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The space-time evolution and driving forces of county economic growth in China from 1998 to 2015

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Abstract

Coordinated growth in regional economies is fundamental for sustainable economic development. In this study, the space-time dynamics of GDP per capita for 2,303 counties in China from 1998 to 2015 were analyzed based on an exploratory space-time data analysis (ESTDA) framework. The results showed that: (a) there was significant and increasing positive spatiotemporal correlation among county-level economic growth; (b) local spatiotemporal correlation pattern demonstrated a high–high cluster at the eastern coast, and low–low dispersion in the vast central and western regions; (c) changes in LISA time trajectory revealed that economic growth in the coastal urban agglomeration and Inner Mongolia was more dynamic, indicating the emergence of a local spatial structure locking feature and trajectory dependence; and (d) industrialization and informatization were the two primary contributors to county economic growth. Our study suggests that Chinese government should construct network channels linking the central region with eastern China, cultivate economic growth poles and growth axis, and focus on technological innovation to unlock path dependence in county economic growth.

1 | INTRODUCTION

Spatial economic inequality has always been an attractive research topic and policy issue for sustainable and healthy regional development, especially in a transitional country such as China (Wei & Ye, 2009). Distinguishing the spatial and temporal inequality of regional economic growth helps identify new changes in China's economic landscape. This provides enormous practical significance necessary for timely adjustments of China's spatial strategies and in breaking through geographical limits of economic growth that would build a holistic model of interconnected development.

The controversy over the emergence and differentiation of economic growth in developing and developed economies started in the 1950s, which raised a variety of regional inequality and economic growth theories. Among these theories, the Neoclassical convergence growth theory stated that regional economic growth was a process of resource redistribution, and regional inequality was influenced by temporary imbalances between demand and factor supply (Wei, Li, & Yue, 2017). However, regional economic growth is a self-reinforcing cyclic accumulation system, and regional inequality will continue to diverge due to human capital and technological preferring for core areas (Wei, 2015). The evolution of regional inequality was more likely an inverted U-shaped curve, which nested the growth convergence and divergence models (Williamson, 1965). The neoclassical growth models assumed that perfect competition and market returns at the microlevel were constant over different period of times. There are limitations to the spatial agglomeration of economic growth and the underlying mechanism of regional inequality. Economic growth often concentrates in a few growth pole areas, for instance engines of innovation, and regional inequality exhibits a core-periphery structure. While, regional inequality has risen to the structural conditions for the existence and operation of capitalism, and it shows a dynamic alternating process of "formation-break-reformation" due to the seesaw movement of capital (Smith, 2008).

Since the 1980s, many new growth theories have emerged, that is, endogenous growth theory, new convergence growth theory, etc. The endogenous growth theory mentioned that the regional inequality will continue to widen due to the endogenous effects of technological progress, human capital, knowledge spillover, externalities, and specialized labor (Lucas, 1988; Romer, 1986). New convergence growth theory validated the existence of three modes of convergence including σ convergence, β-convergence, and club convergence (Tian, Zhang, Zhou, & Yu, 2016). Based on the assumptions of imperfect competition and increasing returns, new economic geography explained the spatial agglomeration and diffusion of economic activities through the complex interactions between surge in market returns, externalities, transportation costs, and industrial linkages etc. Thus, regional convergence and divergence are both possible, while spatial agglomeration usually results in spatial inequality (Krugman, 2011). Institutional economics argued that all kinds of institutions, policy, and government intervention exerted significant impact on the regional inequality (Rodríguez-Pose, 2013). With the development of evolutionary economics and evolutionary geography, the time dimension of regional inequality had also been considered (Wei, 2015). With the global and local integrations, the exogenous and endogenous development process, an integrative multi-scale and multi-mechanism analysis framework is more prevailed to explain the regional inequality (He, Bayrak, & Lin, 2017; He, Fang, & Zhang, 2017).

Based on the hypothesis of economic growth convergence, Chinese scholars employed traditional statistical methods and spatial econometric models to test multi-scale and multi-period convergence growth in China. The findings of these studies reported different conclusions with regards to the convergence possibility at varying scales (Bao & Chen, 2015; Qin, Ye, & Liu, 2017; Tian, Jiang, Yang, & Zhang, 2011; Wang, Zhou, Li, & Feng, 2016). The existing studies documented that China's interprovincial inequality was reduced during the 1980s, increased in the 1990s, remained comparatively stable from the late 1990s to 2004, and has then declined thereafter (Fan & Sun, 2008). Feng, Zeng, and Cui (2015) argued that China's interprovincial economic disparity began to rise slightly after 2000 and has been in decline since 2010. In terms of inequality across intra-provincial counties, Yue, Zhang, Ye, Cheng, and Leipnik (2014) found that the county-level economic inequality in Zhejiang Province shows significant club convergence, while the county-level economic inequality in Guizhou Province has continued to decrease in the context of the spatiotemporal dynamic evolution approach (Sun, Lin, Liang, & Li, 2016). More recently, the researchers and scholars have identified the inequality trend of China's prefectural city-level and the urban–rural inequality (Huang & Wei, 2019; Wu & He, 2017). It is worthwhile to mention here that the provincial and city-level convergence may hinder the inequality of intra-provincial economic development and mask the nonequilibrium characteristics of intercounty economic differences. Hence, studies based on continuous county-level data across the whole country are emerging (He, Bayrak, et al., 2017; He, Fang, et al., 2017; He, Liao, & Li, 2019; Li & Fang, 2016), which contributes to probing the patterns and trends of county-level economic inequality.

The existing literature also has extensively analyzed the impacts of socio-economic factors (FDI, fixed asset investment, industrialization, urbanization, globalization, liberalization, decentralization, and marketization etc.), policy factors (i.e., regional preferential policies, financial policies, and environmental taxation policies), and geography factors (e.g., terrain, climate, and water resources) resulting in regional inequality in China. However, the mechanism and determinants of regional inequality in China is complicated and dynamic (Li & Fang, 2014; Liao & Wei, 2012). The single and static dimension focus is not conducive to reveal the underlying mechanism of regional inequality. The transition of the Chinese economy revealed that the multi-mechanism approach is more valuable to unveil the fundamental features of regional inequality (Wei, 1999). Wei (2002, 2007) conceptualized the triple transition process as globalization, marketization, and decentralization, which contributes to explain the interactive and joint production of uneven landscapes in China. In the same line, other research further synthesizes multiple driving factors to apply and extend the multi-mechanism analytical framework for regional inequality (Gao, Liu, Chen, & Cai, 2019; He et al., 2019; Li & Wei, 2010; Wei, Yu, & Chen, 2010). This provides adequate indicators for selection criteria to analyze the influencing factors of economic growth.

