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Research article

Spatial distribution of floating population in Beijing, Tianjin and Hebei Region and its correlations with synergistic development

Lingling Wei[1], Haiyi Liu[2,*] and Lifeng Wu[1]

[1] School of Management Engineering and Business, Hebei University of Engineering, Handan 056038, China
[2] Shenzhen Polytechnic, Shenzhen 518055, China

* **Correspondence:** Email: fxgh01@163.com; Tel: 18810319252; Fax: 075526731712.

Abstract: Utilizing statistical information from the Seventh National Population Census, statistical yearbook and sampling dynamic survey data, this study examines the distribution characteristics of the floating population in Beijing, Tianjin and Hebei Region as well as the growth trend of the floating population in each region. It also makes assessments using floating population concentration and The Moran Index Computing Methods. According to the study, the spatial distribution of the floating population has a clear clustering pattern in Beijing, Tianjin and Hebei region. Beijing, Tianjin and Hebei region's mobile population growth patterns differ substantially, and the region's inflow population is mostly made up of migrant inhabitants of domestic provinces and inflow of people from nearby regions. Most of the mobile population resides in Beijing and Tianjin, whereas the outflow of people originates in Hebei province. The diffusion impact and the spatial features of the floating population in the Beijing, Tianjin and Hebei area have a constant, positive association, according to the timeline between 2014 and 2020.

Keywords: Beijing, Tianjin; Hebei region; spatial distribution; floating population; synergistic development

1. Introduction

Regional economic integration has become a prominent trend in development because of China's expanding reforms and Opening up, which has also caused the country's floating population to move often and quickly between urban and rural areas in addition to across regions. The constraints of the household registration system were abolished during China's time of reform and opening, which is when the large-scale floating population emerged as a separate social phenomenon. Beginning in 2015, 247 million floating residents, or 17.97% of China's total population, were actively seeking employment. The geographical pattern of socioeconomic growth has multiple effects on local economic, social and cultural development, but it also has restrictions on how people are distributed spatially in growing cities. In early 2017, the national population development plan (2016–2030) advanced the idea that balanced population development should be a major national strategy to develop favorably and successfully in collaboration with the local economy, society and resources as well as the environment. China's population growth had reached a crucial turning point, according to the plan. The coordinated and sustained expansion of regional economies in the Xi Jinping era is influenced by the logical flow and distribution of China's population. It provides Xi with a solid basis and enduring motivation to accomplish his goal of "two hundred years".

According to data from China's seventh census, 110 million people resided in the Beijing, Tianjin, Hebei Region in 2020, which covered an area of 217,000 square kilometers and generated an economic output of 8,639,317 billion. The Beijing, Tianjin, Hebei Region has seen population growth over time and has become one of China's most significant population centers. The region's carrying capacity has been exceeded by the population growth, particularly in Beijing, which has made the "big city syndrome" more prevalent. One of the key justifications for the proposed Beijing-Tianjin-Hebei cooperative development strategy is now due to this. The Beijing, Tianjin, Hebei Region is also plagued by a multitude of problems, such as an aging population structure, uneven regional economic development and environmental deterioration.

China has generally had low rates of birth and death, and migrant labor has replaced fertility as the main driver of population expansion in the area. Due to its unique geographic position, Beijing-Tianjin-Hebei is entrusted with examining regional synergistic growth and reform in China in the Xi Jinping era, and the mobile population plays a key role over there. The main components and factors that drive economic and social progress are appropriate population expansion and the influx of a mobile population. These factors could encourage sound socioeconomic development, the coordinated expansion of the Beijing, Tianjin and Hebei Region to a new turning point and acceleration of regional economic expansion. This research employs prefectural and municipal data as the units of analysis to study and explore the geographical distribution features of the mobile population in the Beijing, Tianjin and Hebei Region and its relationship with synergistic development. It uses a combination of mathematical statistics and spatial autocorrelation analysis and uses prefectural and municipal data as the units. It gathers data from China's Seventh National Population Census and related statistics.

2. Data and concepts

2.1. Definition of concepts

The concept of population floating defined by scholars such as Shryock and Siegel [1] emphasizes

distance between geographic areas and changes in permanent residence, and they noted that changes in permanent residence that do not meet a certain distance and changes in residence that fail to involve permanent residence would not be classified as floating. In comparison, the definition of floating in China has clear Chinese characteristics. The definition of the floating population in China's census has gradually built up experience through continuous trials and experiments. Chinese scholars are defining the floating population according to their individual research perspectives. Duan [2] defines population floating as the process of spatial displacement without corresponding change of Permanent Household Registration over a certain period and across a certain spatial distance, and the movement of the population between the place of residence and the Permanent Household Registration is the mobile population. According to Zhang [3], floating refers to people who leave their domicile temporarily and travel across certain jurisdictions to return from time to time. However, Li [4] argues that due to China's unique household registration system, population movement in China is limited to non-permanent migration, and population floating is confined to permanent changes in legal residence and household registration. In general, a distinction is often made between population floating and population migration depending on whether the population's permanent household registration moves with it, with no corresponding change in permanent household registration as population floating, and population migration accompanied by a corresponding change in permanent household registration. These definitions include both inflow and outflow populations and are defined in terms of space as well as time. Therefore, this paper is used at the discretion of the specific actual situation, such as the cited information.

The mobile population studied in this article refers to the concept of net inflow of population proposed by scholars such as Zhang and Wang [5], the value of the difference between the number of the resident populations in the region and the number of the registered populations in the region. The mobile population of a place mentioned in this article is the net inflow of population in that place.

The regional synergistic development referred to in this article refers to the Beijing-Tianjin-Hebei regional synergistic development, which refers to the synergistic development of Beijing, Tianjin and Hebei as a whole, forming a synergistic development with the same development goals, overall design of development measures, complementary advantages and mutual benefits.

