

Home-Purchase Restriction, Urban Population, and Industry Development: Evidence from Beijing

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ABSTRACT

With the rapid economic development, megacities have gathered a large number of population and industries, and a series of “urban diseases” have also emerged. To alleviate these problems, various administrative measures have been taken to control population and optimize industrial distribution. Meanwhile, home-purchase restriction (HPR) has been introduced to control the soaring housing prices. Existing research focuses on the impact of policy on its own market, without paying attention to the linkage between markets and spillover effect. We take Beijing, the capital of China, as an example to study the impact of the HPR on the population distribution and industry development of megacities. By analyzing the industry location quotient and population economy matching degree, we conclude that HPR effectively promotes the efficiency of population and industry dispersal, but increases the mismatching between industry and population. City is a typical intelligent system that gathers various intelligent agents, and the development of its population and industry is the fundamental evolution of the system. This paper explores the role of policies in the evolution of urban intelligent systems, and therefore has important theoretical and practical significance for intelligent systems.

KEYWORDS

megacity; home-purchase restriction; urban population dispersal; industry layout; location quotient; Beijing

City is a typical complex system that gathers various intelligent agents, and the development of its population and industries is the fundamental evolution of the system. How to improve the efficiency of cities has attracted long attention. Making and implementation of effective policies is an important method used by the municipal government to guide and motivate various intelligent agents to promote the efficiency of the complex system. In this paper, we take Beijing as an example to analyze the efficiency of HPR policy from the viewpoint of spillover effect on labor market and thus on population and industries. It has important theoretical and practical significance on understanding the policy and its spillover effect on the evolution of the city intelligent system.

1 Introduction

Population growth and optimization of industry layout have always been important issues in China’s economic development. As the capital and one of the four super first-tier cities in China, Beijing’s urban population development and reasonable layout of industry are of paramount importance. Since the National Conference on Urban Planning in 1980, “controlling the size of large cities” has become one of the country’s overall urban development policies. In the 21st century, with the rapid expansion of Beijing’s population and production capacity, urban diseases are becoming increasingly severe. Effective population regulation and industry relieving have attracted increasing attention. “The Master Plan of Beijing (2004–2020)” clearly points out to methodically guide the population and function relieving. “The Beijing Main Functional Area Plan” and the “Beijing-Tianjin-Hebei coordinated development Plan” further detail the relieving

plan.

At the same time, the increasingly soaring housing prices also attract the attention of the government. Since the termination of housing allocation in 1998, the prices of commercial housing in China have continued to rise. Especially in 2010, the housing market experienced an explosive rise in housing prices. In response to this situation, Beijing has cooperated with the “Ten National Rules” (“guoshitiao”) issued by the State Council. The HPR has been officially implemented in the housing market, forming a parallel situation of “relieving Beijing of functions non-essential to its role as China’s capital” and the HPR.

The previous literature studies housing policy and population policy separately on its own market, without paying attention to the linkage between markets and spillover effect. The original intention of HPR is to target the housing market, but the demand for housing by labor will inevitably affect the flow, distribution, and employment of the population, thereby affecting the development of urban industries. Therefore, whether the HPR has a promoting or hindering effect on megacities’ population and industry development has become the focus of this paper. We comprehensively examine the effect of HPR on population and industry development. By analyzing the location quotient of each district in Beijing in 2007, 2011, and 2015, as well as the matching degree of population and economic development, we find that the home-purchase restriction (HPR) help optimize the layout of the population and industry of Beijing’s capital function. However, the HPR is also a distortion of the labor market, which leads to a decline in the matching between economy and population.

The rest of the paper is organized as follows. Section 2 provides a review of previous literature. Section 3 introduces the institutional background of population and industry dispersal, as

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well as home-purchase restriction. Section 4 analyzes the location quotient of each district in Beijing, as well as the matching degree between population and economic development. The conclusion is in Section 5.

2 Literature Review

2.1 Urban population development, issues, and regulation

In the process of megacity development, the choice of population migration and agglomeration direction is always consistent with the direction of industrial agglomeration and industrial development^[1]. The existence of spatial agglomeration not only makes scale economy possible, but it also brings additional obstacles which are negative externalities and are reflected in the raising of land and housing prices, congestion costs, ecological environment damage, pollution, and other aspects. The loss of utility brought by the externality is offset by the gains from the agglomeration, and the dividend of the agglomeration behavior is terminated, resulting in the phenomenon of agglomeration diseconomy. When cities fall into the agglomeration diseconomy, the market function that prevents capital and population from excessive agglomeration to megacities is also in a failure state. It makes the city suffer from long-term losses caused by negative externality^[2].

To avoid the negative externalities, population regulation has been carried out in megacities. The effect of population regulation is significant. However, some scholars believe that a decrease in number can only indicate that population regulation policies have weakened rapid population growth in the short term, and have limited effects in the long-term control process^[3]. Some also hold that using the total population as the evaluation criterion for policy effectiveness itself is irrational. For example, Zhao^[4] pointed out that the main problem faced by Beijing's population development is not the excessive population size but the dense population density in the central urban area, as well as a serious separation between job and residence. Another branch of literature discusses the necessity of population regulation. Lu^[5] emphasized that over using population regulation may affect the development of the city itself. Some scholars state that as a super first-tier city, Beijing's economy still has the ability to absorb and carry more people. The current total urban population should continue to expand and not be restricted^[4,6].

2.2 HPR and housing market

Research focuses on the relationship between HPR and housing market. Liu^[7] studied the impact of Shanghai's HPR on the comprehensive index of the real estate market by using the VAR model, it concludes that the HPR suppresses the rapid rise of housing prices in the short term. Jia and Meng^[8] found that the HPR leads to a decrease in both transaction volume and price in the commodity housing market. At the same time, some scholars believed that the HPR does not significantly suppress the rise of housing prices^[9], although the policy intensity is high, the duration is relatively short^[10].

The effect of HPR is more pronounced in cities with continuously high housing prices and a high proportion of real estate investment^[11]. However, some scholars believe that the HPR does not have a direct differential effect on housing prices in different cities^[12]. In terms of urban policy selection, Du and Zhang^[13] constructed a differences-in-differences (DID) through the different HPRs in Beijing and Chongqing, and finds that the HPR reduces housing prices in Beijing by about 7.7%, which is more effective than Chongqing's collection of property tax.

