the per capita expenditure in district B has increased significantly, the average value has nearly tripled, and the average annual growth rate is about 5.8%. From 1998 to the end of 2011, per capita expenditure increased by 1.28 times.

3.2.1. σ Convergence Index. σ convergence index refers to the fact that the dispersion of per capita income between regions tends to decrease over time. When the index tends to decline, there is economic convergence. The time series of changes in per capita GDP in region B from 1998 to 2018 is now plotted, as shown in Figure 4. The economic convergence of region B can be analyzed by directly observing the change in the coefficient of variation on the plot.

In the first stage (1998–2005), the instability of this stage gradually decreased over time, and the economic gap gradually narrowed. In the second stage (2005–2010), the coefficient of variation of this stage gradually increased with time, and the gap widened. In the third stage (2010–2012), the coefficient of variation of this stage showed a gradually decreasing trend with time. In the fourth stage (2012–2018), the coefficient of variation for this stage began to show an upward trend over time.

3.2.2. β Convergence Trend. Convergence trend refers to a trend in which the initial development level of a country or region is inversely proportional to the development speed. In addition to the coefficient of variation, graphs of economic growth rates and output levels can also be used to roughly describe the convergence trend of economic convergence [21]. Figure 5 shows that the trend line shows a downward trend, and the economic growth rate of area B is negatively correlated with the initial output

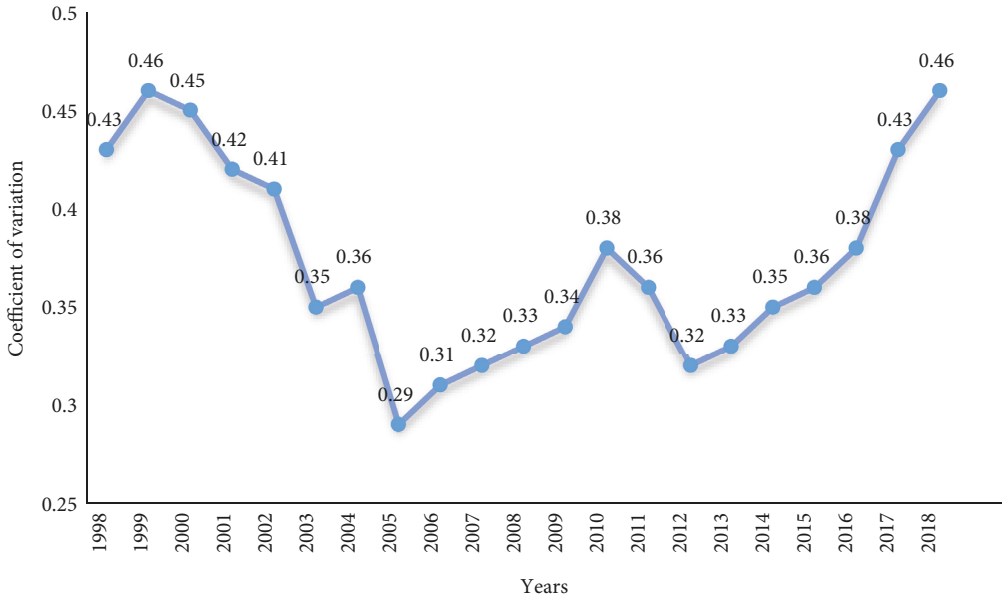

Figure 4: Time series plot of log standard deviation per capita in region B.

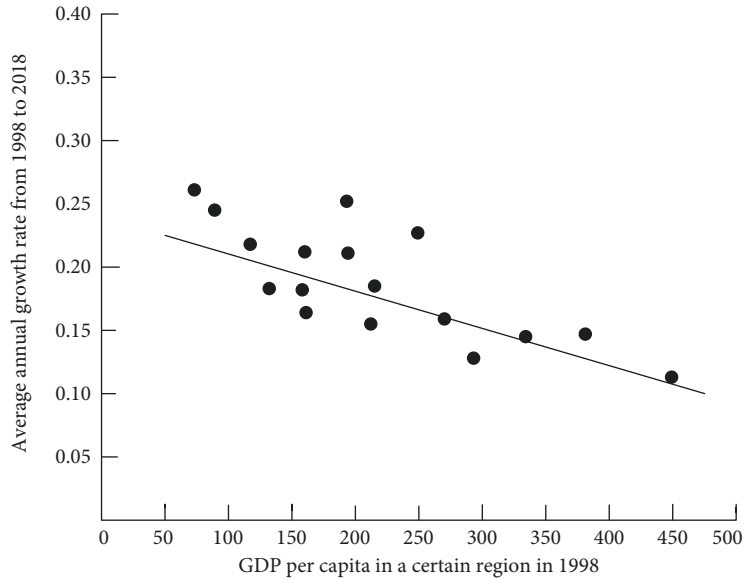

Figure 5: Scatter plot of economic growth rate and initial output level.

level, showing a convergence trend. The slope of the trend line can be approximated as the convergence force of convergence.

