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Spatio-temporal Pattern Characteristics of Relationship Between Urbanization and Economic Development at County Level in China

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Abstract: The relationship between China's urbanization and economic development (RCUED) is an important concern nationwide. As important actors in regional strategy and policy, county-level regions have played an increasingly significant role in the development of China's social economy. However, the existing research on the RCUED lacks the fine depiction of the county-level administrative units. Using 2000 and 2010 census data and the statistical analysis method, we uncovered the evolution characteristics of China's urbanization and economic development and conducted a quantitative identification for the RCUED with improved methods using the quadrant map approach. In addition, we investigated the spatial correlation effect of the RCUED using the spatial autocorrelation analysis method. The results were as follows: 1) In general, a high degree of matching exists between China's urbanization and economic development at the county level at the significance level of 0.01. The correlation coefficients between China's urbanization and economic development in 2000 and 2010 were 0.608 and 0.603, respectively. 2) A significant regional difference exists in the RCUED at the county level. Based on a comparative analysis of 2276 county units in China in the two years, we found that county units can be categorized as under-urbanized, basic coordination and over-urbanized in various areas. No situation was observed where urbanization seriously lagged behind the economic development level, so the levels of urbanization and economic development appear to be basically coordinated, and the coordination state may be gradually optimized over time. 3) Over time, the spatial dependency of the RCUED has weakened and the spatial heterogeneity has increased. Northeast China has always been an area characterized by over-urbanization. The number of county units classified as under-urbanized has begun to decline in eastern coastal urban agglomeration areas, while counties rich in resources have transformed from having point-shaped over-urbanization to plane-shaped under-urbanization along the northern border, and the number of over-urbanized county units has increased in the middle reaches of the Yangtze River. 4) 'Lag-lag' type and 'advance-advance' type accounted for 68% of all counties in China, and these counties were shown to have obvious spatial differentiation characteristics.

Keywords: urbanization; economic development; relationship; spatial-temporal pattern; county; China

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1 Introduction

A close relationship exists between urbanization and economic development (Henderson, 2003; Bloom et al., 2008; Chen et al., 2009; 2013), whereby economic growth promotes the expansion of modern industries and changes the structure of the economy. As a result, the population shifts from the rural areas dominated by

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primary industry to urban areas dominated by secondary and tertiary industries. This process promotes the improvement of urbanization (Henderson, 1988). Urbanization also promotes economic growth by causing the population and industries to gather in and near cities, producing the scale effect (Li, 2017). So, the study of this relationship is the scientific basis for a country or region to formulate relevant strategies, which is a classic topic in geography, demography, economics, and other subjects (Chen et al., 2014). Since the beginning of the 21st century, China's urbanization and economic development have experienced rapid growth, but many problems have appeared, such as the destruction of resources and the environment (Chen et al., 2010; Cao et al., 2014), rural hollowing, land vacancy, increased risks with food safety and land security, and damage to cultural and natural heritages (Deng and Bai, 2014), accompanied by semi-urbanization (Lin, 2006; 2007). Although these problems have different causes, the relationship between urbanization and economic development has not been clarified clearly. At present, urbanization is a national strategy and is in the latter stage of accelerated development. China's economy has simultaneously entered into a critical transition period. Under this background, quantitatively judging the relationship between China's urbanization and economic development and exploring its spatial pattern evolution model would be theoretically and practically significant.

The RCUED has been a longstanding academic interest on which both domestic and overseas scholars have conducted many empirical tests. However, due to the uniqueness of China's urbanization model (Chan, 1992; Zhang and Zhao, 2003; Chen et al., 2013; Wang and Liu, 2015), and the complexity of the relationship, different scholars have varying opinions and inconsistent explanations on the understanding of the relationship (Chen et al., 2014). In general, there are three views on the RCUED: the mainstream view is that China's urbanization lags behind the level of economic development (Ebanks and Cheng, 1990; Dong and Putterman, 2000; Zhang and Zhao, 2003), which means that China was under-urbanized compared with other countries at similar levels of development before the Reform and Opening-up Policy in 1978 and its urbanization started to catch up to other countries in more recent years (Ebanks and Cheng, 1990), Chang and Brada, however, introduced an opposing view, stating that China was not under-urbanized prior to the reform; its urbanization lag only started to grow in the late period of reform despite mass rural-urban migration during this period (Chang and Brada, 2006). Chen et al. (2009) stated that no urbanization in China seriously lags behind economic development level. The lower urbanization levels match the lower economic development levels, which is categorized low-level coordination. Some scholars also think that China's urbanization process is too fast (Friedmann, 2006; Lu, 2007), and over-fast urbanization will seriously affect resources and the environment, and regard the process as the second 'Great Leap Forward' in China (Cao et al., 2014), which would have unprecedented destructive power. Especially since the late 2000s, the average annual growth rate of China's urbanization has reached 1.3%, which has exceeded the normal development track of urbanization, causing driven urbanization (Chen et al., 2010), and producing a series of regional deprivation behaviors (Fang and Liu, 2007). For methods are used for studying this relationship: (1) the quadrant scatter method (Chen et al., 2014), (2) selecting cross-sectional data for direct comparison (Xiong, 2009), (3) comparing the relationship using time series data (Li, 2017), and (4) using the panel data method (Chang and Brada, 2006). Different methods may produce different measurement results, which is one of the reasons for the divergent opinions on the RCUED. From the perspective of research objects, the empirical tests mainly focus on the international comparison of the relationship (Chen et al., 2009), the evaluation of relationship over a long time series in China (Chen et al., 2013), the provincial pattern of the relationship (Chen et al., 2014), and the comparative study of the relationship between different prefectures in a province (Xiu et al., 2017). In general, the existing studies on the relationship mainly concentrated on the national and provincial scales, lacking a microscopic and more detailed description. The analysis based on the individual provinces lacks nationwide consideration and comparison. In geography research, an increasing number of scholars is advocating that it is not appropriate to apply the same theory to different spatial scales. The development trends and underlying mechanisms of geographic phenomena may be different on different spatial scales (Overman, 2004). Therefore, studying the relationship on a small scale can compensate for deficiencies due to a large scale and can describe the relation-

ship more precisely, to better reveal the spatial dependency and spatial heterogeneity of the relationship pattern. In the current studies, the spatial evolution of the relationship is seldom covered; awareness of the spatial correlation pattern is rare. On basis of statistical and geographic information system (GIS) analyses, we first tried to answer the question: what have been the major patterns and changes in urbanization and economic development at the county level? Then, we identified the county pattern characteristics of the RCUED and summarized the RCUED (over-urbanization, under-urbanization, or basic coordination). We probed into spatial association characteristics of the RCUED. Finally, we investigated the change types of the RCUED at the county level.