The inequality of regional economic growth in China fluctuates with existing policy and implementation at different periods (Wei, 2015). Since 1999, China's growth strategy has shifted from unbalanced economic expansion toward coordinated regional development. Due primarily to the implementation of China's Western Development Strategy, the rise of the central region, and the "Belt and Road" initiative, the central and western regions have rapidly developed in recent years. However, the existing literature has emphasized the status quo of China's regional economic inequality rather than focus on emerging spatial patterns or the dynamic spatiotemporal changes in the economy. With the enhancing spatial spillover and synergistic effect of regional economic growth, and the implementation of so many supporting policies, has China's regional economic growth exhibited new spatial structural characteristics? Ni, Li, and Wang (2015) judged that China's economic growth space is showing a new pattern of "integration of east and central as a whole, and sloping periphery." Kuang (2014) asserted that the Belt and Road Initiative will help break through the pattern of the Hu Huanyong Line, activating the resource dividend and location dividend in the western region, directly pushing the vast areas west of the Hu Huanyong Line to the frontier of opening up, which will rapidly deepen economic space to attract and encourage continuous entry of people and goods into the region. Chen, Gong, Li, Lu, and Zhang (2016) argued that the Hu Huanyong Line will not change fundamentally for a long period of time determined by comprehensive natural and geographical conditions. So, how unequal is China's county economic growth and what are the new growth space and the underlying growth influencing factors? These questions need to be further studied by means of new spatial analysis techniques.

Regional economic growth is a dynamic continuum of time and space (Jiang, Zhang, Xiong, & Wang, 2016; Kemeny & Storper, 2015; Ye, Ma, Ye, Chen, & Xie, 2017). Hence, studying regional economic growth involves understanding both the time and space dimensions (Wei, 2015). Therefore, this paper attempts to uses the exploratory space-time data analysis (ESTDA) framework to explore whether county economy growth from 1998 to 2015 tends to form the new pattern of integration of east and central as a whole or a new spatial pattern of economic growth is emerging and further employed the GeoDetector tool to explore the effects of various factors of economic growth.

2 | METHODS AND DATA

2.1 | Methods

The ESTDA was conducted to explore the variations in space-time correlation by integrating the temporal correlations of samples. The study scheme adopted in this research is presented in Figure 1. First, the optimal spatiotemporal correlation order of data was examined using the Box–Pierce statistical test (Mei, Xu, & Ouyang, 2015). The time-delay order and space-delay order were determined using the space-time autocorrelation function and the partial autocorrelation function. Then, the global and local space-time correlation was measured using the global and local spatiotemporal Moran's I index. Next, the space-time dynamics of county-level economic growth were studied according to the length, curvature, and transitional direction of LISA time paths. Finally, the geographical detector was used to discover the impacts of different variables on county economic growth.

2.1.1 | Spatiotemporal autocorrelation and partial function

The space-time series noncorrelation chi square test $\chi^2(h \times k)$ was initially performed to diagnose the existence of spatiotemporal correlation in the given data set. Then, the spatiotemporal autocorrelation function of the space delay (h) and the time delay (k) is given by (Mei et al., 2015):

$$\rho(h,k) = \frac{\sum_{t=1}^{T-k} Z_t' W_h Z_{t-k}}{\sum_{t=1}^{T} Z_t' Z_t} = \frac{\sum_{t=1}^{T-K} Z_t' W_h Z_{t-k}}{NT} \tag{1}$$

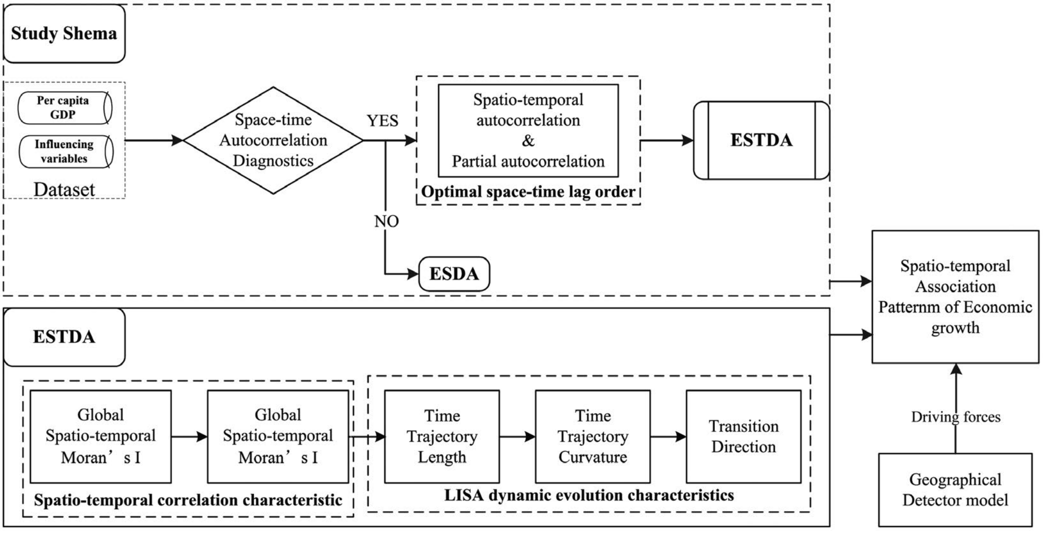

FIGURE 1 Framework of ESTDA

where N is the number of sites; T is the number of temporal observations; Z_t,Z_{t-k} are the mean normalized vector of X_t,X_{t-k} respectively; Z'_t is the transposition of Z_t; and, W_h is the spatial weight matrix of delay h-order.

The spatiotemporal partial autocorrelation function reflects the correlation between $Z_{i,t}$ and $Z_{i+h,t-k}$, which can be expressed by (Pfeifer & Deutsch, 1980):

$$\rho'(h,k) = \sum_{k=1}^{K} \sum_{h=1}^{H_k} \phi_{kh} \rho'(h-1,k) \tag{2}$$

where K and H are the time-delay and space-delay order of the spatiotemporal autocorrelation process, respectively. The spatiotemporal partial correlation coefficient φ_{kh} can be obtained by solving the Yule–Walker equations. The spatiotemporal partial correlation function can be used to determine the time delay (k) and space delay (h).

2.1.2 | Global and local spatiotemporal Moran's I

Based on the determined time delay (k) and space delay (h), the global spatiotemporal Moran's I-index (STI) can be calculated by the formula (López & Chasco, 2007):

$$STI_{k,h} = \frac{\sum_{i=1}^{N} \sum_{j=1}^{N} W_{ij}^{h}(X_{i,t-k} - \bar{X}_{t-k})(X_{j,t} - \bar{X}_t)}{\sqrt{\sum_{i=1}^{N} (X_{i,t-k} - \bar{X}_{t-k})^2} \cdot \sqrt{\sum_{i=1}^{N} (X_{i,t} - \bar{X}_t)^2}} \tag{3}$$

where W_{ij}^{h} is the spatiotemporal weight matrix W for the space-delay h-order; $X_{i,t}$ and $X_{j,t}$ are the observed values of the unit i and j at time t, respectively; $X_{i,t-k}$ is the observed value of unit i at time t-k; $\bar{X}_{t-k}$ and $\bar{X}_t$ are the average variables at time t-k and t, respectively; and, k and h are the time-delay and the space-delay order, respectively.