After China's President Xi Jinping was briefed on the coordinated development of Beijing, Tianjin and Hebei in Beijing in February 2014, he emphasized that realizing the coordinated development of Beijing, Tianjin and Hebei is a need for the Chinese government to build a new capital economic circle for the future and promote the innovation of regional development institutions and mechanisms, a need for the Chinese government to explore the perfect layout and shape of urban clusters and provide a model and demonstration for optimizing regional development and a need for the Chinese government to explore the effective path of ecological civilization construction. It is also one of the major national strategies of China to realize the complementary advantages of Beijing, Tianjin and Hebei, to promote the development of the Bohai Rim Economic Zone and to drive the development of the northern hinterland. Therefore, this paper selects the three regions of Beijing, Tianjin and Hebei as the research object of collaborative development.

This analysis includes data from 11 cities at the prefecture level in the province of Hebei (Shijiazhuang, Tangshan, Qinhuangdao, Handan, Baoding, Xingtai, Langfang, Cangzhou, Hengshui, Chengde and Zhangjiakou) and 13 cities in the Beijing, Tianjin and Hebei Region, including Beijing and Tianjin.

2.2. Data origin

The primary sources of the data used in this work are the Seventh National Population Census, China Statistics Yearbook, Hebei Economic Yearbook, national economic and social development statistics bulletins, local municipal statistical yearbooks, etc.

3. Distribution characteristics of floating population in Beijing, Tianjin, Hebei Region

The Beijing, Tianjin, Hebei Region is among China's areas with the strongest economies and where the majority of the nation's migrants reside. It is possible to predict China's regional population development trend and comprehend the country's measures to optimize the regional spatial structure by looking at the concentration of floating population in the Beijing, Tianjin, Hebei Region in conjunction with the size and structure of population movement in the region and its evolution pattern.

3.1. Theoretical discussions about factors behind the changing distribution of the floating population

The theory of population migration can be traced back to the "push-pull" theory in late 19th century. In the article "Law of Population Migration", Ravenstein [6] pointed out that the key motivation for migration was economic and that the pursuit of better material living conditions was the main motivation for migration. In the paper "The Causes of Rural-Urban Migration a Survey of German Theories", Heberle [7] first proposed the "push-pull" theory, which suggests that population migration is the result of a combination of "push" and "pull" forces at the place of departure and the place of entry. In addition, Bogue [8] analyzed the "push-pull" theory of migration more systematically and argued that population migration is mainly due to the existence of "push" factors in each area that make people move out of the area. These factors include social, environmental, economic, cultural, political and other factors, but the most important is the economic factor. Based on the above theories, Lee [9] extended the theory of population migration by adding the responses of different groups of people to the "gravitational forces" and "resistance" encountered in the process of moving from the outgoing to the incoming place, which improved and enriched the study of the motivation of population migration. The American economist Lewis [10] proposed a model of population migration from the perspective of economics, revealing the process of economic growth and industrialization and the process of labor migration, which also provides a reference for China to formulate an economic development strategy to promote the transfer of surplus rural labor to urban areas.

Combined with the above theories, the changes in the distribution of mobile population in Beijing-Tianjin-Hebei region can be attributed to the favorable policies brought by the public policies introduced and adjusted by the government and economic factors, the latter being the main influencing factor.

3.2. Highly uneven spatial distribution of floating in Beijing, Tianjin, Hebei Region, mainly concentrated in Beijing and Tianjin cities

The ratios of residency to permanent household registration population in 13 urban cities in the Beijing, Tianjin and Hebei region were computed using the method of Wang et al. [11] to examine the population floating of those cities in 2020, measuring the spatial pattern of urban population

concentration with the formula

$$U = CZRS/HJRS. \quad (1)$$

In the formula, CZRS is the total resident population of a city; HJRS is the total registered population of a city; U is the ratio of resident population to registered population of a city.

When U < 1, the resident population of a city is smaller than the registered population, indicating that the trend of population inflow to a city is weak, and a city has a net outflow of population. When U > 1, the resident population of a city is larger than the registered population, which means that a city has a strong population inflow trend and enjoys a net inflow population. Beijing, Tianjin and Hebei as an area have a U that is more than 1, indicating that there is a net inflow of people, and the resident population is higher than the number of households listed on the register. A map showing the geographic distribution of the mobility population in the Beijing, Tianjin and Hebei Region (Figure 1), drawn from the above data, demonstrates that the region is a marked population concentration area. With a ratio of 1.56, Beijing has the highest resident to registered population ratio and has a strong population inflow. Tianjin, with a ratio of 1.22, is second only to Beijing. However, the total resident population in Hebei Province is less than the registered population, with a U-value of 0.97, indicating that Hebei Province is a net population outflow area. Four cities, Shijiazhuang, Qinhuangdao, Tangshan and Lang-fang, all have U-values between 1 and 1.1, with weaker population inflows; seven cities, Hengshui, Baoding, Chengde, Zhangjiakou, Cangzhou, Handan and Xingtai, all with resident to household registration population ratios less than 1, suffered from population outflows. The population aggregation varies greatly, and the population polarization phenomenon is more pronounced in the Beijing, Tianjin and Hebei region. Beijing and Tianjin have larger net floating populations than Hebei Province, and the two cities also have considerably more potential to absorb new citizens.

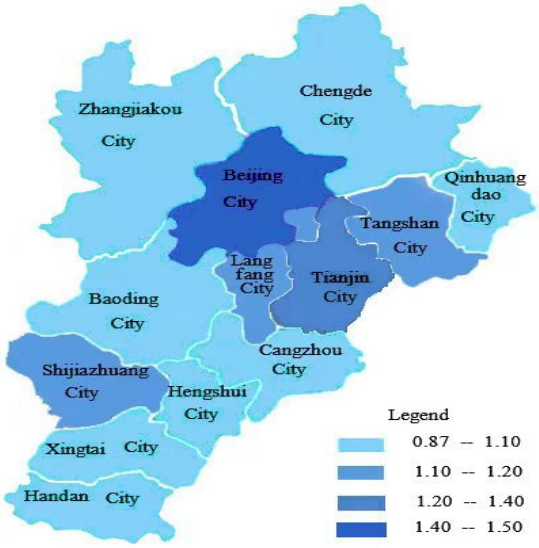

Figure 1. Geographical distribution of mobile population concentration in Beijing, Tianjin, Hebei Region in 2020 (Data source: Data from the seventh census in 2020, calculated from data related to the China Population and Employment Statistics Year).

