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China's different spatial patterns of population growth based on the "Hu Line"

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Abstract: The "Hu Line" has been regarded as one of the greatest geographical discoveries in China because it reveals the significant spatial relationship between human activity and natural environment. The spatial evolution of population on both sides of the "Hu Line" has had important implications for both urbanization and regional development and has attracted widespread attention during the dramatic economic and social changes since the implementation of reform and opening-up policy in China in 1978. Using Geographical Information System (GIS) techniques, this paper studied the stability of the "Hu Line" and the spatial patterns of population growth on each side by constructing a spatial database of China's census data from 1982 to 2010. The findings are as follows: (1) In the last 30 years, the "Hu Line" has remained relatively stable, but a new tendency of population change has begun to emerge. The population ratio either side, namely, the southeast half (SEH) and the northwest half (NWH), of the "Hu Line" remains at roughly 94:6 (SHE : NWH). Noteworthy, the proportion of population in the SEH of the "Hu Line" has been decreasing slightly, while that in the NWH has been increasing slightly, as the latter has benefited from its higher rate of natural population growth. (2) The spatial patterns of population growth on both sides of the "Hu Line" were quite different. The degree of population concentration in the SEH increased faster than the NWH. Regions with a negative population growth rate have rapidly expanded; these were mainly located in the south of the "Qinling Mountains-Huaihe River belt" and northeastern China. Meanwhile, regions with a fast population growth rate were mainly concentrated in the Yangtze River Delta, the Pearl River Delta, and the Beijing-Tianjin metropolitan area. Thus, the spatial pattern of population growth in the SEH presented a concentration pattern that could be called "Matthew effect pattern". (3) The spatial pattern of population growth in the NWH could be regarded as the "Relative Balance pattern." In the NWH, the population growth rate was positive and the degree of population concentration was very low. There were many minority populations located in the NWH that usually lived in a dispersed pattern but had a higher rate of natural population growth due to the preferential population policy. There were also some regions with a negative rate of population growth in the NWH, which were mainly located close to the "Hu Line" and the Ancient Silk Road. (4) In the future, the spatial patterns

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of population growth on both sides of the “Hu Line” may continue to evolve. For the SEH, the capacity to attract more people to small and medium-sized cities and towns should be enhanced. For the NWH, the emphasis should be placed on promoting urbanization and enhancing population agglomeration in its major cities.

Keywords: Hu Line; stability; spatial patterns; population growth; urbanization; China

1 Introduction

Population distribution and its spatial evolution is a key issue for geographical studies (NRC, 2011). In 1935, Prof. Hu Huanyong, a famous Chinese geographer, published the first map of population density in China and proposed the “Hu Line” in his paper on “Distribution of the Chinese population.” The “Hu Line,” which starts from Aihui County (now, Heihe City, Heilongjiang Province) in the northeast to Tengchong City (Yunnan Province) in the southwest, divides China into two halves, the southeast and the northwest. The southeast half region only accounted for 36% of the land but occupied 96% of the population while the northwest half accounted for 64% of the land area but only 4% of the population (Hu, 1935). This famous line was named the “Hu Line” and was widely used in geographical studies of China. Its major contributions are not only to reveal the spatial heterogeneity of China’s population distribution, but also to reflect the relationship between humans and the environment. Prof. Hu compared the spatial distribution of terrain, rainfall, and population and then pointed out that these three distributions “have a very close relationship.” In China, the northwest has a dry climate with a sparse population while the southeast has more plain areas, more rainfall, and a much larger population. Essentially, the “Hu Line” reflects a spatial coupling relationship between China’s population and the physiographical environment. As a result, the “Hu Line” has an important practical significance for China’s regional development, especially for the coordinated development of population, resources, and environment (Yuan, 1993; Ye *et al*., 2001; Feng *et al*., 2007; Fan *et al*., 2010; Fang *et al*., 2012). Studies in China that target the adaptability of humans and the environment, the relationship between climate change and human activities, land use and other fields have emphasized the role of the “Hu Line” (Wang, 1996; Wang, 1998; Liu and Li, 2010).However, since the implementation of reform and the opening-up policy in 1978, population growth and its spatial distribution in China has been disturbed by social policies and the economic situation. On the one hand, population growth has been controlled and suppressed through family planning (*Jihuashengyu*), which is regarded as a basic national policy. The natural growth rate of the population has decreased steadily since the 1990s. On the other hand, regional economic development in China is characterized by a gradient development mode. The imbalance of regional economic development promotes active population mobility (Ding *et al*., 2005; Liu *et al*., 2010; Liu *et al*., 2014). At the same time, the rapid development of transportation increased accessibility to allow regional population mobility (Wang *et al*., 2010). The 2010 census showed that China’s migrant workers, which are called the floating population in China, was around 220 million, accounting for 16.53% of the total population. Therefore, has the “Hu Line” maintained its stability during the dramatic economic and social changes of the last three decades? What is the new trend of China’s population distribution? Those questions attract a great deal of attention among both the academic community and the decision makers of urban development.