The extended spatiotemporal local Moran's I ($STLI$) was also used to measure the local spatiotemporal correlation model, as given by (Mei et al., 2015):

$$STLI_{i,k,h} = Z_{t,i,t} \sum_{j=i,j\neq i}^{N} W_{ij}^{h} Z_{t-k,j} \tag{4}$$

where $Z_{t,i}$ is the normalized value of unit i at time t; and, $Z_{t-k,j}$ is the normalized value of adjacent unit j at time t-k. There are four combinations of local spatiotemporal correlation between the local spatiotemporal object indicated by $STLI_{i,k,h}$ and its adjacent objects. The HH (LL) type indicates a positive local spatiotemporal autocorrelation existing between the object and its surrounding objects with similar high (low) values, while the spatiotemporal HL (LH) type indicates negative local spatiotemporal autocorrelation with diverging high (low) adjacent values. By observing the progression of values in the LISA scatter plot over a continuous-time trajectory, the traditional static LISA can be determined (Ye & Rey, 2013). Through visualization of the GDP per capita of county unit and the spatial displacement of its spatial lags, the LISA time trajectory can explain the spatiotemporal synergetic evolution of county-level economic growth and diagnose the space-time dynamics. The LISA time trajectory is decomposed into relative length and curvature according to its geometric characteristics.

The relative length of LISA time trajectory ($N_i^{\sim}$) is calculated as:

$$N_i^{\sim} = \frac{N * \sum_{t=1}^{T-1} d(L_{i,t}, L_{i,t+1})}{\sum_{i=1}^{N} \sum_{t=1}^{T-1} d(L_{i,t}, L_{i,t+1})} \tag{5}$$

where N is the number of spatial units, T is the annual time interval, $L_{i,t}$ is the LISA coordinate of the spatial unit i at time t, $d(L_{i,t},L_{i,t+1})$ is the displacement distance of spatial unit i from time t to t+1. If $N_i^{\sim}$ is greater than 1, it can be known that the relative displacement distance of county unit i is larger than the average displacement of all county units. This indicates that the more dynamic the local economic growth of a county is, the more dynamic the displacement of the county will be, and vice versa.

The curvature (D_i) of LISA time trajectory is calculated as:

$$D_i = \frac{\sum_{t=1}^{T-1} d(L_{i,t}, L_{i,t+1})}{d(L_{i,t}, L_{i,t+1})} \tag{6}$$

If the LISA relative displacement of county unit i is more complex than the average displacement of all county units, then, D_i is greater than 1. A larger D_i indicates a more curved LISA time trajectory, a more volatile local spatial dependence, and a more volatile GDP. On the contrary, a smaller D_i indicates the county economy has more stable local spatial structure.

2.1.3 | Geographical detector method

The geographical detector method has been developed to assess the association between different geographical phenomenon (Wang, Zhang, & Fu, 2016). In this study, the method was used to determine whether an environmental factor and the growth of the economy showed significant spatial consistency. If the environmental factor and the changes in economic growth were consistent, it would indicate that this environmental factor is pivotal to the growth of the economy. The formula is expressed as:

$$q = 1 - \frac{\sum_{h=1}^{L} N_h \sigma_h^2}{N\sigma^2} \tag{7}$$

where q is the detection index of the influence factors on economic growth; and, N and σ^2 represent the number of county units and the corresponding variance of per capita in the study area, both of which are composed of L strata (h = 1,2,..., L). The value of q is strictly within [0, 1]; a zero value of q would indicate no coupling between economic growth and influencing factor. The larger the q value, the greater the influence of environmental factors on economic growth.

2.2 | Variable measurement

The economic growth of each county and its space-time dynamics were analyzed based on the per capita GDP, which is the most commonly used indicator for measuring the level of economic development. It can also accurately and genuinely reflect the potentials for economic and social sustainable development, income levels, and the prevailing standard of living.

Economic growth is affected by multiple factors, including both natural and socio-economic factors. Based on the Cobb–Douglas production function, labor force and investment are two primary components of production. In this study, the impacts of the labor force (LABOR) and fixed asset investment (FIX) on economic growth were measured. For the new economic geography, in order to explain the spatial development of a city, Krugman (1993) identified two forces that determined the development of city spaces, namely "first nature" and "second nature," which are also applicable in explaining economic growth. Geographical elements, considered to be part of first nature, have stability over long periods of time. They provide primary conditions for economic activities, which can promote or limit growth and are fundamental to economic development (Liu & Wang, 2009). The annual average temperature (TEM), annual average precipitation (PRE), and average elevation (ELE) were selected to characterize the impact of natural elements. Elements considered as second nature, mainly refer to transportation infrastructure and location factors. Due to limitations in available data, no straightforward statistical measure can be used as a direct indicator; instead, related parameters, such as transportation accessibility, must be used as proxies. As location theory suggests, transportation accessibility is one of the vital determinants influencing the location of industries and the service sector (Jiang, Xu, & Zhang, 2018). The per square kilometer industrial output value (IND) and the ratio of tertiary industry to secondary industry (TER) were used as alternatives of second nature on economic growth. Another critical aspect of the economy is the emerging "third nature," which includes human capital, R&D activity, level of informatization, and financialization. In this study, the number of students per capita (HR) in ordinary middle schools was used to quantify the level of county human capital (Li & Fang, 2016). The number of telephone users per capita (INF) at the end of the year was used to measure the level of county informatization development. The per capita year-end deposit-to-loan balance of financial institutions (FIN) was used to indicate the level of county financial development. Also, decentralization provides local governments with more fiscal solvency and resources to independently promote economic growth. To capture the effect on economic growth, the ratio of fiscal expense to regional GDP (FIS) was used to indicate the local government's financial autonomy. To avoid the impacts of price fluctuations, all monetary factors were adjusted for inflation to the base year 1998 level by using the fixed price consumer price index of each provinces. All variables are described in Table 1.

2.3 | Study area and data source

Identifying which county economies are developing faster and where they cluster provide valuable insights toward understanding the economy. As proposed in the 13th National Five-Year Plan, 19 urban agglomerations were identified (see Figure 2) based on their level of urbanization and proximity to other urban centers. Urban agglomeration can transform transportation systems, ecosystems, and the natural environment, social interactions, and infrastructure development for both cities and rural communities. China's administrative division has undergone several major changes during development phases. In this article, the 2008 administrative division excludes Hong Kong, Macao, and Taiwan, from the Chinese provinces, and it is adopted and derived from China's Resource and Environment Data Cloud Platform (http://www.resdc.cn); to keep the research units consistent, some counties directly governed by the provincial government were merged, such as Xiantao city, Qianjiang city, Tianmen city, and Shennongjia Forest District in Hubei province, and county-level cities under the jurisdiction of Xinjiang Production and Construction Corps, etc. Finally, we considered 2,303 research