In addition, in the financial market, the implementation of the

HPR can affect the city's leverage ratio and alleviate the problem of excessive liquidity risk to a certain extent. The credit supply of cities with high leverage ratio can be rationed, thus affecting the housing demand and restraining the house price in the housing market of the first and second tier cities^[14].

2.3 HPR, urban population, and industry development

Researchers have long been concerned about the impact of the housing market on the labor market^[15-17], while only start to notice that the HPR might have great impact on labor market. Scholars believe that the HPR has a significant inhibitory effect on population mobility. On the one hand, the HPR affects the cost of population settlement by affecting housing supply, subjectively changing the willingness to move^[18], and increasing the private cost of population urbanization. On the other hand, eligibility is closely linked with the household residence system and public services, which objectively affects the possibility of the migrant population to purchase houses and settle down and increases the public cost of citizenization.

Due to the HPR, non-local population can only choose to rent, which exacerbates the residential differentiation between the local and the non-local. This significantly reduces the frequency of non-local population participating in community activities and their subjective sense of belonging to the city. The non-local's unwilling to continue living in a city reduces the total population of a city^[19]. Lin et al.^[20] analyzed the destination city of Tsinghua graduates and concluded that after the implementation of the HPR, graduates choose to leave Beijing to work in other cities as newly recruited labor force, because of the strict requirements of the HPR for household registration system. They are also more likely to choose work in party and government agencies, state-owned enterprises, and higher education institutions^[20].

Some scholars believe that the HPR effectively suppresses excessive real estate investment, reduces entrepreneurial costs, and stimulates innovative and entrepreneurial behavior of talents. It is conducive to promoting the development of industry technology innovation activities and ultimately affecting industry layout^[21]. Under the influence of the industrial chain, the HPR directly or indirectly drives the healthy development of more than 60 industries in the upstream and downstream^[22]. Studies also show that the HPR deteriorates the stock market performance and evaluation of real estate enterprises^[23].

To sum up, the existing literature has conducted a detailed study on the population regulation policies and the HPR, respectively. It has basically reached the conclusion that the two policies are effective on their respective regulatory objectives. Some studies have noticed the external effect of HPR, but still leave research gap in the impact of HPR on labour market, especially on the population distribution and industry layout. Meanwhile, the interaction effect of the implementation of population regulation policy and the HPR is overlooked, such as insufficient attention to the changes in the development of urban industries and the matching between industries and populations under the background of the city function and population relieving.

3 Institutional Background

3.1 Population development and regulatory policies in Beijing HPR and housing market

3.1.1 Population development in Beijing

As the capital and super first-tier city of China, Beijing has been in

the process of population growth and industrial agglomeration for a long time from the founding of China. Figure 1 shows the changing trends of the permanent population in the 20th century. Since the beginning of this century (as shown in Fig. 2), Beijing has experienced highly inflationary development of population. The municipal government has issued the “The Master Plan of Beijing (2004–2020)”, which slows down the growth rate of the permanent population. In 2017, the permanent population of Beijing experiences negative growth for the first time and maintains a continuous downward trend as of the end of 2021. The total permanent population of the city is 21.886 million.

There are two main characteristics of Beijing’s population: “the increasing proportion of non-local permanent population” and “uneven distribution of population between urban areas”. Non-local permanent population refers to population that has been in Beijing at least half a year but without Hukou (registered household). After 2000, the growth rate of non-local permanent population is significantly higher than that of registered permanent population. However, due to the impact of population regulation policies, since 2016, the non-local permanent population in Beijing has shown a significant downward trend. Figure 3 shows the development trend of non-local permanent population from 2005 to 2019.

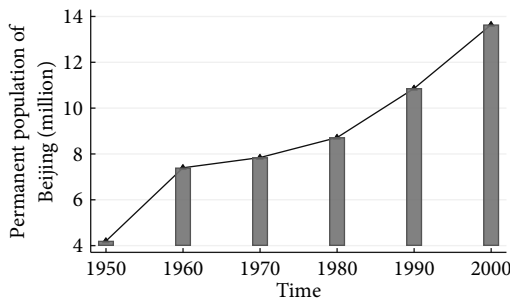


Fig. 1 Changing trends of the permanent population in the 20th century in Beijing. (The data are sourced from the Beijing Bureau of Statistics.)

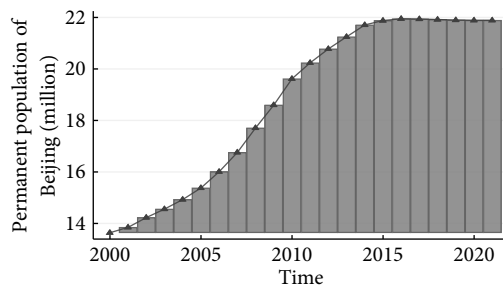


Fig. 2 Changing trends of the permanent population in the 21st century in Beijing. (The data are sourced from the Urban Statistical Yearbook of China.)

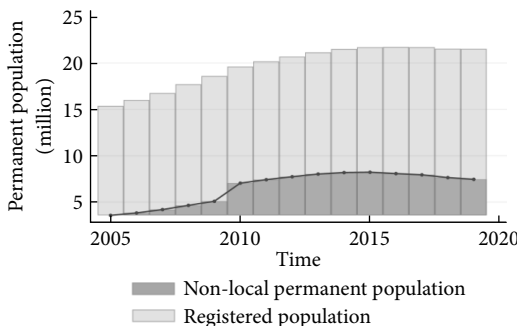


Fig. 3 Changing trends of the proportion of permanent population in Beijing. (The data are sourced from the Beijing Statistical Yearbook.)

Due to the spillover effect of urban industry and residential areas, a dual impact of “double changes of residence and employment” is gradually formed in population migration. On the one hand, housing is an important means of livelihood for labor. The special attributes of housing make the selection and migration of the population constrained by changes in the geographical location. On the other hand, due to the impact of commuting costs and industry wages, population migration is also influenced by the distribution of enterprises. Geographical locations, economic development, and industry distribution are different in each districts of Beijing, and the change trend of its permanent population also shows significant differences. According to the “The Master Plan of Beijing (2004–2020)”, Beijing is divided into the core area of the capital (Dongcheng District (including Chongwen District) and Xicheng District (including Xuanwu District)), urban functional expansion area (Chaoyang District, Haidian District, Fengtai District, and Shijingshan District), new development area (Fangshan District, Tongzhou District, Shunyi District, Daxing District, and Changping District), and ecological conservation area (Mentougou District, Huairou District, Pinggu District, Yanqing District, and Miyun District).