Although many studies focus on China's population distribution, few have directly investigated the "Hu Line." As the national boundary of China has changed and is different from that in 1935, Prof. Hu himself updated the data on both sides of the "Hu Line" according to the third census data. The result showed that the southeast half accounted for 42.9% of the land but 94.4% of the population while the northwest half accounted for 57.1% of the land area but only 5.6% of the population (Hu, 1990). Based on population census data, some scholars also investigated population concentration patterns in China, which focused on the descriptive analysis of the overall pattern of the country (Ge and Feng, 2008; Liu *et al.*, 2010). Some scholars used the latest data of land use, DMSP/OLS lighting data, and other new data to simulate the population density and came to a similar conclusion as the "Hu Line" (Lo, 2001; Liu *et al.*, 2003; Tian *et al.*, 2004; Yue *et al.*, 2005; Zhuo *et al.*, 2005; Zhuo *et al.*, 2009). Scholars subsequent to Prof. Hu attempted to investigate the stable and dynamic characteristics of the "Hu Line." However, most of these studies only involved one or a few years, and therefore lacked studies of continuous changes of spatial patterns. Accordingly, this paper analyzed the data of previous censuses and constructed a spatial database of China's census data at a county- and city-level in 1982, 1990, 2000, and 2010. By employing GIS and spatial analysis tools, we analyzed the stability of the "Hu Line," emphasizing the spatial evolution of population on both sides and its influencing factors. We strove to provide a reference for the study of population geography and urban development in China.

2 Research data and method

2.1 Research data

In this paper, we used population data at the county level from census data in 1982, 1990, 2000, and 2010. The basic spatial data was a 1:1,000,000 scale administrative boundary map in 2009 provided by the data center of the Resources and Environmental Sciences of the Chinese Academy of Sciences. As the administrative boundaries have varied over the years, the boundaries with their population data are merged into those adjustment areas to make the annual data comparable, according to the concise edition of "the administrative division of China" from 1982 to 2011. Finally, 2171 basic spatial units at the county level were identified. Our study area did not include Hong Kong, Macao, and Taiwan. This paper also included some demographic and economic data. Population natural growth data, the proportion of minority population data, and floating population data were also taken from census data in different years. We took the sum of the immigration population from other areas in one specific province and the immigration population from other provinces as inflow population and took the discrepancy between resident population and registered population as the net migrant population; the net migration rate is the ratio of the net migration population to the resident population. For urbanization rate, we adopted the ratio of urban population to resident population. For the economic situation, we use the per capita GDP. The economic data was acquired mainly from the county statistical data in *The Regional Economic Statistical Yearbook of China in 2011* and *The Urban Statistical Yearbook of China in 2001*"

The "Hu Line" starts from Heihe City and ends at Tengchong City. This paper uses the geographic coordinates of the two cities to draw the "Hu Line," which divides Chinese territory into two halves: the northwest half (NWH) and the southeast half (SEH). For the counties that intersected with the "Hu Line," we use the area of the county as the weight to divide the population into two parts. This had little effect on the macro characteristics of the population. Figure 1 shows the location of the "Hu Line" on a population density map of China in 2010. All spatial analyses were predominantly examined in ArcGIS.

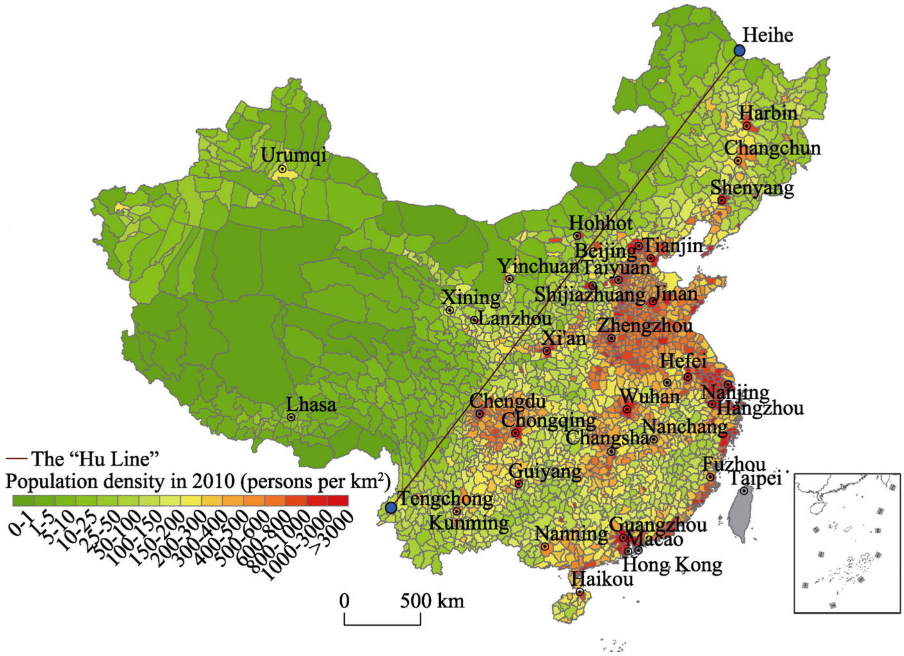

Figure 1 The location of the "Hu Line"

2.2 Measurement of population distribution

2.2.1 Concentration index

The concentration index aims to measure the concentration of population distribution (Chen *et al*., 1989; Han *et al*., 2009). The resident population of n units was ranked from small to large with rank i (i=1, 2…n). A_i represents the cumulative percentage of the total resident population in each rank. Here are two extreme cases: one is that the population is evenly distributed in each space unit, then the cumulative percentage of each unit i would be$100i/n$. Another is that the populations are concentrated in one space unit, then the cumulative percentages of all units would be 100%. The concentration index is the deviation-standardized data of the cumulative percentage of the total resident population. The formula for the calculation is as follows:

$$I_p = \frac{\sum_{i=1}^{n} A_i - \sum_{i=1}^{n} \frac{100i}{n}}{100n - \sum_{i=1}^{n} \frac{100i}{n}} \tag{1}$$

where I_p represents the population concentration index, which ranges from 0 and 1. If the index is closer to 1, it indicates a higher degree of population concentration.