TABLE 1 The influencing factors of county economic growth

Variable category	Variable	Description	Source
The first nature	TEM	The annual average temperature	Chinese Academy of Sciences Resource and Environment Data Cloud Platform
	PRE	The annual precipitation	Chinese Academy of Sciences Resource and Environment Data Cloud Platform
	ELE	The average elevation	Chinese Academy of Sciences Resource and Environment Data Cloud Platform
The second nature	IND	The per square kilometer industrial output value	China Social and Economic Statistical Yearbook in counties (1999–2016)
	TER	The ratio of tertiary industry to secondary industry	China Social and Economic Statistical Yearbook in counties (1999–2016)
The third nature	HR	The number of students in middle school per capita	China Social and Economic Statistical Yearbook in counties (1999–2016)
	INF	The number of telephone users per capita	China Social and Economic Statistical Yearbook in counties (1999–2016)
	FIN	The per capita year-end deposit-to-loan balance of financial institutions	China Social and Economic Statistical Yearbook in counties (1999–2016)
Decentralization	FIS	The ratio of fiscal expense to regional GDP	China Social and Economic Statistical Yearbook in counties (1999–2016)
Traditional economic elements	LABOR	The number of labor employment	China Social and Economic Statistical Yearbook in counties (1999–2016)
	FIX	Fixed asset investment per capita	China Social and Economic Statistical Yearbook in counties (1999–2016)

units, including counties, autonomous counties, county-level cities, and municipal districts in the country level data.

The economic growth of each county and its space-time dynamics were analyzed based on the 1998–2015 GDP per capita of each county. All the related statistical data were derived from the China County Statistical Yearbook, the China City Statistical Yearbook, the China Statistical Yearbook for Regional Economy, the Provincial Statistical Yearbook, the Prefecture-level City Yearbook, and the Economic and Social Development Statistics Bulletins of the State, City, County, or District. For average elevation, annual average temperature, and annual average precipitation, the data were downloaded from the Chinese Academy of Sciences Resource and Environment Data Cloud Platform (http://www.resdc.cn/).

3 | RESULTS

3.1 | Time lag period and space lag order

Based on the Box–Pierce statistical test (χ^2 = 352,938.1; $p < .01$), the spatiotemporal correlation in county economic growth was confirmed. The temporal and spatial scale of the optimal spatiotemporal correlation was determined using spatiotemporal autocorrelation function and spatiotemporal partial

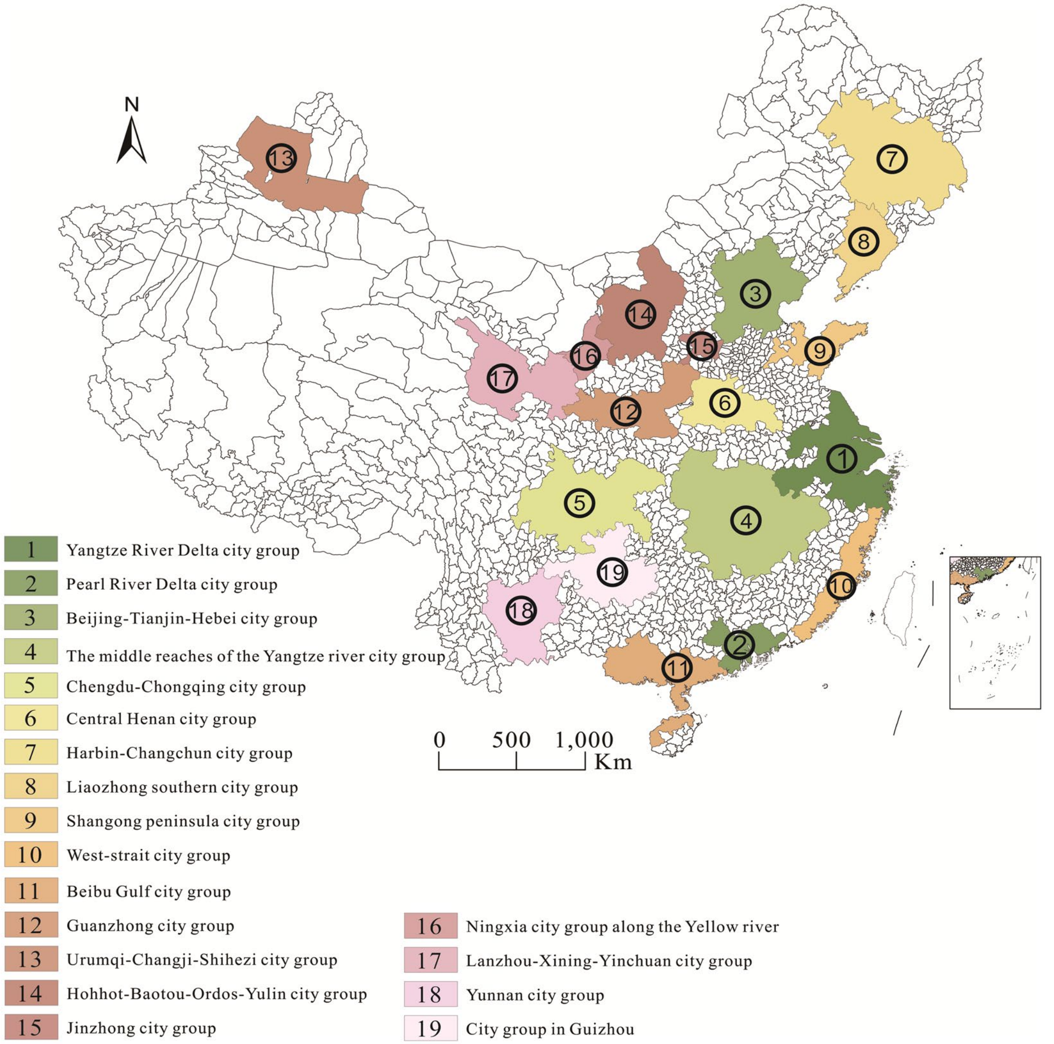

FIGURE 2 Spatial diagram of the study area and city group

autocorrelation function. These autocorrelation functions of county economic growth were calculated using Equations (1) and (2). Table 2 shows that the spatiotemporal autocorrelation function value of county economic growth decreases as k and h increases. Table 3 shows that the spatiotemporal partial autocorrelation function was tending to 0 after phase 3 at space-delay order 0 and 1. Since the set spatial weight cannot be adjacent to itself, the time delay $k = 3$ and space delay $h = 1$ were determined as the optimal temporal and spatial scales.