3.3. Significant disparities may be seen in the growth patterns of the mobile population in the Beijing, Tianjin, Hebei Region

Based on the calculation method proposed by Zhang and Wang [5] to measure the net in-flow of population, for the net inflow of population in a region, it is possible to calculate the value of the disparity between the region's resident population and household registration population. In Beijing, Tianjin and Hebei, information on the resident population and the household registration population could be obtained in the Hebei Statistical Yearbook, the China Population and Employment Statistical Yearbook and the China City Statistical Yearbook. By examining the data on the resident and household populations for the five years from 2015 to 2019, the figures linked to the net inflow of population in Beijing, Tianjin and cities in Hebei province were calculated. See Table 1. Considering the adoption of the Beijing-Tianjin-Hebei cooperative development approach in China, Beijing and Tianjin have continued to have the biggest net influx of population among the 13 cities in the region, with average annual net inflows of 8,238,800 and 3,497,800, respectively. In the Beijing, Tianjin, Hebei Region, these are the two cities where the most people are moving in. The two cities in the region with the greatest reduction in net inflow population out of the 13 cities are Beijing and Tianjin, and this decline is linked to the various stages of urban growth. In these two cities, the yearly average net growth in immigration is negative.

Table 1 shows an analysis of 11 additional cities in the Beijing, Tianjin, Hebei Region, and it shows that cities with positive net inflows of population are places where there are net inflows. Particularly, Shijiazhuang, Tangshan and Qinhuangdao, the three cities with net population inflows, have stronger absorption power for the mobile population. Additionally, these cities are more alluring to the floating population in terms of employment opportunities, levels of materials, social and environmental resources and potential opportunities for personal development. Shijiazhuang, with an average annual net inflow of 721,500 people, is the most attractive city in Hebei Province; Tangshan and Qinhuangdao, two coastal cities with convenient transportation, developed investment and port trade, attract more inflow of mobile populations. Cangzhou, Chengde, Zhangjiakou, Hengshui and Langfang have a negative average net inflow of population, and all have net exodus of population. These cities provide relatively less employment opportunities for the mobile population and are not attractive to the mobile population. Also, these cities have more surplus agricultural labor, which fails to meet the employment demand of the regional population. Especially, Handan has an average net outflow of 847,700 people in this five-year period and is a large net outflow district. In four cities, Handan, Baoding, Chengde and Zhangjiakou, the yearly average net inflow population growth turns positive. It is obvious that Hebei province's cities shrank as more people moved in and out of the region. As a result of the influx of mobile population, Beijing and Tianjin's diffusion effect is growing. The economic synergy development initiatives in the Beijing, Tianjin and Hebei Region have been effective. Hebei Province in particular has seen a reduction in the demographic outflow trend, and it has made significant progress in taking on Beijing's non-capital responsibilities and promoting the deeper and wider spread of Beijing-Tianjin-Hebei synergistic development.

Table 1. Values related to annual net inflow (outflow) of population in Beijing, Tianjin and Hebei cities from 2015 to 2019. Unit: 10,000 people.

Number	City	2015	2016	2017	2018	2019	Annual average net inflow population	Annual net inflow increment
1	Beijing	843.1	832.5	835.2	815.9	792.7	823.88	−10.08
2	Tianjin	412.1	398.6	360.01	301.37	276.82	349.78	−27.06
3	Shijiazhuang	41.32	40.46	114.7	113.56	50.73	72.15	1.88
4	Tangshan	25.16	24.36	34.7	35.58	40.42	32.04	3.05
5	Qinhuangdao	11.68	11.46	13.08	13.42	13.63	12.65	0.39
6	Handan	−106.4	−105.72	−99.89	−105.19	−106.03	−104.65	0.07
7	Xingtai	−50.95	−56.01	−54.84	−59.56	−61.48	−56.57	−2.11
8	Baoding	−46.95	−43.55	−29.95	−34.86	−27.34	−36.53	3.92
9	Zhangjiakou	−26.84	−27.49	−21.69	−21.64	−22.67	−24.07	0.83
10	Chengde	−29.34	−29.82	−23.5	−24.11	−24.73	−26.3	0.92
11	Cangzhou	−30.06	−29.45	−22.51	−24.4	−32.57	−27.8	−0.5
12	Langfang	−4.81	−8.5	0.09	4.66	9.05	0.1	2.77
13	Hengshui	−8.72	−9.69	−7.96	−8.76	−9.43	−8.91	−0.14

Note: Source: Hebei Economic Yearbook 2016 to 2018, China Population and Employment Statistical Yearbook 2016 to 2020, http://info.hebei.gov.cn/hbszfxxgk/6806024/6810698/6810700/6860707/index.html.

3.4. The primary source of the region's mobile population as well as inflows of people from nearby contribute to the demographic growth in the Beijing, Tianjin, Hebei Region

Out-of-region inflow refers to the inflow of people from other regions to Beijing, Tianjin and Hebei rather than the mobile population with household registration in these cities. According to data from the national mobile population health and family planning dynamic monitoring sample in 2017, many new residents in Beijing and Tianjin came from Henan and Shandong provinces. In Beijing, the new residents from Henan province accounted for 13.5% of the population, while those from Shandong province made up 10.02% of the population. In Tianjin, the new residents from Henan province made up 11.2% of the population, while those from Shandong province made up 21.4%.