2.2.2 Coefficient of variation

The coefficient of variation reflects discrete trends of indicators, such as population density, population growth amount, and population growth rate. The mathematical meaning of the coefficient of variation is the fluctuation of data. In essence, it is the ratio of the absolute value of the standard deviation and the mean value. The formula is as follows:

$$C.V = \frac{\sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \overline{x})^2}}{|\overline{x}|} \tag{2}$$

where $C.V$ is the coefficient of variation, x_i is the value of the variable i, $\overline{x}$ is the mean value of each variable, and n is the number of variables. The higher of the $C.V$ of population density, the larger the gap between dense and sparse areas. The higher of the $C.V$ of population growth and population growth rate, the larger the gap between population clustering areas and population decentralizing areas.

3 Results

3.1 Stability and population ratio changes on both sides of the "Hu Line"

Table 1 shows population changes on both sides of the "Hu Line" from 1982 to 2010. The total population increased from 1004 million to 1333 million. The population of the SEH grew from 945 million to 1249 million while the population of the NWH grew from 58 million to 84 million. Correspondingly, the population density of the SEH grew from 230.25 persons per km^2 to 303.92 persons per km^2 while the population density of the NWH grew from 10.82 persons per km^2 to 15.72 persons per km^2. We can see that the rounding ratio of population between the two halves, 94:6, remained relatively stable in 1982, 1990, 2000, and 2010. Accordingly, the ratio of population density between the two halves also remained around 20. From this point of view, the "Hu Line" has remained relatively stable. However, if we consider the decimal changes, the population share of the SEH continued to decrease slightly while that of the NWH continued to increase slightly. The population share of the SEH decreased from 94.23% to 93.68% in 1982–2010, with a total reduction of 0.55%. Although the value of 0.55 is very small, when considering the huge base population of about 1 billion people in China, this share represents 5–6 million people, which is equivalent to the population of a large city.

Table 2 presents the population changes in 1982–2010. During the periods 1982–1990, 1990–2000, and 2000–2010, the change of population share in the NWH always showed a slight increase compared with the population of the southeast region. Calculating the ratio of population density of the SEH and the NWH, the ratios were 21.17, 20.88, 20.03, and 19.33 from 1982 to 2010, respectively. This increase of population share of the NWH benefited from rapid population growth. From 1982 to 2010, the population of the SEH grew by 0.996% while the population of the NWH grew by 1.34%. The population growth rate of both the NWH and the SEH showed a decreased trend, but the former was higher than the latter during the three periods. From this perspective, the stability of the "Hu Line" was disturbed.

In the long history of human beings, people have preferred warm, wet, and rainy areas

(Zhang, 1999; Gu, 2012). The SEH is more humid while the NWH has more cold and drought-prone areas. Over the years, the natural environment of China has remained stable overall and the population share both sides of the "Hu Line" has remained relatively stable with a ratio of 94:6. The slight change in the population share of the "Hu Line" was mainly due to a difference in population growth on both sides. From a viewpoint of natural growth, the natural population growth rate in the NWH was significantly higher than that in the SEH. The family planning policy, a basic national policy of China, profoundly changed the birth rate and natural growth of China's population (Zhang and Zeng, 2005). However, the fertility policy was not as strict for ethnic minorities; therefore, the NWH, which had lots of minority people, received a certain fertility advantage. The average natural population growth rate in Xinjiang, Tibet, Inner Mongolia, Ningxia, Gansu, and Qinghai in the NWH was 19.3‰, which was higher than the national average. In 2010, this figure was 7.39‰, which was 1.53 times the national average growth rate (4.83‰). From the viewpoint of migratory growth, the population in the NWH generally flowed into the SEH, but the majority of the floating population was mostly distributed in the latter. As for the inter-provincial flow, the SEH occupied 90.83% of the inflow population and 93.17% of the outflow population in China in 1990, which increased up to 94.74% and 95.51% in 2010. In other words, most migration occurred within the SEH, which indicated that migratory growth had limited effects on population growth in the SEH. However, the SEH did not have any advantages in natural growth. Therefore, due to the high rate of natural growth, the population share of the NWH continued to increase during 1982 and 2010.

Table 1 The population on both sides of the "Hu Line" during 1982–2010

Year	Total population (100 million)		Share of total population (%)		Population density (persons per km^2)	
	Southeast	Northwest	Southeast	Northwest	Southeast	Northwest
1982	9.45	0.58	94.23	5.77	230.25	10.82
1990	10.64	0.66	94.13	5.87	259.00	12.40
2000	11.67	0.76	93.89	6.11	283.98	14.18
2010	12.49	0.84	93.68	6.32	303.92	15.72

Table 2 The population changes on both sides of the "Hu Line" during 1982–2010

Period	Population growth (100 million)		Change of population share (%)		Annual population growth rate (%)	
	Southeast	Northwest	Southeast	Northwest	Southeast	Northwest
1982–1990	1.19	0.08	–0.10	0.10	1.48	1.72
1990–2000	1.03	0.10	–0.24	0.24	0.92	1.35
2000–2010	0.82	0.08	–0.21	0.21	0.68	1.04