3.2 | The overall space-time dynamics of county economic growth

Based on the optimal time delay and space delay, the global spatiotemporal autocorrelation index STI (see Figure 3) for forward third-order time length and first-order space length at $k = 3$ and $h = 1$ was calculated using Equation 3. From Figure 3, the STI value remained significantly positive and was

TABLE 2 Spatiotemporal autocorrelation function value of county economic development

	klag = 1	klag = 2	klag = 3	klag = 4
hlag = 0	0.9018	0.8026	0.6577	0.5216
hlag = 1	0.7418	0.6643	0.5425	0.4210
hlag = 2	0.6641	0.5943	0.4841	0.3732
hlag = 3	0.6118	0.5455	0.4425	0.3366
hlag = 4	0.5966	0.5307	0.4264	0.3196

TABLE 3 Spatiotemporal partial autocorrelation function value of county economic development

	klag = 1	klag = 2	klag = 3	klag = 4
hlag = 0	0.9018	−0.0713	−0.3738	0.0208
hlag = 1	0.0944	−0.3287	−0.3074	0.0642
hlag = 2	0.0029	−0.1617	−0.1181	0.0862
hlag = 3	−0.0101	−0.0658	−0.0193	−0.0475
hlag = 4	−0.0054	−0.0625	−0.1484	−0.0599

FIGURE 3 Changes in the STI index of county economic growth

increasing slightly during the entire period. This indicates that China's county economic growth, in general, demonstrates positive spatiotemporal correlation and that the county economic growth is in high–high or low–low adjacent spatiotemporal clustering distribution. The STI value increased slowly from 2001 to 2007 at an average annual rate of 2.24%. This indicates that the spatiotemporal correlation had increased slightly before 2007 and that the growth difference among counties narrowed. However, the STI value declined from 2007 to 2012, indicating increased divergence in county economic growth. From 2012 to 2015, the STI value again surged, suggesting a decrease in growth differences among counties.

As for the variations in the Gini coefficient, the Gini value marginally increased from 2001 to 2007, and then, slightly decreased from 2007 to 2009. It increased again from 2009 to 2013, until it reached a peak value at 0.453. These variations could be the result of various factors including strong agglomeration capacity of the eastern region against the backdrop of globalization; the adverse effects of the international financial crisis on the development of the central and western regions; the low efficiency and hysteresis effect of inland tilt policy (e.g., strategies of West Development, the revitalization of the Old Industrial Base in Northeast China, and the rise of central China implemented to promote economic growth of the central and western regions). The Gini value has rapidly declined since 2013, which could be attributed to various reasons, including the convergence of regional economic differences, decreased county economic agglomeration effect, and synergistic growth effect with the promoting of various regionally coordinated development policies. County economic difference is linked to the change in spatiotemporal correlation, because the spatial agglomeration or diffusion of county economic growth is the manifestation of the relative difference change of economic growth.

Overall, the global STI values of China's county economic growth at all-time points were relatively high, suggesting strong spatiotemporal correlations. The STI value did not change drastically before 2007, indicating that the overall spatiotemporal correlation pattern from 2001 to 2007 had been stable. From 2007 to 2012, the STI value changed substantially, amidst declining overall agglomeration and strengthened diffusion effects. In 2012, the STI value sustained drastic changes, and the spatiotemporal agglomeration pattern was restrengthened.

3.3 | Evolution of local spatiotemporal correlation structure of economic growth

Global spatiotemporal correlation can be used to reveal the level of county economic growth. However, it may ignore spatiotemporal heterogeneity and fail to reflect local spatiotemporal correlations. For that reason, the local spatiotemporal correlation index STLI of county economic growth at forward third-order time length and first-order space lag was calculated using Equation 4. The spatial pattern evolution is presented in Figure 4. For visualization, the local spatiotemporal correlation index STLI in five-year intervals was selected and is presented in Figure 4. The local positive STLI of the county economic level in 2001, 2006, 2011, and 2015 were 78.07%, 77.59%, 79.42%, and 80.46%, respectively, which was consistent with the results from the global analysis. The proportions of the *HH*-type zone for the given years were 22.58%, 21.23%, 21.67%, and 23.23%. In those four time periods, 62.87% of the units' local spatiotemporal correlation did not change, indicating that most of the county economic growth appeared to have a stable correlation structure.

Overall, the local spatial correlation pattern of county economic growth in the four-time periods evolved steadily. The *HH*-type areas were mainly distributed along the eastern coastal regions and were particularly clustered in the Liaozhong southern city group, Beijing-Tianjin-Hebei city group, Yangtze River Delta city group, West-strait city group, and Pearl River Delta city group. The development axis in the east-west direction of the Longhai–Lanxin railway line, as well as the eastern coastal belt in the south-north direction, may develop in the future. The *LL*-type areas were scattered in the vast central and western regions. A large-scale *LL*-type zone in the north-south direction appeared in the transition zone from the eastern coastlines to the Beijing–Kowloon Railway Line, and then, connects into an *LL*-type fault zone, forming the so-called Jing-Shan Economic trough Belt (Li, Zhong, Huang, & Wu, 2015). The GDP, GDP per capita, and growth of the Jing-Shan Economic trough Belt had been below the national average. The construction of the Beijing–Kowloon Railway did not generate new areas of growth but instead caused several issues, such as slow growth and economic

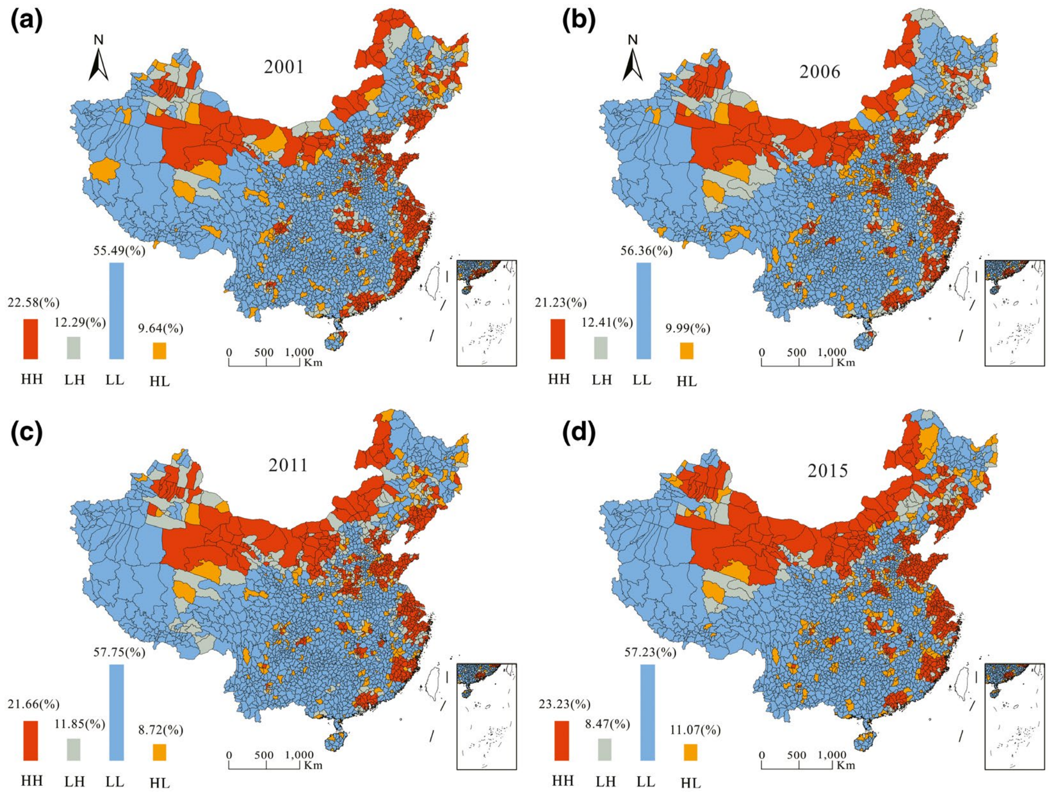

FIGURE 4 Evolution of local spatiotemporal correlation pattern of county economic growth

polarization. *HL* and *LH*-type regions were limited in number, changed marginally, and were mainly distributed around the *HH*-type county.

