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Population Dynamics and Its Driving Forces in China from 2000 to 2020

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Abstract: Exploring population dynamics and its driving factors has important practical significance for guiding reasonable population distribution. In view of this, this paper systematically analyzes the population dynamics and driving factors in China based on the latest three decennial censuses, using research methods such as the population concentration index, the center of gravity model, relative change in population density and multiple linear regression. The conclusions are as follows: (1) China's population distribution is uneven, and the trend of polarization in population distribution is increasingly evident. The spatial differences in population growth are shifting from east–west to north–south. Under the influence of the "core–periphery effect", more people are gathering in a few large cities. (2) The factors affecting population changes have obvious temporal variability: terrain and temperature have an increasing impact on China's population changes. Temperature in particular has become an important factor in China's population changes. Population changes are gradually shifting from being driven by a single economic factor to being driven jointly by social and economic factors. (3) The factors affecting population changes also have obvious spatial heterogeneity: temperature affects population changes in both the eastern and central–western regions, while terrain only affects population changes in the central–western regions. Currently, population changes in the economically developed eastern region are more driven by economic factors, while the central–western regions are driven by both economic and social factors. Central cities in the central–western regions are experiencing accelerated population agglomeration, while central cities in the eastern region are losing their ability to attract population agglomeration. The above conclusion basically clarifies the patterns and influencing factors of China's population changes since the 21st century, which can provide a useful reference for future population development and regional planning.

Keywords: population dynamics; influencing factors; population agglomeration; urbanization; population census; China

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1. Introduction

People are the main wealth of a place, and their spatial agglomeration and diffusion profoundly affect the evolution of the urban system and the regional economic and social development pattern [1–6]. From conceptions of urban decay and resurrection to legends of New York and London, the waxing and waning of the population has traditionally been used to proclaim the rise and fall of cities. Throughout the world's history, attracting people to locations and keeping them there has always been a top priority for local governments [3]. China's many cities are no exception, and the current desire for people is growing in many cities. Although China's population has surpassed 1.4 billion, China's working-age population has been shrinking since it peaked in 2015, and it is an inevitable reality that the nation's population will reach its peak in the coming years [7,8]. In response to the growing population crisis, the Chinese government has made significant changes to its fertility policy. China announced in October 2015 that its famous one-child policy would be replaced by a universal two-child program, the first time in more than 30 years that no one in China was restricted to having only one child. Only six years later, however, this universal two-child policy was replaced by a three-child policy that would allow almost all Chinese citizens to have children as they wished [9]. The constant adjustment of China's population and fertility policies reflects the increasingly anxious attitude of Chinese policymakers towards the imminent population crisis and their desire to obtain more newborns. Reflected at the local level, in order to increase the population to promote local development, many cities in China have joined the competition for population, with particular emphasis on attracting talented residents [10]. Given the important role of the population in local socio-economic development, the population changes and its driving forces have received unprecedented attention from academia and policymakers. Studying the population dynamics and its driving factors is important for understanding and predicting future population changes.

The pattern of population dynamics among cities is closely related to population migration. Population migration generally follows two basic paths, namely upward and downward along the urban hierarchy, both of which have important effects on the inter-city population distribution dynamics [11–13]. For example, upward population migration brings about an increase in population in large cities and a decrease in population for small and medium-sized cities (SMSC), resulting in an uneven inter-city population distribution. Conversely, downward population migration reduces the population of large cities in the core area and increases the population of SMSC in the periphery, which makes the inter-city population tend to be evenly distributed [11]. Different countries and regions have different population migration paths at different stages of development, with developed countries tending to follow downward migration paths, while upward migration paths are more common in developing countries [14–17]. Agglomeration economies and diseconomies effects and, on this basis, Friedman's core–periphery theory of regional development are the theoretical basis for explaining the different paths of population migration [18,19]. In addition, previous studies have found that the population distribution of cities at different levels is consistent with the cyclic urbanization model (urbanization, suburbanization, counter-urbanization and reurbanization) [20,21]. In the early stages of urbanization, the population mainly is concentrated in small towns, and this situation currently mainly occurs in developing countries and regions. In the accelerated development stage of urbanization, influenced by economies of scale and agglomeration effects, the population congregates towards large and medium-sized cities [22,23], which can provide more employment opportunities and higher wage levels, thus promoting further population agglomeration in large cities [24,25]. However, when the urbanization level reaches a certain level, urban problems such as traffic congestion, increasing crime and serious pollution in large cities force people to leave for lower-ranked cities. This can also be referred to as the process of counter-urbanization [26], which has become a common phenomenon of population mobility between cities in western developed countries [12,17]. In the reurbanization stage, the urban center attracts population inflow again through urban renewal, such as London and New York, where the urban population began to decline half a century ago, but grew again in the 1990s through urban renewal policies [3].

Regional population changes can be divided into two parts: natural growth and migration or mechanical growth. Currently, the natural population growth rate is very low in some countries and regions. For example, in China, the natural population growth rate was only 0.3‰ in 2021, and the population growth in 2022 was negative for the first time in 61 years, indicating that the contribution of natural population growth to regional population growth is quite limited. With the development of the economy, population migration has gradually become the decisive factor in regional population changes. The push–pull theory has become the theoretical basis for population migration, suggesting that the purpose of population mobility is to improve living conditions. The pull factors of the destination, such as the good economic development level, sufficient employment opportunities, perfect public service system, and beautiful natural environment, become the pulling factors, while the push factors of the origin, such as poor natural conditions, lower level of economic development, limited job opportunities, and low quality of public services, become the pushing factors. Population mobility is determined by these two forces [27–30]. As a result, the differences in the natural environment, economic development level, employment opportunities, quality of public services, and administrative status between inflow and outflow areas have become important factors affecting regional population distribution changes [4,8,11]. Some scholars have used urban amenity theory to explore the factors influencing the population dynamics, which include economic amenity, social amenity, and natural amenity [11,31]. In fact, the impact of economic amenity and non-economic amenity (social amenity and natural amenity) on population dynamics, as emphasized by urban amenity theory, is similar to that of push–pull theory, which suggests that population migration is influenced by supply pull and demand push, i.e., population dynamics are influenced by various factors such as physical and geographical environment and economic and social development.

