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Research Article

The Spatial-Temporal Dynamics of China's Changing Urban Hierarchy (1950–2005)

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This paper examines the dynamic spatial and temporal patterns of China's urban hierarchy from 1950 to 2005. We limit the study to mainland China's 137 urban agglomerations of 750,000 or more population as of 2005. The paper improves upon a classic approach to measuring shifting ranks within an urban hierarchy by applying advanced spatial analysis techniques. We use a Getis-Ord G_i^*, a space-time Moran scatter plot, and dynamic LISA paths to examine the regional difference and change for these urban agglomerations. Our study revealed a north-south divide in the changing urban hierarchy of China after 1990. The analysis demonstrated that the spatial and temporal shift of urban dominance in China was closely associated with policy and economic factors. The paper concludes with a discussion of the differences across the six different time periods of change from 1950 to 2005.

1. Introduction

The United Nations estimates on urban population show that China has urbanized rapidly between 1985 and 2005 with a 23 percent urban population in 1985 that had grown to 40 percent by 2005 [1]. This is even more remarkable when considering newer 2011 estimates that show 311,760,000 people living in China's 237 urban agglomerations with 500,000 or more population [2]. This makes China the country with the world's largest population living in large urban agglomerations. A number of warnings often accompany such world urban comparisons, especially when Chinese cities are involved as they are often overbounded—that is, referring to a larger territory, which may include a substantial rural population [3]. The use of an urban agglomeration definition by the United Nations lessens these concerns as it is a more standardized measure. An urban agglomeration is composed of a contiguous territory of a built-up area with urban density levels regardless of the placement of administrative boundaries [4]. Therefore, it is safe to say that China's recent urban growth is spectacular in both contemporary and historical contexts.

Under this background, our study aims to examine the dynamic spatial and temporal patterns of China's urban hierarchy from 1950 to 2005. We limit the study to mainland China's 137 urban agglomerations of 750,000 or more population as of 2005. Since 1950, China's population has experienced steady growth. Although the urban population grew dramatically particularly after the 1990s, there was a considerable variation in growth rates among these urban agglomerations. As a result, China's urban agglomeration hierarchy has changed significantly in this period as some urban agglomerations have ascended while others have descended.

Mapping population change for these urban agglomerations is dismissed at the outset of this paper as population change is not necessarily related to rank changes as an urban agglomeration can actually decrease in rank even though it has increased in population, for instance, the latter can happen if an urban agglomeration lower in rank has increased its population at a faster rate. To overcome the shortcoming of mapping population change as a way to visualize change in urban dominance, this study uses a rank mobility index (RMI) for analyzing the rank changes for China's urban agglomerations [5, 6]. An RMI compares the change in rank of cities within a city system between two points of time instead of strictly comparing population change. Therefore, the RMI can capture the dynamics

of urban ranks in relation to population changes. Please refer to Section 3 for details on the computation of RMI values. Based on the urban population of the 137 urban agglomerations from 1950 to 2005, we mapped the RMI values and examined the rank change dynamics using local spatial autocorrelation techniques—Getis-Ord G_i^*, space-time Moran scatter plot, and LISA path. The results helped reveal regional differences in the changing picture of China's urban hierarchy. They also demonstrated the great potential of using the RMI to explore China's urban hierarchy in the path of this spectacular urbanization process.

The remainder of the paper is organized as follows. The second section reviews other studies on China's urbanization and its urban hierarchy. The third section describes our research methods. The fourth section discusses our results and findings. The last section concludes the paper with a discussion of the significance of our findings and future work.

2. Background and Related Work

2.1. China's Urbanization. The United Nations Population Fund (UNFPA) noted that for the first time in human history, the world's urban population had surpassed the rural population in 2008 [7]. On this news, China's rapid urbanization rate began to attract the world attention as it was clearly a large player in the global trend. When China was established in 1949, there were only 132 cities (defined by local administrative and jurisdictional entities) with a total of about 39.49 million urban population, about 7.3% of the country's population [8]. Owing to economic reforms and globalization, China's urbanization started to accelerate since the 1980s. In 1980, only 51 cities had half a million inhabitants in China. Another 50 cities joined this group between 1980 and 1995 and 134 cities were added between 1995 and 2010 [9]. Although the overall population growth has slowed down, China's 2010 census revealed that nearly half of the country's population, 49.7%, now lived in its urban areas compared to just 19% in 1980 [10].

While the rapid pace of urban development in China was widely understood to be a result of economic development, economic factors were not the sole determinant in China's urbanization process. Based on a decade of research on Chinese urbanism, Kirkby argued that Chinese urbanism was more of an ideological result than one of economic considerations in the early stages and such a situation changed after the open-door policy, which emphasized economic growth that started to be implemented in late 1978 [11]. Still, as pointed out by Fan, compared to Western countries, China's city system has been shaped more by institutional factors than by economic factors. Urban and regional development policies, changes in the urban administrative system, and state and local government interests together all played an important role in China's city system today [12]. Lin also noted that as the centers for economic and social transformation, the development of cities in China was largely attributed to both growth and nongrowth considerations [13].

Starting from a planned economy and migrating to a market economy with Chinese characteristics, the Chinese government played an important role in its urbanization process. Zhao divided the course of urbanization in China into four stages: (1) Recovery Phase (1949–1957); (2) Capricious Phase (1958–1965); (3) Stagnant Phase (1966–1982); and (4) Rapid Development Phase (1983–now) [14]. In the first three stages, the central government dominated the urbanization plans and policies. Local governments had very limited power in the decisions of their development. Seeking a fast industrialization of the economy, the first five-year plan (1953–1957) pushed the urbanization process mainly by incentivizing peasant immigration to cities in the recovery phase. During the capricious stage, the Great Leap Forward plan created a chaotic urbanization process. During the first three years (1958–1961), millions of people flushed to cities under the flag of economic expansion and later on were ordered to go back to the country as a consequence of famine. Yet the 10-year Cultural Revolution from 1966–1976 heavily destroyed the economy. The urbanization level was brought down to about 8.5% in the third stage [1]. In the fourth stage the economic reform empowered local governments in their economic development. The implementation of the open-door policy in 1978 and thereafter the publication of the regulations on temporal urban residents brought more opportunities to cities. These policies triggered and pushed waves of peasant immigrants to seek jobs in cities. China's urbanization then accelerated at a pace and scale never seen before in world history.