Based on the previous research work, we used the 2000 and the 2010 national census data and statistical yearbook data, taking county areas as the research unit, in an attempt to accurately depict the RCUED, and to integrate the advantages of macro pattern research and micro scale evaluation. Compared to previous similar studies, our results provide better guidance for urbanization and economic development at the county level.

2 Data and Methods

2.1 Data

The population data used in this study were collected from the fifth and sixth national censuses conducted at the county level in 2000 and 2010. The administrative division system in 2000 was adjusted to be in accordance with that in 2010. After the adjustment, there were 2276 county jurisdictions in total. The Hong Kong Special Administrative Region, the Macao Special Administrative Region, and Taiwan Province were not included in this study due to missing data. Two key indicators were selected to measure the development level: gross domestic product (GDP) per capita and the urbanization level. Availability (there are two main ways to obtain Chinese population data: one, the comprehensive and detailed census data, but there may be time-lag, which means that such data can only be obtained in the years of census; two, the data recorded in the statistical yearbook, due to the incomplete and unspecific statistical indexes, the data is not sufficiently accurate, but it has fine real time performance. The statistics of census data is made based on the resident population, so it has relatively high quality, can fully reflect the mobility characteristics of the Chinese population, and precisely describe the urbanization level according to the resident population) and accuracy of data were the main considerations for selecting 2000 and 2010 as the evaluation years (for a long time, China has kept calculating per capita GDP with household registered population rather than resident population, thus overestimating per capita GDP in regions such as Guangdong and Shanghai with large influx of population, and underestimating per capita GDP in regions such as Hunan and Henan with large outflow of population, so it is hard to reflect the economic development level of a region. In view of this situation, the State Statistics Bureau issued the Notice on Improving and Regulating Regional GDP Accounting on January 6, 2004 according to the spirit of the 28th Executive Meeting of the State Council, which required all provinces, autonomous regions and municipalities calculating per capita GDP with resident population. But it is hard to accurately monitor the migrant population, so per capita GDP calculated based on population would always be overestimated or underestimated. The population census could provide the relatively accurate data on the resident population, so per capita GDP calculated based on which could be more accurate). In this study, the urbanization rate (urbanization level) refers to the ratio of urban population in a county to the total permanent population in the county (the demographic data are based on the permanent population rather than the household population, and was calculated using 2000 and 2010 censuses data), which was used to reflect the process and aggregation of population to urban areas. Notably, many potential explanatory variables exist for the level of urbanization, but economic development level is the most significant, which can be represented by per capita GDP, because the per capita GDP can explain as much as 75% of the variation in the urbanization level in most countries in the world. GDP per capita is a comprehensive index that is widely used by the United Nations (UN) and the World Bank to represent each country's economic development level, which is also a multi-dimensional index that reflects the structure of industry and salary income (Chang and Brada, 2006; Chen et al., 2014). Therefore, the economic development level is represented by GDP per capita, which is defined as the ratio of total GDP to total population. The GDP data in 2000 were derived from the *China County*

Statistical Yearbook (National Statistical Bureau of China, 2001a), *China City Statistical Yearbook* (National Statistical Bureau of China, 2001b), *China Statistical Yearbook for Regional Economy* (National Statistical Bureau of China, 2011a), and *China City Statistical Yearbook* (National Statistical Bureau of China, 2011b). GDP per capita was calculated without making adjustments for inflation because *Z*-score normalization was applied to the cross-sectional data used in this study. Using this method, GDP per capita data can be compared in ways that reduce the impact of changes in the consumer price index (CPI) on research results.

2.2 Methods

2.2.1 Quadrant scatter method

We applied the quadrant scatter method proposed by Chen et al. (2014) to the quantitatively judge the RCUED at the county level, which avoids some limitations in investigating the evolvement, diversity, and the incompatibility of a nonlinearity model generated using time-series data. The results obtained using the method can be more easily visualized. We used improved methods using the quadrant map approach by incorporating the degree of deviation to investigate the county pattern of the relationship between urbanization and economic development. The detailed processing steps are as follows:

(1) Prepare the data on per capita GDP (GDPP) and urbanization rate (URBAN) for each county unit.

(2) Standardize the per capita GDP and urbanization rate and formulate new variables, named ZGDPP and ZURBAN, respectively. The formula for standardization can be written as:

$$z = (x_i - \overline{x}) / s \tag{1}$$

where i is the observed data; $\overline{x}$ is the average value of x_i, $\overline{x} = \sum x / n$, and s is the standard deviation,

$$s = \sqrt{\sum (x_i - \overline{x}) / (n-1)} \tag{2}$$

(3) ZGDPP is defined as the X axis and ZURBAN as the Y axis. Generate a point set for the per capita GDP and urbanization rate of each county (ZGDPP, ZURBAN), and the quadrant scatter is displayed on this point set.

(4) The discriminant principle: $-0.1 \leq ZURBAN–ZGDPP \leq 0.1$ means that the relationship is a pattern of basic coordination, $0.1 < ZURBAN–ZGDPP \leq 0.5$ means that the relationship is a pattern of slight over-urbanization, $-0.5 \leq ZURBAN–ZGDPP < -0.1$ means that the relationship is a pattern of slight under-urbanization, $0.5 < ZURBAN–ZGDPP \leq 1$ means that the relationship is a pattern of medium over-urbanization, $-1 \leq ZURBAN–ZGDPP < -0.5$ means that the relationship is a pattern of medium under-urbanization, $ZURBAN–ZGDPP > 1$ means that the relationship is a pattern of sharp over-urbanization, and $ZURBAN–ZGDPP < -1$ means that the relationship is a pattern of sharp under-urbanization.

2.2.2 Spatial autocorrelation analysis

The spatial autocorrelation analysis method is based on the first law of geography, which is a quantitative measure of the potential interdependence used to investigate the structural mode of the spatial correlation of the entire study area. In this paper, the global spatial autocorrelation statistics measure Moran's I was used to verify the relationship distribution patterns between county urbanization and economic development level. Global Moran's I formula is written as (Gatrell, 1979; Li et al., 2012):

$$I = \frac{n\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_i - \overline{x})(x_j - \overline{x})}{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_i - \overline{x})^2} \tag{3}$$

where x_i and x_j represent the values of *ZURBAN–ZGDPP* for counties i and j, respectively; w_{ij} is the corresponding element of the spatial weight matrix w; and n denotes the number of cities and counties in the region. The values of I range from –1 to 1, where the sign represents the spatial autocorrelation type and the absolute value represents the autocorrelation intensity. When the value of Moran's I is 0, there is no spatial autocorrelation. The statistical significance of Moran's I is represented by Z-scores: $Z(I) = [I - E(I)] / \sqrt{Var(I)}$.