According to “The Beijing Main Functional Area Plan” and the “Beijing-Tianjin-Hebei coordinated development Plan”, the core functional area of the capital is positioned as a gathering place for historical and cultural heritage and a national financial management core area, with focusing on developing industries such as culture industry and finance. The functional expansion area is positioned as a “a modern international metropolis”, with focusing on high-tech, culture industry, finance, and commerce. The new development area mainly undertakes the evacuation of enterprises that transfer the functions of the core and expansion areas and forms modern agricultural production bases, mainly focusing on modern agriculture, industry, construction, tourism, and finance. As a key area for sustainable development, the ecological conservation area is positioned as a “demonstration area for the development and construction of ecological friendly industries”, with traditional agriculture, modern agriculture, and tourism as the main development industry.

Specifically, as the core area, Dongcheng District and Xicheng District, due to their special positioning as political, cultural, and international communication centers, have the strictest control over the total population. With a large number of non-local permanent population and non-core functional industries being relocated to other regions, the overall development of the permanent population is relatively flat. In 2014, the plan of relieving Beijing of functions non-essential to its role as China’s capital was launched, a large number of general industries in the core functional areas has been relocated, resulting in a rapid decline in the permanent population (as shown in Fig. 4).

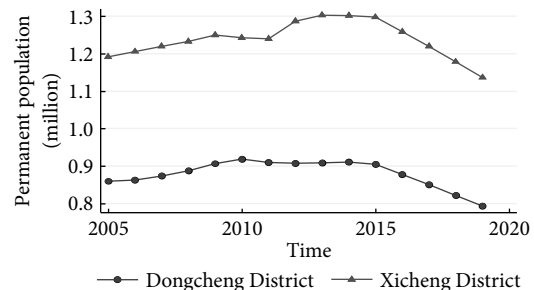


Fig. 4 Permanent population in the core area of the capital. (The data are sourced from the Beijing Area Statistical Yearbook.)

The urban functional expansion area can be classified as the former and the latter. The former functional expansion area includes Chaoyang District and Haidian District. The latter functional expansion area includes Shijingshan District and Fengtai District. The former functional expansion area is closer to the core area and has developed earlier. Its permanent population has shown a significant increase since 2005, and after 2015, it also has a sharp downward trend in the permanent population (as shown in Fig. 5) due to the population relieving policy. This is consistent with the core area. The latter functional expansion area is geographically remote. Lacking of radiation from commercial districts, the change in permanent population is also more gradual (as shown in Fig. 6).

The new development area with relatively complete conditions such as education and medical care and relatively low housing prices, are favored by non-local populations. The construction of rail transit (such as the Changping Line and Daxing Line) provides convenience for labor commuting and accelerates this flow (as shown in Fig. 7). For ecological conservation area, although the permanent population has also increased, the incomplete rail transit, inconvenient commuting, low population base, and the emphasis on environmental protection in regional positioning and green development concept make the growth rate slowly (as shown in Fig. 8).

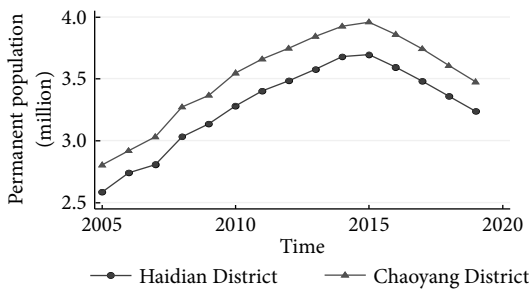


Fig. 5 Permanent population in the former urban functional expansion area. (The data are sourced from the Beijing Area Statistical Yearbook.)

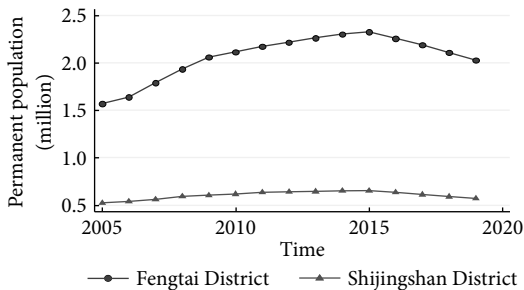


Fig. 6 Permanent population in the latter urban functional expansion area. (The data are sourced from the Beijing Area Statistical Yearbook.)

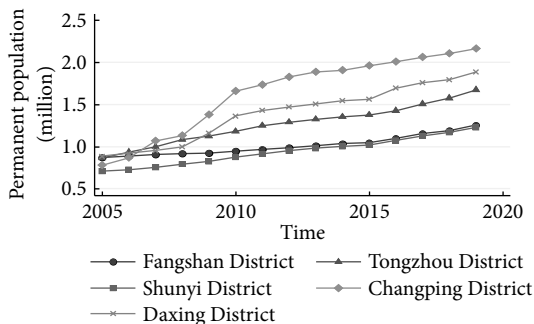


Fig. 7 Permanent population in the new development area. (The data are sourced from the Beijing Area Statistical Yearbook.)

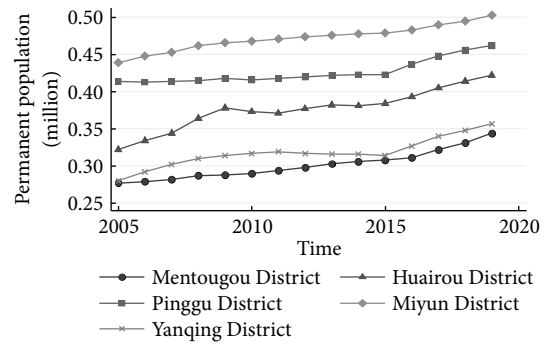


Fig. 8 Permanent population in the ecological conservation area. (The data are sourced from the Beijing Area Statistical Yearbook.)