The fast movement of urbanization in China sparked excitement and interest among urban scholars on the underlying factors, patterns, and implications of urban change, as well as inquiring into the impacts, ranging from political, social, and economic issues, to environmental, housing, migration, and other urban land use challenges, and so forth [15, 16]. It is worth noting that in studying China's urbanization, scholars have called into question the reliability of the data. Lin pointed out that while the official data are subject to error and discrepancy, they do serve as a useful source for understanding the overall trends patterns, and changes of Chinese cities [17]. Concerning the inconsistency of urban definition and urban population data in China, Shen has done extensive work on clarifying and estimating the urban population of China [18–21]. Based on the concept of dual-track urbanization, he proposed an approach to estimating urban agricultural and nonagricultural population separately. He argued that because of the mixed character of development from a planned economy to a market economy in China, a comprehensive dual-track urbanization approach would provide a more realistic estimation of urban population in the transition. His studies provide valuable insights on determining urban population more consistently.

Lin analyzed changes in nonagricultural land as a result of China's urbanization between 1984 and 1996 [17]. He found that in most cases, small- and medium-sized cities experienced higher growth rates and claimed more land for urban expansion than did larger cities. In particular, he found that about two-thirds of urban land increases were

concentrated in East China. Among the superlarge cities (with a population over 2 million), there was a clear pattern of change that could be discerned moving from east to west. Cities in the east had the highest increase of land area, followed by the cities in the central, and the smallest gains in land area were within the cites of the western regions. In a very recent study, Ding examined the overall urban growth pattern in China [22]. It provided a comprehensive assessment of emerging urban forms and their impacts on urban sustainability. He suggested that to promote smart growth, mixed land use development may not be appropriate in the case of Chinese cities.

Focusing on the Yangtze River Delta megapolitan region, Tian et al. investigated the spatial and temporal dynamic pattern of urbanization process in five urban areas (Shanghai, Nanjing, Suzhou, Wuxi, and Changzhou) from 1990 to 2005 [23]. Their findings suggest that policy and economic development in that megapolitan region shaped the urban growth pattern and pace within the region's individual urban areas. In a study of another fast growing megapolitan region, the Pearl River Delta, Ouyang et al. analyzed the relationships between cropland, population, GDP, and urbanization [24]. They argued that urbanization in that area boosted the agglomeration advantages found in the national and international economy.

Focusing on urban influence, Liang applied the gravity model to examine the geometric characteristics of urban influence domains of 670 cities in China [25]. The study identified unbalanced regional patterns of China's urban development as a result of differences in national conditions and economic development. Based on the urban influence of the cities, this study further attempted to divide China into 13 economic regions. In a recent study, Ho and Li analyzed the change of urban output per capita from 1984 to 2003 [26]. They found that cities with comparable output per capita tend to be in the same region. Their findings suggest that if the current economic development pattern continues, the regional difference is unlikely to change.

2.2. Studies on Global Urban Hierarchies and China's Urban Hierarchy. One of the well-known tools used to study urban hierarchies is Zipf's law, first proposed by Harvard's linguist George Kingsley Zipf, which states that a city's population size and rank are closely related and that city rank-size distributions can be represented by a log-normal distribution [27]. Zipf's law has been applied extensively to the analysis of urban hierarchies in many countries [28–31]. While Zipf's law was supported by some empirical evidence in city rank-size distributions throughout the world, there were also violations [32, 33]. Autocorrelation in city growth rates could cause deviation from the linearity in the log-normal distribution, thus violating Zipf's law [33]. Although Zipf's law has been used to analyze the evolution of city size distribution, it did not address rank changes in an urban system over time. In order to account for the variability in the movement of city ranks, Markov's chain models have gained wide popularity and have been applied to analyze the evolution of city size distributions [34–38].

A Markov chain model is a discrete process model. The model assigns cities into a set of initial states (or classes) based on their sizes. Then it defines a transition probability matrix to estimate the evolution of city sizes over time. Based on the relative frequencies of the changing of classes between consecutive time periods, the model can estimate the number of cities in each size class over time. Therefore, the transition probability matrix is essential to characterize the dynamics of city rank changes [33]. In the simplest Markov model, the change of a city's state at the next time period depends solely on its current state. Some research has attempted to incorporate the influences from neighbors, for example, integrating with cellular automata models [39]. Based on state changes, Markov's chain models can suggest the up and down in the movement of city ranks, in other words, the trajectories of individual cities. Upon examining the locations of the cities that changed their states, it is possible to investigate if there are any spatial/regional patterns of such changes [38]. In addition, to reveal the evolution of city states in the past, Markov's chain models help suggest possible long-run tendencies in city hierarchies.

Examining China's changing urban hierarchy could help shed light on urban and regional development policies influencing urban growth. While there is an increasing interest among urban scholars on China's urbanization, studies on its urban hierarchy are limited. In the 1980s, an early study by Zhou and Tang divided China's cities and towns into 17 classes and examined their territorial sizes from 1964 to 1980 [40]. Their study suggested that while medium and small size cities grew more rapidly, the government controlled the growth of large cities. They also found that there was no direct connection between urban territory size and urbanization level. The latter study provided some insights into the factors that affected the urban size before the economic revolution started. In a later study, Chen investigated China's city hierarchy, urban policy, and development in the 1980s [41]. Chen's study noted the growing discrepancy in socioeconomic development between inland and the coastal region due to policy preferences.

Using city-level data from 1991 and 1998, Song and Zhang examined China's city size and the evolution of the city system [42]. Based on the Pareto law or the rank-size rule, they analyzed city size relative to city hierarchy. Their study suggested that China's cities became more evenly distributed among size groups in 1998. They also found that larger Chinese cities tended to be more evenly distributed in size than smaller cities. Although their study demonstrated that the distribution of China's city sizes can be well explained by the Pareto law, it did not seek to examine the dynamics of the changing urban hierarchy. In a more recent study, Zhou and Yu analyzed China's city population based on 2000 Census counts and attempted to build an urban hierarchy of China's cities [43]. To examine the competiveness among Chinese cities in 2000, Jiang and Shen built a four-level indicator system to compare the competitiveness of 253 Chinese cities at the prefecture level or above [44]. The findings showed the sharp gap between the east and west. Most of top 20 cities are located in eastern

China while the bottom 20 cities are mainly in western China.

Furthermore, to assess the spread and backwash effects in the Chinese urban hierarchy, Chen and Partridge applied central place theory to examine the heterogeneity in urban growth [45]. They found that at the cost of smaller cities and rural communities, the megacities of China grew fastest, while positive spread effects were identified in the growth of medium-sized cities. A recent study by Chan pointed out the lack of spatial agglomeration in China's urban system [46]. From the perspective of economic efficiency, he suggested that a freer migration policy could help develop an urban system with fewer but larger-size cities. Such a system could likely better fit the diversity in regional and local development.