We applied the local spatial autocorrelation statistics measure local Moran's I (LMI) to reveal the heterogeneous features of the spatial differences. The LMI is calculated as (Anselin, 1995):

$$I_i = \frac{(x_i - \overline{x})}{\sum_i (x_i - \overline{x})^2} \sum_j w_{ij}(x_j - \overline{x}) \tag{4}$$

where county *i* is influenced by county *j*. Thus, LMI reflects the change trend in the spatial difference between the two counties.

3 Results

3.1 Evolution characteristics of county pattern for urbanization and economic development in China

Overall, China's urbanization and economic development maintained rapid growth in 2000–2010. In 2010, China's GDP and per capita GDP were 41.30 trillion yuan (RMB) and 30 876 yuan, respectively, increasing from 10.03 trillion yuan and 7942 yuan in 2000, representing annual increases of 15.2% and a four-fold growth in China's GDP and a 3.9 fold growth in per capita GDP. China simultaneously underwent large-scale urbanization (Yang et al., 2019), and the rate of urbanization has increased dramatically from 36.9% in 2000 to 50.3% in 2010, an annual increase in urbanization rate of 1.34 percentage points. The urban population increased from 0.46 billion to 0.67 billion, which is an average annual increase in urban population of 21 million.

A cluster analysis of the urbanization rate and per capita GDP was conducted for China in 2000 and 2010. Urbanization development can be divided into four stages according to the urbanization process introduced by Fang et al. (2008): the initial stage (urbanization rate <30%), the intermediate stage (30%–60%), the later stage (60%–80%), and final stage (80%–100%). Similarly, economic development level can be grouped into four categories according to the World Bank classification criteria for regional economy (Yang, 2011): low level regions (per capita GDP is less than 50% of the national average), lower-middle level regions (per capita GDP is 50%–100% of the national average), higher- middle level regions (per capita GDP is 100%–150% of the national average), and high level regions (per capita GDP is more than 150% higher than the national average). Based on the above criteria, the county-level pattern of differences between China's urbanization and economic development is depicted in Fig. 1.

(1) In 2000, most counties in China had a low urbanization rate, with obvious regional differences (Fig. 1a). Of all counties, 1577 were in the initial stage of urbanization, accounting for 69.3% of the total, with an average urbanization rate of 16.48%. These counties were mainly distributed in the southwestern Xinjiang, the Qinghai-Tibet Plateau, the Midwestern Loess Plateau, Huanghe-Huaihe-Haihe Region, the poverty belts around Beijing and Tianjin, and the hilly region in the southern China. Of all counties, 20.4% were classified as being in the intermediate stage, with an average urbanization rate of 41.9%. They were particularly distributed in the eastern coastal areas, border areas of Inner Mongolia, and three provinces in Northeast China. The remaining 10.3% counties were classified into the later and final stages of urbanization, of which 4.7% were in the later stage, and 5.6% in the final stage. These counties were mainly distributed in Northeast China with an advanced state-owned economy; Xinjiang, Inner Mongolia, and Qinghai, characterized by advanced industrial and mining industry; and Beijing, Tianjin, Shanghai, Guangzhou, and Shenzhen, characterized by advanced comprehensive economies (Liu and Yang, 2012; Wang and Li, 2016).

(2) Compared with 2000, the rate of county urbanization obviously increased in 2010, reaching 50.3% from 36.9% in 2000 (Fig. 1b). Of the four major regions, the rates in eastern, central, western, and northeastern regions reached 59.7%, 43.6%, 41.6%, and 57.6% in 2010 from 45.7%, 29.3%, 28.8%, and 52.4% in 2000, respectively, increasing by 14%, 14.3%, 12.8%, and 5.2% over the 10 years, respectively. The number of county units in the initial stage decreased significantly, from 1577 in 2000 to 821 in 2010, but these counties were still concentrated in the southwestern Xinjiang, Qinghai-Tibet Plateau, Loess Plateau, Yunnan-Guizhou Plateau, and the central Plain Traditional Agricultural Region. The number of counties in the intermediate stage obviously increased, exceeding 50% of the total number of counties, and showing a wider spatial distribution range and a more obvious plane-shaped distribution trend. The counties in the later stage and the final stage increased in proportion, reaching 13.3% of the total. These counties showed an obvious gathering momentum, and the high urbanization belt primarily formed along the eastern coastal areas.

(3) An obvious spatial variation in per capita GDP was observed at the county level in 2000 (Fig. 1c). The 'herringbone' shape regional pattern of high economic development was gradually highlighted, created by the counties along the northern border and in the eastern

coastal areas. The economic development of the counties along Beijing–Guangzhou Railway was significantly higher than that of the surrounding counties. These three belt regions jointly formed a high-value region of economic development in China. The low-value regions were mainly located in Southwestern Xinjiang, Qinghai-Tibet Plateau, Loess Plateau, Yunnan-Guizhou Plateau, and the Central Plain Traditional Agricultural Region.

(4) Compared with 2000, the disparity in county economy relatively decreased, and the variation coefficient of per capita GDP at the county level dropped from 0.841 in 2000 to 0.829 in 2010, which conforms to the spatial differentiation characteristics of China's economic development from unbalanced to gradually rebalanced trajectory (Fig. 1d). The current relatively balanced state is the result of the competition between eastern coastal areas, resource-rich counties, such as Inner Mongolia and Xinjiang, and the inland areas (Qi et al., 2013).

Through the analysis of the spatial patterns of county urbanization and economic development in 2000 and 2010, we found that county urbanization level highly matches the economic development level, which means that the high-value county urbanization rate regions are also high-value regions of economic development; similarly, the low-value regions in terms of county urbanization rate generally have relatively low economic development. The correlation analysis of county urbanization rate and per capita GDP for the two years were analyzed, and the correlation coefficients were 0.608 and 0.603 for 2000 and 2010 at the 0.01 significance level, respectively, and the above assessment was preliminarily verified.