The term "mobile population" in the Beijing, Tianjin, Hebei Region referred to all people who have registered their homes in Beijing, Tianjin and Hebei. In terms of population movement, very few people relocated from Beijing to Tianjin and the other 11 cities in Hebei Province. In addition, a small number of people relocate from Tianjin to Beijing and 11 cities in the Hebei region. Hebei Province, on the other hand, accounts for a larger proportion of the people moving to Beijing and Tianjin. It is the same as moving 66 times as many people from Beijing to Tianjin and Hebei province and moving 17 times as many people from Tianjin to Beijing and Hebei province, respectively. When it comes to the quantity of inflows, Hebei Province accounts for 92.3% of the total influx from Tianjin and Hebei Province to Beijing. The inflow of people from Hebei Province to Tianjin accounts for 98% of the inflow of people from Beijing and Hebei Province to Tianjin. The number of people flowing into Hebei province from Beijing and Tianjin, respectively, do not differ much from each other, and their percentages are both around 50%. Therefore, by the flow and direction of population, it shows that Hebei Province is a net outflow province.

Table 2. Source composition of inflow in Beijing, Tianjin, Hebei region (10,000 people, %).

Place of the household registration		Current residence					
		Beijing		Tianjin		Hebei	
		Population	Proportion	Population	Proportion	Population	Proportion
Beijing-Tianjin-Hebei region (Including 11 cities in Hebei province)	Beijing	–	–	19	0.38%	17	0.34%
	Tianjin	155	2.21%	–	–	32	0.64%
	Hebei	1855	26.50%	1064	21.28%	–	–
	Shijiazhuang	132	1.89%	44	0.88%	645	12.9%
	Tangshan	71	1.01%	95	1.9%	150	3.0%
	Qinhuangdao	28	0.40%	33	0.66%	69	1.38%
	Handan	193	2.76%	146	2.92%	337	6.74%
	Xingtai	148	2.11%	95	1.9%	490	9.8%
	Baoding	413	5.90%	82	1.64%	323	6.46%
	Zhangjiakou	219	3.13%	60	1.2%	255	5.1%
	Chengde	193	2.76%	44	0.88%	154	3.08%
	Cangzhou	100	1.43%	294	5.88%	234	4.68%
	Langfang	197	2.81%	61	1.02%	51	1.02%
	Hengshui	148	2.11%	110	2.2%	128	2.56%
Major provinces outside the Beijing-Tianjin-Hebei Region	Henan	945	13.50%	560	11.2%	445	8.9%
	Shandong	701	10.02%	1057	21.4%	161	3.22%
	Anhui	414	5.92%	339	6.78%	144	2.88%
	Heilongjiang	396	5.66%	482	9.64%	285	5.7%
	Shanxi	352	5.03%	153	3.06%	103	2.1%

Note: Source of data: 2017 national mobile population health and family planning dynamic monitoring data and related calculations.

4. Characteristics of the mobile population's spatial distribution in the Beijing, Tianjin, Hebei Region

4.1. Geographical concentration index of floating population

The population geographic concentration index, first proposed by American economist Hoover, reflects the level of population concentration in a certain region and macroscopically reveals the distribution of population in the region. The index of geographic concentration of population is a useful indicator to depict the geographical distribution pattern of people when considering the elements of total population and size of the region. Based on this index, it is possible to calculate the floating population's spatial distribution in the area and to visualize its characteristics. The calculation formula is as follows:

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

In the formula, C_{CZLD} is the floating concentration index; n is the number of regions in total; x_i denotes the proportion of mobile population in area i to the entire regional mobile population; y_i denotes the proportion of land area of area i to the land area of the whole region. Among them, C_{CZLD}

is in the interval (0, 1), and the larger its value is, the more concentrated the mobile population is in a certain area and the more significant its polarization effect; the smaller its value is, the more balanced the mobile population is in a certain area and the more significant its diffusion effect.

According to Xiao et al. [12], Huang and Lv [13] on the measurement and division of the population concentration index, the concentration index was divided into four stages: C_{CZLD} less than 0.3, the mobile population is more evenly distributed within the region; C_{CZLD} between (0.3, 0.5), the distribution of mobile population in the region is relatively balanced; C_{CZLD} between (0.5, 0.7), the mobile population is more unevenly distributed in the region; C_{CZLD} greater than 0.7, the distribution of mobile population within the region is absolutely unbalanced.

4.2. Analysis of spatial correlation

Based on earlier research in the paper, it was discovered that Moran's Index, Getis-Ord G and Geary's C are the most frequently used methods to measure spatial autocorrelation. These correlation characteristics of the spatial distribution of mobile population and regional socioeconomics are analyzed further spatially. The spatial characteristics of a mobile population and economic activity are examined from a regional level perspective in accordance with the research goals of this study, and the most popular Moran Index is chosen for spatial correlation analysis: in other words, if the spatial distribution of socioeconomic factors in nearby study regions is correlated in a similar, dissimilar or in-dependent manner. The following formula is used to determine the Moran Index:

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

$$S^2 = \frac{1}{n}\sum_i (x_i - \bar{x})^2,\ \bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

S^2 is the sample variance, $\bar{x}$ is the sample mean, and x_i and x_j are the respective attribute values for regions i and j, representing the total mobile population in each province and city, and w_{ij} is the matrix of spatial weights used to describe the region between i and j. The Moran Index I takes values in the range of [−1, 1]. A spatial correlation that is greater than zero, less than zero or zero shows that there is no spatial connection at all and that the spatial distribution is random. The identical economic development levels of the two regions have different consequences on spatial interactivity. In this paper, we choose the economic weight matrix w_{ij}. The specific expressions are as follows:

$$W_{ij} = \begin{cases} 1 / \left|\overline{X}_\iota - \overline{X}_J\right|, if\ i \neq j \\ 0,\ \ if\ \ i = j \end{cases} \tag{4}$$

For the economic weighting matrix w_{ij}, the values are related to the content of the study. Based on the spatial correlation of population distribution in the Beijing, Tianjin, Hebei Region, the economic variables of Beijing, Tianjin and Hebei are the dominant factors in the formation of spatial effects, so the mean weighting relationship based on GDP per capita is used. $\overline{x_i}$ is the average value of GDP per capita in region i over the period 2014 to 2020, and x_j represents the average value of GDP per capita in region j between 2014 and 2020.