The core area and the functional expansion area are also collectively referred to as the “urban area”. We further analyze the overall trend of permanent population changes in the urban area at the overall level of the six districts (as shown in Fig. 9). Similar as the specific district, the overall urban area shows an increase and then decrease trend in permanent population changes. The overall population increases dramatically in the new development area, and remains a slight increase in the ecological conservation area.

In addition, the overall male to female ratio of the permanent population in Beijing is relatively stable. However, due to varying degrees of family constraints, the male population is more likely to migrate compared to the female population. In the early stages of population influx, the male ratio slightly increased, but remained around 1.06 after 2010 (as shown in Figs. 10 and 11). Due to the introduction of talents and the enrollment expansion, the overall resident population in Beijing is showing an upward trend in average educational quality, and the proportion of people with university degrees or above is increasing. However, it is worth noting that in terms of age distribution, the population relieving policy has greatly reduced the proportion of eligible labor force. From 2015 to 2019, the working age population of Beijing decreased from 17.286 million to 16.89 million, with the

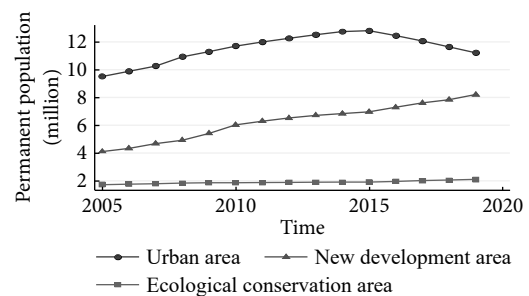


Fig. 9 Permanent population in the urban area. (The data are sourced from the Beijing Area Statistical Yearbook.)

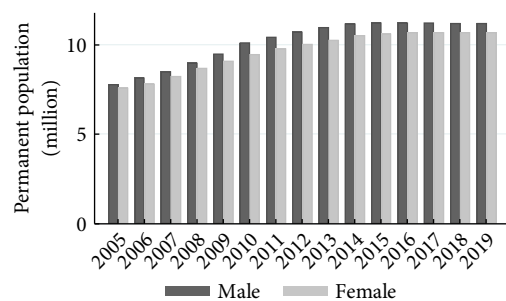


Fig. 10 Number of both genders in Beijing. (The data are sourced from the Beijing Statistical Yearbook.)

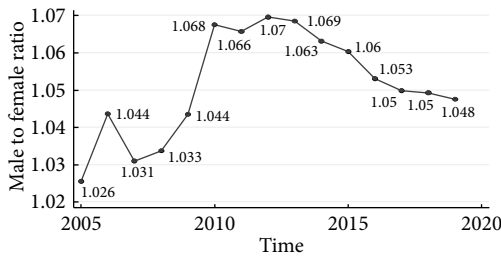


Fig. 11 Male to female ratio in Beijing. (The data are sourced from the Beijing Area Statistical Yearbook.)

proportion decreasing from 79.64% to 78.05%. At the same time, the 65 years old population increased to 11.42%, indicating a severe degree of aging. In 2019, the elderly dependency ratio has reached 14.64%, becoming a serious social problem. Figures 12 and 13 respectively reflect the above two trends.

3.1.2 Capital population regulation policy

Beijing basically experiences three stages of population regulation from tightening to relaxation and then to tightening again. The “Beijing’s Urban Master Plan” in 1983 marks the initial implementation of population regulation in Beijing. The first population regulation stage is roughly from 1983 to 1995, which is mainly on the management of migrant workers. Since the 1990s, to attract more talents to Beijing, the restriction on the household registration system has gradually been eased for innovative talents.

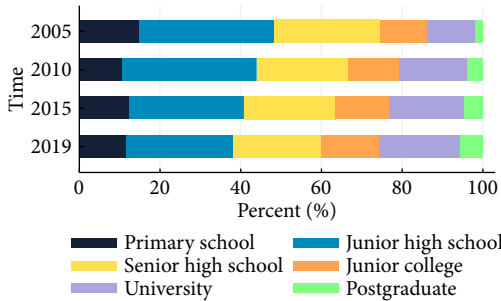


Fig. 12 Education level distribution in Beijing. (The data are sourced from the Beijing Statistical Yearbook.)

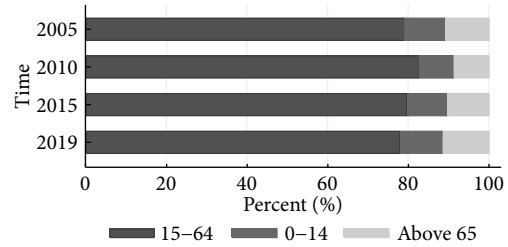


Fig. 13 Age distribution in Beijing. (The data are sourced from the Beijing Statistical Yearbook.)

A few population restriction policies have been abolished, leading to a rapid increase in Beijing’s population. After 2010, Beijing’s control measures for the total population once again become strict, with restrictive policies such as HPR, forming a population alleviation system that integrates “managing by housing, limiting by certificate, and controlling by industry”. In 2015, the “Beijing-Tianjin-Hebei coordinated development Plan” clarifies a new way to drive population dispersal through urban functional relieving. According to the “Beijing’s infrastructure development for the 13th Five-Year Plan” and the “Regulations of Beijing Municipality on Population Regulation”, Beijing will continue to implement population control policies. Table 1 shows some of the main population regulation policies.

3.2 Housing market and the HPR in Beijing

Since the housing reform in 1998, the housing market has gone through a period of rapid development, before the implementation of the HPR, China’s housing market has shown a rapid upward trend. According to the National Bureau of Statistics, the average sales price of commercial housing in China has increased by 2.74 times from 2000 to 2017. As a result, housing prices have been consistently above a relatively high level.

To stabilize the housing price, an administrative action, the HPR is implemented. As in Beijing, the policy stipulates that each family can hold at most two houses, while individuals can only own one. The HPR began with the purchase restriction order proposed by the “Ten National Rules” in 2010. Beijing, as the first city in the country, introduced the implementation rules of the

Table 1 Schedule of capital population control policy.