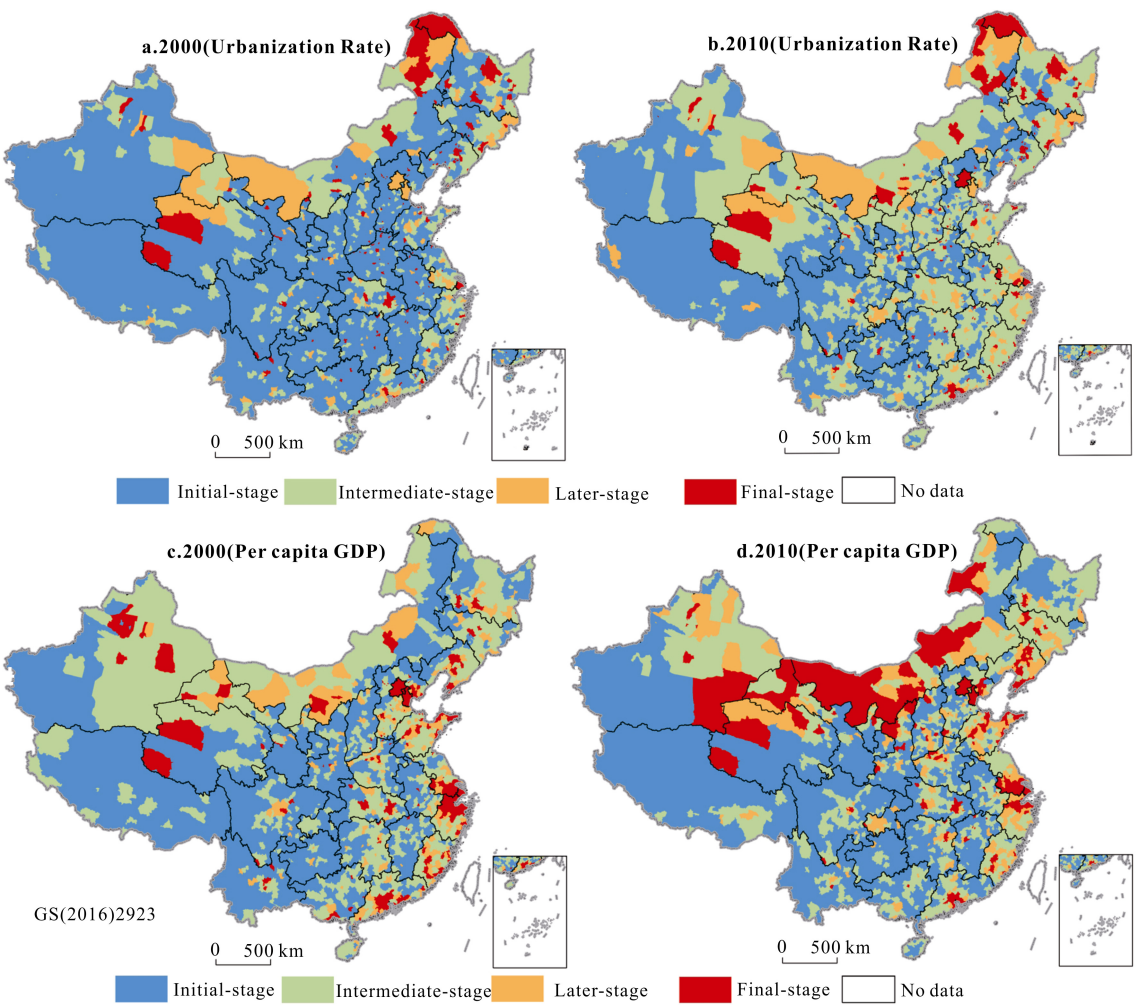

Fig. 1 The spatial patterns of China's urbanization and economic development at county level in 2000 and 2010

3.2 Quantitative identification of the relationship between China's urbanization and economic development at the county level

Using the quadrant scatter method proposed by Chen et al. (2014), the regions typifying the relationship between county urbanization and economic development can be divided according to the threshold setting criteria, so the 2276 counties in China can be classified into seven types (Table 1 and Fig. 2).

Table 1 shows that the number of the counties with slight under-urbanization, slight over-urbanization, and basic coordination in 2000 and 2010 ranked one to three among all types, respectively. These three types accounted for 64% and 60% of the total number of counties in China in 2000 and 2010, respectively. Many counties were classified as medium under-urbanization and over-urbanization, but only a few as sharp under-urbanization and over-urbanization. We spatially visualized the results to better identify the spatial distribution of each type (Fig. 2).

(1) Regions with sharp over-urbanization: in 2000, these regions were mainly concentrated in Northeast China, Western Inner Mongolia, and Western Qinghai. These regions had a mean urbanization rate of 73.8% and per capita GDP of 8068 yuan, which indicated that they were located in regions in the later-stage of urbanization and moderate-and high-levels of economic development. In 2010, except for some of the counties along the northern border that transitions from sharp under-urbanization to sharp over-urbanization, other counties maintained their distribution pattern. With an average urbanization rate of 81.1% and per capita GDP of 36 727 yuan, their urbanization development classified as the final stage, and economic development was at the lower level of higher-middle. The main reason is that as, an old industrial base, Northeast China has many state-owned enterprise employees and forest workers, but a lower agricultural population, which increases the urbanization rate (Wang and Li, 2016). The system and structural constraints have led to industrial structure aging, sluggish economic growth, and inadequate urban vitality. These are the reasons for the urbanization level being ahead of the economic development in Northeast China. It is worth noting that the Central Party Committee and the State Council made decisions on revitalizing the old industrial bases in Northeast China in 2003. The old industrial base revitalization strategy produced phased results. During 2000–2010, the average annual growth rate of GDP in Northeast China was higher than the national average. However, the urbanization growth rate was much lower than the national average. As a result, the number of over- urbanized counties in Northeast China decreased in 2010, especially in Liaoning Province. This is the result of economic revitalization in Northeast China, which has not changed the present situation where urbanization is ahead of the economic development in Northeast China. Western Inner Mongolia and Western Qinghai are resource-rich regions, which have the statistically virtual high urbanization and relatively high economic development. However, with the implementation of the Western Development Campaign and rapid economic development, this situation has significantly changed.

(2) Regions with medium over-urbanization: in 2000 and 2010, regions with medium over-urbanization were scattered. In general, more were distributed in counties in the midwestern China, and less was distributed in the counties along the eastern coastal areas. The urbanization rate and per capita GDP were 56.2% and 8574 yuan in 2000, and 56.6% and 28 717 yuan in 2010, respectively. The urbanization rates in the two years were higher than the national average. The economic development level was slightly higher than the national average in 2000, but lower than the national average in 2010.