As shown in Figure 4, the number of *HH*-type spatiotemporal correlation regions in the Pearl River Delta city group decreased from 21 in 2001 to 16 in 2015, and the range of radiation diffusion also shrank during this period. Economic growth rates tend to contract from pressures of new cycles of industrial upgrading and adjustment. The number of *HH*-type counties in the Yangtze River Delta city group remained almost unchanged, which accounted for at least 78, and the economic growths of additional surrounding counties improved. The number of spatiotemporal *HH*-type counties increased in the Shandong Peninsula city group, Beijing-Tianjin-Hebei city group, and Liaodong peninsula areas. Northeastern spatiotemporal *HH*-type counties had been concentrated in the middle-south parts of Liaozhong southern city group. The central and western *HH* regions were mainly located in central cities of the Central Henan city group, the middle reaches of the Yangtze River city group, and the Chengdu-Chongqing city group. This region type decreased in number, indicating that the central region's economic growth had weak radiation effects, and the strategy of the rise of central China had achieved limited results. The spatiotemporal *HH*-type extended from the northwestern regions of the Lanzhou-Xining-Yinchuan city group to the northern economic zone of the Urumqi-Changji-Shihezi city group and has been expanding, due mainly to the economic growth effect brought by regional resource development and transportation improvements.

The spatiotemporal correlation type significantly changed in some regions. From a time, evolution perspective, the number of *HH*-type regions increased from 520 in 2001 to 535 in 2015, indicating that the radiation range was expanding. In recent years, the number of *HH*-type regions had significantly increased due to the impact of Inner Mongolia's economic growth, and the economic rebound in the Shandong peninsula city group and Liaozhong southern city group. The range of *LL*-type continued to expand. The periphery around the original *LL*-type pattern expanded from 1,278 areas in 1998 to 1,318 areas in 2015. The *LL*-type regions significantly outgrew other regional types, indicating that China still faced the arduous task of promoting economic development in backward areas. The number of *LH*-type spatiotemporal correlation regions decreased from 283 in 2001 to 195 in 2015, while the number of *HL*-type spatiotemporal correlation regions increased from 222 in 2001 to 255 in 2015.

3.4 | The spatiotemporal dynamics of economic development

The displacement direction of counties and cities was detected using LISA time trajectory displacement direction. The directional range of 0°–90° indicates positive synergetic growth of county unit and its neighboring units, while the direction range of 180°–270° indicates a corresponding negative synergetic growth. The 90°–180° and 270°–360° directional ranges indicate reverse growth between county unit and its adjacent units. As shown in Figure 5, the spatial distribution of counties and cities with positive and negative synergetic relation was consistent with the local spatial correlation pattern, reflecting a certain local locking or trajectory dependence.

The spatial geometric characteristics of LISA time trajectory for each county unit were obtained based on the local spatiotemporal correlation and were visualized by the natural break point method in ArcGIS 10.5 software. As shown in Figure 6a, the counties with the largest relative length of LISA time trajectories were mainly distributed in the Shandong peninsula region, Yangtze River Delta region, Pearl River Delta region, Hohhot-Baotou-Ordos-Yulin urban agglomeration, most of the counties in the Xilin Gol League, the Wuhan urban agglomeration, and the northwestern part of Qinghai province. This observation was consistent with the results of the local spatial correlation pattern. This

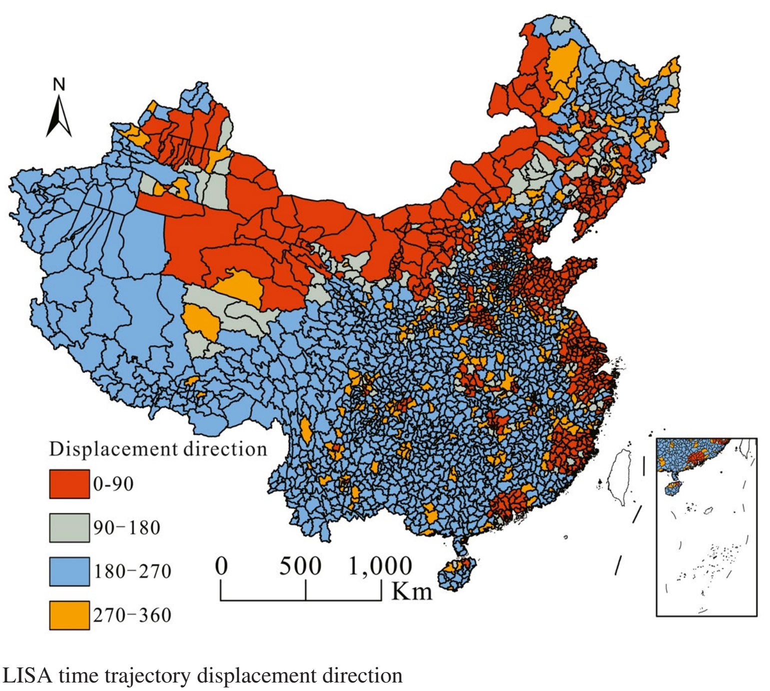

FIGURE 5 LISA time trajectory displacement direction

indicated that counties and neighborhoods within this range had more dynamic local spatial structure, more economic growth potential and vitality, and could achieve a higher level of economic growth. On the contrary, LISA time trajectory length was relatively short in most of the central and western China and most counties in northeastern China, indicating backward economic growth.

The region with longer LISA time trajectory relative length had a lower curvature value. As shown in Figure 6b, the counties with the highest curvature were scattered in regions along the Beijing–Kowloon railway, bilateral area of 110°E, the Hexi corridor region, southwest regions of Yunnan province, Urumqi-Changji-Shihezi city group, and Lanzhou-Xining-Yinchuan city group. These areas showed more volatile local spatial dependence and lacked the growth pole for sustained economic growth. The local space correlation in the eastern coastal counties had relatively lower curvature indicating stable spatial dependence, which resulted from having economically strong surrounding counties.

3.5 | Long-term evolutionary stability characteristics

The local Moran's I transition probability matrix and the spatiotemporal transition can be used to describe the transition of the county scatter in different local correlation types, and further reveal local spatiotemporal agglomeration characteristic of county economic growth (Rey, 2001). The transition of local spatiotemporal correlation types of county economic growth can be divided into four types: Type I represents the relative transition of a county, including $HH^t \rightarrow LH^{t+1}$, $HL^t \rightarrow LL^{t+1}$, $LH^t \rightarrow HH^{t+1}$, $LL^t \rightarrow HL^{t+1}$; Type II represents the transition of spatially adjacent counties while maintaining an unchanged state of the county unit, including $HH^t \rightarrow HL^{t+1}$, $HL^t \rightarrow HH^{t+1}$, $LH^t \rightarrow LL^{t+1}$, $LL^t \rightarrow LH^{t+1}$; Type III indicates the transition of both the county and the adjacent counties, including $HH^t \rightarrow LL^{t+1}$ and $LL^t \rightarrow HH^{t+1}$ (concurrent change), and $HL^t \rightarrow LH^{t+1}$ and $LH^t \rightarrow HL^{t+1}$ (incongruous change); and, Type IV represents no transition in county and adjacent counties. From the four types of division, the local spatial cohesion $S_t = \frac{F_{0,t}}{n}$ can be obtained, where $F_{0,t}$ is the number of transitions of Type IV in time period t, and n is the number of all possible transitions.