In general, the existing studies on population dynamics are mainly focused on developed countries, while studies on developing countries are still insufficient. For China, although existing studies have systematically explored the population dynamics and their influencing factors, due to the limitation of data acquisition, previous studies only focused on the population distribution in 2010 and earlier, lacking the tracking of the latest dynamics and comparative studies across time. Since 2010, China's regional development strategies and economic development patterns have undergone drastic changes, and thus the spatial variation in population dynamics and its influencing factors may take on different characteristics than before, which requires a reinterpretation of population dynamics and its formation mechanism to deepen the understanding of China's population redistribution. In addition, existing studies have conducted fewer comparative studies across regions. In fact, due to the differences in the social and economic development stages of the regions (eastern and central–western regions), the driving factors of their population changes are not necessarily the same. The conclusions drawn from national-level studies may not be entirely applicable to these two types of regions, so it is necessary to conduct separate examinations and comparative analyses. The aim is to fill the aforementioned gap and better grasp the trends and mechanisms of balanced population distribution, promote optimal population layout, and achieve long-term balanced population development. This paper explores the spatial pattern and influencing factors of China's population changes using spatial analysis and multiple linear regression methods. More specifically, three research questions are explored: (1) Has the basic pattern of population distribution in China changed, and what are the new changes? (2) How have the effects of natural conditions, economic and social development, and policy factors on population changes changed over time? (3) What are the differences and similarities in different regions? The remainder of the paper is structured as follows: Part II introduces the data sources and research methods used in this study; Part III analyzes the new dynamics of population distribution in China over the past 20 years; Part IV presents the analysis results of influencing factors of population dynamics; Part V and Part VI present the discussion and conclusion, respectively.

2. Materials and Methods

2.1. Data Sources

Taking prefecture-level units and municipalities directly under the Central Government as a research object, due to the lack of data, the Hong Kong SAR, Macao SAR, and Taiwan Province are not included in the scope of this study. To maintain spatial continuity and facilitate analysis, individual county-level administrative regions that are under provincial administration are consolidated or listed separately. Based on the research needs, some statistical data were pre-processed by integrating the corresponding data from three years into the administrative division system in 2020 to ensure the accuracy and reliability of longitudinal comparison. Based on this, a total of 341 prefecture-level units were included in the study. The population data used in this study were obtained from the fifth, sixth, and seventh national censuses. The socio-economic data involved in the econometric model were obtained from *China City Statistical Yearbook 2001*, *China County (City) Socio-Economic*

Statistical Yearbook 2001, *China Regional Economic Statistical Yearbook 2011*, *China City Statistical Yearbook 2021*, and *China County Statistical Yearbook 2021*. The meteorological data were obtained from the National Ecosystem Research Network of China, and the relief degree of land surface (RDLS) was calculated by referring to the terrain relief extraction method proposed by Feng et al. [32].

2.2. Methods

2.2.1. Population Concentration Index

The population concentration index describes whether a region's population distribution is relatively dispersed or concentrated, with a value ranging from 0 to 1. The more it tends to 1, the more concentrated the population distribution is; the more it tends to 0, the more dispersed the population tends to be [4], and its mathematical expression is:

$$C = \frac{1}{2}\sum_{i=1}^{n}|x_i - y_i| \tag{1}$$

where n is the number of samples; x_i is the proportion of the population of study unit i to the total population of the study area; y_i is the proportion of the area of study unit i to the total area of the study area.

2.2.2. Population Center of Gravity Model

The population center of gravity is an important indicator of population distribution, and its change trajectory reflects the basic trend of population distribution and its evolution. The calculation formula is [33]:

$$\overline{x} = \sum_{i=1}^{n} P_i X_i / \sum_{i=1}^{n} P_i \;\; \overline{y} = \sum_{i=1}^{n} P_i Y_i / \sum_{i=1}^{n} P_i \tag{2}$$

where X_i and Y_i are the longitude and latitude of region i, respectively; P is the population of region i; and n is the sample size.

2.2.3. Relative Change in Population Density

By calculating the relative change in population density, the changes in population density are classified to reveal the regional characteristics of population changes. The calculation formula for the relative change in population density is as follows [2,34]:

$$F = \frac{d_t - d_0}{D_t - D_0} \tag{3}$$

where F is the relative change in population density; d_t and d_0 denote the population density of a prefecture-level unit at the end and the base period, respectively; D_t and D_0 represent the national population density at the end and the base period, respectively. Based on the values of the relative change in population density, population density changes can be divided into four types: $F > 1$ indicates a rapid increase, $0 \leq F \leq 1$ indicates a slow increase, $-1 \leq F < 0$ indicates a slow decrease, and $F < -1$ indicates a rapid decrease.

2.2.4. Multiple Linear Regression Model

This study adopts a multiple linear regression model to investigate the factors influencing population changes and compares and analyzes the changing characteristics of the influence of each factor in different time periods and regions. The model is set as follows:

$$PG_{it} = \beta_0 + \beta_1 GDP + \beta_2 hos + \beta_3 cap + \beta_4 pre + \beta_5 tem + \beta_6 rdls + \beta_7 den + \varepsilon \tag{4}$$

where PG_{it} denotes the population growth rate in i area during t period, β is the regression coefficient, and GDP, hos, cap, pre, tem, $rdls$, and den represent per capita GDP, number of hospital beds per 10,000 people, provincial capitals or high-ranking cities (High-ranking cities include: Beijing, Tianjin, Shanghai, Chongqing; Harbin, Changchun, Shenyang, Shijiazhuang, Jinan, Nanjing, Hangzhou, Fuzhou, Guangzhou, Haikou, Taiyuan, Zhengzhou, Hefei, Wuhan, Changsha, Nanchang, Urumqi, Xining, Lanzhou, Xi'an, Chengdu, Kunming, Lhasa, Nanning, Hohhot, Yinchuan, Guiyang; Dalian, Qingdao, Ningbo, Xiamen, and Shenzhen). This variable is a binary variable and is assigned a value of 1 in the regression model for high-ranking cities and 0 for the rest of the cities, multi-year average rainfall, multi-year average temperature, RDLS, and population density, respectively, and ε is the error term. Except for the time-constant variables, all other variables adopt the level of the study base period to reduce the endogenous effects.