(3) Regions with slight over-urbanization: these regions were mainly distributed in Mideastern Loess Plateau, Yunnan-Guizhou Plateau and Eastern Sichuan Basin in 2000. With an average urbanization rate of 30.4% and per capita GDP of 5106 yuan, the urbanization level

Table 1 The number of counties in seven types of the relationship between China's urbanization and economic development in 2000 and 2010

Type	Sharp under-urbanization		Medium under-urbanization		Slight under-urbanization		Basic coordination		Slight over-urbanization		Medium over-urbanization		Sharp over-urbanization	
Year	2000	2010	2000	2010	2000	2010	2000	2010	2000	2010	2000	2010	2000	2010
Number	146	152	278	309	568	508	414	363	480	486	180	261	210	197

was in the intermediate stage, and per capita GDP was classified into the middle level. In 2010, the spatial distribution considerably changed and such regions were mainly distributed in Loess Plateau, middle reaches of the Yangtze River, and Southwestern China, with an average urbanization rate of 50.2% and per capita GDP of 31 450 yuan.

(4) Regions with basic coordination: in 2000, regions with basic coordination regions were widely distributed in the Midwestern Loess Plateau, the middle reaches of the Yangtze River, Sichuan Basin, and the Yunnan-Guizhou Plateau, with an average urbanization rate of 21.8% and per capita GDP of 4461 yuan. The urbanization and economic development was much lower than the national average, categorizing the regions as having low urbanization and low economic development levels. In 2010, these regions extended to the eastern provinces and cities, but were still mainly distributed in Loess Plateau, the middle reaches of the Yangtze River, and the Yunnan-Guizhou Plateau, with an average urbanization rate of 41.5% and per capita GDP of 27 929 yuan. In 2000, the urbanization rate was 15.1% lower than the national average, but it was only 8.8% lower than the national average in 2010, and the per capita GDP accounted for 90.5% of the national average in 2010, a change from 56.2% in 2000. Basic coordination, compared with the condition in 2000, transitioned to a greater coordination state in 2010, and urbanization and economic development were showing potential.

(5) Regions with slight under-urbanization: in 2000 and 2010, most regions with slight under-urbanization were mainly distributed in the poverty belts around Beijing and Tianjin, Southern-Central Shandong, and the periphery of the Yangtze River Delta. A small number were distributed in three provinces in Northeast China and Inner Mongolia. In 2000, the urbanization rate was 26.7%, which was 10.2% lower than the national average, and the per capita GDP was 6785 yuan, which was 1157 yuan lower than the national average. In 2010, the urbanization rate increased to 34.4%, which, was 15.9% lower than the national average, and the per capita GDP increased to 25 815 yuan, which was 5061 yuan lower than the national average. These regions were classified as having both urbanization rate and economic development level slightly lagging behind the national average, but urbanization rate lagged more. The spatial distribution of these regions was deeply influenced by strong polarization and weak drip effects from central cities, national subject function localization, terrain, and other natural and socio-economic factors.

(6) Regions with medium under-urbanization: in 2000, regions with medium under-urbanization were mainly distributed in Southern-Central Hebei, Northwestern Shandong, and Central Henan, with an average urbanization rate of 28%, which was nearly 9% lower than the national average, with a per capita GDP of 9223 yuan, which was 1.16 times that of the national average. Compared with the situation in 2000, the county-level distribution of these regions considerably changed in 2010. In addition to Henan Province, they were also mainly distributed in Tibet and Southwestern Xinjiang, but fewer counties were distributed in other provinces and cities. The urbanization rate reached 44%, accounting for 87% of the national average, and per capita GDP reached 45 143 yuan, 1.46 times higher than the national average. The main reason for the differentiation in the time period is that the industries in the traditional rural areas are fragile and inefficient. The elements of production flow sluggishly, spatial aggregation is not obvious, and the urbanization progresses slowly. For Tibet, since the Democratic Reform in 1959, Tibet has made great progress in social and economic development. However, restricted by natural and economic conditions, the process of urbanization was relatively low (Fan et al., 2010).

(7) Regions with sharp under-urbanization: in 2000, these regions were mainly distributed in the urban agglomerations along the eastern coastal areas that already had a developed economy. The urbanization rate was 50.2%, 1.36 times higher than the national average, and their per capita GDP was 19 561 yuan, 2.46 times higher than the national average. Compared with the situation in 2000, the county-level distribution of these regions greatly changed in 2010; they were sporadically distributed in eastern coastal areas, but intensively distributed in county-level regions along the northern border in Inner Mongolia, especially the resource-rich county units. The urbanization rate was 45.8%, which was lower than the national average, and per capita GDP reached 72 752 yuan, which was far higher than the national average. The spatial variation of such regions in 2000 and 2010 was caused by different factors. In 2000, these regions were mainly distributed in the economically developed coastal areas with many township enterprises,

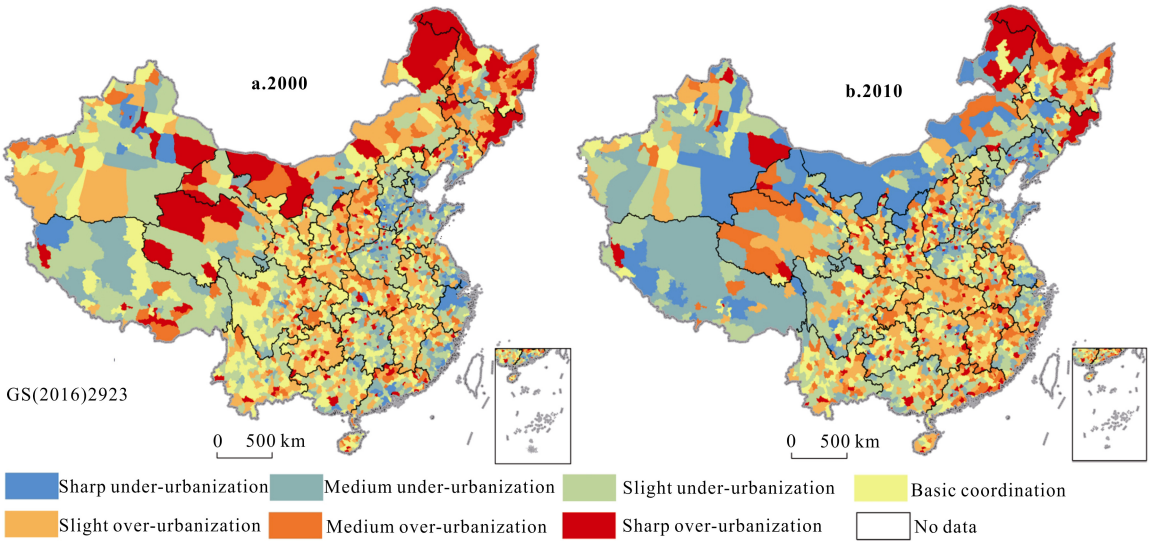

Fig. 2 The spatial pattern of relationship between China's urbanization and economic development at the county level in 2000 and 2010

advanced manufacturing industry, and high rural population in these regions. These regions represented by the 'Sunan Model', 'Wenzhou Model', and 'Pearl River Delta Model'. Some scholars classified them as the semi-urbanized regions (Lin, 2006). In 2010, under the Western Development Campaign, large scale development started for resource-rich cities. From 2000 to 2010, due to the development of mineral resources, large enterprises settled in these resource-rich counties, making the areas hot spots of economic growth in China. Although they had a high economic development level, the urbanization rate seriously lagged, causing the problems including economic structural imbalance and social development lagging. Therefore, decision makers and academic circles should focus on such matters (Qi et al., 2013).