Stage	Time	Policy
Tightening stage	1983	“Beijing’s Urban Master Plan”
	1984	“Notice on Farmers Entering Market Towns and Settling Down”
	1985	“Interim Provisions on the Management of Temporary Urban Residents”
	1993	“The Master Plan of Beijing (1991–2010)”
	1995	Temporary residence permit card
Relaxation stage	1999	Enrollment expansion
	1999	The rapid development of Zhongguancun Science Park
	2003	“Research on the Development Strategy of Urban Space in Beijing”
	2004	“The Master Plan of Beijing (2004–2020)”
	2005	“Opinions on the Management and Service of Migrant Population”
Tightening stage	2012	“The Beijing Main Functional Area Plan”
	2015	“Beijing-Tianjin-Hebei coordinated development Plan”
	2016	“Beijing’s infrastructure development for the 13th Five-Year Plan”
	2016	“Regulations of Beijing Municipality on Population Regulation”
	2017	“The Master Plan of Beijing (2016–2035)”

“Ten National Rules”, which first stipulated that “each household can only purchase one new set of commercial housing”. With the promulgation of the “New Eight National Rules” by the State Council, 46 cities announced their joining the list of HPR between 2010 and 2011. The HPR experienced a tightening period from 2010 to 2013, with major cities successively issuing HPR orders and gradually relaxing them around 2014. We summarize the main notices issued by the State Council since 2003 when the policy entered the continuous regulation range, and use Beijing as an example to demonstrate the specific policies implemented by the city to reflect the trend of policy construction (as shown in Table 2).

Meanwhile, due to the close connection between the housing market and the labor market, the changes in the housing market are linked with the plan of relieving Beijing of functions non-essential to its role as China’s capital during the same period, forming a situation of “managing by housing”. Specifically, it includes purchasing housing management and leasing housing management. In the housing market, it limits the purchase of housing by establishing “household registration” and “payment of social security years”.

In the rental market, Beijing issued the “Several Regulations on the Management of Housing Leases in Beijing” in 2007, which standardized the housing management, clarified the legal responsibility of supervision and inspection, and rectified the chaos of rental housing, which indirectly increased the cost of staying. Ultimately, the policy of “managing by housing” connects population and housing, manages them together, and promotes population dispersal while suppressing the growth of housing prices. With the continuous development of the economy, although there has been some relaxation from a policy perspective, the degree of correlation between the two markets is bound to become increasingly close.

4 HPR and the Development of Different Industries

In the plan of relieving Beijing of functions non-essential to its role as China’s capital, optimizing industry layout and promoting regional coordinated development is one of the expected goals of

the policy. Theoretically, the HPR linked with population forms a “managing by housing” system, however, there is not enough empirical evidence. Thus, we analyze the impact of the HPR on the industry layout and the matching between population and economics by comparing the location quotient in industries before and after the implementation of the HPR in 2010. In addition, we also compare the matching degrees between regional population and economic development before and after the HPR to further analyze the effect of the HPR on population and industries.

4.1 Location quotient statistics in industries

We follow the method used by Xiao and Wang^[24] to calculate location quotient of urban industries as Eq. (1).

$$LQ_{ijk} = \frac{E_{ijk}/E_j}{E_{ik}/E_i} \quad (1)$$

where LQ_{ijk} represents the location quotient value of industry k in district j of Beijing during the year period i , E_{ijk} represents the total number of employees in industry k in district j during the year period i , E_j represents the total number of employees in all industries in district j during the year period i , E_{ik} represents the total number of employees in industry k during the year period i , and E_i represents the total number of employment in Beijing during the year period i . When the location quotient is greater than 1, it proves that the industry is a specialized department in a certain region of the corresponding year and belongs to an advantageous industry. In terms of year selection, considering the availability of data and the objective fact that the HPR has been implemented on a large scale in Beijing since 2011 and gradually relaxed nationwide in 2014, we ultimately select 2007, 2011, and 2015 data from the Beijing Regional Statistical Yearbook. We select representative industries from the primary, secondary, and tertiary industries. In the primary industry, we select traditional agriculture and agritourism; In the secondary industry, we select the most representative industries of industry and construction; In the tertiary industry, we select the traditional retail, hotel & catering industries, as well as the increasingly important finance, culture industry, and folklore tourism. The financial practitioners

Table 2 Schedule of capital population control policy.

Time	Policy
2003	“Promoting the Sustainable and Healthy Development of the Real Estate Market”
March 2005	“Eight National Rules”
May 2006	“Notice on Adjusting the Housing Supply Structure and Stabilizing Housing Prices”
December 2008	“Opinions on Promoting the Healthy Development of the Real Estate Market”
January 2010	“Eleven National Rules”
April 2010	“Ten National Rules”
April 2010	Beijing introduce the detailed rules for the implementation of the “Ten National Rules”
January 2011	“New Eight National Rules”
April 2011	Beijing distinguishes between local and non-local household residence residents
February 2013	“New Five National Rules”
March 2013	Beijing stipulates that single household residence can only purchase one house
2014	Some cities relax the HPR
May 2016	“Opinions on Accelerating the Cultivation and Development of the Housing Rental Market”
March 2017	Beijing increases the down payment ratio for residents purchasing second housing.
October 2017	The 19th National Congress of the CPC emphasizes “housing should not be speculation”

in our article mainly include two major industries: banking and insurance. From Table 3 to Table 5, we present the location

quotient of each district in Beijing.

According to the location quotient and its changes in various

Table 3 Location quotients of various districts in Beijing by industry in 2007.

Region	Traditional agriculture	Agritourism	Industry	Construction	Retail	Hotel & catering	Culture Industry	Finance	Folklore tourism
Core area of the capital	0.00	0.00	0.58	0.53	1.15	1.47	1.06	1.96	0.00
Dongcheng	0.00	0.00	0.55	0.49	1.59	2.34	1.15	0.47	0.00
Xicheng	0.00	0.00	0.49	0.56	0.88	0.95	1.01	2.51	0.00
Functional expansion area	0.10	0.30	0.88	1.08	1.16	0.95	1.19	0.78	0.01
Chaoyang	0.08	0.23	0.93	0.74	1.83	1.39	1.28	0.62	0.01
Fengtai	0.17	0.29	0.97	1.70	0.90	0.49	1.19	0.25	0.00
Shijingshan	0.00	0.05	1.25	0.91	1.09	0.44	0.67	0.50	0.00
Haidian	0.09	0.39	0.72	1.10	0.75	0.87	1.19	1.01	0.02
New development area	2.85	2.70	1.39	1.23	0.55	0.57	0.54	0.65	1.24
Fangshan	4.88	3.93	1.47	1.68	0.61	0.46	0.51	0.25	5.42
Tongzhou	3.37	0.58	1.54	2.38	0.86	0.40	0.46	0.95	0.31
Shunyi	1.64	2.26	1.55	1.03	0.39	0.54	0.67	0.20	0.06
Changping	1.68	2.90	1.18	0.66	0.47	1.28	0.66	0.80	1.82
Daxing	3.54	3.71	1.17	0.88	0.56	0.28	0.39	0.19	0.52
Ecological conservation area	6.57	5.41	1.14	1.56	0.36	0.70	0.51	0.77	12.43
Mentougou	1.80	2.60	1.43	0.88	0.38	0.68	0.45	0.63	4.45
Huairou	4.96	2.22	1.30	2.55	0.44	1.07	0.49	0.29	11.41
Pinggu	8.08	14.68	1.29	1.76	0.19	0.52	0.50	0.61	23.94
Miyun	8.10	3.47	1.12	1.17	0.44	0.20	0.52	1.02	10.42
Yanqing	10.07	2.96	0.51	1.32	0.32	1.25	0.64	0.59	10.05