Regional population changes are the result of both natural growth and population migration. However, with socioeconomic development and enhanced population mobility, regional differences in natural growth are no longer an important force shaping the spatial pattern of population changes, especially for China, which has entered negative population growth and has small differences in natural growth among regions. Instead, population migration has increasingly influenced regional population growth. This study analyzes the changes in regional population distribution from the perspective of population migration. Existing studies have shown that population migration is influenced by various factors such as natural, economic, political, and cultural factors [8,11]. In particular, physical geographic conditions, economic and social development, and policy factors shape the spatial patterns of population distribution and its changes. The reasons for selecting each variable are as follows:

(1) Economic and social factors

Economic and social factors play a dominant role in population distribution, particularly in the redistribution related to population migration [4,11,28,29,35]. The regional differences in population growth in China are largely determined by the differences in economic and social development. Since the reform and opening-up in 1978, the eastern region has benefited from its excellent geographical conditions and policy advantages and has attracted a large amount of surplus labor force from central and western regions with a higher income level, achieving rapid population growth. With the improvement of living standards and the upgrading of demand levels, more attention has been paid to the role of social factors in population distribution changes. Among these factors, public services have an important influence on population agglomeration and have become one of the main driving factors for population growth [8,29,35]. In this paper, we choose GDP per capita to characterize the regional income level, which measures economic conditions, and the number of health beds in medical institutions per 10,000 people to characterize public services such as medical access, which measures social conditions.

(2) Natural factors

Different combinations of temperature and precipitation result in significant regional differences in population spatial distribution. Overall, population density shows a significant positive correlation with precipitation and temperature [36–38]. RDLS is one of the important factors affecting population distribution, and it is an important indicator for natural evaluation of human settlements [32,38,39]. The majority of the population in China lives in areas with low RDLS, while areas with high RDLS carry very few people [32]. In this paper, we choose multi-year average precipitation, multi-year average temperature and RDLS to characterize the influence of natural environmental factors on population distribution in China.

(3) Policy factors

Studies have shown that the administrative level plays a non-negligible role in urban development [40]. Cities with higher administrative levels can obtain more resources from the central government in terms of construction funds, education, healthcare and various preferential policies, which are key elements that attract and gather population [35]. Compared with general prefecture-level cities, high-level cities represented by provincial capitals, cities specifically designated in the state plan and municipalities directly under the central government have more financial and administrative independence, and urban construction is also more complete. Therefore, these high-level cities are more attractive to the population than general prefecture-level cities. This article selects whether a city is a higher-level city to characterize the impact of policy factors on population distribution.

(4) Initial population density

Influenced by economies of scale and agglomeration, the expansion of production scale will lead to an increase in production efficiency, which in turn will attract the population to accelerate agglomeration. However, due to the crowding effect, overpopulation may lead to a decrease in urban efficiency, thereby causing a decrease in population [4]. We introduce the base-period population densities for two periods, 2000–2010 and 2010–2020, to explore the impact of initial population size on China's population changes and to quantify the overall clustering and dispersal trends of China's population. The descriptive statistics of these variables are shown in Table 1.

Table 1. Descriptive statistics of variables.

Variables	2000				2010			
	Mean	SD	Min	Max	Mean	SD	Min	Max
PG	7.88	15.21	−35.58	146.47	3.56	16.86	−46.39	88.62
GDP	7384.77	5645.40	1305.65	51,285.56	30,788.56	21,941.21	5138.10	181,927.22
hos	27.61	13.42	7.28	161.94	36.70	11.11	12.36	108.28
cap	0.11	0.31	0.00	1.00	0.11	0.31	0.00	1.00
pre	998.96	517.10	111.45	2075.10	998.96	517.10	111.45	2075.10
tem	12.90	6.20	−3.44	25.39	12.90	6.20	−3.44	25.39
rdls	1.02	1.25	0.00	5.79	1.02	1.25	0.00	5.79
den	360.17	386.17	0.26	3518.49	399.66	500.79	0.32	5199.99

Note: The growth rates of the permanent population in 2000 and 2010 are the growth rates of the permanent population from 2000 to 2010 and from 2010 to 2020, respectively; All other variables are current year values.

3. The Evolution of China's Population Distribution Patterns

3.1. Overall Distribution Characteristics

The population concentration indices for the three years 2000, 2010, and 2020 were 0.5645, 0.5684, and 0.5813, respectively, indicating that China's population is unevenly distributed. The population concentration index increased by 0.0039 between 2000 and 2010, while it rapidly increased by 0.0129 between 2010 and 2020. The speed of population concentration is more than three times that of the previous 10 years, indicating that the concentration trend of China's population distribution has significantly strengthened. These findings are also corroborated by the Lorenz curve (Figure 1). The Lorenz curves for different years all deviate significantly from the absolute mean line of population distribution, and the degree of deviation gradually increases. Compared to the two curves in 2010 and 2000, which are close to overlapping, there is a clear distance between the two curves in 2020 and 2010. Different measurement indicators have drawn the conclusion that China's population distribution is uneven and the spatial concentration of population distribution continues to increase. This is the result of the accelerating agglomeration of China's population in a few areas, forming significant sparsely populated and densely populated areas.