Based on the above analysis on the development pattern of the RCUED, we drew the following conclusions:

(1) Except for the counties with basic coordination, there were 870 and 992 counties with over-and under-urbanization in 2000, respectively; in 2010, the corresponding numbers were 944 and 969. Regions of over-and under-urbanization coexisted at county level around China. Urbanization did not seriously lag behind the economic development level, but they were basically coordinated. This coordination state may be gradually optimized over time. The basic coordination between the provincial scale and the national scale on the RCUED was verified (Chen et al., 2009; 2014).

(2) Significant regional differences exist in the relationship between urbanization and economic development at the county level in China. Through the comparative analysis of 2276 county units in 2000 and 2010, China had different counties where the urbanization lagged behind economic development level, and counties where the urbanization was ahead of the economic development level. The degrees of lagging or advancing were different between different counties.

(3) In 2000 and 2010, the counties with over-and under-urbanization presented obvious spatial agglomeration features. In 2000, the eastern coastal urban agglomeration areas were contiguous areas with a lagging urbanization pattern. In 2010, this type had undergone some changes that were reflected in a reduction in the number of the type of counties in the eastern coastal urban agglomeration areas, and an increase along the northern and southwestern borders. Counties classified as over-urbanized were mainly distributed in Northeast China, the mideastern Loess Plateau, the middle reaches of the Yangtze River, and the Yunnan-Guizhou Plateau. The degree of centralization weakened in Northeast China and the mideastern Loess Plateau, but increased in the middle reaches of the Yangtze River.

3.3 Spatial autocorrelation of the relationship between China's urbanization and economic development at the county level

To further characterize the spatial correlation effect of the RCUED, a spatial autocorrelation analysis was con-

ducted to investigate the distribution of the RCUED in 2000 and 2010. As a result, we found that the relationship in the two years was positively spatially correlated at the 0.01 significance level. The Global Moran's *I* indexes were 0.2642 and 0.2346 for 2000 and 2010, respectively. This shows that the spatial dependency of the RCUED decreased, and the spatial heterogeneity increased. All characteristics identified in the quantitative identification analysis for the RCUED were verified (Fig. 3). For example, Northeast China has always been a predominantly over-urbanized area. The lagging trend of urbanization in the eastern coastal urban agglomeration areas has weakened, and the resource-rich counties along the northern border have transitioned to plane-shaped under-urbanization from point-shaped over-urbanization, and the over-urbanization of the counties in middle reaches of the Yangtze River further strengthened.

As for spatio-temporal changes of four types (H-H, H-L, L-H, and L-L), since there were few counties with H-L and L-H, and the spatio-temporal changes were not obvious, we only analyzed the spatio-temporal changes in L-L and H-H types.

(1) The L-L type: in 2000, the L-L type was mainly distributed in the Beijing-Tianjin-Hebei Urban Agglomeration, the Yangtze River Delta Urban Agglomeration, and the Pearl River Delta Urban Agglomeration. In 2010, the type began to shift to the Inner Mongolia and the Tibet Autonomous Region. The Beijing-Tianjin-Hebei Urban Agglomeration and the Yangtze River Delta Urban Agglomeration were driven by the optimization and upgrading of industrial structure, the large population agglomeration capacity, and the excellent public service quality, so the urbanization growth rate was faster than the national average (Table 2). As the urbanization level in the Pearl River Delta Urban Agglomeration was relatively high in both the base and end periods, which agrees with the convergence (the urbanization growth rate in the regions with low urbanization level is fast growing, while it is slow in the regions with high urbanization level) (Wang and Li, 2016). However, compared with the urbanization growth rate, the speed of economic growth in the three urban agglomerations was lower than the national average, caused by the shift in the economic development model that led to a slowdown in economic growth in more recent years in China, especially in the developed east coast regions. The relationship has undergone some drastic changes in Inner Mongolia. From medium over-urbanization in 2000 to medium under-urbanization in 2010, the urbanization growth rate was slightly higher than the national average, due to the economic growth being influenced by large-scale development of resources (Qi et al., 2013), whose growth rate was much higher than the national average. Restricted by natural and economic conditions, the urbanization development speed in Tibet was comparatively slow (Fan et al., 2010). With the implementation of the Western Development Campaign, the state financial transfer payments increased and other related policies were altered, thus making the speed of economic development slightly higher than the national average.

(2) The H-H type: in 2010, the H-H type was mainly distributed in Northeast China and the middle reaches of the Yangtze River. As an old industrial base, Northeast China contains many state-owned enterprise employees and forest workers, but a smaller agricultural population, which increases the urbanization rate (Wang and Li, 2016). For a long time, the deformed development in the industrial structure and the appearance of the 'Northeast phenomenon' affected the economic development (Liu and Li, 2009), both of which caused its economic growth rate to be lower than the national average. The urbanization was ahead of the economic development in the middle reaches of the Yangtze River. The lower economic development level was caused by many young and a middle-aged person escaping from the rural areas; new-type urbanization related-systems and policy innovation is insufficient. The strong population absorption capacity in the plain of Hubei and Hunan centered in Wuhan City led to the urbanization being higher than the national average.