The model is constructed based on the related concepts of economic convergence. The convergence mainly examines the changes in the level of economic development between different economic systems over time [22]. If the standard deviation tends to decrease, it means that the economic growth of each region is converging. On the contrary, it shows that the economic growth of different regions is different. The types of tests introduced in convergence concepts are used below. The definition of Equation (1) can be obtained by constructing a regression model, namely, $(y_{it} = \log Y_{it})$. The logarithmic form of the per capita GDP of each region in the tth period is $(\overline{y}_t = 1/N \sum_{i=1}^{N} \log Y_{it})$, and the unbiased estimate of the variance of the random error term ε_{it} after regression is σ_t^2. The regression model is as follows:

$$\begin{aligned} y_{it} &= \overline{y}_t + \varepsilon_{it}, \\ \varepsilon_{it} &\sim iid, N\left(0, \sigma_t^2\right). \end{aligned} \tag{5}$$

Among them, y_{it} and $\overline{y}_t$ are as defined in parentheses above, and the area is $i = 1, 2, \cdots, N$; time is $t = 1, 2, \cdots, T$. For this regression model, since this regression model assumes a standard normal distribution, the regions are independent of each other at the same time t, and the regions are considered as independent individuals, there is no spatial correlation between regions, these are all true. After constant

regression of Equation (5), a random error term is generated. The unbiased variance estimator is as follows:

$$S_t^2 = \frac{\sum_{i=1}^{N} e2/\text{it}}{N-1}. \tag{6}$$

Among them, the residual term $e_{\text{it}} = y_{\text{it}} - \overline{y}_t$ is obtained according to equation (1), that is, the mean square error σ_t in the result obtained by performing Stata regression on the model. Using the data from each region to perform a temporal regression and calculate a set of values σ_t, the time series of design values σ_t are shown in Figure 6, in which the difference in economic growth in region B shows obvious volatility. Overall, the variance patterns roughly matched the variance trends of the variance coefficients from descriptive statistics studies, which also suggested that the variance coefficients could be measured and converged to describe economic disparities between regions.

3.2.3. β Convergence Model. The convergence model is similar to the analysis of convergence, before the introduction of the spatial matrix, the convergence modeling of the regional spatial correlation is not considered. Absolute convergence phenomena in region B are analyzed using equations that define the concept of convergence. The regression model used for absolute convergence is as follows:

$$\frac{1}{30}\log\left(\frac{\widehat{Y}_{i,2018}}{Y_{i,1998}}\right) = \alpha + \beta \log Y_{i,1998} + \varepsilon_{i.1978,2018}. \tag{7}$$

Using Stata software to perform regression analysis on this equation, the regression equation obtained is as follows:

$$\begin{gathered}\frac{1}{30}\log\left(\frac{\widehat{Y}_{i,2018}}{Y_{i,1998}}\right) = 0.286 - 0.022 \log Y_{i,1998},\\ (0.007)\,(0.038),\\ (-3.04^{***})\,(7.52^{***}),\\ R^2 = 0.352, \text{Fstatistics} = 9.25^{***}, \text{Prob} > F = 0.007, \text{Sample size} = 19.\end{gathered} \tag{8}$$

The value in parentheses in the first row below the equation is the standard deviation of the regression coefficient, and the second row is the statistic t, *** which means significant at the 1% confidence level. This shows that the regression result, the statistic F is significant at the 1% confidence level. The regression equation is established, and the value of the regression coefficient is very important to the confidence.