The trajectory curve of population center of gravity change, which depicts the direction of population distribution and its evolution, is obtained by connecting the population center of gravity of each year in turn. In terms of the population center of gravity location, it was in the Henan Province in 2000 and 2010, and in the Hubei Province in 2020 (Figure 2). China's population center of gravity deviated from China's geometric center of gravity for all three years (103.23° E, 35.33° N), indicating that China's population distribution has been in an uneven state. In terms of the population center of gravity's trajectory, China's population center of gravity traveled primarily in an east–west direction from 2000 to 2010, and then primarily in a north–south direction from 2010 to 2020. Since the reform and opening up, particularly since the turn of the century, the rapid economic development of the eastern coastal areas has resulted in a continuous widening of the gap in economic development levels between regions, driving rapid population growth in the eastern coastal areas. Between 2000 and 2010, the eastern coastal areas saw a population increase of up to 13.59%, with its proportion in the national population rising from 35.6% in 2000 to 37.98% in 2010—an increase of 2.38 percentage points over the course of a decade. Meanwhile, during the same period, the population growth rate of the central–western regions was only 3.22%, and its proportion in the national population fell from 55.97% in 2000 to 53.81% in 2010—a decrease of 2.16 percentage points in ten years. Over the past decade, with the rise of new first-tier cities represented by provincial capitals in central and western China and the transfer of labor-intensive industries from the eastern coastal areas to central and western regions, more and more people have returned to the inland areas, resulting in a shift of the population center of gravity to the west. However, compared with the short distance movement of population center of gravity in the east–west direction during this period, the shift of population center of gravity in the north–south direction is more drastic. Between 2010 and 2020, the population growth rate in northern China sharply declined, with an increase of only 2.20 percentage points over ten years, while the population growth rate in southern China reached as high as 8.52 percentage points. As a result, the proportion of the southern population in the national population rose from 57.92% in 2010 to 59.41% in 2020, an increase of 1.48 percentage points. During this period, several provinces in northern China experienced a population shrinkage phenomenon, and the permanent population in the three provinces of Northeast China decreased, leading to a shift in the population center towards the south. In conclusion, the spatial differences in population growth changes in China over the past 20 years are shifting from east–west to north–south differences.

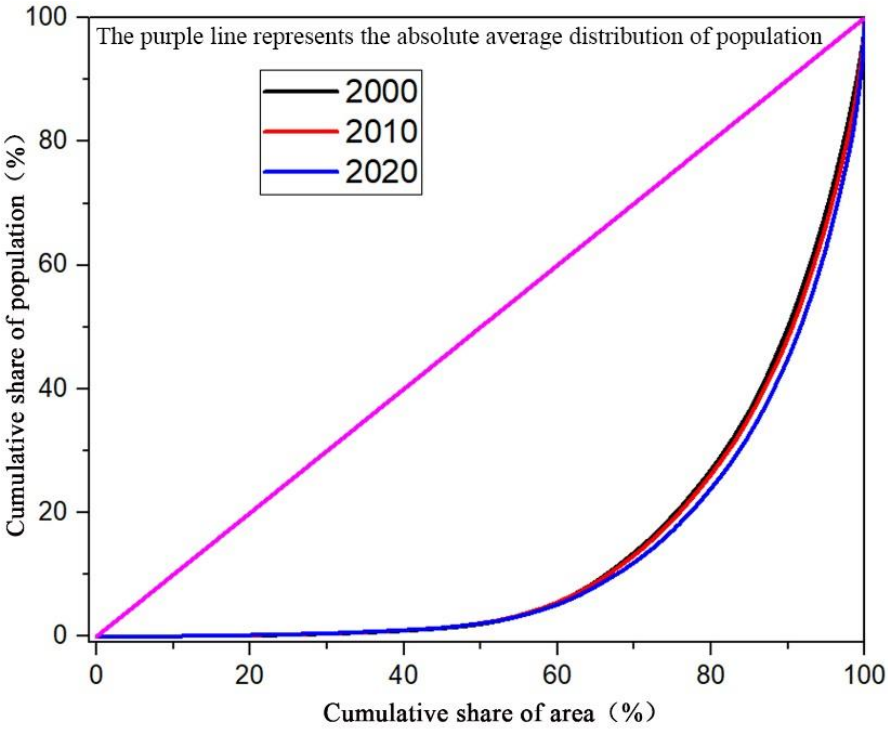

Figure 1. Lorenz curve of China's population distribution.

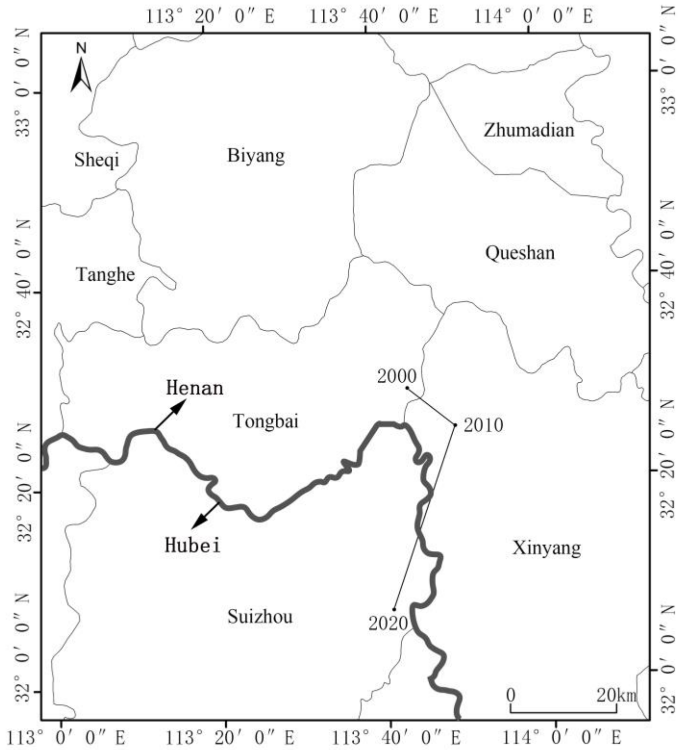

Figure 2. The movement trace of population center of gravity in China during 2000–2020.

3.2. Spatial Distribution Evolution Characteristics

As shown in Figure 3, it can be seen that the spatial pattern of China's dense eastern and sparse western population remains stable from 2000 to 2020, and its long-term stability is determined by the difference in the natural geographical environment on both sides of the Hu line [3,8,36,41,42]. The region with the higher population density, often exceeding 400 people/km^2, is on the southeast side of the Hu line, and includes the Huang–Huai–Hai Plain, the Yangtze River Delta, the Pearl River Delta, the middle reaches of the Yangtze River, and the Sichuan Basin. In contrast, the northwestern side of the Hu line, including the Inner Mongolia Plateau, the Qinghai–Tibet Plateau, and the Northwest arid regions, is a sparsely populated area with a low population density. Most areas have a population density below 25 people/km^2, making this a sparse area of China's population distribution.