Among these studies, territory size, economic indicators, and population were the typical variables used to determine urban size and growth. Few of them examined the spatial and temporal dynamics of urban rank changes in China. Most of these studies also focused on cities instead of urban agglomerations. Because city boundaries are often determined by political factors, the definition of urban agglomeration is more precise [8]. Based on the extended area of cities, particularly in China, urban agglomerations provide a more objective and standard way to represent urban dimensions. Furthermore, as discussed earlier, population change does not necessarily suggest a rank change as an urban agglomeration can actually decrease in rank even though it has increased in population. An urban agglomeration lower in rank could have increased its population at a faster rate. RMIs have the advantage of revealing such hidden facts. This quality is not usually captured by Zipf's law and Markov's chains. It is worth noting that it is possible to integrate RMI with Markov's chains to investigate the changes though. However, it is beyond the discussion here. In this study, we will only focus on exploring the spatial and temporal pattern of RMIs. Based on the RMI values from 1950 to 2005, our study would provide a better picture of the changing dominance of urban areas and also reveal the regional pattern in both historical and contemporary contexts.

3. Methodology

3.1. Data. Our study is based on the 2007 United Nation (UN) population database [1]. The database provides population size in 5-year increments for urban agglomerations with 750,000 inhabitants or more in 2007 from 1950 to 2025. We limit our study to mainland China by excluding Hong Kong and Macau. In total, 137 urban agglomerations were included in this study. Although much has been written on the problem of city definitions in China, we prefer the current UN urban agglomeration list even though we recognize its limitations as highlighted by Chan [47]. We hope by only analyzing these urban agglomerations within China that we minimize the problem as we are not comparing across countries where no international standard exists. The UN defines urban agglomeration as the "population contained within the contours of a contiguous territory in-habited at urban density levels without regard to administrative boundaries" [4]. Under this definition, an urban agglomeration includes both the city and its adjacent suburbs. It is worth noting that in order to provide consistent population estimates over historical time periods, the UN may adjust the historical population to conform to the current definition [48]. In addition, when only population for metropolitan area or city proper is reported by a country, the UN may adjust the data to conform to the urban agglomeration concept [9]. Therefore, using urban agglomerations could help lessen the concerns of inappropriate inclusion of nonurbanized area when comparing the urban hierarchy in China. Nevertheless, it is not to say that using the UN's data frees one of these known problems. The dual-track approach proposed by Shen could help improve the data, but such an intensive exercise applied to the entire urban system of China is beyond the scope of this paper [20].

3.2. Rank Mobility Index (RMI). Rank mobility index (RMI) is a measure of a city's change in population rank among a group of cities [5, 6], as in

$$M = \frac{R_1 - R_2}{R_1 + R_2}, \tag{1}$$

where M is the RMI, R_1 is the city's rank at the beginning time—time 1—, and R_2 is the city's rank at the end of a time period—time 2. An RMI value can range from -1.0 to $+1.0$. A negative RMI value indicates a decrease in rank, whereas a positive RMI value reflects an increase in rank. An RMI value of 0 indicates no change in rank. Based on the RMI definition, we can see that a city's population may be growing, but the RMI of the city may be negative as other cities can grow faster and overtake the rank of the city. Therefore, the RMI is a good measure for representing the change of state in an urban hierarchy.

To calculate RMI values, we first ranked the 137 urban agglomerations by their populations for different years from 1950 to 2005. Then we computed the RMI values for the urban agglomerations from 1950 to 2005 in 10-year increments with the exception of the time period from 2000 to 2005. In summary, we obtained RMI values for six time periods: 1950–1960, 1960–1970, 1970–1980, 1980–1990, 1990–2000, and 2000–2005.

3.3. Getis-Ord G_i^*. Mapping the RMI values of the urban agglomerations for the six time periods could show the spatial variations of urban rank changes. However, it does not shed light on any possible trends or clustering of the RMI values over time. Therefore, we further used Getis-Ord G_i^* to explore the spatial and temporal pattern of RMIs [49]. Getis-Ord G_i^* is a local spatial autocorrelation measure defined as

$$G_i^* = \frac{\sum_j w_{ij} x_j}{\sum_j x_j}. \tag{2}$$

The G_i^* is standardized as

$$Z(G_i) = \frac{G_i - E(G_i)}{SE(G_i)}, \tag{3}$$

where x_i is the attribute value of an observation i, $i = 1, \ldots, n$; w_{ij} is the spatial weight between observation i and j; $E(G_i)$ is the expected value of G_i; $SE(G_i)$ represents the standard deviation of G_i; $Z(G_i)$ is the Z-score of G_i^*. There are different ways to define spatial weights. Given that the western most city (Urumqi) is separated far from the others, we set the distance from Urumqi to the closest city as the threshold to search for neighbors. All urban agglomerations located within such a distance are weighted equally.

Different from LISA statistics, Getis-Ord G_i^* is better at suggesting the clusters of high RMI/low RMI values. Although LISA statistics can also be used to reveal hot/cold spots, it is based on the difference between the value of an observation with the average value. Because we are more interested in identifying the pattern of increase or decline in urban ranks in different regions in China, we chose Getis-Ord G_i^* to perform the analyses. A positive high Z-score indicates clustering of high values, whereas a negative low Z-score indicates clustering of low values. We calculated Getis-Ord G_i^* statistics of the RMIs for the six time periods, respectively. Based on the results, we expect to identify any regional effects on the change of urban dominance over time.

3.4. Space-Time Moran Scatter Plot and LISA Path. Recent development in exploratory space-time data analysis provides some other tools that could help further investigate the temporal dynamics of China's changing urban hierarchy [50]. Space-time Moran scatter plot, built upon the concept of spatial Moran's I scatter plot, is used in this study to compare the difference in the temporal changes of RMI values of the 137 urban agglomerations. Moran scatter plot, originally introduced by Anselin [51], is commonly used to plot the relationship between a location's value and its neighboring values. The scatter plot plots the variable of interest on the X-axis. The Y-axis represents the weighted average (or spatial lag) of the corresponding neighboring values. Therefore, the scatter plot can indicate how similar an observation is to its neighbor's. Based on the concept of Moran scatter plot, we can create a space-time Moran scatter plot based on the RMI values of one time period and their spatial lags at the previous time period. We selected 1990–2000 and 1980–1990 to compare because the G* maps suggest that a dramatic turn of urbanization occurred during the 1990s. The RMI values of 1990–2000 are plotted on the X-axis. Then instead of plotting the spatial lags of the neighboring values in the same time period, we plot the spatial lags of the RMIs of 1980–1990 on the Y-axis (Figure 6). Therefore, the plot would reveal how the ranks of urban agglomerations changed compared to their neighbors from a temporal perspective. The slope of the regression line in the plot indicates the overall strength of such a relationship in general.