Based on the results of the spatiotemporal transition measurement, the LISA of China's county economic growth did not change significantly from 1998 to 2015. The proportion of the spatiotemporal Moran's I scattered in the same quadrant (IV type transition) was 93.44%, and the spatial cohesion of spatiotemporal Moran's I was $S_t = 0.934$. The number of Type I transition was the same with the

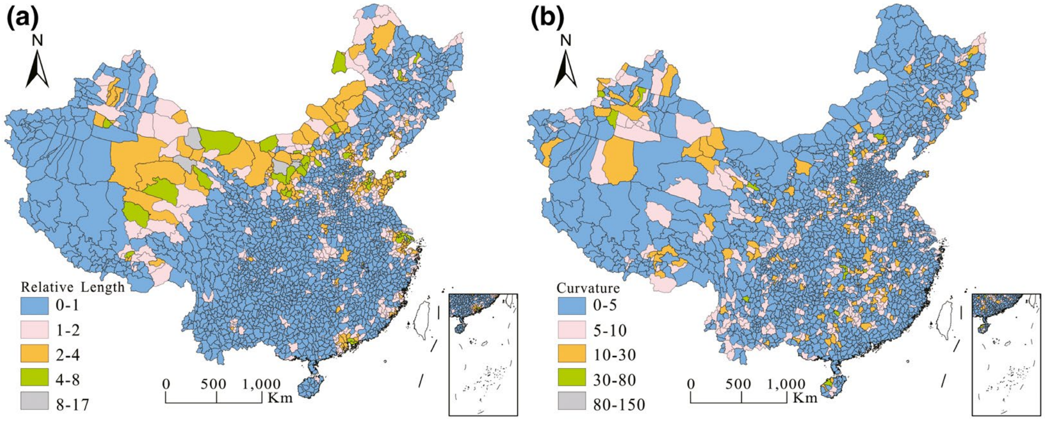

FIGURE 6 The geometrical characteristics of LISA time trajectories

number of Type II transition, which is 616, accounting for 3.15%; while the number of type III transition was 106, accounting for only 0.27%. According to the 1998–2015 Local Moran's I spatiotemporal transition matrix in Table 4, the transition between regional spatiotemporal correlation classes of the county was not immutable but may be moved upward or downward. The highest probability of being simultaneously transferred upward ($HL^t \rightarrow HH^t$) was 2.23%, while the highest probability of being simultaneously transferred downward ($HH^t \rightarrow LL^t$) was 9.07%. The probability for elements on the main diagonal of the spatiotemporal transition matrix to remain in IV type was at least 82.85%. The probability of $LL^t \rightarrow LL^t$ was highest at 96.47%, while the probability of $LL^t \rightarrow HH^t$ transition was only 1.46%.

3.6 | The driving forces of county economic growth

Before using the geographical detector method to detect the influencing factors of county economic growth from 1998 to 2015, the Natural Breaks classification method was used to convert all independent variables into categorical. Then, using Equation 5, the power of determinant values (q) was calculated, and the summary of results are presented in Table 5. All the influencing factors were significant at 1% level ($p < .01$). Based on the differential power of factors on spatial heterogeneity of economic growth, they could be ranked as: IND > INF > FIS > LABOR > FIX > TER > PRE > HR > ELE > FIN > TEM.

Based on the results, three natural factors (TEM, PRE, and ELE) were shown to have less influence on economic growth, with the impact power being less than 0.03. This validated Bukharin's conclusions suggesting that although natural differences in the conditions of production were essential, they receded more and more into the background compared with differences resulting from an uneven development of productive forces (Bukharin, 1972). With developments of productive forces, the logic behind geographic location retreated more and more from such natural considerations (Smith, 2008). In modern China, the space-time distance between regions is greatly compressed with the improvement of various modes of transportation, particularly the high-speed railway system. Also, most raw materials are not directly derived from mining or agriculture, which are highly labor-intensive. Thus, the impact of natural factors on county economic growth will continue to decrease.

Industrialization was shown to exert the most substantial impact on county economic growth, indicating that China's economic expansion is mainly dependent on industrial growth. Industry continues

TABLE 4 Space-time transition matrices for economic development

	HL	LH	*LL*	*HH*
HL	0.9418	0.0318	0.0042	0.0223
LH	0.0688	0.8285	0.1001	0.0026
LL	0.0021	0.0185	0.9647	0.0146
HH	0.0529	0.0030	0.0907	0.8534

TABLE 5 Results of geographical detector

	LABOR	FIX	IND	TER	FIS	FIN	INF	HR	TEM	PRE	ELE
q statistic	.0887	.0418	.1654	.0191	.0949	.0009	.1310	.0027	.0009	.0031	.0014
p value	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000

to play an extremely important role in the county economy, such that the county's level of industrialization directly determines its technological and economic status. In particular, the manufacturing sector has made increased contributions toward the acceleration of China's real GDP from 1996 to 2008 (Zhao & Tang, 2018).

Next to industrialization, informatization was revealed to have significant impact on county economic growth. Improvements in the level of informatization can directly increase the unit productivity of the factors. It can also promote the flow between the various elements in the county, which must be from sectors (or industries) with relatively low production efficiency to sectors (or industries) with high production efficiency, thus, increasing the county structure dividend.

The ratio of fiscal expense, the number of the labor force, the scale of fixed asset investment, and the proportion of tertiary industry had influencing power greater than 0.0100, indicating significant impact on county economic growth. During economic development, the increase in fiscal expenditure is usually conducive to providing the necessary support for economic growth, such as for infrastructure and public services. An abundant supply of labor constitutes a significant and sustained demographic dividend, providing strong support for rapid economic expansion. Fixed asset investment has a direct pulling effect on county economic growth. With continuous upgrading of the industrial structure, the proportion of tertiary industry will increase, which plays a vital role in optimizing industrial structure, promoting economic growth, and expanding employment.

More advanced production factors, including human capital and financial capital, had relatively little impact on county economic growth. This suggested that at the present stage most of the counties' economic growth had not eliminated its dependence on traditional production factors to remain in a state of relatively extensive mode.

4 | DISCUSSION

Exploring the space-time dynamics of regional economic growth is an essential geographic issue and a fundamental issue toward sustained economic growth (Qiao, Lee, & Ye, 2016; Ye & Wei, 2012). By doing so, we can evaluate the implementation effect of coordinated regional development policies, obtain reference for regional policy implementation and regulation, and provide full play to the radiation and driving function of growth pole (He, Ye, & Wang, 2012; Ye & Carroll, 2011). In this study, the time factor was primarily introduced into the exploratory spatial data analysis using the ESTDA frame via the LISA time path. The evolution of space mode on time, as well as the distribution of temporal behavior on space, can then be analyzed.