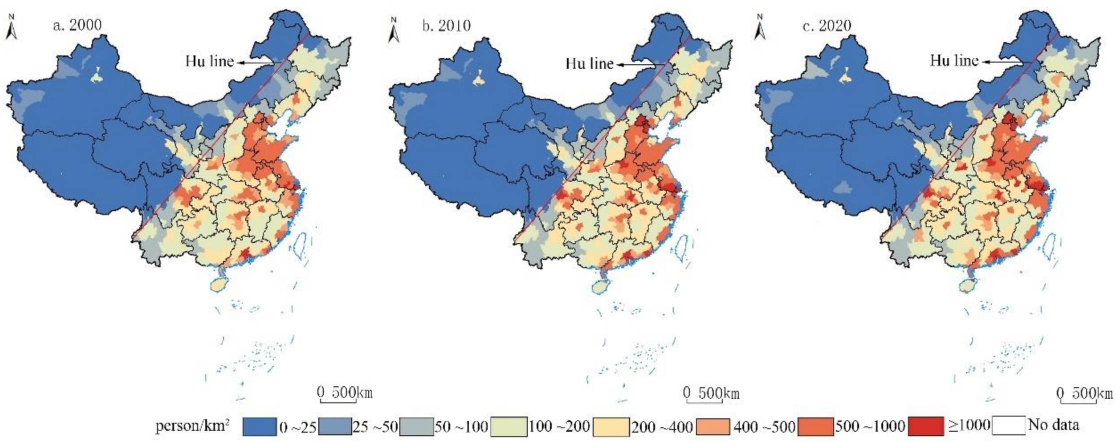

Figure 3. Spatial distribution of population density at prefecture-level units in China during 2000–2020.

Within the province, the population distribution shows an obvious center–periphery feature, and this characteristic has become even more pronounced over time. Provincial capitals usually have a higher population density, while prefecture-level units far from the provincial capitals tend to have a lower population density, particularly in the central and western regions. This is because provincial capitals have a higher economic development level and improved public service facilities, which can attract population aggregation, while prefecture-level units far from the provincial capitals find it difficult to benefit from the radiation-driven effect of the provincial capitals, and therefore have weaker attractiveness to the population and lower population densities.

Comparing the dynamic changes between the periods 2000–2010 and 2010–2020 (Figure 4), it is found that the greatest change in the distribution of density-increasing and density-reducing regions is the shift from general growth to general shrinking in Northeast China, with only 11 cities experiencing a decrease in population density from 2000–2010, while only three cities—Changchun, Shenyang and Dalian—experienced an increase in density from 2010–2020. The other three significant changes in the distribution of population-shrinking regions are: from western Shanxi and southern Shaanxi to the Hexi Corridor, forming the second-largest population-shrinking region in China after the Northeast. Except for a few cities with advantageous locations and good economic foundations achieving continuous population growth, the rest of the cities in the Hunan and Jiangxi provinces in central China have shifted from growth to shrinkage; almost the entire province of Yunnan in southwestern China has transitioned from a population growth area to a shrinking area, becoming a "laggard" in regional development and a continuous source of population migration. There are also three new characteristics in the distribution of population growth areas: The Sichuan–Chongqing region and the junction area of Su-Lu-Yu-Wan used to be major population shrinking areas in China, but they achieved population growth from 2010 to 2020; higher-ranking cities mainly consisting of provincial capitals have generally experienced a rapid increase in population attraction, which is true on both sides of the Hu line; regions with faster population density growth are more dispersed spatially, forming a new pattern of interlacing between growth and shrinkage areas.

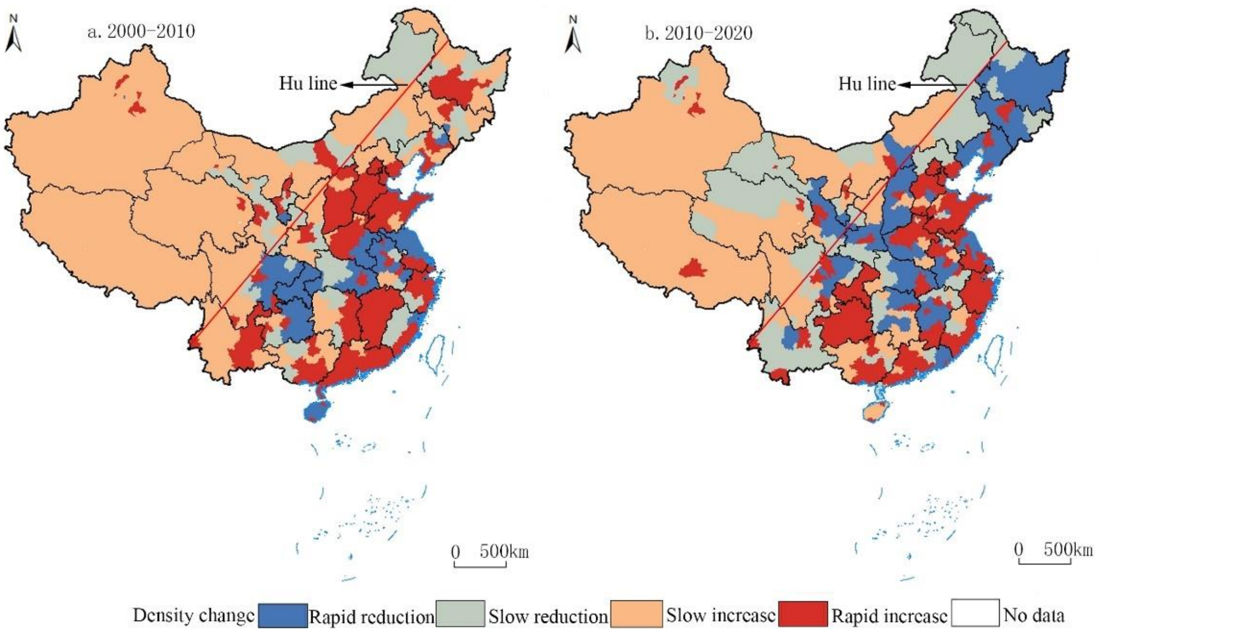

Figure 4. The spatial pattern of population density changes in China during 2000–2010 and 2010–2020.

Population growth exhibits a certain inertia (the prefecture-level units with rapid population growth from 2000 to 2010 will also experience rapid population growth from 2010 to 2020), which is especially true for higher-ranking cities (Figure 5). In fact, 34 of the 36 high-ranking cities achieved population growth in both periods, except for Chongqing, which went from a decrease to an increase, and Harbin, which went from an increase to a decrease, and most of them grew faster in the latter period than in the former period.