3.2 The "Matthew effect pattern" of spatial population growth in the southeast region

Table 3 shows the calculation results of the relative index of population concentration over years in the SEH of the "Hu Line." The population concentration index, which increased from 0.419 to 0.473, kept growing from 1982 to 2010. Moreover, the variation coefficient of population density, average annual growth rate amount, and average annual growth rate all continuously increased. Figure 2 presents a further illustration. With reference to the mean change and the results of the natural breakpoint method, ">800 persons per km^2," "<100 persons per km^2," ">2%," and "<0%" were selected as the thresholds for the Densely Populated Region (DPR), the Sparsely Populated Region (SPR), the Rapid Growth Region (RGR), and the Negative Growth Region (NGR), respectively, for the southeast. As shown in Figure 2a, the area of the SPR occupied roughly 30% while the DPR area was below 10% with a slight growth. However, the population share of the SPR was below 10% with a continuous decline while the population share of the DPR increased from 10.92% in 1982 to 31.50% in 2010. As shown in Figure 2b, both the area share and population share of the RGR were less than 30% during 1982–2010. Furthermore, the area share of the RGR kept decreasing and its population share showed slight growth during 2000–2010. However, the area share and population share of the NGR had rapid growth during 1982–2010, which increased by 41.46% and 28.09%, respectively. Both Table 3 and Figure 2 show that the spatial gaps of population density and population growth in the SEH grew notably. Only a few regions enjoyed population agglomeration while many regions faced population decline, which could be described as the "Matthew effect pattern."

Table 3 The concentration degrees in the southeast region of the "Hu Line"

Year	The population concentration index	Coefficient of variation (*C.V*) of population density	*C.V* of annual population growth amount	*C.V* of annual population growth rate
1982	0.419	0.945	/	/
1990	0.422	0.992	1.517	0.803
2000	0.445	1.151	4.332	2.164
2010	0.473	1.350	5.674	5.592

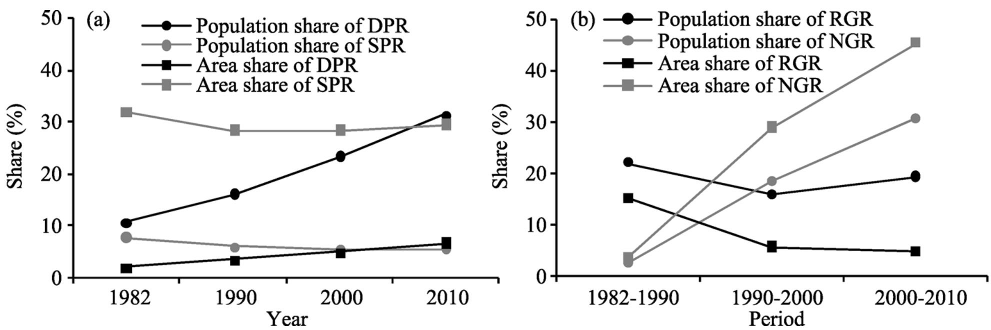

Figure 2 Zonal statistics of population and area in the southeast region of the "Hu Line"
(DPR, SPR, RGR and NGR are short for the Densely Populated Region, the Sparsely Populated Region, the Rapid Growth Region and the Negative Growth Region respectively)

Figure 3 shows the spatial evolution process of the DPR and SPR in the southeast of the "Hu Line." The DPRs were mainly located and expanded in the central plains (Henan Province and nearby region) and the coastal regions, especially in The Yangtze River Delta (Shanghai, Nanjing, Hangzhou, and nearby cities), The Pearl River Delta (Guangzhou, Shenzhen, and nearby cities), and the Beijing-Tianjin region. Besides, most provincial capital cities and their neighboring areas in central China and northeastern China also enjoyed a high population density, such as Xi'an, Chongqing, Chengdu, Wuhan, Taiyuan, Shijiazhuang, Shenyang, and Harbin. Table 4 lists the details of the DPR in the southeast region. Completely different, the SPR were steadily distributed in mountainous land in northeastern

China and southern China, the Loess Plateau in north China and the Yunnan-Guizhou Plateau in southwestern China. Figures 4 and 5 show the spatial evolution process of the RGR and NGR respectively. The RGR were concentrated and expanded in the three biggest urban agglomeration and metropolitan regions: the Yangtze River Delta, the Pearl River Delta, and the Beijing-Tianjin region. The advantage of population growth faded gradually in the Central Plains Regions. Meanwhile, the RGR presented a massive expansion, especially during 1990–2010. The RGRs in the southeast are mainly distributed and expanded in northeastern China and the southern region of the "Qinling Mountains-Huaihe River" belt (the belt is from southern Shaanxi Province to northern Jiangsu Province, which is a famous geographic division line for northern China and southern China). In general, it is obvious that population growth advantages became transferred from inland regions to coastal regions during the past 30 years, which revealed the spatial "Matthew effect pattern" of population agglomeration and evacuation processes in the SEH of the "Hu Line."