Note: The relevant data of Xiao and Wang^[24] are used in the calculation of location quotient in the industry and finance in 2007.

Table 4 Location quotients of various districts in Beijing by industry in 2011.

Region	Traditional agriculture	Agritourism	Industry	Construction	Retail	Hotel & catering	Culture industry	Finance	Folklore tourism
Core area of the capital	0.00	0.00	0.34	0.64	1.07	1.49	0.82	2.27	0.00
Dongcheng	0.00	0.00	0.15	0.59	1.39	2.28	1.00	1.57	0.00
Xicheng	0.00	0.00	0.46	0.67	0.86	0.97	0.70	2.72	0.00
Functional expansion area	0.11	0.27	0.60	0.97	1.21	1.00	1.41	0.71	0.01
Chaoyang	0.07	0.38	0.53	0.85	1.90	1.38	1.18	0.91	0.00
Fengtai	0.23	0.20	0.55	1.36	0.81	0.56	0.35	0.28	0.02
Shijingshan	0.00	0.00	1.62	1.57	1.37	0.48	0.89	0.42	0.00
Haidian	0.11	0.24	0.54	0.80	0.80	0.96	2.16	0.78	0.01
New development area	2.53	2.29	2.33	1.37	0.62	0.59	0.42	0.52	1.03
Fangshan	5.19	2.65	1.73	2.38	0.65	0.54	0.37	0.74	4.25
Tongzhou	3.57	1.07	2.25	1.94	0.80	0.30	0.53	1.03	0.21
Shunyi	1.20	0.96	1.87	1.38	0.45	0.60	0.21	0.33	0.04
Changping	1.86	3.60	2.08	0.65	0.45	0.92	0.56	0.55	1.89
Daxing	2.65	3.40	1.05	0.72	0.36	0.45	0.19	0.31	0.66
Ecological conservation area	6.56	6.07	2.03	1.26	0.38	0.73	0.25	0.67	12.73
Mentougou	2.11	3.27	2.32	0.90	0.63	0.76	0.13	0.47	8.84
Huairou	5.42	4.32	2.78	1.30	0.42	0.97	0.37	0.75	12.65
Pinggu	6.83	12.49	1.78	1.52	0.20	0.51	0.18	0.70	19.41
Miyun	8.10	4.73	2.15	1.41	0.38	0.71	0.23	0.69	8.51
Yanqing	9.43	3.21	0.90	0.90	0.37	0.73	0.37	0.69	13.23

Table 5 Location quotients of various districts in Beijing by industry in 2015.

Region	Traditional agriculture	Agritourism	Industry	Construction	Retail	Hotel & catering	Culture industry	Finance	Folklore tourism
Core area of the capital	0.00	0.00	0.30	0.54	1.10	1.54	0.75	2.07	0.00
Dongcheng	0.00	0.00	0.16	0.58	1.52	2.42	0.84	1.36	0.00
Xicheng	0.00	0.00	0.40	0.51	0.82	0.94	0.69	2.55	0.00
Functional expansion area	0.10	0.13	0.54	1.10	1.07	0.90	1.43	0.78	0.00
Chaoyang	0.05	0.04	0.42	0.95	1.51	1.23	1.00	0.95	0.00
Fengtai	0.27	0.14	0.63	1.34	0.76	0.49	0.42	0.69	0.00
Shijingshan	0.00	0.00	1.22	1.82	1.51	0.52	1.00	1.21	0.00
Haidian	0.10	0.22	0.54	1.07	0.73	0.79	2.23	0.62	0.01
New development area	2.50	1.90	2.50	1.15	0.90	0.79	0.38	0.54	1.05
Fangshan	6.74	4.21	2.12	1.91	0.74	0.58	0.29	1.19	5.29
Tongzhou	3.82	1.47	2.52	2.23	0.95	0.37	0.37	0.91	0.23
Shunyi	1.21	0.64	2.26	1.22	0.41	0.78	0.18	0.36	0.05
Changping	1.96	4.14	2.08	0.62	0.54	0.80	0.48	0.53	2.07
Daxing	2.12	1.24	1.05	0.69	0.47	0.59	0.13	0.36	0.48
Ecological conservation area	7.20	9.13	2.15	1.18	0.40	0.73	0.31	0.79	13.34
Mentougou	2.28	6.88	2.35	1.49	0.56	0.96	0.20	0.64	7.43
Huairou	5.92	14.76	3.27	1.03	0.29	1.06	0.42	0.75	14.44
Pinggu	6.81	9.78	1.66	1.03	0.40	0.64	0.20	0.83	13.74
Miyun	10.07	8.09	2.41	1.24	0.57	0.50	0.42	0.97	14.34
Yanqing	9.28	3.64	0.92	1.30	0.17	0.62	0.30	0.62	14.32

districts and industries in 2007 and 2011 (as shown in Tables 3 and 4), the special regional positioning and land use administrative planning make the core functional area of the capital do not develop industries related to the primary industry. Moreover, the industry location quotient in the secondary industry also shows a significant downward trend. In contrast, driven by the two major financial districts, Financial Street and Jinbao Street, the finance location quotient value of the core functional area is significantly greater than 1. The attraction of scenic spots promotes the development of related supporting industries. The retail and hotel & catering industries in Dongcheng District have a location quotient greater than 1, showing a trend of specialization. The overall development pattern of the region is in line with the positioning of the core area of regional financial management and the historical and cultural gathering area.