Starting from the turning point in 2003, we compare and analyze the convergence situation before and after 2003. The regression model used for absolute convergence from 2003 to 2018 is as follows:

$$\frac{1}{15}\log\left(\frac{Y_{i,2018}}{Y_{i,2003}}\right) = \alpha + \beta \log Y_{i,2003} + \varepsilon_{i,2003,2018}. \tag{9}$$

Using the software to perform regression analysis on this equation, the regression equation obtained is as follows:

$$\begin{gathered}\frac{1}{15}\log\left(\frac{Y_{i,2018}}{Y_{i,2003}}\right) = 0.203 - 0.037 \log Y_{i,2003},\\ (0.033)\,(0.01),\\ (6.18^{***})\,(-3.86^{***}),\\ R^2 = 0.235, \text{FStatistics} = 14.91^{***}, \text{Prob} > F = 0.0013, \text{Sample size} = 19.\end{gathered} \tag{10}$$

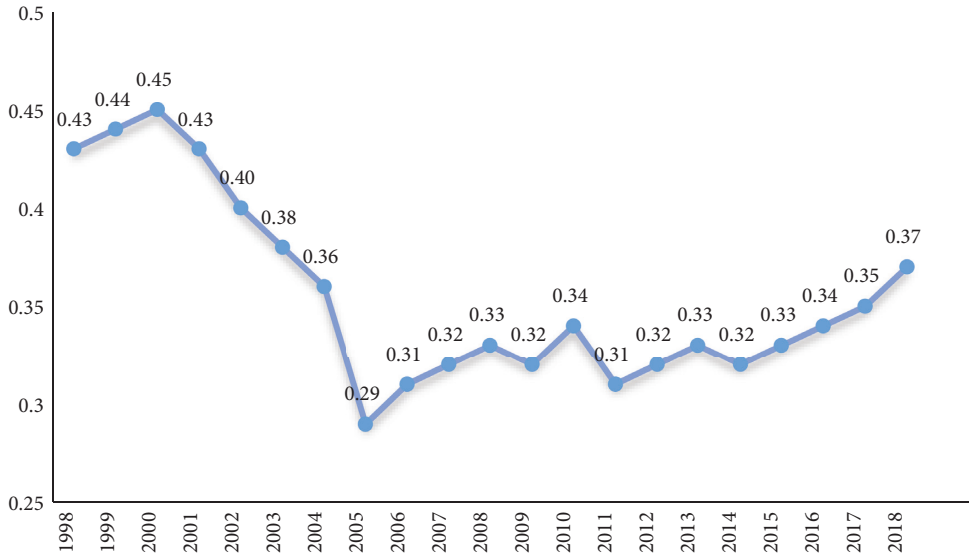

Figure 6: Time series plot of log standard deviation per capita in region B.

At this time, the equation is still significant, but the value of β increases significantly, and the convergence speed is accelerated. The regression model used for the absolute β convergence for 1998–2003 is as:

Using the software to perform regression analysis on this equation, the regression equation obtained is as follows:

$$\frac{1}{15}\log\left(\frac{\hat{Y}_{i,2003}}{Y_{i,1998}}\right) = 0.118 - 0.021 \log Y_{i,1998},$$
$$(0.018)\,(0.008),$$
$$(6.65^{***})\,(-3.86^{***}),$$
$$R^2 = 0.264, \text{FStatistics} = 7.05^{***}, \text{Prob} > F = 0.0167, \text{Sample size} = 19. \tag{11}$$

The current β convergence rate is about 2.1% per year. Based on the availability and reliability of the data to analyze the conditional convergence, take 2003 as the data starting point, and carry out the convergence regression according to the degree of industrialization and the explanatory variables that affect the degree of convergence. The regression model is used as:

$$\frac{1}{15}\log\left(\frac{Y_{i,2008}}{Y_{i,1993}}\right) = \alpha + \beta \log Y_{i,2003} + \gamma_1 R_{i,\text{pop}} + \gamma_2 R_{i,i} + \gamma_3 R_{i,g} + \gamma_4 IS_i + \gamma_5 IO_i + \varepsilon_{i,2003,2018}. \tag{12}$$

$R_{i,\text{pop}}$ represents the natural growth rate of population in district i, and γ_1 is the measure of the impact of population on economic development. $R_{i,i}$ represents the percentage of investment in the region, γ_2 is the measure of the impact of investment on economic development, $R_{i,g}$ is the level of government spending in region i, γ_3 is the impact of government behavior on economic development, and IS is the level of industrialization in region i. γ_4 is measured by the proportion of the secondary and tertiary industries in economic development in the industrial structure, IO is the degree of international openness, and γ_5 is the impact of the degree of openness on economic growth.