From 2000 to 2010, the population growth rates of high-ranking cities and outside them were 20.97% and 3.84%, respectively. China had a growth of 4.08 percentage points in the population of high-ranking cities, from 24.72% to 28.80%. Against the background of a significant decline in the national population growth rate, the population of high-ranking cities increased by 24.27% from 2010 to 2020, while that of other prefecture-level units was only 0.39%, resulting in an increase in the share of high-ranking cities in the national population from 28.8% to 35.65%, an increase of 6.85 percentage points. Based on the established fact that the population share of high-ranking cities increases at a higher rate in 2010–2020 than in 2000–2010, and combined with the findings of the above analysis that the population distribution is concentrating at a significantly faster rate, this "co-variation" feature suggests that the increase in the population attractiveness of high-ranking cities is the main driving force for population concentration in China, and that the main direction of population redistribution in China is towards high-ranking cities, which reinforces the center–periphery pattern of population dynamics.

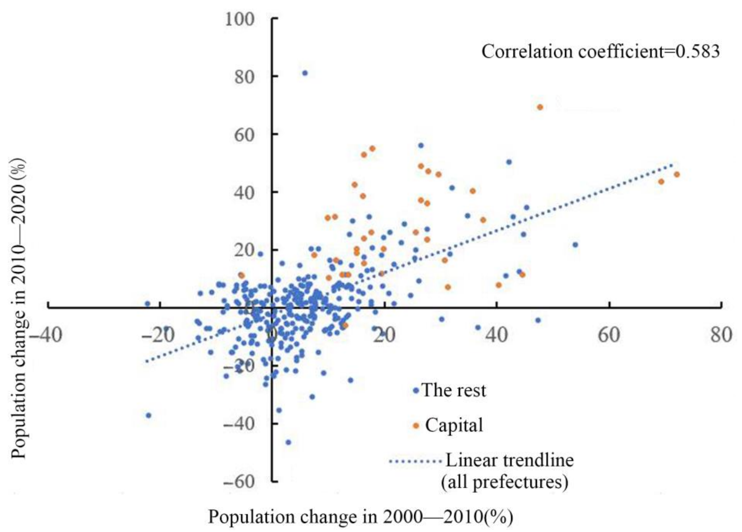

Figure 5. Prefectures that changed direction in population growth 2000–2020.

4. Factors Influencing Population Dynamics

To examine the factors influencing population changes, this study conducts a regression analysis using population growth rates as the dependent variable for the periods 2000–2010 and 2010–2020, respectively, incorporating the independent variables described previously. We first performed collinearity diagnostics on the variables, and the variance inflation factor (VIF) for each independent variable was less than five, indicating no serious issue of multicollinearity among the variables. For the regression analysis, we first fitted the model to the entire sample and then estimated separate models for the eastern and central–western regions; the results are listed in Table 2. The goodness-of-fit of all models is greater than 0.35, which is better than or roughly equivalent to the goodness-of-fit of models in existing similar studies [4,8,11,28].

From the regression results, it can be found that physical, economic, social, and policy factors all play a role in population changes, but the direction and intensity of their effects change over time. In the full sample model, compared with 2000–2010, the impact of natural factors on China's population distribution evolution has been strengthened during 2010–2020, and the rapid population growth areas have shifted to mountainous areas with higher temperatures. Specifically, temperature and topography had small explanatory power for regional differences in population changes during 2000–2010, but in 2010–2020, the standardized regression coefficients of these two factors ranked first and second among all variables, becoming important factors affecting population growth in this period. During this stage, populations in some less favorable and steep mountainous areas grew faster, while regions with flat terrains more suitable for human habitation experienced serious population outflows due to experiencing rapid population growth earlier and entering the population transition stage [8]. The correlation between temperature and population growth largely reflects the southward shift of the population center of gravity. The impact of economic factors, represented by GDP per capita, on population changes has declined in the past decade, while social factors represented by the number of hospital beds per ten thousand people have started to play a positive role in population growth. A higher income level remained a critical factor attracting population in both periods, especially during 2000–2010 when the standardized regression coefficient of per capita GDP ranked first among all influencing factors, demonstrating the crucial role of economic factors in population growth at that time. However, in the past decade, the impact of economic factors on population changes has decreased significantly, while the importance of social factors in population growth has emerged. This is in line with Maslow's hierarchy of needs theory, which suggests once people's basic needs (access to income to meet basic living expenses) are met, access to higher-level needs, such as public services, will become a priority. It also indicates that regional population changes are gradually transitioning from being driven solely by economic factors to being jointly driven by social and economic factors, reflecting an important shift in the patterns and dynamics of China's population migration. The standardized regression coefficients for high-ranking cities were larger and increased compared to the previous period, indicating that these cities had advantages in terms of population attractiveness, and this advantageous position is being further strengthened. High-ranking cities have the advantages of economies of scale and agglomeration and are able to provide higher income, sufficient employment opportunities, and improved public services, making them highly attractive to migratory populations. During 2000–2010, population growth in high-ranking cities was 17.13 percent higher than other prefecture-level units, while during 2010–2020, this difference expanded to 23.88 percentage points, which further confirms that high-ranking cities, as administrative resource centers, have an unmatched attractiveness to population growth compared with other prefecture-level units. Finally, the relationship between initial population density and subsequent population growth shifted from being insignificant to significantly positive, which indicates that densely populated areas experienced more rapid population growth, verifying the previous finding of an enhanced polarization trend in population changes and a more uneven distribution of population spatially.

Table 2. Regression results of factors influencing population changes.