The four quadrants in the scatter plot would suggest the difference in the temporal paths of RMIs for each urban agglomeration. For example, the first quadrant includes all urban agglomerations that experienced the increase of ranks from 1990 to 2000 while their neighbors all had growth in the previous time period. This could suggest a regional spillover effect and an overall growing pattern. The second quadrant represents the urban agglomerations that had a decrease in their ranks from 1990–2000, but their neighbors all achieved promotion in their ranks from 1980–1990. This could suggest a shift of urban dominance regionally. The urban agglomerations in the third quadrant all experienced rank declines, coupling with the rank decline of their neighbors from 1980 to 1990. Therefore, it may suggest an overall down path of urbanization of these urban agglomerations. The urban agglomerations in the fourth quadrant represent those that gained rank with dramatic growth in the 1990s against the declining ranks of their neighbors in the 1980s. The urban agglomerations in the second and fourth quadrants, therefore, represent two opposite paths in the urbanization process and are worthy of extra attention.

The regional effect would be further revealed by combining the space-time scatter plot with a map showing the relationship between the RMIs of the 1990–2000 period and the spatial lags of the 1980–1990 period (Figure 7). Please see the detailed discussions of these results in the next section.

In addition to the space-time Moran scatter plot, temporal LISA paths are also used to illustrate the dynamics of rank change for selected cities from 1950 to 2005. Rey and Janikas provided detailed discussions on LISA path in their work on the STARS (Space–Time Analysis of Regional Systems) project [50]. In the LISA path graph, the X-axis represents the values of a selected observation during different time periods. The Y-axis represents the spatial lags of the observation corresponding to the same set of time periods. Therefore, the LISA path can reveal the change of urban ranks of an urban agglomeration related to its neighbors across time. It can also help suggest a possible regional regime in the urbanization process.

4. Results

4.1. RMI Results. Figure 1 shows the overall RMI values from 1950 to 2005 while Figure 2 shows the RMI values for 1950–1960, 1960-1970, 1970-1980, 1980-1990, 1990-2000, and 2000–2005, respectively. These maps suggest considerable spatial variation in rank changes across these time periods. We can see that the top-ranked large cities, for example, Beijing, Shanghai, Chongqin, did not experience any rank changes in these time periods (except that Chongqin experienced a decrease between 1960 and 1970). Based on Figure 1 and Table 1, 34 out of the 137 urban agglomerations maintained their ranks from 1950 to 1960. The first ten-year period coincided with a relatively slow process of urbanization as China just started to reorganize and develop its economy after the Chinese Revolution.

After 1960, more cities experienced rank changes. As a result of the Cultural Revolution, less rank changes happened in the 1970s compared to the previous 10 years. We can see that the ranks changed more dramatically after 1980. This suggests that China's urbanization occurred along a more rapid pace and on a larger scale after 1980. Over 85% of the urban agglomerations experienced up or down movement in their ranks. This was especially pronounced from 1990 to 2000. Only five urban agglomerations did not experience changes in their ranks during the latter time

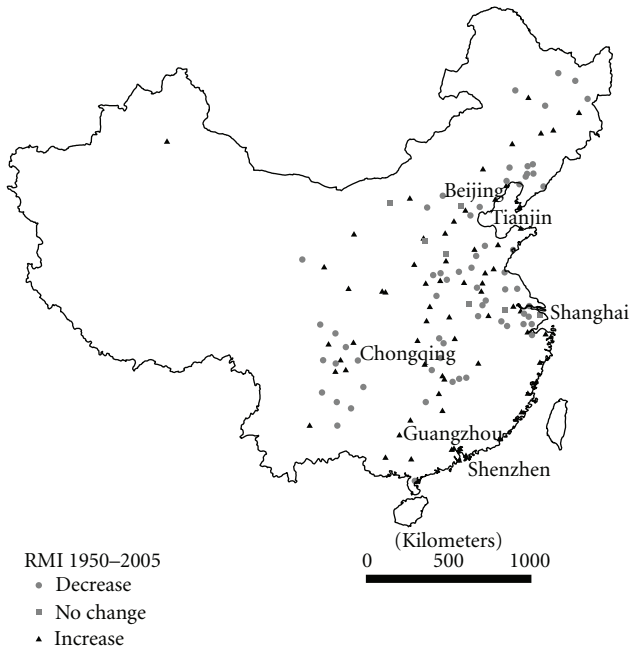

Figure 1: RMI values from 1950 to 2005.

period. Four of them were among the ten largest cities, including Beijing, Shanghai, Chongqing, and Chengdu. It is worth noting that in recent years, public media has reported Chongqing as the world's largest city after it was separated from Sichuan province and created as a municipality in 1997 [52]. In China, municipalities have an equivalent administrative status to that of a province. Chan pointed out that the large geographic coverage of Chongqing incorporated substantial rural populations [46]. Although claimed to have a population of 31.39 million, Chongqing only has about 36 percent urban population [46]. Using urban agglomerations helped us examine the changing urban dominance in China in a consistent way.

Maps in Figures 1 and 2 demonstrated the strength of using the RMI index. They show that the RMI is an excellent index for capturing the changing dominance of urban agglomerations in China. We especially like the property of the RMI value that rewards the taking over of an agglomeration formerly at the top end of the urban hierarchy. This means that the larger the urban agglomeration, the more difficult it is to overtake, as shown in the cases of Beijing and Shanghai. Consider another example, Guangzhou which in 1950 was the 6th ranking urban agglomeration of China. By 2005, Guangzhou had climbed to the 3rd ranked urban agglomeration in China, resulting in an RMI value of 0.33. Also consider Zhuhai, which moved up 41 positions, starting at rank 137 in 1950 and ended in rank 96 by 2005 for an RMI value of 0.18. Zhuhai increased its rank more than 10 times that of Guangzhou, but its rank mobility index reflects that it was not over taking urban agglomerations at the top of the urban hierarchy.

4.2. Getis-Ord G_i^* Results. It is possible to observe spatial tendencies of the positive RMI values from a simple visual inspection of Figure 1 and 2. However, it is difficult to identify any regional patterns of the RMI values, up or down. The results from the Getis-Ord G_i^* analyses, on the other hand, can help address this weakness.

Table 1: Number of cities with rank changes.