Running the sample data to estimate the model. Finally, it is found that only investment and the degree of opening to the outside world have an impact on economic growth, while the three factors of population growth rate, government public expenditure rate, and industrial structure are not significant. The population growth rate is 0.5, the P rate is 0.28, the public expenditure rate is 0.057, the P rate is 0.763, the industrial structure rate is 0.038,

and the P rate is 0.245. So the final estimated regression equation is as follows:

$$\begin{aligned}\frac{1}{15}\log\left(\frac{Y_{i,2018}}{Y_{i,2003}}\right) &= 0.236 - 0.0413\ \log\ Y_{i,2003} + 0.0397R_{i,i} + 0.008IO_i,\\ &\quad (0.048)\,(0.015)\,(0.021)\,(0.0034),\\ &\quad \left(4.9^{***}\right)\left(-2.73^{**}\right)\left(1.9^{*}\right)\left(2.41^{**}\right)\\ R^2 &= 0.449, \text{FStatistics} = 7.73^{***}\,\text{Prob} > F = 0.0024, \text{Samplesize} = 19.\end{aligned} \tag{13}$$

The first line is the standard deviation of the estimated factor, and the second line is the statistical t, ***which means significant at the 10% confidence level, **means significant at the 5% confidence level, and *means significant at the 1% confidence level. Compared with absolute convergence, the convergence speed is significantly faster.

3.3. Spatial Econometric Model. Spatial econometric models are mainly divided into two types: spatial lag model and spatial error model. Both of these models are based on the introduction of the spatial weight table to modify the basic model [23]. The spatial lag model is suitable for the behavior of adjacent areas, which affects the behavior of other areas in the whole area, and the spatial error model is suitable for the impact of uncertainty shocks on local economic variables in adjacent areas. The estimation of the spatial model adopts the maximum likelihood estimation method and the generalized least squares method.

3.3.1. Spatial Lag Model. In order for σ to converge, after introducing the constant regression (1) into the spatial table, the spatial lag model is as follows:

$$y_t = \alpha_t I + \lambda_t W_{y_t} + \varepsilon_t. \tag{14}$$

Among them, $y_t = (y_{1t}, y_{2t}, \cdots, y_{Nt})$, is the vector model, α_t and λ_t are constants, W is spatial weight table, and λ_t is weight factor. Write the vector model in the form of a component model:

$$y_{\text{it}} = \alpha_t + \lambda_t W_i y_t + \varepsilon_{\text{it}} = \alpha_t + \lambda_t \sum_{i\neq j,j=1}^{N} w_{ij} y_{jt} + \varepsilon_{\text{it}}. \tag{15}$$

W_i is a vector with i rows, W_{ij} is a value with i rows and j columns. In this way, the establishment $\alpha_t + \lambda_t \sum_{i\neq j,j=1}^{N} w_{ij,} y_{jt}$ of the area balance is not only related to t, but also to the area i. For absolute β convergence, after substituting equation (2) into the spatial weight table, the spatial delay model is as follows:

$$\begin{aligned}\left[\frac{1}{T}\log\left(\frac{Y_{i,t_0+T}}{Y_{i,t_0}}\right)\right]_{N\times 1} &= \alpha I + \beta\left[\log\ Y_{i,t_0}\right]_{N\times 1}\\ &\quad + \lambda W\left[\frac{1}{T}\log\left(Y_{i,t_0}\right)\right]_{N\times 1} + \varepsilon_{t_{0,}t_0+T}.\end{aligned} \tag{16}$$

This is again a vector equation, with a column vector of local growth rates on the left, which is a unit vector, and a table of coefficients and spatial weights to be estimated. Writing the equation in terms of components, it can be got:

$$\begin{aligned}\frac{1}{T}\log\left(\frac{Y_{i,t_0+T}}{Y_{i,t_0}}\right) &= \alpha + \beta\ \log\ Y_{i,t_0} + \lambda\sum_{i\neq j,j=1}^{N} w_{ij}\left(\frac{1}{T}\log\left(Y_{j,t_0}\right)\right)\\ &\quad + \varepsilon_{i,t_0,t_0+T}.\end{aligned} \tag{17}$$

It can be seen from this equation that the economic growth rate of the i th region is not only related to time T and the initial level $\log\ Y_{i,t}$, but also to the growth rate of the j th region, so the spatial lag model can test the spatial diffusion of this region.

For condition β convergence, a series of variables are introduced on the basis of the absolute convergence model to constitute the regression model.