Variables	**Full Sample**		**Eastern**		**Central and Western**	
	2000–2010	**2010–2020**	**2000–2010**	**2010–2020**	**2000–2010**	**2010–2020**
GDP	0.446 ***	0.244 ***	0.276 ***	0.316 ***	0.312 ***	0.220 ***
	(8.557)	(5.452)	(2.664)	(2.756)	(5.270)	(4.380)
Hos	0.064	0.279 ***	−0.008	0.130	0.145 **	0.288 ***
	(1.288)	(6.033)	(−0.097)	(1.127)	(2.150)	(5.420)
cap	0.250 ***	0.258 ***	0.382 ***	0.188 **	0.274 ***	0.286 ***
	(5.114)	(5.901)	(3.758)	(2.067)	(5.000)	(5.558)
pre	0.008	−0.051			−0.187 **	−0.076
	(0.105)	(−0.721)			(−2.147)	(−0.948)
tem	0.131	0.520 ***	0.346 ***	0.434 ***	0.239 **	0.444 ***
	(1.406)	(6.501)	(4.141)	(4.864)	(2.255)	(4.927)
rdls	0.329 ***	0.481 ***	−0.096	0.108	0.356 ***	0.564 ***
	(5.949)	(9.925)	(−1.076)	(1.305)	(5.656)	(9.989)
den	0.037	0.218 ***	−0.053	0.221 **	−0.189 ***	0.231 ***
	(0.679)	(4.542)	(−0.521)	(2.102)	(−2.866)	(3.801)
N	341	341	88	88	253	253
Adj. R^2	0.377	0.518	0.429	0.507	0.400	0.519

Note: Data in parentheses are t-values, *** and ** indicate 1% and 5% significance levels; temperature and precipitation in the eastern region are highly correlated, and precipitation is removed from the model to eliminate the effect of covariance on the regression results.

From the sub-regional model of population changes, the impact of natural, economic, social, and policy factors are not consistent in the two types of regions, indicating that the drivers of population changes vary depending on the development stage of the region. Comparatively speaking, population changes in the central–western regions are influenced by multiple natural factors, with rapid population growth areas shifting toward mountainous areas with higher temperatures, moderate precipitation, and steeper slopes, while the eastern coastal region's topography and rainfall differences are so small that both factors have little explaining power in the region's population changes, and population growth in the region is more influenced by temperature, with warmer areas experiencing more rapid population growth. On the whole, the population changes in both eastern and central–western regions are influenced by temperature, but the central–western regions are also affected by topography and rainfall. Per capita GDP has a positive effect on population growth in both types of regions, but its influence has increased in the eastern region and decreased in the central–western regions, indicating that economic factors play an important role in population changes, but the trend of influence also varies depending on the development stage. As the most economically developed region in China, the differences in healthcare resource conditions among cities in the eastern region are not significant enough to affect the spatial pattern of their population changes. For long-distance migratory populations, obtaining higher income and enjoying city life are their core goals [35], and they may not care about this factor when the level of public services is generally higher. They care more about which cities will allow them to obtain a higher income. For the central–western regions, the medical resources have an important impact on population changes, and the population growth is also faster in areas with abundant medical resources. This is because along with the improvement of living standards and the rise of demand levels in the central–western regions, the population has a higher demand for public services, and thus medical resources play a more important role in the population growth, especially migration growth. Evidence indicates that economic and social factors have a mutually reinforcing and antagonistic relationship in terms of their impact on population changes. When a region is in a lower stage of development, economic factors have an important impact on population growth, while social factors have no effect or play a small role. As the level of development increases, both economic and social factors have an impact on population growth. When the region reaches an advanced stage of development, the impact of social factors on population changes decreases, and population changes may be influenced by higher-level needs, such as an attractive environment. High-ranking cities have a significant impact on population changes in both types of regions, but this factor has weakened in the eastern region while it has strengthened in the central–western regions. The population growth advantage of high-ranking cities in the central–western regions in 2010–2020 has increased significantly compared with that in 2000–2010, and they are in the stage of accelerated population agglomeration in central cities. However, the opposite trend appears in the eastern region, where the population growth advantage of high-level cities has slightly declined. With the construction of urban agglomerations and metropolitan areas, some central cities in the eastern region are gradually shifting from population agglomeration to population diffusion after long-term population aggregation. Lastly, there is a positive correlation between initial population density and subsequent population growth in both types of regions, indicating that the unevenness of population distribution within the central–western regions is increasing.

5. Discussion

This article shows that population distribution in China is extremely uneven, and the rate of population concentration has noticeably accelerated. One important reason for this is the continuous migration of population to large cities, which have become an important carrier of China's population. This challenges the argument that major Chinese cities cannot sustain continued population growth due to their large size and inefficient clustering. The population growth patterns in major Chinese cities are different from those in London and New York, whose populations declined during the economic readjustment period [3], yet China's major megacities such as Beijing, Shanghai, Guangzhou, and Shenzhen have continued to grow in population despite the downside and structural adjustment facing the Chinese economy. This trend in population dynamics contradicts Friedman's core–periphery four-stage regional development model, which asserts that a country's economy in general goes through pre-industrial, transitional, industrial, and post-industrial stages, each of which gives rise to a series of spatial changes in population at the regional level. Since 2010, China's economy has experienced a continuous decline for many years and has entered a new normal stage [43], characterized by a decrease in the proportion of the secondary sector in GDP. China has entered the third stage of Friedman's model, the industrial stage, in which the increase in production costs in the core areas, coupled with the decrease in transportation costs brought about by easy access to external transportation links, has prompted population dispersion from core areas to peripheral areas. In theory, population dispersion has already occurred in large Chinese cities, and cities that previously experienced rapid population growth are now beginning to experience population decline. However, in fact, large Chinese cities continue to experience population growth, and at an even faster rate. This may be because China's cities are still in the agglomeration economy stage and have not yet experienced agglomeration diseconomies. With the outward transfer of industries and highly interlinked transportation, as well as the population restrictions imposed by urban master plans, some people have started to migrate from the megacities to lower-tier cities in search of better living conditions. This is reflected in the fact that although the population of Beijing and Shanghai has grown, the population growth rate has slowed down significantly compared to the previous period. There is a possibility that the population will decrease in the future as it did in London and New York half a century ago, entering the third stage of the urbanization process: the counterurbanization stage.

In the past decade, the Chinese government has explicitly proposed restricting further population growth in large cities in several policy documents. However, based on the research results of this article, it is evident that these policies have not been effective. In fact, the conclusion drawn in this study that high-ranking cities are increasingly important in shaping China's population distribution also implies to some extent that a trend of population aggregation towards large cities is occurring. From this perspective, the core cities of the three major urban agglomerations represented by Beijing, Shanghai, Guangzhou and Shenzhen, coastal provincial capitals, and central and western inland core cities will continue to attract population inflows. The government needs to face this reality and should not be overly reliant on administrative means to control population inflows into large cities.