4.3. Spatial distribution characteristics of mobile population in Beijing, Tianjin and Hebei

Based on the formula (2), the mobile population concentration index for Beijing, Tianjin and Hebei was calculated from 2014 to 2020 (Table 3). With a year-over-year decline, the spreading effect of the floating population is more pronounced, since it is distributed unevenly in Beijing, Tianjin and Hebei from the stage of urbanization to reasonably balanced development. This is a result of recent efforts by the Chinese government to decentralize Beijing's non-capital functions, combat Beijing's "big city illness" and put in place a stringent population control strategy.

Table 3. Concentration index of mobile population in Beijing, Tianjin and Hebei in 2014, 2016, 2018 and 2020.

Year	2014	2016	2018	2020
Concentration index of mobile population	0.576	0.537	0.51	0.3695

The spatial autocorrelation index of the mobile population in the Beijing, Tianjin Hebei Region in 2014, 2016, 2018 and 2020 was calculated using MATLAB statistical software, and it was found to be 0.7461, 0.6182, 0.7446 and 0.5997, respectively, based on data from the China Statistical Yearbook from 2015 to 2021. In these four years, the mobile population's Moran's I in Beijing, Tianjin and Hebei is more than 0. The mobile population continues to exhibit spatial agglomeration, reaching its highest value in 2014, when there is a substantial association with the mobile population in Beijing, Tianjin and Hebei, and this results in market size effect and polarization impact. The mobile population has the same development trend and positive correlation between 2014 and 2020. Additionally, over this time, Moran's I index for the mobile population of Beijing, Tianjin and Hebei gradually declines, suggesting that the spatial autocorrelation of this group has diminished in recent years.

5. Floating population and regional synergy

5.1. Floating concentration, Moran Index, and Beijing, Tianjin, Hebei synergy index

Since 2010, the National Bureau of Statistics, the Beijing Bureau of Statistics and the Chinese Academy of Social Sciences have been working together on the Beijing, Tianjin, Hebei Regional Development Index Research Project, which is being done to meet the needs of the national strategy. This project is being done to develop a system for scientifically evaluating a regional development index indicator. The assessment index system offers an index system with 5 fundamental indicators, 18 subsidiary indicators and 48 tertiary indicators based on the five main development ideas of innovation, coordination, green, openness and sharing. The Beijing, Tianjin, Hebei Regional Synergy Development Index, produced by the National Bureau of Statistics, is the subject of this study's investigation of the impact of the mobile population. Table 4 displays the results of comparing the floating concentration, Moran Index, and Beijing, Tianjin, Hebei synergy index.

In the region of Beijing, Tianjin and Hebei, the concentration of the mobile population has been decreasing yearly since 2014, while the corresponding regional economic synergy has been steadily rising, according to Table 4. In other words, the country revealed the main structure of the strategy for the coordinated development of Beijing, Tianjin and Hebei beginning in 2014. The spreading impact of the Beijing, Tianjin and Hebei Region has become increasingly clear as the synergistic development

strategy has been put into practice. Radiation also drives the growth of the hinterland economy nearby, creating new economic growth poles. Beijing's non-capital functions become less congested as the entire mobile population's concentration in Beijing, Tianjin and Hebei declines. Additionally, more mobile people and production elements like capital, labor and resources move to the new economic growth poles. Based on achieving synergistic development, the economic sector promotes population synergy, and the trend of the mobile population distribution in the Beijing, Tianjin Hebei Region changes from one that is more uneven to one that is more balanced.

Table 4. Indicators related to mobile population and regional economic synergy in Beijing, Tianjin, and Hebei, 2014–2020.

	2014	2016	2018	2020
Concentration of mobile population	0.576	0.537	0.51	0.3695
Moran Index	0.7461	0.6182	0.7446	0.5997
Beijing-Tianjin-Hebei synergy degree	100	108.02	114.21	119.33

The trend of large-scale population influx into Beijing, Tianjin and Hebei is decreasing, while the synergy of Beijing, Tianjin and Hebei development is increasing year after year, according to an analysis of the changes in the regional economic synergy and Moran's Index between 2014 and 2020 (Table 4). This clearly demonstrates the synergistic development strategy for Beijing, Tianjin and Hebei has been implemented with tremendous success. However, Beijing's evident advantage in luring a movable populace in the Beijing, Tianjin Hebei Region, which practically spans the entire region, is plain. However, the scale effect, the accumulation of human capital and the knowledge spillover effect produced in Beijing are all becoming more and more apparent, resulting in a considerably significant spatial diffusion effect in the region where the mobile population's economic activities are located. The spatial dependency of the concentration of mobile population in Beijing, Tianjin and Hebei decreased, demonstrating a tendency toward balanced and decentralized growth. It also demonstrates that the association between the two is fading year after year.

5.2. Regression model of the interaction between floating population and regional synergistic development

1) Regression Model instruction

To explore the relationship between the floating population and the synergistic development of Beijing-Tianjin-Hebei, a panel econometric model was selected for this article, and regressions were conducted using STATA software based on data from 2007–2018 in 13 cities in the Beijing-Tianjin-Hebei region.