Time periods	Decrease	No change	Increase
1950–1960	56	34	47
1960–1970	64	16	57
1970–1980	58	22	57
1980–1990	83	11	43
1990–2000	85	5	47
2000–2005	55	18	64
1950–2000	62	7	68

Figure 3 provides an overview of the change of urban hierarchy in China from 1950 to 2005. It is quite evident that there is a clear "north-south divide" of the RMIs. The majority of the cities with positive Z-scores are located in the south. On the contrary, almost all cities in the north experienced small or negative changes in their RMIs. In the south, clearly two groups of cities stand out well above others in their RMIs during this entire time span. One is in the southwest around Chongqing and Chengdu. The other is in Central China around Wuhan. The development is largely attributed to the resources (southwest) and transportation advantages (Wuhan). Although not all cities in these two areas experienced RMI increases (see Figure 1), it demonstrates a regional effect in the urbanization process. Ke and Feser also reported these spread-backwash effects in a recent study of nonagricultural gross domestic product and employment growth in Central China between 2000 and 2005 [53].

Although Figure 3 provides an overall picture of the change in urban dominance, it fails to visualize any dynamics in this long time path. Can the patterns observed from Figure 3 explain the changing urban dominance for the entire time span? Were there different stages of such changes? The maps in Figure 4 can help address these questions. Comparing the G* values for the six time periods side by side, we can clearly identify different patterns over the fifty-five years. There is an obvious shift of urban dominance from north to south from 1950 to 2005, notably after 1990. During the early stages of China's industrialization, it was the north and northeast region that grew faster than the south (Figure 4(a)). Heavy industries, particularly steel industries, were largely located in this northern region. From the 1960s to the 1970s, northeast China continued to serve as a major base for heavy industries. At the same time, concerning the possible consequences of the cold war, a significant number of factories moved from east to west and to southwest China in order to protect the country's backbone industry. Millions of people moved inland to build new factories and infrastructure. That is why most cities in the east experienced declines in their RMIs. Meanwhile, this shift provided a historic opportunity for the cities in the southwest to grow (Figure 4(b) and Figure 4(c)).

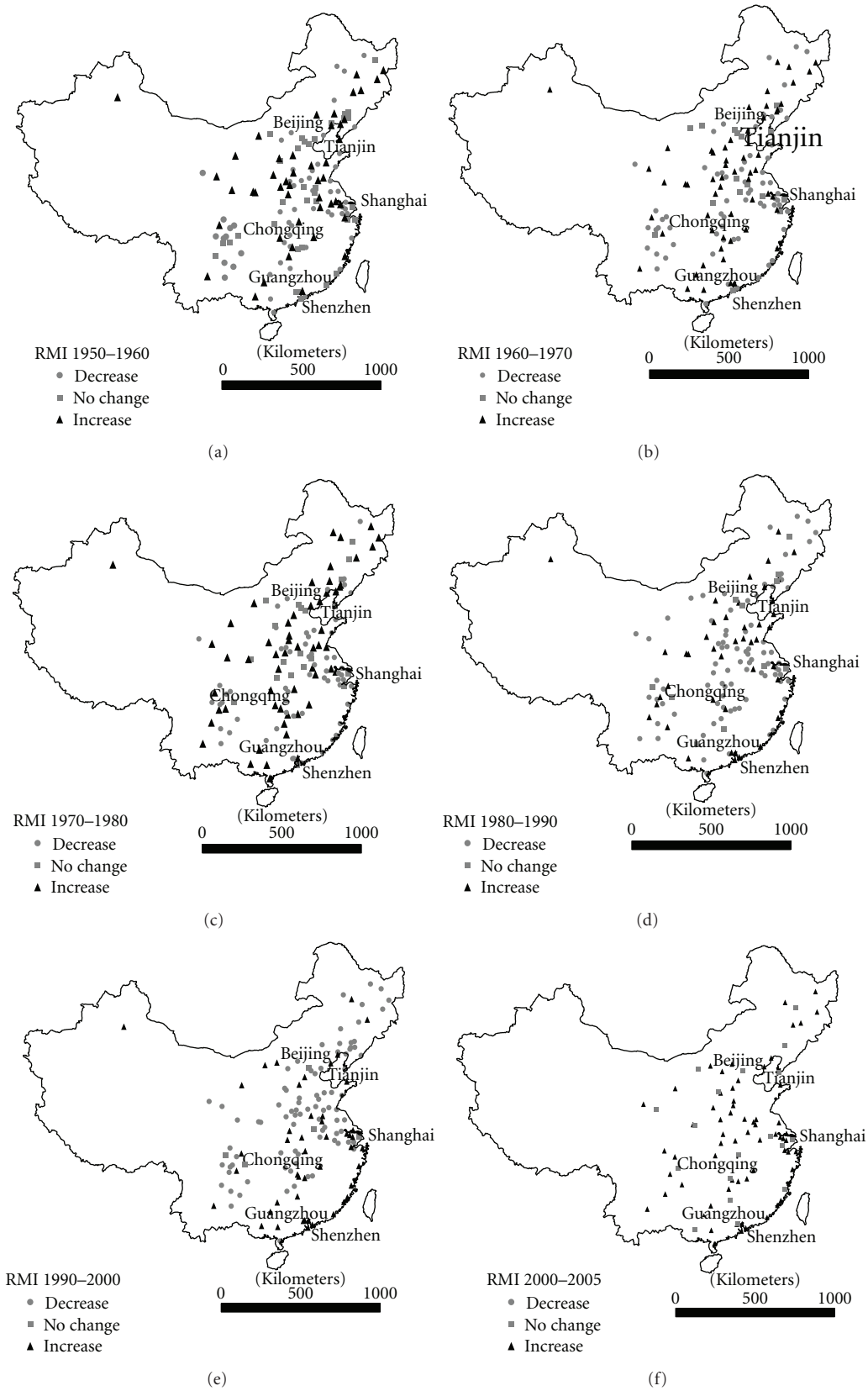

Figure 2: RMI values for six time periods from 1950–2005.

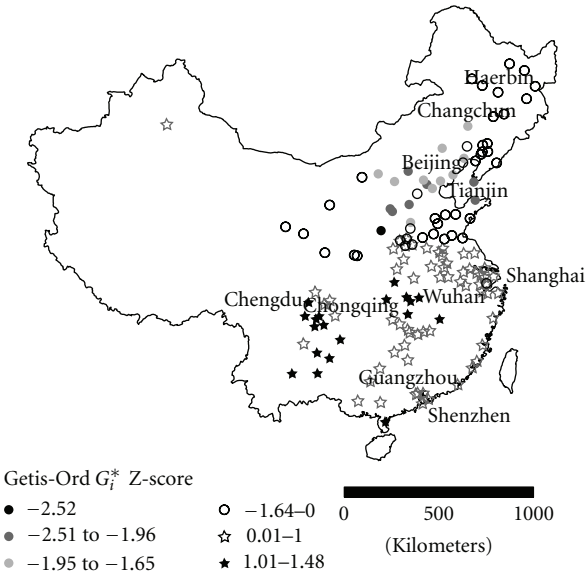

Figure 3: Overview of the hot spots and cold spots of the changing urban hierarchy: 1950–2005.