3.3.2. Spatial Error Model. Spatial error models fall into two categories: spatial error autocorrelation models and overlapping moving average error models. The spatial error autocorrelation model is as follows:

$$\left.\begin{aligned}y &= X\beta + \varepsilon\\ \varepsilon &= \lambda W\varepsilon + u\end{aligned}\right\} \Rightarrow y = X\beta + (I - \lambda W)^{-1}u \qquad u \sim iid, N\left(0, \sigma^2\right). \tag{18}$$

Among them, λ spatial error is the autocorrelation coefficient and $W\varepsilon$ is the lag spatial error term. The moving average spatial error model is as follows:

$$\left.\begin{aligned} y &= X\beta + \varepsilon \\ \varepsilon &= u - \theta W u \end{aligned}\right\} \Rightarrow y = X\beta + (I - \theta W)u, \quad u \sim iid, N\left(0, \sigma^2\right). \tag{19}$$

θ is the moving average error rate for spatial error, and Wu is the concept of spatial delay error.

For σ converging, the constant regression (1) are identical in model form, so only the moving average model needs to be considered in the comparative analysis.

$$\begin{aligned} y &= \alpha I + (I - \theta W)u, \\ u &\sim iid, N\left(0, \sigma^2\right). \end{aligned} \tag{20}$$

For absolute β convergence, the equation for the spatial error autocorrelation model is as follows:

$$\left[\frac{1}{T}\log\left(\frac{Y_{i,t_0+T}}{Y_{i,t_0}}\right)\right]_{N\times 1} = \alpha I + \beta\left[\log Y_{i,t_0}\right]_{N\times 1} + (I - \lambda W)^{-1}u. \tag{21}$$

This is a vector equation with u representing a column of random error terms in N regions and λ representing the power of the spatial relationship between the regression residuals.

The condition β convergence model goes on to introduce additional variables on top of the absolute convergence model. The abovementioned describes the form of the spatial econometric model and introduces the tests of two pairs of models. Before proceeding with the spatial modeling analysis, the spatial correlation is first checked.

$$\text{Moran's}I = \frac{\sum_{i=1}^{N}\sum_{j=1}^{N} w_{ij}\left(Y_i - \overline{Y}\right)\left(Y_i - Y\right)}{S^2\sum_{i=1}^{N}\sum_{j=1}^{N} w_{ij}}. \tag{22}$$

Among them, $S^2 = \sum_{i=1}^{N}\left(Y_i - \overline{Y}\right)^2/N, \overline{Y} = \sum_{i=1}^{N} Y_i/N$, is the observed value of a variable in the Y_i th region; W_{ij} is the value of the element in the W th row and j th column.

4. Convergence of Economic Growth Results

As can be seen from the abovementioned, as far as the GDP of each region in country M is concerned, there is a spatial correlation between adjacent regions. Figures 7 and 8 are Moran scatter plots of M country GDP in 2010 and 2015.

Scatter plots exhibit the common characteristic of positive spatiality. Most of the country M falls into the first and third quadrants, showing a spatial relationship. In the third quadrant more than in the first quadrant, mostly low-aggregation type. The fourth quadrant represents the high and low agglomeration area, and the two quadrants are in a negative spatial relationship.

4.1. σ Analysis of Convergence Results. As shown in Figure 9, the per capita GDP of area B fluctuates greatly, but the overall trend is a slight downward trend, indicating that the economic development of area B tends to converge.

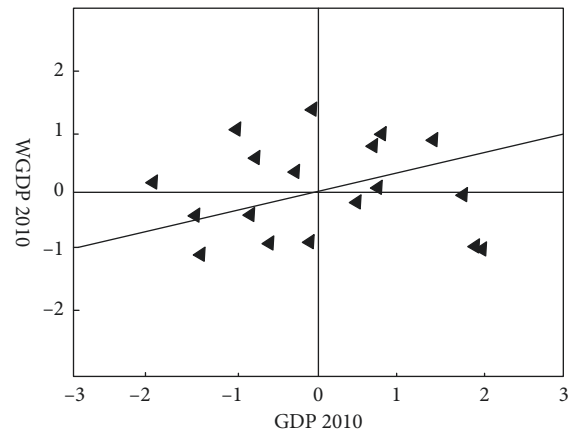

Figure 7: Moran scatter plot of GDP in 2010.