Both the neoclassical economic growth theory represented by the Solow model [14] of economic growth and the endogenous growth theory represented by the Roemer model [15] and Lucas model [16] take labor, capital and technological progress as the most important sources of economic growth. With the evolution of modern economics and research perspectives, the endogenous economic growth model under open conditions has become an important paradigm for analyzing economic growth paths. For example, Grossman and Helpman [17] and Coe and Helpman [18] studied economic growth from the perspectives of foreign direct investment and international technology diffusion, respectively. In addition, Young [19], the founder of the division of labor theory, regarded the division of labor as the source of long-term economic growth, and the path of the division of labor for economic growth is

mainly through the division of labor to increase productivity and thus expand market size. The expansion of market size further triggers the deepening of the division of labor, and the deepening of the division of labor further promotes higher market size [20]. Based on the economic growth theory, this article tries to explore the relationship of floating population on the synergistic development of Beijing-Tianjin-Hebei. In the model setting, labor force (floating population: nip, local population: hrp), capital input (fipc), technological progress (pat), opening up to the outside world (inopen) and market size (inms), as the main factors affecting economic growth, are taken as the six independent variables of this model. The dependent variable is proposed to be the gross regional product per capita (GDP per capita), which reflects the average level of economic development of a region, as the dependent variable of the model. GDP per capita reflects the overall level of a region's economic development. By narrowing the relative gaps of GDP per capita among regions in the region, its overall degree of synergy also increases relatively, so the gross domestic product per capita (gdppc) of each city in Beijing, Tianjin and Hebei represents the level of synergistic development of Beijing, Tianjin and Hebei. Based on the research needs, the panel data econometric model for this study is the following:

$$gdppc_u = \beta_1 nip + \beta_2 hrp + \beta_3 fipc + \beta_4 pat + \beta_5 open + \beta_6 ms + \varepsilon_u \quad (5)$$

2) Regression results

To make full use of the panel data and better estimate the parameters of the regression equation effectively, the model was fitted and estimated by mixed least squares, individual fixed effects model, and tested. The regression results are presented as Table 5.

Table 5. Regression results.

	(1)	(2)
	_1ols	_1fe
VARIABLES	gdppc	gdppc
nip	84.257***	43.801***
	(11.829)	(15.788)
hrp	1.076	15.374
	(3.974)	(28.222)
fipc	0.813***	0.476***
	(0.055)	(0.067)
pat	0.573***	0.456***
	(0.083)	(0.058)
lnopen	−22,545.153***	6,682.324
	(6,841.068)	(4,732.240)
lnms	152,563.851***	−24,887.684
	(44,081.169)	(28,537.583)
Observations	156	156
R-squared	0.910	0.898
Number of id		13

Note: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1，(in parentheses are test values).

From the above model regression results, the coefficients of the core explanatory variable net inward population (nip) on the dependent variable GDP per capita (gdppc) are all positive and pass the

test at the 1% significance level. The coefficients R^2 are all around 90%, which is a good fit, confirming that the independent variable has a good explanatory strength for the changes in the dependent variable. It indicates that the net inflow of population to Beijing, Tianjin and Hebei has a significant contribution to the synergistic development.

6. Discussion

The principal hub for the nation's migrant population is the Beijing, Tianjin, Hebei Region metropolitan cluster, one of the most prosperous areas in China. Consolidating the advantageous position of drawing population in Beijing and modifying the unfavorable position of attracting population flow in Hebei province are the keys to simultaneously increasing population flow and regional economic synergistic growth in the Beijing, Tianjin, Hebei Region. The following tactics might be used by the Chinese government in the future to achieve this goal.

First, the Chinese government will keep tightening the control over population density while taking into consideration the features of population development in the Beijing, Tianjin and Hebei Region. There is a glaring mismatch between the geographical distribution of people and economy in the Beijing, Tianjin and Hebei region due to the severely unequal spatial distribution of the mobile population. The norm of population movement from Hebei province to Beijing and Tianjin, as well as the notable regional variations in population gathering in the Beijing, Tianjin and Hebei Region, are to blame for this. Because of China's ambitious urbanization program and their propensity for profit, most of the mobile population in the Beijing, Tianjin and Hebei region is still concentrated in Beijing and Tianjin. Their geographic distribution is also closely interconnected. It is challenging to stop Beijing from outsourcing its labor resources, and the Chinese government still has significant challenges in containing the region's mobile population in Beijing, Tianjin and Hebei. As a result, the Beijing, Tianjin, Hebei Region will continue to receive target-oriented population management from the Chinese government. For the metropolitan area's development planning, China will uphold the principle of "respecting the laws of economic development and following the trend" to achieve industrial linkage and a balanced development of regional public services to promote the synergistic development of Beijing, Tianjin and Hebei and serve the interests of national development. Strengthen the spatial dispersion of mobile population management efforts to counter the tendency of population concentration in Beijing and Tianjin. The second objective is to improve the equilibrium in the Beijing, Tianjin and Hebei Region to restrain the concentration of population growth. The starting point and main objective of balancing regional growth is to address and relieve Beijing's overall population density. It is also an alternative policy of the Chinese government to strictly control the increase of floating population in Beijing, decongest the population stock in urban areas, guide the orderly flow of population, coordinate and promote the coordinated and interactive development between urban areas and build a good undertaking and gathering place for the decentralization of functions and population in central urban areas. Finally, if a comprehensive plan is made to develop an integrated population management system in Beijing, Tianjin and Hebei, it is also a future policy option to combine complete population control with population layout modification. In the future, the Chinese government may break the administrative management by building an integrated Beijing-Tianjin-Hebei mobile population information management platform, realize the docking of population management departments in Beijing-Tianjin-Hebei, allocate social management resources with the regional population pattern, form an integrated population regulation and control mechanism, accurately study and judge the future population flow trends, enhance the social public resource allocation capacity of the population concentration areas and thus better target the inter-regional mobile

population. As a result, guiding policies will be developed, and macro policymaking by the government will become more scientific and effective.