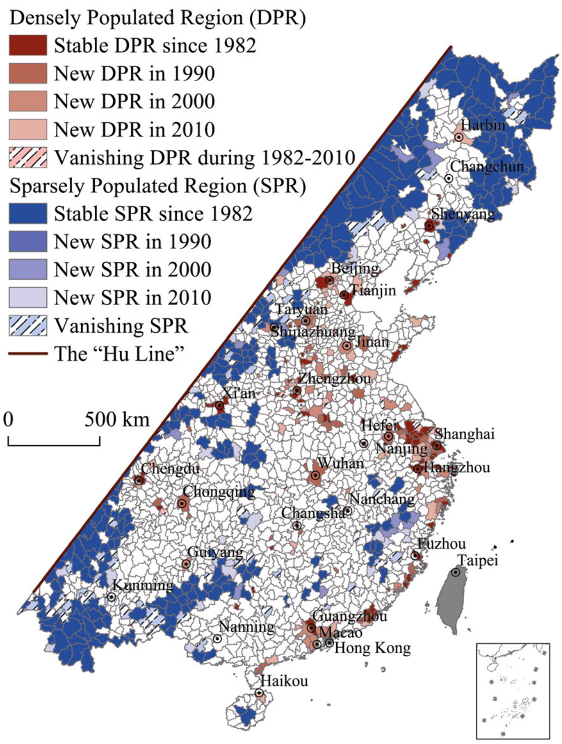

Figure 3 Spatial evolution of population density in the region southeast of the "Hu Line"

Table 4 Population and area statistics of Densely Populated Regions (DPRs) in the region southeast of the "Hu Line"

Region	Area of DPR in 2010 ($\times10^4$ km^2)	Includes: ($\times10^4$ km^2)		Population of DPR in 2010 ($\times10^2$ million)
		Area of stable DPR since 1982	Area of new DPR in 1990, 2000 and 2010	
Yangtze River Delta	6.67	2.44	4.22	0.98
Central Plains Region	4.11	1.04	3.06	0.47
Pearl River Delta	3.27	0.80	2.47	0.63
Beijing-Tianjin region	3.15	0.98	2.17	0.47
Wuhan-Changsha-Nanchang region	1.71	0.23	1.48	0.27
Chengdu-Chongqing region	1.50	0.39	1.11	0.22
Shandong coastal region	1.46	0.32	1.14	0.16
Fujian coastal region	0.86	0.41	0.45	0.15
Southern Liaoning region	0.78	0.78	0.00	0.14
Central Shaanxi region	0.54	0.51	0.03	0.09

How do we explain such a "Matthew effect pattern" in the SEH? Qualitatively, since reform and opening up, those coastal regions and the Yangtze River gradually became the core regions for economic development in China, as they had more job opportunities and faster urban development. Three urban agglomerations, the Yangtze River Delta, the Pearl River Delta, and the Beijing-Tianjin region, developed rapidly due to location advantages and policy support. Other coastal regions in Fujian Province, Liaoning Province, Shandong Province, and Guangxi Province also enjoyed rapid development. However, only provincial capital cities or some big cities in inland provinces enjoyed faster economic growth. As a result, people migrated from inland regions to big cities, especially big cities in coastal regions, which caused a large-scale population decline in the inland regions of the southeast. Quantitatively, as shown in Figure 6, we selected county-level data during 2000–2010 to compute the relationships for the three groups of variables. All data were normalized to make the value range from 0 to 1. The first group was the minority population share and natural growth rate in 2010, which showed a poor fitting result. The second group was per capita GDP and net migration ratio in 2010, which showed a positive significant relationship (R^2 = 0.242). The third group was the urbanization level in 2010 and population growth rate during 2000–2010, which also showed a positive significant relationship (R^2 = 0.213). Obviously, the regional development gap in the economy and urbanization was the key factor to the "Matthew effect pattern" of population changes in the SEH.

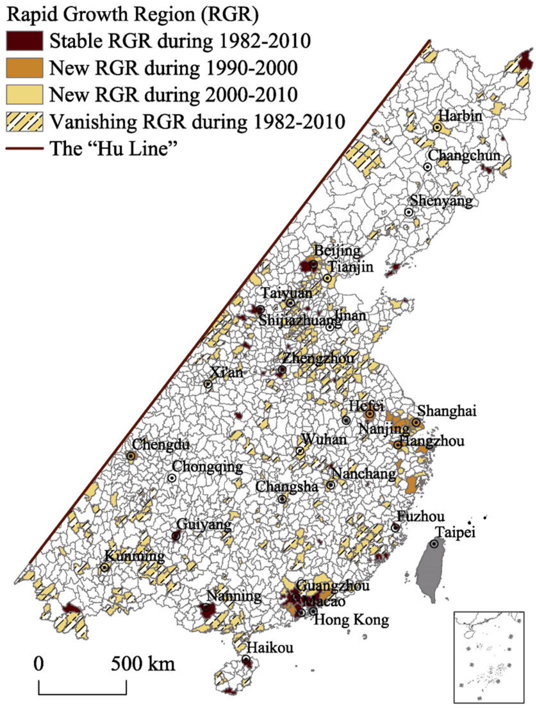

Figure 4 Spatial evolution of Rapid Growth Regions in the region southeast of the "Hu Line"

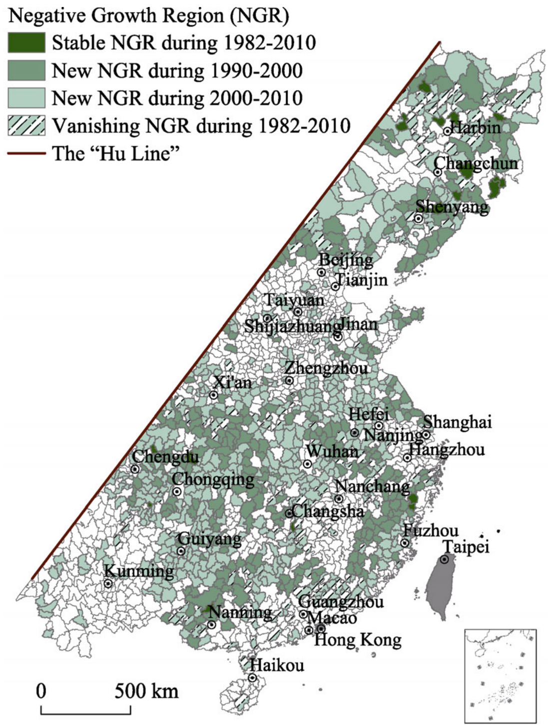

Figure 5 Spatial evolution of Negative Growth Regions in the region southeast of the "Hu Line"