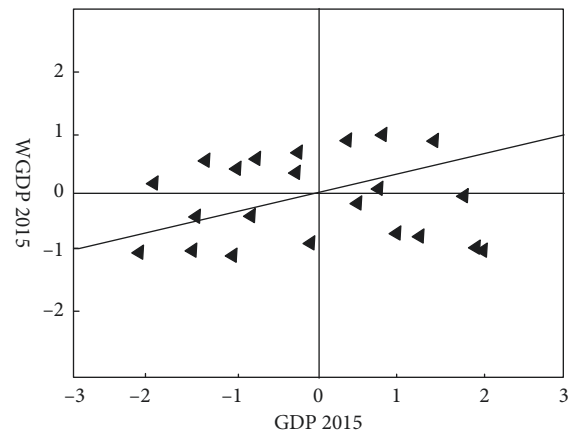

Figure 8: Moran scatter plot of GDP in 2015.

4.2. Absolute 55 Convergence Analysis Results. Regression analysis was performed using the OLS model. From Table 3 the regression coefficient between the average GDP growth rate in region B and the baseline level of per capita GDP is negative. If $P = 0.000$ is at a significant level, through the significance test, the economic growth of area B has a global correlation convergence under the spatial interaction.

As can be seen from Figure 10, the global Moran index of per capita GDP in region B is positive. Except for the three years of 2006, 2007, and 2008, the Moran index value in other years did not change much. And all passed the significance test at the significance level of 0.05. It shows that the distribution of per capita GDP in region B has a long-term spatial dependence.

As can be seen from Figure 10, the Moran index of per capita GDP in region B is always positive. Except for 2006, 2007, and 2008, the Moran index values in other years did not change much, and the significance level was 0.05. The test showed that the distribution of per capita GDP showed long-term spatial dependence.

The comparison of the accuracy results of the spatial econometric analysis model based on big data and other analysis models is shown in Figure 11.

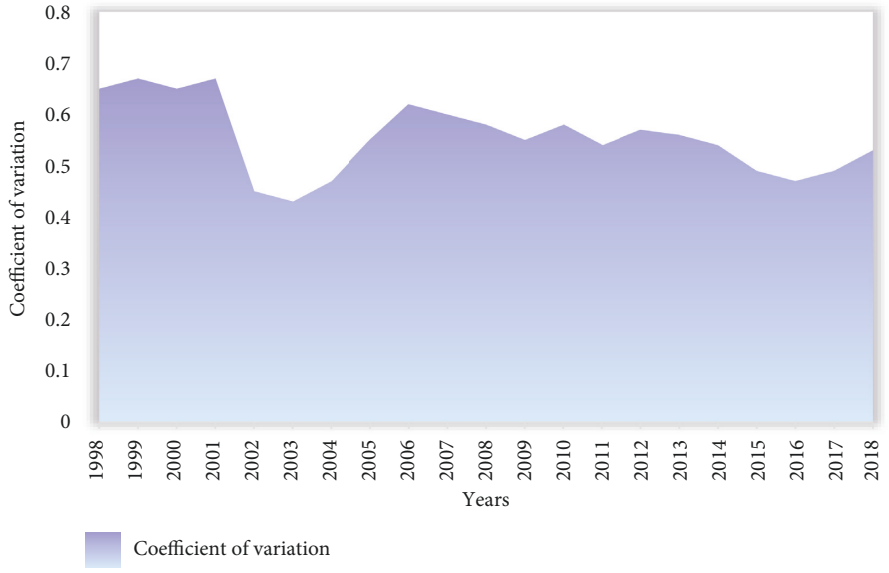

Figure 9: Coefficient of variation of GDP per capita in area B.

Table 3: OLS model parameter estimation results.

Estimated results	Coefficient	P value	Model checking	P value
α	0.26554	0.000000	Jarque-Bera	0.14637
β	−0.01815	0.000000	Breu–Pagan	0.00039
Adjustment R^2	0.368724	—	Koenker–Basett	0.00738
LJK	103.6845	—	White	0.00651
AIC	−289.257	—	LM (lag)	0.478465
SC	−263.348	—	LM (Lerro)	0.91724

Figure 10: Global Moran index of GDP per capita in region B.