Additionally, update the differentiated household registration system and increase the accuracy and scientific rigor of regulation and control. The three primary tasks of China's household registration system now are welfare restriction, population flow controls and population registration. Beijing is the primary region, Jizhongnan is the lowest area, and Beijing and Tianjin are still the mobile population concentrations, according to the examination of the mobile population's geographical distribution in Beijing, Tianjin and Hebei province. In addition, the impact of COVID-19, the intensification of Sino-US competition and other factors, the weakening of external demand, the aging of the population growth rate, the slowing down of China's regional economic growth, the structural contradictions and risks are highlighted. To construct a new development pattern of dual circulation and mutual promotion in China's domestic and foreign markets, the Chinese government has so recommended a strategy to increase domestic demand. Apart from a few megacities, the Beijing, Tianjin, Hebei Region may therefore go forward with the policy of liberalizing and loosening restrictions on urban settlement, and it may also take the lead in implementing the cumulative mutual recognition of the years of household registration in the same city in the qualified urban areas. To start with, urban settlement policies are appropriately liberalized or relaxed. For example, mega-cities with more than 5 million people and Beijing and Tianjin have implemented improved household registration policies, streamlined the points program and improved the household registration management service platform. It is believed to be conducive to stimulating the possibility of population floating and sharing of high-end talents among the cities surrounding Beijing and Tianjin. Next, fully alleviate the settlement conditions in Shijiazhuang and Tangshan, two large cities of type I with a resident population of 3 million to 5 million. The cumulative mutual recognition of household registration access years within the same city promotes deeper regional industry transfer and engagement as well as complementary advantages. It also has a slight decongesting effect on population flow in Beijing, Tianjin and Hebei Region. Lastly, the complete elimination of settlement restrictions in cities such as Qinhuangdao, Handan and Baoding with a resident population of less than 3 million, the sharpening of the reform of the household registration system and the quickening of the agricultural transfer population's civilization will provide a significant boost to the Beijing, Tianjin, Hebei Region in terms of improving the overall level of urbanization, stabilizing the urban industrial workforce and expanding the urban industrial workforce. Public services like social security are also gradually becoming regionally integrated. Improve the registration system of household registration management with time as the axis and improve the analysis system of Beijing, Tianjin, Hebei Regional resident population with space as the scale.

Third, remove the barriers of floating, drive radiation with industrial chains and guide the reasonable flow of population. Population floating is the source of urbanization, and large-scale and continuous population floating will occur with the increase of agricultural modernization and urbanization rate. The city is a concentration of population, which in turn follows the migration of industries. To control population growth, the labor force is transferred across industries during the process of industrial structure optimization and upgrading. Hebei Province's outflow trend has improved, but its urbanization rate is much lower than that of Beijing. The floating population in Beijing, Tianjin and Hebei has the same development trend, but there is still spatial agglomeration in all three regions. The diffusion effect is increasing in the two inflow areas of Beijing and Tianjin, and economic synergy between the cities is playing a role. Therefore, options for bridging the industrial gradient gap and promoting industrial and demographic synergy have become realistic. The Beijing, Tianjin, Hebei Region, traditionally slated for development around Beijing, has a glaring vacuum in its economic development. This is due to the region's large concentration of traditional industries and

challenges with industrial re-structuring and upgrading. To define each city's position regarding industrial growth of the Beijing, Tianjin and Hebei Region: Beijing should focus on creating a high-precision industrial structure, Tianjin should optimize new industries and con-temporary service industries, and Hebei should actively pursue the transformation of scientific and technological achievements transferred. Beijing is at the stage of factor spillover and continuously evacuating non-capital function industries. Beijing is also promoting industrial restructuring and upgrading, accelerating the alternation of "old and new" industrial transformation, clarifying the direction of development and improving the linkage mechanism between industry and science and technology innovation. Beijing and Xiong'an New Area will serve as the urban agglomeration's two center cities, and the surrounding areas will play a key role in the development of a super industry chain with science and technology innovation at its core. This urban agglomeration will be in the Beijing, Tianjin and Hebei Region. Xiong'an New Area will aggressively absorb the inventive resources of Beijing, Tianjin, and the globe, resulting in the fast convergence of high-tech businesses and the coordinated growth of industries in Beijing, Tianjin, and Hebei province. The coordinated development of regional industry is frequently appealing to the floating population. This mechanism facilitates the Chinese government's macro-control of the floating population in Beijing, Tianjin, and Hebei Region. Eliminate the institutional and governmental restrictions on population movement. This also creates advantageous institutional conditions that allow surplus labor in rural areas or other underdeveloped cities in Beijing, Tianjin and Hebei Region to easily transition between urban, rural and city settings, achieving the goal of fostering population synergy across Beijing, Tianjin and Hebei as well as a helpful strategic layout that logically encourages labor floating.

In addition, strengthen the construction of the labor market for a migrant population. It is not possible to migrate the mobile population in one step overnight, as it is a gradual process. In this process, the capacity of cities to accommodate the population is also limited. Especially, the population flow from rural to urban areas should be guided and managed to make it orderly, instead of having restrictions and hinderance. To effectively allocate labor resources and achieve the balance of labor supply and demand, the labor market should be strengthened, with population blindness reduced and the flow of mobile people with different qualities, cultures and skills directed toward the areas that are in need. These changes should be made in each of Beijing, Tianjin and Hebei. To achieve the coordinated economic and social development of Beijing, Tianjin and Hebei as well as the key to promoting the improvement of population flow, it is therefore essential to remove obstacles to mobile population migration, direct the reasonable flow of population in an orderly manner and avoid the negative effects brought on by the flow of population.