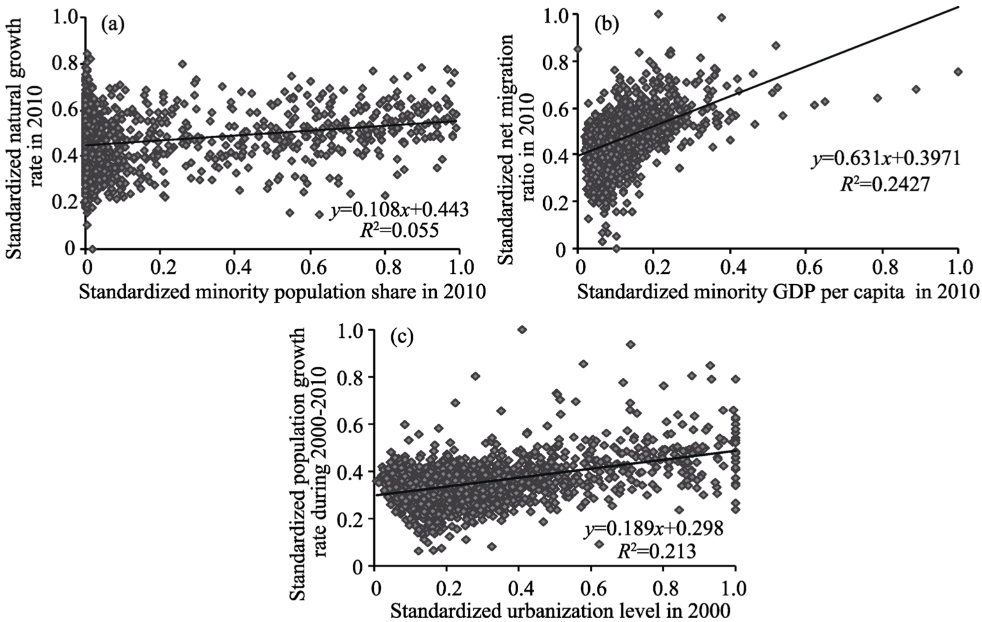

Figure 6 Correlation analysis of factors affecting population growth in the region southeast of the "Hu Line"

3.3 The "relative balance pattern" of spatial population growth in the northwest region

As shown in Table 5, in the NWH of the "Hu Line," the population concentration index increased from 0.543 in 1982 to 0.570 in 2010. Furthermore, the population concentration index and variation coefficient of population density remained higher than that in the southeast. The gap of population density in the NWH was obvious and became bigger, but the variation coefficient of average annual growth amount and average annual growth rate continuously increased. However, both of them were lower than that in the SEH, which meant the northwest had a smaller gap of population growth. As shown in Figure 7, ">150 persons per km^2," "<20 persons per km^2," ">2%," and "<0%" were selected as the thresholds for the DPR, SPR, RGR, and NGR, respectively, for the northwest. As shown in Figure 7a, the DPR area occupied only roughly 1% while the SPR area occupied approximately 90%. However, the population share of the DPR increased from 19.37% in 1982 to 35.22% in 2010 while the population share of the SPR was below 30% with a slight decline. As shown in Figure 7b, the area share of the RGR kept decreasing and the population share of the RGR had a slight increase during 2000–2010. Moreover, the area share and population share of the NGR had rapid growth during 1982–2010, which was similar to that in the SEH. Unlike in the SEH,

Table 5 The concentration degrees in the region northwest of the "Hu Line"

Year	Population concentration index	Coefficient of Variation (*C.V*) of population density	*C.V* of annual population growth amount	*C.V* of annual population growth rate
1982	0.543	2.545	/	/
1990	0.546	2.584	0.712	1.668
2000	0.558	2.822	1.182	2.700
2010	0.570	3.249	1.916	3.964

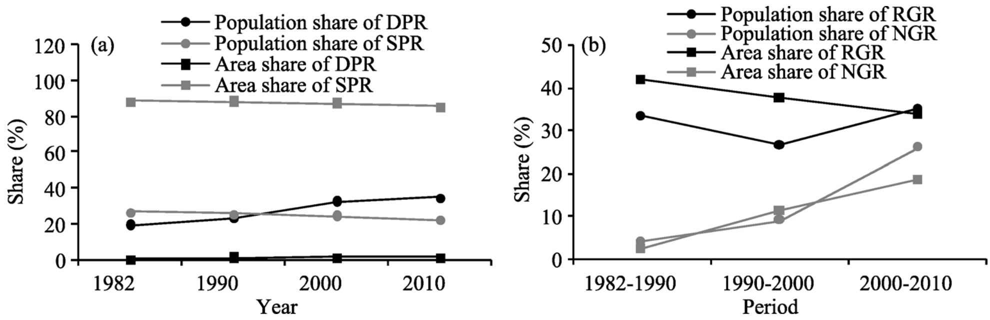

Figure 7 Zonal statistics of population and area in the region northwest of the "Hu Line"
(DPR, SPR, RGR and NGR are short for the Densely Populated Region, the Sparsely Populated Region, the Rapid Growth Region and the Negative Growth Region respectively)

the shares for both area and population of the RGR remained higher than that of the NGR. Most regions in the NWH enjoyed population increase, which could be described as the "Relative Balance pattern."