3.4 Changing patterns of relationship between China's urbanization and economic development at the county level in 2000–2010

An overlay analysis on the RCUED at the county level in 2000 and 2010 was completed to explore the changes in the regional types in the 10 year period. The original seven types of regions were divided into regions of over-urbanization and under-urbanization according to the criteria $ZURBAN–ZGDPP>0$ and $ZURBAN–ZGDPP<0$, to reduce the complexity of change types. The regions were divided into four types: lag-lag,

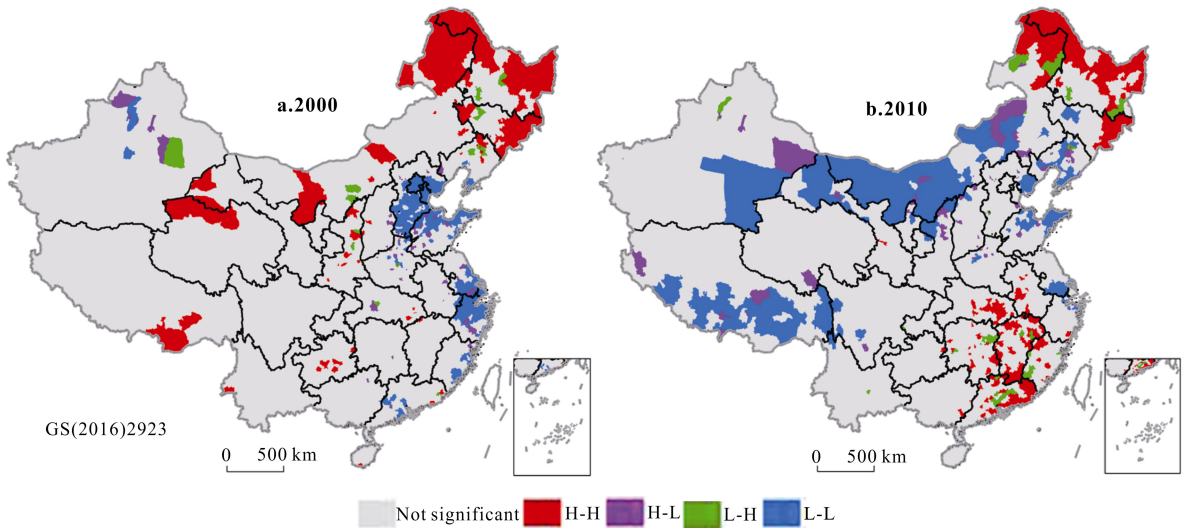

Fig. 3 Spatial autocorrelation of the relationship between China's urbanization and economic development at county level in 2000 and 2010

Table 2 The zoning statistics of the relationship between China's urbanization and economic development at the county level in 2000 and 2010

Name	Urbanization Rate (%)		Per Capita GDP (Yuan)		ZURBAN–ZGDPP		$ZURBAN_t$–$ZURBAN_0$	$ZGDPP_t$–$ZGDPP_0$
	2000	2010	2000	2010	2000	2010		
Beijing-Tianjin-Hebei Urban Agglomeration	38.97	56.15	10660.75	42283.80	–0.6189	–0.0966	0.403	–0.119
Yangtze River Delta Urban Agglomeration	50.36	64.95	14316.25	57356.85	–0.6781	–0.4563	0.143	–0.078
Pearl River Delta Urban Agglomeration	68.95	82.72	17574.00	67150.05	–0.0622	0.1898	–0.032	–0.284
Northeast China	52.33	57.61	9649.17	39500.99	0.7056	0.1950	–0.549	–0.038
Middle Reaches of Yangtze River	32.48	45.63	6003.09	24627.94	0.0921	0.3092	0.150	–0.068
Inner Mongolia autonomous region	42.92	55.67	5924.77	50901.89	0.9398	–0.7046	0.055	1.700
Qinghai-Tibet Plateau Region	21.98	30.41	4140.69	19600.60	–0.2499	–0.4676	–0.130	0.088

Notes: When $ZURBAN_t$–$ZURBAN_0$>0, it means the urbanization rate in a region is faster than the average speed of the country; when $ZURBAN_t$–$ZURBAN_0$=0, it means the urbanization rate in a region is equal to the average speed of the country; when $ZURBAN_t$–$ZURBAN_0$<0, it means the urbanization rate in a region is slower than the average speed of the country; and similarly, when $ZGDPP_t$-$ZGDPP_0$>0, it means the economic development in a region is faster than the average speed of the country; when $ZGDPP_t$–$ZGDPP_0$=0, it means the economic development in a region is equal to the average speed of the country; when ZGDPPt-ZGDPP0<0, it means economic development in a region is slower than the average speed of the country

advance-advance, lag-advance, and advance-lag (Fig. 4).

(1) In the lag-lag type, urbanization level lags behind the economic development level in 2000 and 2010. This type had a total of 824 county units, accounting for 36.2% of the total number of study regions. They were mainly distributed in Southeastern Liaoning, Shandong Peninsula Urban Agglomeration, and the Yangtze River Delta Urban Agglomeration. In 2000, the urbanization rate and per capita GDP were 27% and 8843 yuan, respectively, and the corresponding values in 2010 were 41.2% and 39 576 yuan. We observed that the urbanization rates in both years were 9% lower than the national average, but the per capita GDP was higher than the national average over the same period. In the future, these counties should strive to synchronize the urbanization rate with their economic development level. Specifically, the eastern coastal areas still need to promote the key leading role of human capital, attract immigrants, and play a role in advertising the superior geographical location. The central and western regions should follow the trend of optimization and upgrading of industrial structure and continue to emphasize the transformation and upgrading of the manufacturing industry and employment absorption capacity, and pay

close attention to the system feedback from resource and environmental factors.

(2) In the advance-advance type, urbanization level is ahead of the economic development level in 2000 and 2010. There were 725 county units in this type, which were mainly distributed in Northeast China, the Loess Plateau, and the middle reaches of the Yangtze River. The mean urbanization rate and per capita GDP for both years were 50% and 7095 yuan, and 60% and 29 667 yuan respectively, which indicates that the urbanization rate was about 10% higher than the national average in the same period, whereas per capita GDP was lower than the national average. According to the criteria for urbanization growth rate, the annual urbanization rate was 1%, categorized as medium and high speed growth. Therefore, these counties should be appropriately slowed down in terms of the urbanization growth rate. These counties should simultaneously improve their economic development level, pay more attention to the coordinated development between the productive service industry and the life service industry, increase awareness of environmental protection, and improve the carrying capacity for resources and the environment.

(3) In the lag-advance type, urbanization lags behind the economic development level in 2000, whereas urbanization was ahead in 2010. Only 409 county units were classified as this type. The urbanization rate and per capita GDP were 34.4% and 9464 yuan in 2000, and 52.85% and 33 287 yuan in 2010. In the 10 years, the average annual growth rate of urbanization increased by 1.84%, which is classified as rapid urbanization growth. In the future, the urbanization growth rate should be moderated, so that it can be coordinated with the economic growth rate.

(4) In the advance-lag type, urbanization was ahead of the economic development level in 2000, whereas urbanization lagged behind in 2010. The fewest county units, 318, were included in this type. In general, the eastern coastal provinces were less distributed, whereas the central and western inland provinces and cities were more widely distributed. In 2000, it was a 'double-low' advance type, meaning the urbanization rate and per capita GDP were low. In 2010, the per capita GDP was close to the national average, but its urbanization rate was 15% lower than the national average. In the future, these counties should continue to maintain a rapid economic growth, while improving the urbanization level so that the people in the middle and western regions can share the modernization.