7. Conclusions

This article examines the kind, flow direction and time and source composition of the mobile population in Beijing, Tianjin and Hebei from several geographical perspectives. It also examines the spatial distribution pattern of the mobile population and how it relates to the coordinated economic growth of Beijing, Tianjin and Hebei from two angles: the concentration of the mobile population and Moran's I of the mobile population. The following conclusions are made:

According to the spatial distribution of the population's mobility in the Beijing, Tianjin and Hebei Region, Beijing is the city with the highest population, followed by Tianjin, the provincial capital of Shijiazhuang, and developed coastal counties in the northeast, which are ranked second and third, and inland cities in central and southern Hebei, like Hengshui, which are ranked last. Hebei has a net population outflow, while Beijing and Tianjin have a net population influx. The net movement of

people is higher in the former than the latter, and the two cities are far better at absorbing people than Hebei.

Considerable spatial grouping in the floating population may be seen in the Beijing, Tianjin, Hebei Region. However, the spatial Moran Index and the concentration of the mobile population both clearly demonstrate a diffusion impact, as the agglomeration of the mobile population in the Beijing, Tianjin, Hebei Region shrinks year by year, and geographical dependence decreases between 2014 and 2020. In the meantime, the Beijing, Tianjin and Hebei Region's synergistic development index has been rising, indicating that the implementation of the Beijing-Tianjin-Hebei synergistic development strategy is a national strategy to deal with the Beijing-specific "big city disease" as well as the deeply ingrained problems in the region and to create a strong and competitive city cluster in China. Promote the rapid growth of coastal cities in the Beijing, Tianjin and Hebei Regions (including the extension of the Tianjin Binhai New Area opening policy to the coastal port areas of Caofeidian and Huanghua in Hebei) and draw people from these regions to the coastline and Hebei areas. The Beijing, Tianjin and Hebei Region's coordinated development will be mostly carried by Hebei Province and will see the construction of significant synergistic elements like the Xiong'an New Area, the airport economic zone and other significant synergistic carriers, as well as the promotion of the province's industrial transfer. Additionally, it lessens the pressure brought on by Beijing's excessive floating population concentration and, to a lesser measure, Beijing's excessive floating population growth. Beijing's mobile population's information and technological spillover also enables Tianjin and Hebei Province to share the economic and social benefits produced by high-quality knowledge and talented workers. A smart port and an ecosystem for green manufacturing have been established because of the Beijing, Tianjin Hebei synergistic development plan, which also fully uses the geographic advantages of both Tianjin and Hebei Province. The region's well-designed industrial structure and social public services including healthcare, education and social security have also grown to be significant draw factors for luring new residents. Human capital has been steadily building up in both Tianjin and Hebei Province because of the ongoing influx of mobile population. In terms of innovation, cooperation, becoming green, being open and sharing, it has widened the development gap between Hebei Province, Tianjin and Beijing while enhancing the inherent mechanisms of economic growth in both Tianjin and Hebei Province.

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Conflict of interest

The authors declare there is no conflict of interest.

References

1. H. S. Shryock, J. S. Siegel, *The Methods and Materials of Demography*, Academic Press, Salt Lake City, 1976.

2. C. Duan, The "mobile population" in China, *Northwest Popul.*, **1** (1999), 2–5.
3. Q. Zhang, On the concept of population migration and mobile population, *Popul. Res.*, **3** (1988), 17–18.
4. J. Li, *A New Edition of Population Theory*, China Population Press, Beijing, 2001.
5. C. Zhang, Z. Wang, *Study on the rational distribution of population in China: spatial distribution of population and coordinated regional development*, China Social Science Press, Beijing, 2015.
6. E. G. Ravenstein, The laws of migration, *J. Stat. Soc. London*, **48** (1885), 167–235. https://doi.org/10.2307/2979181
7. R. Heberle, The causes of rural-urban migration a survey of German theories, *Am. J. Sociol.*, **43** (1938), 932–950.
8. D. J. Bogue, *Principles of Demography*, Johnson Wiley and Sons, New York, 1969.
9. E. S. Lee, A theory of migration, *Demography*, **3** (1966), 47–57. https://doi.org/10.2307/2060063
10. W. A. Lewis, Economic development with unlimited supplies of labor, *Manchester Sch.*, **22** (1954), 139–191. https://doi.org/10.1111/j.1467-9957.1954.tb00021.x
11. Z. Wang, Z. Jiang, D. Zheng, L. Wang, Study on the evolution of population spatial structure and optimization path of Beijing-Tianjin-Hebei urban groups, *Northwest Popul. J.*, **37** (2016), 31–39. https://doi.org/10.15884/j.cnki.issn.1007-0672.2016.05.005
12. L. Xiao, X. Li, G. Zhang, R. Wang, Empirical analysis of social stratification of the resident population in Xiamen and policy recommendations, *Prog. Geogr.*, **31** (2012), 183–190.
13. D. Huang, C. Lv, Characteristics of the evolution of the spatial pattern of Beijing's population-an analysis based on the 2000 and 2010 census data, *Sci. Technol. Ind.*, **17** (2017), 107–114.
14. R. M. Solow, Technical change and the aggregate production function, *Rev. Econ. Stat.*, **39** (1957), 312–320. https://doi.org/10.2307/1926047
15. P. M. Romer, Increasing returns and new developments in the theory of growth, (1989), Available from: https://www.nber.org/papers/w3098
16. R. E. Lucas, On the mechanics of economic development, *J. Monetary Econ.*, **22** (1988), 3–42. https://doi.org/10.1016/0304-3932(88)90168-7
17. G. M. Grossman, E. Helpman, *Innovation and Growth in the Global Economy*, MIT press, Cambridge, 1993.
18. D. T. Coe, E. Helpman, International R&D spillovers, *Eur. Econ. Rev.*, **39** (1995), 859–887. https://doi.org/10.1016/0014-2921(94)00100-E
19. A. A. Young, Increasing returns and economic progress, *Econ. J.*, **38** (1928), 527–542. https://doi.org/10.2307/2224097
20. D. Zheng, Market size, division of labor, and endogenous growth models-and a discussion of whether endogenous growth theory misunderstands Young?, *World Econ. Pap.*, (2015), 76–90.

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