Figure 11 shows the results of the convergence of economic growth in region B from 1998 to 2018 based on the spatial econometric model under big data and the general model. It can be seen from the spatial econometric model based on big data and the general analysis model are roughly the same, but slightly higher. This shows that the

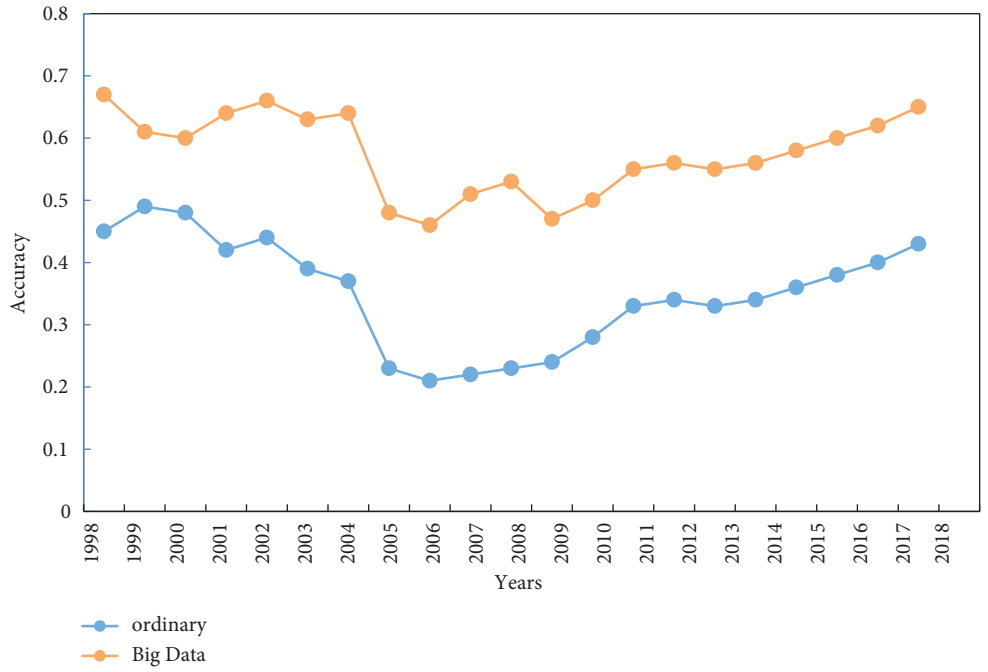

Figure 11: Spatial econometric model comparison.

introduction of big data has significantly enhanced the accuracy of economic convergence analysis, and the accuracy has increased by 4.1%.

5. Conclusions

Based on big data, this paper uses a spatial econometric model to test and analyze the convergence mechanism of economic growth. The economic convergence index is used to construct the spatial weight table, the spatial and geographical factors are introduced into the economic growth convergence model, the real GDP per capita is used as the indicator to measure economic growth, and the per capita income and expenditure ratio is used as the factor of economic convergence. Studies have shown that considering the correlation between regions, especially the correlation between economies, the differences between regions have been significantly reduced. There are σ convergence and periodic fluctuations between regions, but the general trend is still convergent. As big data's revolutionary impact on economic analysis grows, so too had economic policymakers and academia. When studying the convergence of economic growth, the addition of big data technology can predict the change law of data, thereby reducing data errors, optimizing research results, and providing a stronger scientific basis for the development of a coordinated regional economy.

Data Availability

Data sharing is not applicable to this article as no datasets were generated or analyzed during the current study.

Conflicts of Interest

The authors declare no potential competing interests.

Authors' Contributions

All authors have seen the manuscript and approved for publication.

Acknowledgments

This work was supported by the National Nature Science Foundation of China (No. 41930101), Innovation engineering scientific research consulting project of Party School of Gansu Provincial Party Committee of the CPC (Gansu Institute of Public Administration) "Study on carbon peak and carbon neutralization in Gansu Province," Soft science project of Gansu Provincial Department of science and technology "mechanism of social forces participating in emergency management of major emergencies," and Science and Technology Program of Gansu Province (20YF3GA013).

References

[1] G. Zhang, "Construction of the college education quality management system based on big data and its evaluation," *Agro Food Industry Hi-Tech*, vol. 28, no. 1, pp. 3124–3127, 2017.

[2] P. Ni, B. Liu, and G. He, "An online optimization strategy for a fluid catalytic cracking process using a case-based reasoning method based on big data technology," *RSC Advances*, vol. 11, no. 46, pp. 28557–28564, 2021.

[3] S. Pingping, "Research on the innovation of enterprise employee incentive way management based on big data background," *Agro Food Industry Hi-Tech*, vol. 28, no. 1, pp. 1434–1438, 2017.

[4] L. Wang, Q. Chen, and H. Gao, "Framework of fault trace for smart substation based on big data mining technology," *Automation of Electric Power Systems*, vol. 42, no. 3, pp. 84–91, 2018.