Figure 8 shows the spatial evolution process of the DPR and SPR in the NWH of the "Hu Line." The DPRs were located and expanded only in provincial capital cities or some big cities and their neighbors. The Lanzhou-Xining region was the biggest DPR in the NWH, with more than 13 million people residing there in 2010. Yinchuan, Urumqi, Hohhot, Kashgar, and Lhasa also enjoyed relatively dense populations as the spatial single core in each province. Table 6 lists the details of the DPRs in the SEH. Unlike DPR, the SPR covered a vast expanse in the NWH, with a relative stable spatial distribution. Only

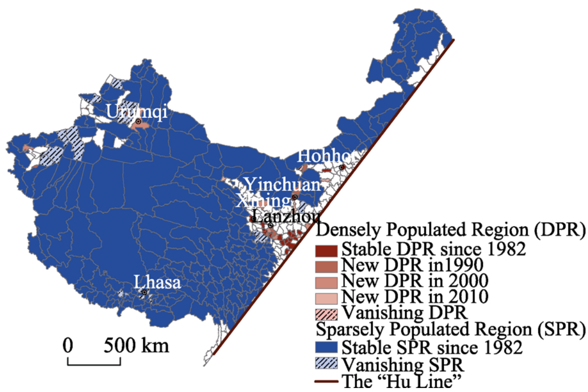

Figure 8 Spatial evolution of population density in the region northwest of the "Hu Line".

Table 6 Statistics of population and area of Densely Populated Regions (DPRs) in the area northwest of the "Hu Line"

Region	Area of DPR in 2010 ($\times10^4$ km^2)	Includes: ($\times10^4$ km^2)		Population of DPR in 2010 ($\times10^2$ million)
		Area of stable DPR during 1982–2010	Area of stable DPR during 1990–2010	
Lanzhou-Xining region	4.37	3.23	1.14	0.13
Urumqi and its nearby regions	1.45	0.05	1.40	0.03
Yinchuan and its nearby regions	1.27	0.27	1.00	0.04
Hohhot and its nearby regions	0.68	0.47	0.21	0.05
Kashgar and its nearby regions	0.47	0.00	0.47	0.01
Lhasa and its nearby regions	0.09	0.00	0.09	0.003

a few counties located in north Xinjiang and around Lhasa transferred from SPR to non-SPR. Figures 9 and 10 show the spatial evolution process of the RGR and NGR, respectively, in the NWH. The RGR occupied most regions, which covered not only the well-developed provincial capital cities or some big cities but also lots of sparsely populated counties. There were also some counties that lost their advantage of rapid population growth, but most of them continued to grow. Accordingly, the NGR only occupied a small portion in the NWH. The NGR were mostly distributed along the "Hu Line" and the Ancient Silk Road (Shaanxi- Gansu-Xinjiang), which was close to mountains or big cities. In general, most regions in the NWH had a low population density but enjoyed population growth, which showed a spatial "Relative Balance pattern." However, there were still some counties facing a population decline, so such a "balance" was relative.

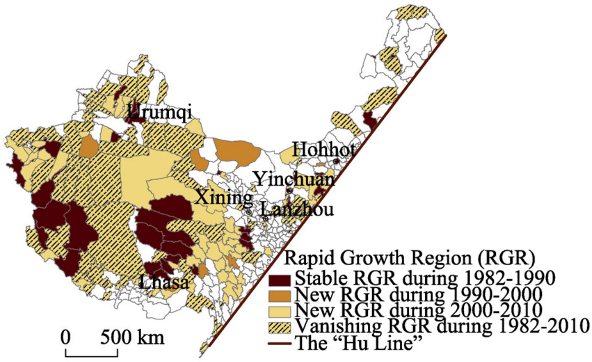

Figure 9 Spatial evolution of the Rapid Growth Region in the area northwest of the "Hu Line"

How do we explain such a "Relative Balance pattern" in the NWH? Qualitatively, lots minority people are dispersed in the NWH, but enjoy the preferential policies of family planning. A higher natural population growth rate brings population growth advantages. What's more, out-flow migration is not very large in the northwest region. Xinjiang even became a popular in-flow destination since there were many agricultural job opportunities. The urbanization level was relatively lower in the NWH than in the SEH. However, some big cities and their nearby regions enjoyed rapid development, which was similar to the urbanization process in the SEH. Quantitatively, as shown in Figure 11, three groups of normalized data were computed. The first group was the minority population share and natural growth rate in 2010, showing a positive-significant relationship ($R^2 = 0.442$). The second group was the per capita GDP and net migration ratio in 2010. The third group was the urbanization level in 2000 and population growth rate during 2000–2010. The R^2 of both the second and third groups was very low, which suggests poor fitting results. In general, natural population growth rate advantage played an important

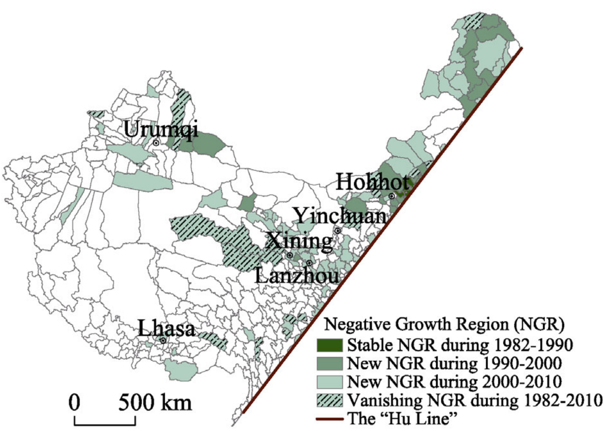

Figure 10 Spatial evolution of the negative growth region in the area northwest of the "Hu Line"

role in the "Relative Balance pattern" of population changes in the SEH during the past 30 years.