During the first thirty years, the policies based on a planned economy played a very important role in the urban hierarchy and urban configuration. Yet the 10-year Cultural Revolution slowed down the entire urbanization process. The RMI changes stepped into a highly dynamic phase after 1980. The open door policy and market reform were introduced after 1978. Coastal cities received policy incentives to develop their economies. The central government also started to grant more power to local governments. During the transitional time from 1980 to 1990, we can observe a declining pattern of the RMI values in the west (Figure 4(d)). That was just the beginning of the movement of migrant workers from the west to the east. The cities in the middle and lower Chang Jiang Valley experienced relatively faster growth than the others, owing much to the booming of township factories.

The southern phenomenon bumped up after the 1990s (Figure 4(e) and Figure 4(f)). The north-south divide became evident since then. A major factor that triggered this movement was the reform of the housing market. As shown by Shen, the migration from 1995 to 2000 increased much more than the period from 1985 to 1990 [54]. The early 1990s was just the start. The real phenomenal boom happened after 1998. The abolishment of welfare housing and the opening of the private housing market soon rattled China's urban hierarchy. Cities in the middle and lower Chang Jiang valley maintained steady growth. Cities in the south, particularly those along the coast attracted a tremendous amount of investment as well as waves of migrant workers. Income was a major pull factor in this mass movement. Urbanization accelerated at a startling pace in these places. A very good example is Shenzhen. Shenzhen had enormous growth during the 1980–2005 period. It was ranked as the 117th urban agglomeration in 1980 and soared up to the 4th ranked urban agglomeration by 2005, largely owing to its status as one of the four early established special economic zones. We further plotted the G* Z scores of Shenzhen along with that of two other cities, Wuhan and Changchun (Figure 5). Wuhuan is located in Central China and Changchun is located in northern China. The figure clearly presents the temporal shift of urban ranks for these three cities. While both Shenzhen and Wuhan climbed up the hierarchy after 1980, Changchun on the other hand experienced a sharp decline in its rank between 1980 and 1990.

Figure 4(f) also revealed some effects of the so-called "Go West" policy. Beginning in 2000, China started its western development program to reduce the gap between the west and east. Although still far from reaching this goal, the program more or less boosted the economy through infrastructure projects. We can see that several cities in the southwest moved up in their ranks after 2000. From a regional perspective, Figure 4(e) and Figure 4(f) also indicate that the urban system was more balanced in the south than in the north. As one of the strategies to reduce the pressure on these superlarge cities, such as Beijing, Shanghai, and Guangzhou, developing medium-size cities and towns started to show hierarchical effects in the south. More such development policy effort is still seen by some as necessary in North China.

In summary, our observations suggest that although urbanization happened in China on a broad scale, its extent in the south is truly remarkable. While the gap between the west and the east in China is well known, this study reveals a clear divide in the urbanization process between the north and south. Over the last two decades, East and Southeast China has undergone much more rapid development than China's other regions. The ongoing high-speed rail projects in China are likely to bring profound implications to this pattern.

4.3. Space-Time Moran Scatter Plot and LISA Path. Figure 6 shows the 1990–2000 RMI values of each urban agglomeration versus their spatial lags of 1980–1990. Figure 7 mapped the urban agglomerations into five groups based on the relationship between the RMIs of 1990–2000 and their spatial lags of 1980–1990. The observations of Figures 6 and 7 also confirmed our findings based on the G* maps. In Figure 7, the first group appearing as dark stars includes all urban agglomerations in the fourth quadrant of the scatter plot. Figure 7 suggests that the majority of them are located in the southern part of China. Clearly, Shenzhen stands out well above the others, leading the increase of RMIs from all other urban agglomerations. Among the urban agglomerations labeled in Figure 6, Zhuhai and Xiamen are coastal cities in southern China. Yantai, although located in Northern China, is a coastal city too. The urban agglomerations in the second group in Figure 7 correspond to those in the first quadrant of the scatter plot. They are spatially scattered in both southern and northern China. These urban agglomerations maintained their pace of growth with regional support. Upon examining those located in the second and third quadrants of the scatter plot and the third and fourth groups in Figure 7,