The factors influencing population changes vary across time: in the early period, population growth occurred more in areas suitable for agricultural production and human habitation, such as flat terrain and abundant precipitation. However, with the reduction in population restrictions caused by physical factors, population growth began to shift gradually to inland mountainous areas with higher temperature and larger slope. It is worth noting that the statistical results show that temperature has a significant impact on population changes. On the one hand, it may reflect people's preferences for comfort in warm areas, and on the other hand, it may also reflect factors such as cultural, institutional, and social psychology that the model did not consider and may show differences between the North and South. Economic development can be regarded as the physiological needs of people, which are always important for population growth, but along with the improvement of living standards and the rise of demand levels, the positive role of social factors such as public services in population growth is becoming increasingly apparent [11]. When a region develops to an advanced stage, the influence of social factors on population changes decreases, and population changes may be influenced by higher-level needs, such as an attractive environment. Additionally, the differences in environmental quality among different regions may become an important factor affecting future population spatial pattern changes [26,31]. In the middle stage of urbanization, the population tends to gather in the central cities and continues to strengthen, while in the later stage of urbanization, the population may spread outward from the central cities [5].

The main findings of this paper are of practical significance for guiding the orderly distribution of population, promoting the optimal allocation of resources, and achieving a balanced population distribution. Currently, China's population distribution is becoming more polarized, with the eastern region and central cities experiencing rapid population concentration and increased pressure in a resource and environmental carrying capacity, while the northeastern region and non-central prefecture-level units are generally facing population shrinkage and insufficient economic and social development momentum. The challenges faced by these two types of regions are completely different, and policy responses should also emphasize different aspects. The former should focus on improving resource supply capacity, while the latter should implement targeted policies. For some areas with development potential, we should cultivate and undertake new industries, improve the regional income level, increase employment opportunities, and increase investment in public services to enhance population attractiveness. For other areas, we should strengthen measures to cope with population shrinkage, shift from the development idea dominated by population growth, and focus on improving the quality of life of the population rather than expanding the population size.

The conclusions of this article have certain reference significance for grasping the overall pattern and dynamics of China's population distribution, but due to limited space and data, some topics have yet to be explored. This article explores the overall population, eastern and central–western population distribution patterns, and change mechanisms. However, the spatial distribution and changes in specific groups such as floating population, highly educated talents, and the elderly population are also extremely important for factor allocation and policy formulation and need to be carried out as soon as possible. In addition, this article is based on the analysis and discussion at the prefecture-level scale, but due to the scale effect, the analysis conclusions based on different scales may vary, and multi-scale population distribution pattern analysis is needed to test the consistency of the conclusions.

6. Conclusions

Based on the data of the fifth, sixth, and seventh censuses, the population concentration index, the center of gravity model and the relative change in population density have been used to characterize China's population dynamics since 2000, and on this basis, natural, economic and policy factors are selected to explore the temporal evolution and regional divergence of factors influencing population changes. Additionally, new dynamics, trends and factors in population distribution changes in China in the last decade are identified. The conclusions are as follows:

In the past 20 years, China's population concentration index has been increasing and the population distribution has become increasingly uneven. There has been a significant change in China's population agglomeration trend. In the first ten years, the trend was clearly skewed towards the eastern regions. However, in the past ten years, the difference in population growth between the north and the south has become prominent, and the center of gravity of China's population has shifted to the south. Geographically, the spatial differentiation pattern of China's population being dense in the east and sparse in the west remains unchanged. The Huang Huai Hai Plain, the Yangtze River Delta, the Pearl River Delta, and the Sichuan Basin, with flat terrain, suitable climate, rich rainfall, and developed economies, are the most densely populated areas in China. Meanwhile, the Inner Mongolian Plateau, Qinghai Tibet Plateau, and northwest arid areas with poor natural conditions and underdeveloped economy have low population density and are sparsely populated areas in China. In addition, with the increasing population agglomeration ability of central cities, the population growth advantage of large cities has begun to emerge, forming a core–periphery structure of population distribution centered around provincial capitals within provinces.

By comparing the influencing factors of population dynamics in two periods, this study reveals the evolution trend of the influencing factors of population dynamics over time. The impact of physical factors on population dynamics has increased: the impact of terrain factors has been strengthened in the past 10 years, and the population growth area has shifted to mountainous areas with steeper slopes. The temperature has shown different effects between the two 10-year periods, with no effect on population dynamics in the first 10 years, while temperature has become an important factor in China's population dynamics in the latter 10 years. Temperature has a very clear latitude differentiation, indicating a clear north–south differentiation process in the pattern of population growth in China, which echoes the southward shift of China's population center of gravity in the last decade. Secondly, population dynamics are gradually transitioning from being driven solely by economic factors to being jointly driven by economic and social factors. Although economic factors have dominated China's population dynamics for a long time, the latest data show that the role of income in promoting population growth is weakening, while social factors such as medical resources are playing an increasingly important role in population growth. Finally, the trend of population agglomeration towards high-ranking cities is strengthening. China is in a phase of accelerated population concentration towards central cities.

By analyzing the similarities and differences in the factors influencing population growth in the eastern and central–western regions, this study found that the drivers of population dynamics vary depending on the economic and social development stage in the region: in the eastern region, the impact of natural factors on population dynamics is only reflected in temperature, while for the central–western regions, temperature, terrain and precipitation all have significant impacts on population dynamics, especially in the past decade, in which terrain and temperature have become the important factors driving population dynamics in the central–western regions. As the most economically developed and industrialized region in China, the eastern region has attracted a large number of migrant workers, resulting in population changes that are always strongly influenced by income levels, while the impact of social factors on population changes is not significant. Population changes in the central–western region are jointly affected by economic and social factors, but as social factors such as medical resources play an increasingly important role in population changes, the contribution of income level to population growth is diminishing. High-ranking cities play an important role in population changes in both types of regions, with the central cities in the eastern region showing a slowdown in population growth after experiencing population clustering, while in the central–western regions with low levels of economic development, the population agglomeration ability of central cities is further strengthened.

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