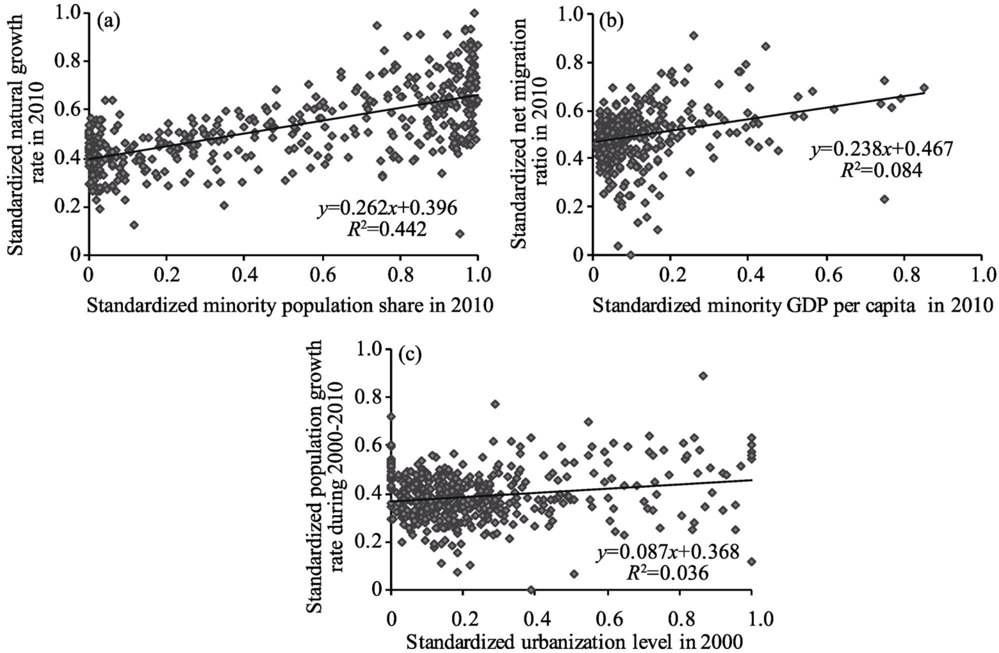

Figure 11 Correlation analysis of factors affecting population growth in the region northwest of the "Hu Line"

4 Conclusions and discussion

With the support of GIS, this paper built spatial databases for four census periods in China since the reform and opening up. Spatial analysis techniques and some mathematical indexes were used to investigate the spatial evolution on both sides of the "Hu Line." The main conclusions can be drawn as follows.

(1) The "Hu Line" was relatively stable during 1982–2010. The population ratio of the SEH and the NWH remained at 94:6 (southeast: northwest). However, when considering the fractional part of the ratio, the population share of the SEH had been decreasing slightly while the population share of the NWH had been increasing slightly. The higher population natural growth rate contributed to the advantage of population share growth in the NWH.

(2) The spatial patterns of population growth on both sides of the "Hu Line" were quite different. The degree of population concentration in the SEH increased faster than the NWH. The SEH presented the "Matthew effect pattern." On the one hand, only a few regions enjoyed a higher population density. Furthermore, the positive population growth advantages gradually transferred from the inland region to the coastal region, especially in the Yangtze River Delta, the Pearl River Delta, and the Beijing-Tianjin metropolitan region. On the other hand, NGR presented a massive expansion, which was mostly distributed in northeastern China and the southern region of the "Qinling Mountains-Huaihe River belt." Meanwhile, the NWH presented the "Relative Balance pattern." Most counties enjoyed positive population growth, but only the provincial capital cities or some other big cities and their neighbors had a high population density. There were also a few negative population growth regions

located close to the "Hu Line" and the Ancient Silk Road.

(3) The relatively stable natural environment was the major determinant of the relative stability of the "Hu Line." However, the spatial difference of population natural growth and population mobility could disturb the stability of the "Hu Line." The imbalance of the regional economic development and urbanization process in the southeast produced large numbers of migrant workers and contributed to the "Matthew effect pattern" in the southeast. Otherwise, the higher natural population growth rate, which resulted from the preferential policies of family planning enjoyed by the minority populations, was the primary contributor to the "Relative Balance pattern" in the NWH.

The "Hu Line," which reveals the spatial distribution rules of the population in China, will continue to play an important role in Chinese urban development. With the change of various factors such as family planning policy, economic development in central and western China, the current household register policy, and information construction, the spatial pattern on both sides of the "Hu Line" will continue evolving. For the SEH, the capacity to attract more people to small- and medium-sized cities and towns should be enhanced. For the NWH, the emphasis should be placed on promoting the rate of urbanization and enhancing the capacity of population agglomeration in major cities. The Lanzhou-Xining region, Xi'an-Tianshui region, and Chengdu-Chongqing region, which are close to the "Hu Line," could be the key spatial nodes for coordinating urban development in the SEH and the NWH.

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