[5] Y. Du and T. Zhao, "Network teaching technology based on big data mining and information fusion," *Security and Communication Networks*, vol. 2021, no. 9, pp. 1–9, Article ID 6629563, 2021.

[6] L. Guo, M. Wang, and Y. Lin, "Electromagnetic environment portrait based on big data mining," *Wireless Communications and Mobile Computing*, vol. 2021, no. 3, pp. 1–13, Article ID 5563271, 2021.

[7] G. Yan and H. Wang, "Autonomous coordinated control strategy for complex process of traffic information physical fusion system based on big data," *IEEE Access*, vol. 12, no. 99, p. 1, 2020.

[8] Y. Song, D. Liu, and Q. Wang, "The dual-financial-threshold effect in the "club convergence" of economic growth: a dynamic panel threshold model," *Empirical Economics*, vol. 3, pp. 1–25, 2020.

[9] L. Chakraborty and P. Chakraborty, "Federalism, fiscal asymmetries and economic convergence: evidence from Indian States," *Asia-Pacific Journal of Regional Science*, vol. 2, no. 1, pp. 1–31, 2018.

[10] S. Mei, "Study on the China regional economic growth and energy consumption intensity difference convergence," *AIP Conference Proceedings*, vol. 1829, no. 1, pp. 1–4, 2017.

[11] N. Ibrahim, F. O. Economics, and S. Muhammad, "Does social capital affect the convergence of economic growth in Indonesia," *Journal of International Business and Economics*, vol. 19, no. 1, pp. 68–76, 2019.

[12] A. Glodowska, "Business environment and economic growth in the European union countries: what can Be explained for the convergence?" *Entrepreneurial Business & Economics Review*, vol. 5, no. 4, pp. 189–204, 2017.

[13] M. Malik and T. Masood, "Economic growth, productivity, and convergence of Middle East and north africa countries," *Journal of Economic Cooperation and Development*, vol. 41, no. 4, pp. 1–25, 2021.

[14] M. Min, W. Zhao, and T. Hu, "Influential factors of spatial distribution of wheat yield in China during 1978–2007: a spatial econometric analysis," *Ieee Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, vol. 7, no. 11, pp. 4453–4460, 2017.

[15] X. Zhao and G. Yu, "Data-driven spatial econometric analysis model for regional tourism development," *Mathematical Problems in Engineering*, vol. 2021, no. 4, pp. 1–7, Article ID 6631833, 2021.

[16] L. Zhu, Q. Gan, and Y. Liu, "The impact of foreign direct investment on SO 2 emissions in the Beijing-Tianjin-Hebei region: a spatial econometric analysis," *Journal of Cleaner Production*, vol. 166, no. 10, pp. 189–196, 2017.

[17] Y. Ren, "Intelligent statistical analysis on the influence of industrial agglomeration on innovation efficiency of spatial econometric model," *Journal of Intelligent and Fuzzy Systems*, vol. 5, pp. 1–10, 2020.

[18] Y. Cao and W. S. Zhang, "Innovation efficiency of pharmaceutical industry in China and its influencing factors: a spatial econometric analysis," *Chinese Journal of New Drugs*, vol. 26, no. 12, pp. 1351–1356, 2017.

[19] T. Sipos, Z. Szabó, and R. Trk, "Spatial econometric cross-border traffic analysis for passenger cars – Hungarian experience," *Promet - Traffic - Traffico*, vol. 33, no. 2, pp. 233–246, 2021.

[20] J. J. Mora and A. Cendales, "Employment and development in cali and the valley of cauca: evolution and a spatial econometric analysis," *Regional and Sectoral Economic Studies*, vol. 18, no. 1, pp. 5–12, 2018.

[21] G. Zkubat and S. Selim, "Socio-economic development of provinces in Turkey: a spatial econometric analysis," *Alphanumeric Journal*, vol. 7, no. 2, pp. 449–470, 2019.

[22] S. A. Ahmad and S. Subash, "Do Indian states mimic, compete or interact in local public spending? A spatial econometric analysis," *Asian Economic Journal*, vol. 32, no. 2, pp. 187–213, 2018.

[23] K. Liu and B. Lin, "Research on influencing factors of environmental pollution in China: a spatial econometric analysis," *Journal of Cleaner Production*, vol. 206, no. 1-1156, pp. 356–364, 2018.