4 Discussion

As the county is the basic administrative unit in China, the quantitative identification of the relationship between urbanization and economic development can be used to accurately analyze the relationship in each county from a microscopic perspective, and to grasp the overall relationship from a macro perspective. This has important guiding significance for coordinated urbanization and economic development. The improved quadrant method was used to reinvestigate the RCUED, which showed that the RCUED was basically coordinated. Our finding supports previous research conclusions (Chen et al., 2009; 2014). However, China's urbanization has been growing too fast in recent years. The urbanization turning point occurred in 2004, as the relative level of urbanization exceeded the relative economic development level (Chen et al., 2013). The rapid growth of urbanization has caused many problems and challenges. Firstly, in terms of urbanization speed, the improvement in the urbanization quality has been neglected, (Wang et al., 2011), resulting in low urbanization quality (Li, 2017). Secondly, the speed of land urbanization is much faster than that of population urbanization (Chen et al., 2013; Li, 2017). As a result, disorderly expansion of many cities and the occurrence

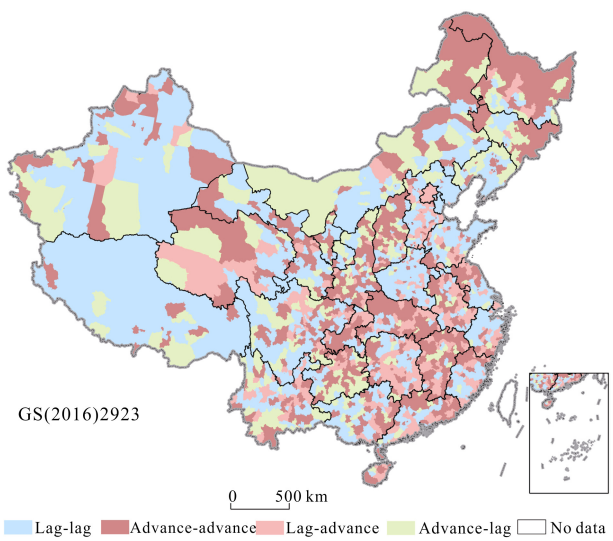

Fig. 4 The change types of the relationship between China's urbanization and economic development at the county level in 2000–2010

of 'city disease' have led to a large separation between homes and places of work, which has increased commuting time and urban environment pollution.

For simplification, we ignored the influence of the geographical features, such as topography, hydrology, climate, land area, population size, and economic density, on the relationship. In general, for differences in basic geographical features, a comparative study on the relationship could be conducted. A comprehensive consideration of the impact of multiple factors on the relationship is necessary and the impact should be corrected, given the impacts of the differences in the basic county conditions on the evaluation results, which would considerably improve the evaluation accuracy. On the basis of understanding the complexity of comprehensive evaluation, new evaluation methods should be explored. GDP per capita is often used as an indicator of economic development in development economics and is also one of the most important macroeconomic indicators. However, per capita GDP has deficiencies when used to characterize economic development, such as the high per capita GDP in most of the resource-based counties, but it cannot hide the low development level in social security, medical and health, education, environment, and ecological construction. The urbanization rate in these counties is not necessarily very high, so using per capita GDP alone to represent the economic development level is inaccurate. In the future, when evaluating the relationship, the composite index system should be considered in the selection of economic development indicators. In addition, the application of rational assessment methods (subjective empowerment and objective empowerment should be selected based on actual conditions) and scale indicators and efficiency indicators should be considered simultaneously to avoid blindness and omission in the selection of indicators.

We investigated the evolution patterns of urbanization and economic development, identified the RCUED, and examined the spatial association effect of the RCUED. The research conclusions provide information that may be useful for promoting the coordinated development of urbanization and economy according to local conditions. However, the formation mechanism of this relationship was not analyzed, and further studies are needed to theoretically explore how the spatial scale affects the relationship, and how healthy urbanization and spatial sustainable development can be implemented in reality (Chen et al., 2014). Due to the time-delayed nature of the data, we focused on the RCUED in 2000 and 2010 only; the latest RCUED was not analyzed, which may adversely affect on the formulation of strategies related to urbanization and economic development. Therefore, determining how to obtain comprehensive demographic data with better consistency in time and space and establish a perfect population spatio-temporal database are directions for future work.

5 Conclusions

Using empirical testing, we concluded the following: Firstly, China's urbanization rate and economic development level in 2000 and 2010 had an obvious difference in spatial distribution. The high-value regions were mainly distributed within eastern coastal urban agglomeration areas with strong population agglomeration ability, high economic development, excellent public service quality, and excellent infrastructure. The central and western regional center cities showed strong polarization and weak drip effects, as did some resource-enriched counties along northern border. However, a vast number of areas were undergoing urbanization and economic development depression, with poor natural conditions, serious population loss, negative economic development, poor public service, and inadequate infrastructure, such as traditional agricultural areas, old revolutionary base areas, land border areas, hilly and mountainous regions, and areas of severe stony desertification and desertification. The findings indicate that a high degree of matching between the urbanization rate and the economic development level. That is, the high value county-level urbanization areas were also the high value areas of economic development. Similarly, the low-value areas of county-level urbanization generally had relatively low levels of economic development, indicating a close relationship between urbanization and economic development. Secondly, the relationship between urbanization and economic development in China was basically coordinated, and this state may be gradually optimized over time. In China, the urbanization lagged behind economic development in some counties, and in others, the urbanization was ahead of economic development. Different counties were significantly different in regard to the degrees of lagging or advancing. There-

fore, studying the relationship between urbanization and economic development requires an overall recognition on the national scale to develop a scientific and rational strategy for urbanization and regional development, On the county scale, it is inappropriate to implement a unified urbanization policy in China. The relationship between urbanization and economic development should be clarified according to the actual conditions in each county, providing county-specific guidance and promoting the harmonious development. Thirdly, the spatial dependency of the RCUED has weakened and the spatial heterogeneity has increased. Northeast China has always been a centralized area of over-urbanization in China. The number of under-urbanized county units has begun to decline in the eastern coastal urban agglomeration areas, while counties rich in resources have transformed from over-urbanization into under-urbanization along the northern border, and the number of over-urbanized county units has increased in the middle reaches of the Yangtze River. The change types with respect to the RCUED at the county level were mainly lag-lag and advance-advance, followed by the lag-advance and advance-lag types. We proposed countermeasures and suggestions for future development, showing that our findings provide important guidance for the formulation of regional urbanization and economic development strategy.

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