For functional expansion area, the primary industry also maintains a relatively low level of development, while the secondary industry has also decreased except for Shijingshan District, which has a relatively small area and employment population, the location quotient of the secondary industry is prone to change. Affected by the relieving of the secondary industry in the core area and combined with the remaining original location advantages of Shougang Company, some secondary industries have relocated to this area, resulting in an increase in the location quotient of the industrial and construction industries in the short term. In the tertiary industry, Haidian District is influenced by science park as well as the geographical advantages of university clusters, the culture industry shows a clustering phenomenon, with a location quotient significantly greater than 1. Chaoyang District is benefiting from commercial districts such as Sanlitun, showing professional development in the retail and catering industry. However, it is worth noting that

although Haidian District and Chaoyang District have good development trends, the other two latter functional expansion area has not appeared in a large-scale and specialized industry, which deviates from its positioning. Although there are prosperous financial areas such as CBD in the functional expansion area, because of the large area and population base, the development of areas outside the Fifth Ring Road is slow, and the location quotient has not yet developed into a specialized attribute at the overall location level.

For both new development area and ecological conservation area, they mainly focus on the primary and secondary industries, exhibiting professional development. Specifically, except for Shunyi District: the location quotient of the primary industry in Shunyi District is relatively low, which may be due to the objective demand for the construction of the Capital Airport, occupying a large amount of arable land in the primary industry, leading to the lack of professional development in Shunyi District, the traditional agriculture and agritourism have a location quotient greater than 1. With the trend of industrial relocation, the industry location quotient is on the rise, giving it more advantages. In the tertiary industry, except for the folklore tourism industry is influenced by the Beijing suburban tourism circle (such as Gubei Water Town etc.) and rural revitalization in the ecological conservation area, the other tertiary industries have basically not formed geographical advantages in the corresponding regions. This series of layout and development situation, on one hand, meets the construction needs of modern agricultural production bases and the needs of ecological friendly green development, but on the other hand, facing the goal of developing strategic emerging industries in the new development area, there is a slow construction of the tertiary industry, the location quotients of culture industry and finance are both less than 1, and the industrial clustering has not been achieved.

Compared to the changes from 2007 to 2011, the changes from 2011 to 2015 are more due to the implementation of the HPR (as shown in Table 5). From the results of the changes in location quotient, the significant changes are mainly concentrated in the new development area and the functional expansion area such as Shijingshan District, Changping District, and Fangshan District, which have lower housing prices and are closer to the core urban area.

As a latter functional expansion area, Shijingshan District successfully finished the “Shougang Company’s transfer” in 2015, resulting in a significant decrease in industry location quotient from 1.62 to 1.22. Shijingshan District has convenient transportation to the core area, and low housing prices due to the HPR. While relieving a large number of industrial population, it has attracted a large number of high-quality population. A series of high-tech industrial parks have been built, such as the “Rongke Creative Center”, “Beijing Bank Insurance Industrial Park”, and “Shougang Park”, to promote the rapid development of the local finance and culture industry.

For the new development area, many secondary industries have further migrated from the urban area due to the plan of relieving Beijing of functions non-essential to its role as China’s capital. In addition, due to the “points-based hukou system” of Beijing, buying a house and meanwhile working outside the urban area could add more points for getting registered (hukou), the labor force has further migrated to the suburban areas. Some labor force chooses to work in the secondary industry that has been relocated under the “double changes of residence and employment”. In terms of location quotient, most the new development area and ecological conservation area have improved their industry location quotient, presenting a more competitive industrial agglomeration layout.

Under the “managing by housing”, the HPR affects the employment choices of the labor force by changing living conditions. It also changes the labor force allocation in different locations and industries. For some new development area and ecological conservation development area, they are most strongly affected because of the relatively low housing prices. For the latter functional expansion area, the change in location quotient mainly reflects in the substitution effect on the former: it attracts more tertiary industries to develop with its more advantageous housing prices and similar geographical location, achieving specialization in industries such as finance and culture industry.

Under the influence of the HPR, it effectively accelerates the development of the latter functional expansion area and further supports the radiation and control power of the capital economy. For the new development area and ecological conservation development area, it has also accelerated the process of local industries, population, and urban functions. However, the lack of strategic emerging industries in the new development area has not been effectively resolved, except for Fangshan District, which has a location quotient greater than 1 due to the driving effect of the construction of Beijing Financial Security Industrial Park, the tertiary industry in other districts has not yet formed a professional trend.

The HPR mainly affects the living conditions of the labor force population, changing the distribution of labor force and driving the optimization of industry layout, but the construction of the tertiary industry places more emphasis on the quality of labor force rather than quantity. For the finance industry, a geographical location far from the urban area is also not conducive to attracting investment in the long term.

Compared to the latter functional expansion area, the the new

development area may also have the advantage of low housing prices. However, because of the remote geographical location, the construction of infrastructure and education is not perfect, which does not have the conditions to attract high-quality talents and high-tech enterprises to settle in, making it difficult to form professional industrial development.

4.2 Matching degree between regional population and economic development

While removing non-capital functions, whether the labor force population matches the regional economic development and whether the market is distorted by policies are also important. HPR affects both the housing choice of labor force and the redistribution of industries under the “double changes of residence and employment”, so we also study whether this dual impact is beneficial for matching the labor market with industries. We follow the method of measuring the mismatch between population and economic development, by calculating the ratio of the per capita Gross Regional Product (GRP) that measures the total added value of various industries in a specific district to the per capita Gross Domestic Product (GDP) that measures the overall economic development status of the region^[25,26]. The specific methods of R index and M index are shown in Eqs. (2) and (3), which measure the mismatch between the economic development and the local population.

$$R_i = \frac{\text{per capita GRP}_i}{\text{per capita GDP}} = \frac{\frac{\text{GRP}_i}{\text{POP}_i}}{\frac{\text{GDP}}{\text{POP}}} = \frac{\text{GRP}_i}{\text{GDP}} \times \frac{\text{POP}}{\text{POP}_i} = S'_y / S'_p \quad (2)$$

$$M = \sum_i M_i = \sum_i \left| \frac{\text{GRP}_i}{\sum_i \text{GRP}_i} - \frac{\text{POP}_i}{\sum_i \text{POP}_i} \right| = \sum_i |S'_y - S'_p| \quad (3)$$