The disparity in China's county economic growth showed fluctuations from 1998 to 2015, while the spatiotemporal correlativity of county economic growth was relatively strong. The evolution of *HH*-type local spatiotemporal correlation, LISA time trajectory displacement direction range of 0°–90°, and the high value of LISA relative length exhibited a consistent spatial pattern. Also, the spatial cohesion of spatiotemporal Moran's I was higher than 0.9. These imply that the radiative interaction between developed and underdeveloped counties did not develop because of the rigid constraints of physical geographic boundaries, transportation and industry factors, and the lack of motivation for economic growth in the central and western regions. Thus, China's county economic growth may fall into local locking or path dependence. In the context of a stable spatiotemporal evolution, China's economic growth pattern of "east and central as a whole" will probably fail to develop in the future. Current efforts should be made to enhance the role of the Jing-Shan Trough Belt in linking the eastern and western regions so that the network channel connecting the east and central can be built.

By implementing a series of coordinated regional development strategies, such as China Western Development, the revitalization of the Old Industrial Base in Northeast China, the rise of central China, and One Belt and One Road (Sarker, Hossin, Yin, & Sarkar, 2018), regional inequality in county development has gradually decreased since 2013. The number and concentration of developed counties in the central and western regions have also expanded. New growth axis and growth poles are expected to arise, such as along the east side of 110°E and Longhai–Lanxin railway line, and regions of the Midwestern urban agglomeration. In these areas, county economic growth has shown great potential and economic vitality. In developing future economic policies, resources, and regulations should provide more incentives in these areas to take advantage of economic overflow and positive driving force, thus, forming an integrated pattern of coordinated economic development of surrounding counties.

The Geographical Detector Method found that the first natural factors had only circumstantial impact on county economic growth, the second nature factors provided the primary source of contributions toward county economic growth, and the emerging third nature factors did not play a significant role. Capital accumulation makes use of regional comparative resource advantages to form a differentiated productive industry or industry growth path, and thereby expanding growth differences. Although industrialization is still the main driver for economic growth, regional differences in horizontal development tends to decline with strong industrial migration from the eastern regions (Wu, Li, Sun, & Liang, 2014). However, inequality development trends have not shown significant reduction in vertical division of labor. This is due to emerging capital accumulation momentum (i.e., intellectual capital) that can recreate relative spatial difference to sustain social development and progress for social reproduction. The developed counties in the eastern coastal areas will more likely transform industrial capital into intellectual capital advantage and become new leaders in economic growth, and thus, further expand the inequality with the central and western counties.

5 | CONCLUSIONS

The spatiotemporal correlation pattern in economic growth was analyzed with the ESTDA framework using GDP per capita as an index. A total of 2,303 county-level administrative units were used in this research. The following conclusions were determined:

The inequality of economic growth among counties in China had generally been widening, and there was a strong positive spatiotemporal correlation among them. The change in spatial correlation was consistent with shifts in county development. The transition in relative inequality of economic growth was the result of spatial agglomeration or diffusion of economic development. The local spatiotemporal correlation pattern of county economies had relatively been stable. The high–high areas were concentrated in blocks of the eastern coastal area, while the low–low areas were scattered in the central and western regions. The numbers of high–low and low–high areas have changed marginally. The east-west development axis of the Longhai–Lanxin railway line and the eastern coastal north-south radiation belt may develop in the future.

Counties with more substantial changes in LISA time trajectory displacement length were mainly concentrated in the eastern coastal urban agglomerations, developed urban agglomerations in the central and western regions, and most counties of Inner Mongolia. In contrast, county LISA time trajectory for the majority of the central and western regions had short length, the economic growth lacked vitality, and their development was lagging behind. Regions with the largest time trajectory curvature were mainly distributed along the Beijing–Kowloon railway, near the 110°E, and in some counties of Tibet where stable spatial dependence were lacking. The consistent pattern of LISA spatiotemporal displacement and correlation reveals stability in the local spatial structure in China's economy growth. Results from the geographical detector model showed factors of the first nature only had marginal impact on county economic growth, factors of the second nature made large contributions to growth, and factors of the third nature showed very minimal effect. This indicates that the current county economic growth still relies heavily on the traditional economic growth model, which means continued dependence on labor and capital investment.

Exploring the spatiotemporal dynamics of county-level economic growth is beneficial to evaluate the implementation effects of coordinated regional development policy and reports a reference in formulating management strategies. Based on the significant spatiotemporal association of county economic growth, we suggest that the policy makers should establish a unified national market system, create systems, and mechanisms conducive to the free flow of production factors between regions, and optimize and guide the rational allocation of factors conducive to economic growth in space. Simultaneously, the county governments should rely on the local comparative advantages, actively participating in intra-regional and inter-regional cooperation and division of labor.

At present, to promote the coordinated development of eastern, central, and western regions in an orderly manner, the policy makers should vigorously promote the integrated development strategy of “east and central as a whole” to break the administrative division restrictions of economic development, establish and improve the coordination mechanism of regional economic development. The study further proposes that the development of the Jing-Shan Economic Trough Belt and road should be promoted as a national development strategy, construct a transportation network channel linking central and east China, improve the east-west linking function of Jing-Shan, thus, undertakes industrial transfer in the east. Furthermore, the realization of “east and central as a whole” should be supported by infrastructure integration, equalization of public services, and institutional integration, with market integration, factor integration, and industrial integration at its core.

Against the background of the Belt and Road Initiative, we propose to construct the westward circulation network and organizational node of the circulation of goods based on the west corridor to integrate the coordinated development of land and sea. More specifically, we recommend that actively cultivating the potential economic growth poles of the central and western urban agglomerations might promote the network and clustering of the urban system and drive the economic progress. In a similar context, the study proposes to optimize the strategic layout of the national agglomeration development axis, activates the growth axis of the bilateral side of 110°E and Longhai–Lanxin railway line, and further constructs the national agglomeration, including the Shanghai-Kunming Axle Belt, the Jinglan Axle Belt, and the Qingyin line, to drive the development of the northern hinterland of China and balance the north-south economy.

In terms of county economic growth itself, the rationalization of industrial structure is the main driving force for the economic growth in China's counties. Hence, the county governments should actively adapt to the industrial structure transformation and upgrading, to ensure that the channels for the flow of factors between various industries are unblocked, free allocation of factors, and to enable the factor inputs and the output being optimally allocated. Further, the county governments should accelerate the comprehensive service capabilities of information infrastructure and network construction, use of information technology and the constructed information network to promote agricultural, industrialization, urban construction, and ecological construction in counties. More importantly, county governments should emphasize innovation-driven development strategy, improve local quality of life to attract and retain high-quality talents and avoid the “siphon effect” of cities on counties due to China's overall industrial structure upgrade. The mentioned implications can be considered as essential steps to unlock the path dependence of economic growth and enhancing the sustainable development of county economy.

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