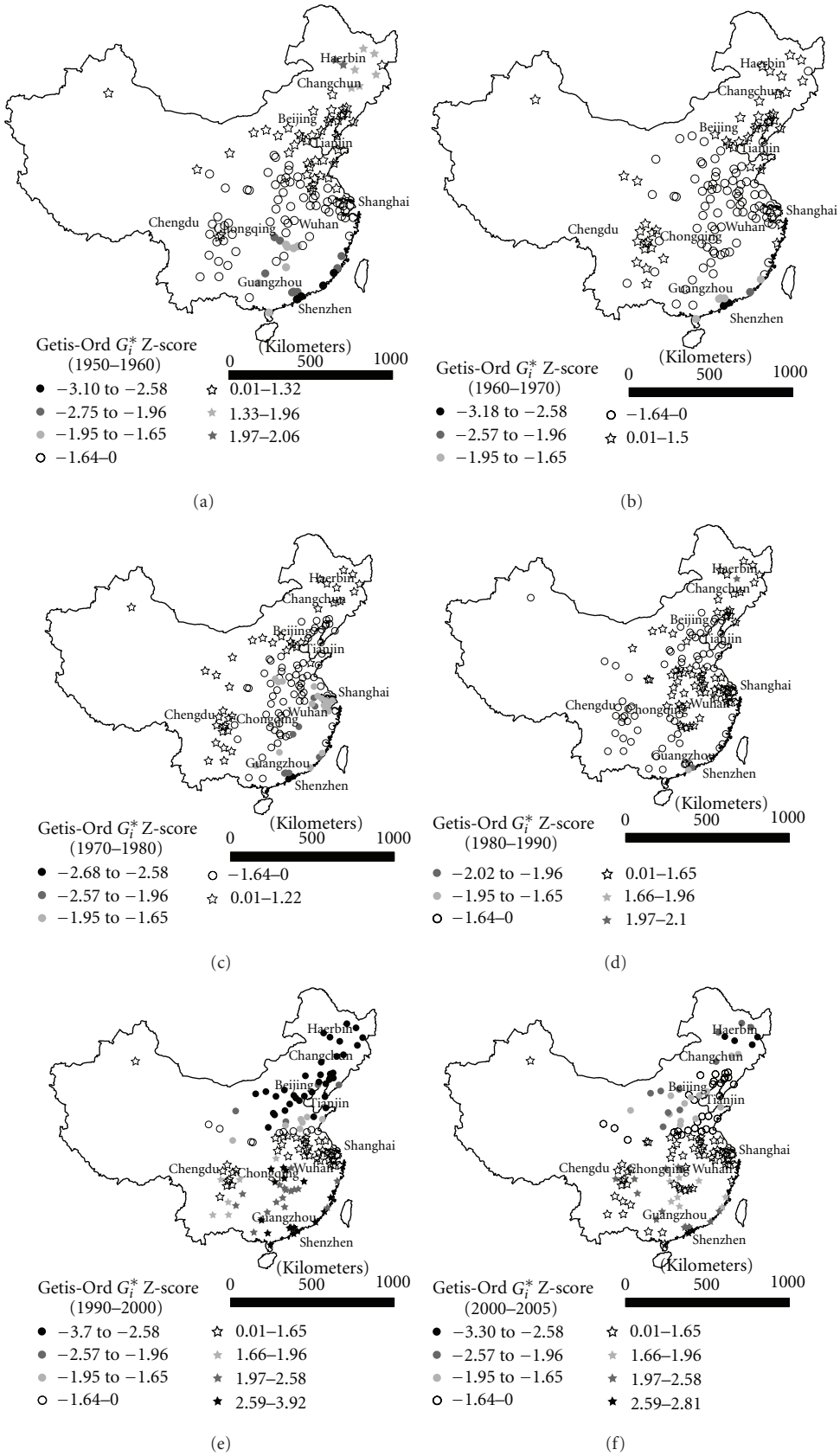

Figure 4: The spatial and temporal dynamics of urban hierarchy for the six time periods.

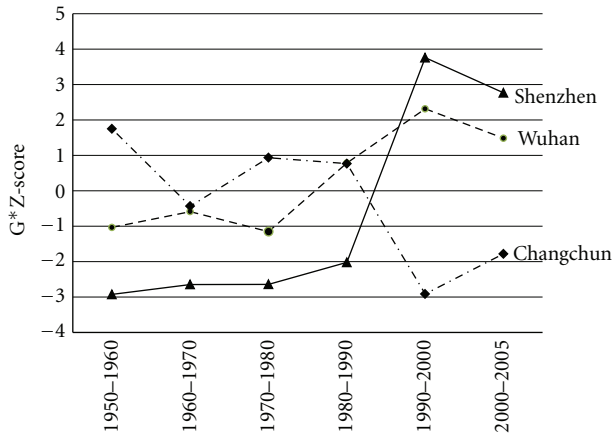

Figure 5: G* Z scores of Shenzhen, Wuhan, and Changchun from 1950–2005.

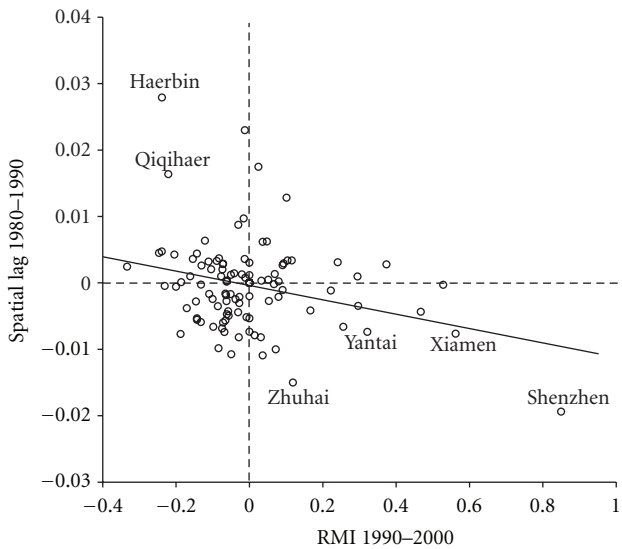

Figure 6: Space-time Moran scatter plot of the RMI values.

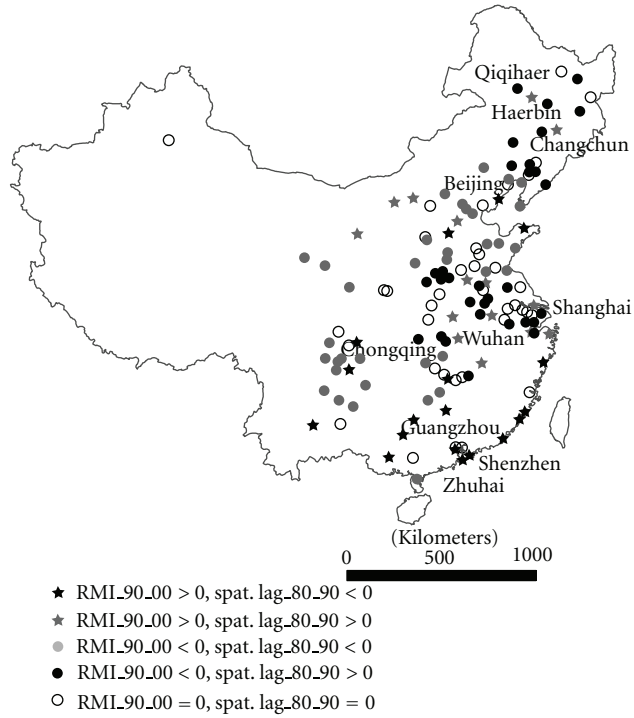

Figure 7: RMI values of 1990–2000 versus the spatial lags of 1980–1990.

we note that although some of them are in southwestern and central China, there is a clear concentration of these urban agglomerations in the northern part of the country. In Particular, those that experienced a rank decline in the 1990s in the context of an increase of their neighbors rankings in the 1980s are mostly in northern China (group four in Figure 7). For example, Haerbin and Qiqihaer, which had the biggest gaps between their RMIs and their spatial lags, are both located in the Upper Northeastern China (Figures 6 and 7). The findings further confirmed the shift of China's urbanization in the 1990s. Benefited greatly from the open-door policy and economic reform, the southern phenomenon started to emerge in the 1980s but achieved its fascinating growth in the 1990s.