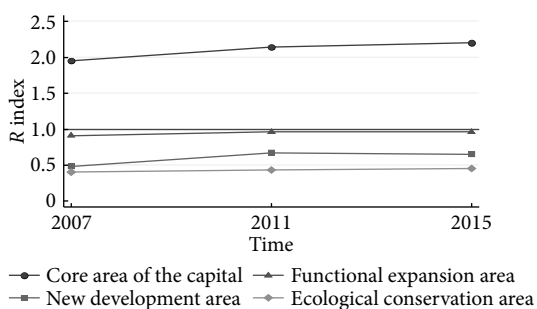
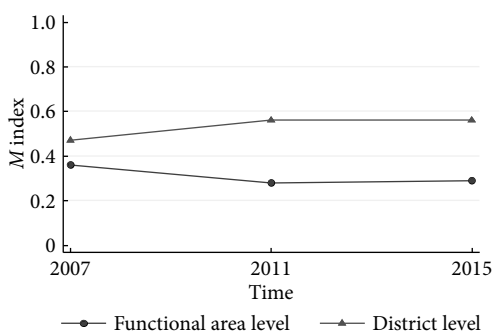
where GRP_i is the regional GRP of district, GDP is the overall GDP of Beijing, POP_i is the permanent population in district, POP is the overall population of Beijing, S'_y is the economic share of district, and S'_p is the population share of the district. The R index is used to measure the deviation degree between the labor force population and economic development in district. Its value ranges $[0, \infty)$. When $R > 1$, the economy development is over the population development. When R approaches 1, the population and economy are matched. The M index measures the mismatching degree between the economy and population of Beijing, with a range of $[0, 2]$. When M is equal to 0, it means that the two are completely matched. The smaller the M value, the higher the degree of matching between the economy and population. The R index and M index for year 2007, 2011, and 2015 are reported in Table 6.

In Table 6, the R indexes of the four functional areas all approach 1 except for the core area from 2007 to 2011, and the M index also decreases at the functional area level (as shown in Figs. 14 and 15).

It proves that under the guidance of different functional positioning of districts, the surplus labor force population that has been dispersed and the industries that have been relocated have carried out a new round of matching for the local area. The R index of the core area of the capital and the M index at district level show a more mismatching trend. Combined with the changing trends in location quotients in Tables 3 and 4, we conclude that under the plan of relieving Beijing of functions non-essential to its role as China’s capital, a large number of relocated enterprises are mainly concentrated in the primary and secondary

Table 6 *R* index and *M* index of various districts and functional areas in Beijing.

Index	Region	2007	2011	2015
<i>R</i> index	Core area of the capital	1.95	2.14	2.20
	Dongcheng	1.66	1.83	1.94
	Xicheng	2.15	2.36	2.38
	Functional expansion area	0.91	0.96	0.96
	Chaoyang	0.99	1.11	1.11
	Fengtai	0.48	0.48	0.47
	Shijingshan	0.72	0.63	0.62
	Haidian	1.13	1.16	1.18
	New development area	0.48	0.67	0.65
	Fangshan	0.41	0.53	0.50
	Tongzhou	0.34	0.40	0.41
	Shunyi	0.84	1.38	1.33
	Changping	0.53	0.33	0.32
	Daxing	0.35	0.30	0.31
	Ecological conservation area	0.40	0.43	0.45
	Mentougou	0.37	0.44	0.44
	Huairou	0.67	0.57	0.58
	Pinggu	0.30	0.41	0.44
	Miyun	0.37	0.43	0.45
Yanqing	0.31	0.30	0.32	
<i>M</i> index	Functional area level	0.36	0.28	0.29
	District level	0.47	0.56	0.56

**Fig. 14** *R* index in functional area level.**Fig. 15** *M* index in functional area and district level.

industries, and the per capita economic profits brought by the industries are relatively low. The industries that remain in the core area of the capital and former functional expansion area are mainly the finance and culture industry. The relieving of labor

force and the concentration of high profit industries towards the center have led to a trend of overall economic and population distribution, where the economy gathers towards the central urban area and the population spreads towards the suburbs. However, the population regulation policy by relieving industries has mainly promoted the matching between economy and population.

The change of *R* index and *M* index from 2011 to 2015 mainly reflex the impact of the HPR adding on the function relieving policy. The *R* index and *M* index of the four functional area have shown a more mismatching trend except for the ecological conservation area. The HPR directly affects the labor force and their living conditions, which leads to a distortion of the labor market. Thus, the sustained reduction of population and the increasing refinement of industries have led to a continuous upward trend in the *R* index and *M* index. This result shows that the HPR has distorted the population, thus has offset the optimization of industry layout and population distribution.

5 Conclusion

We take Beijing as an example to study the impact of policies on the efficiency of city intelligent system. We find that the HPR policy has spillover effect on population distribution and industry development of megacities. Specifically, under the plan of relieving Beijing of functions non-essential to its role as China's capital, the HPR optimizes population migration in the context of "managing by housing" and "double changes of residence and employment", promoting the scale and specialization of local industries, improving the efficiency of local industries, and contributing to the implementation of the "The Beijing Main Functional Area Plan" and the "Beijing-Tianjin-Hebei coordinated development Plan". However, the HPR introduces a distortion of matching between population and industry.

The findings are of great importance for municipal government to make and implement effective policies, especially when external effect would be produced by the policy. When a city implements the HPR, on the one hand, it will greatly reduce the number of non-local permanent population, which can alleviate the population and reduce the burden on the city. On the other hand, the HPR will cause labor mismatch, which is not conducive to the flow of high education talents. It will directly lead to a significant reduction in urban high-tech labor force, thereby leading to a decline in technological innovation capabilities. Thus, the government might adopt different HPRs for populations in different industries. For regions mainly developing the secondary industry, the government might improve indemnificatory housing while enhance the HPR, ensuring sufficient labor supply and preventing overpopulation. For regions developing high-tech industries, the government might give appropriate relaxation of the HPR for high-tech talents, such as talent introduction, to prevent talent loss.

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