We plotted the LISA paths for Shenzhen, Wuhan, and Changchun too. Figure 8 shows obvious difference in the RMI changes among them. The results are consistent with findings from the G* analysis. The Shenzhen (or southern) phenomenon started in the 1980s and peaked in the 1990s. Its neighboring cities also experienced fascinating growth in the 1990s, indicated by the positive slope and big jump in the LISA path. Wuhan's path also suggests its significant growth along with its neighbors between 1990 and 2000. But its dominance was suggested by the gap between its RMI value and the spatial lag from the 1990–2000 period. The path of Changchun is quite different from the other two. While it showed the growth at the very beginning, its rank dropped somewhat later. The most dramatic decline was observed after 1990.

Figures 6 and 7 demonstrated the advantages of using a space-time Moran scatter plot to reveal the regional effect of RMI changes. Figure 8 provides more details regarding the individual paths and regional effect from a temporal perspective. The G* maps, although static, were able to pick up the dramatic turn of China's urban hierarchy after 1990 in general (as shown in Figure 4(e)).

5. Discussions and Conclusions

We are aware that the data used in this study might be subject to some inconsistency across historic time periods. It is a great challenge to obtain reliable and consistent data in studying China's urbanization. Scholars had depended on census data at different levels while some others strived to adjust the data based on different approaches. We hope that by using the urban agglomeration definition by the UN, we have addressed some of the data concerns raised in these other studies. We also hope that by using urban rank change

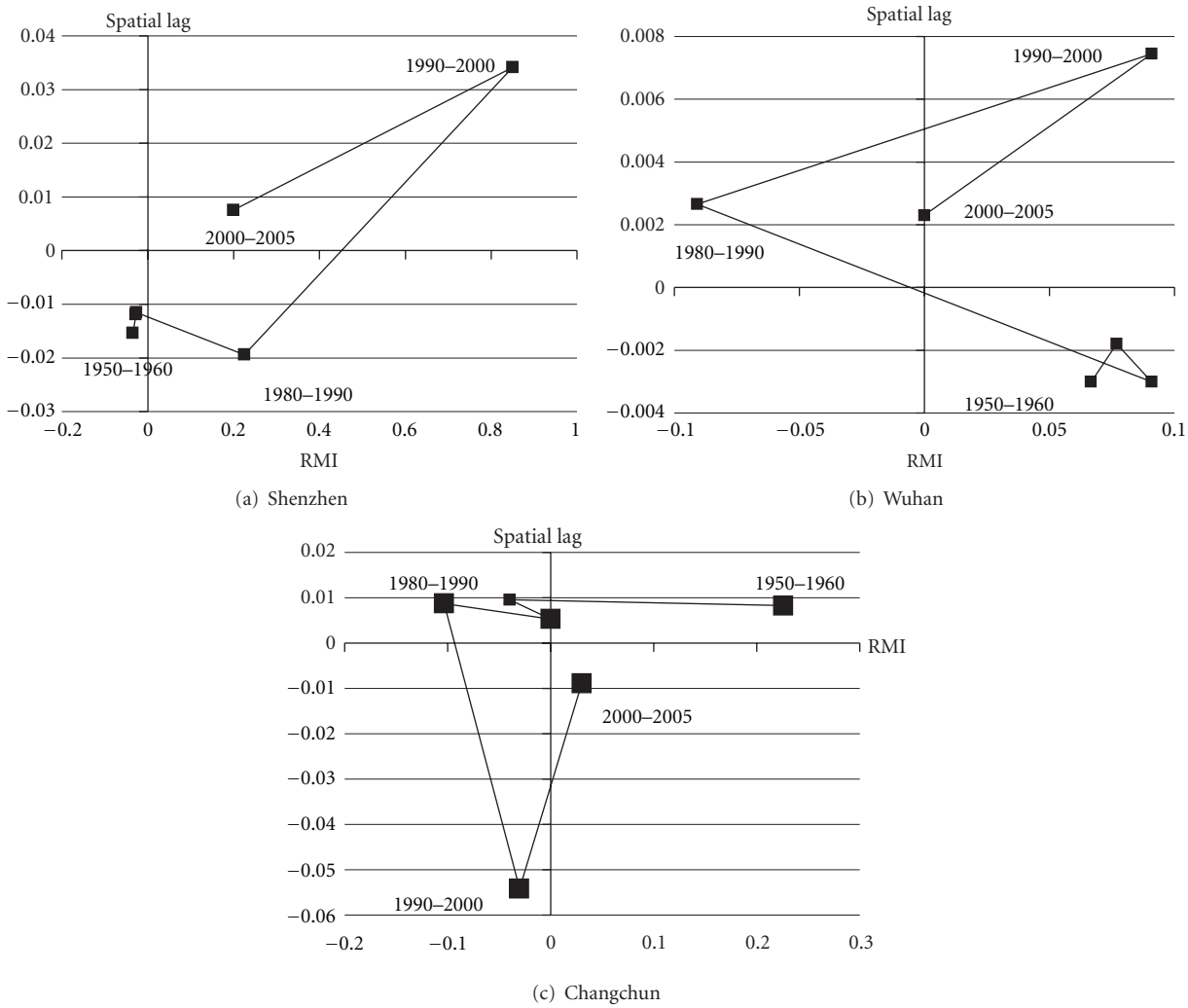

Figure 8: LISA paths of selected urban agglomerations: (a) Shenzhen, (b) Wuhan, and (c) Changchun.

instead of urban population growth that the concerns are further lessened.

Using a rank mobility index, we explored and visualized the spatial and temporal dynamics of the urban hierarchy in China from 1950 to 2005. This study demonstrated that the RMI is an excellent index for capturing the changing dominance of urban agglomerations in China. The findings suggest that China's urban hierarchy experienced considerable changes over time. Policy and economic factors played a significant role in shaping this path. There were clear regional patterns in the dynamics of China's urban hierarchy. We identified a north-south divide in the urbanization process after 1990. The south and southeast has dominated this process since economic reform.

For historical and political reasons, cities in China present and convene opportunities and wealth. The unprecedented urbanization process has put a tremendous amount of pressure on urban infrastructure and the environment in these superlarge cities. As suggested by Chen and Partridge' study [45], China's urban-centric development process needs to be reevaluated so that the growth of megacities can provide positive spread effects rather than reduce growth elsewhere. Our study provides some important policy implications on the development of a more balanced urban system in China. China's urbanization in recent years was largely associated with the growth of coastal cities and dominant regional centers. Migrant workers undoubtedly have served as a major force underpinning this process. However, to achieve sustainable and harmony development of the economy and society, more policy support should be provided to the inland and less-developed rural areas. Creating job and economic opportunities in these places would certainly help reduce the regional and societal disparities in the long run, contributing to a balanced urbanization process across the country.

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