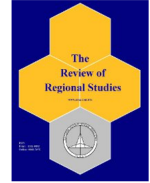




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The Population Dynamics in China: Understanding the Role of Spread and Backwash Effect*

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Abstract: Considering the declining population growth and increasing intra-provincial migration in China, the population issue becomes crucial for the sustainable development of the Chinese economy. We utilize data of 2010 and 2020 China Census to study the impact of the “spread-backwash” effects of large cities on county-level population dynamics over the past decade and investigate the potential mechanisms. We find that the spillover effects generated by cities have significantly increased the population of neighboring counties. Regarding the mechanism, the “spread-backwash” effects of large cities facilitate the integration of county-level secondary industries into urban industrial chains, leading to new enterprise investments and job creation. In counties where spillover effects are significant, the number of new enterprises in the tertiary industry is higher, positively impacting local population growth.

Keywords: Population change; Migration; Market potential; Spread and backwash effect; Spillovers

1. INTRODUCTION

Since the reform and opening-up policy, significant changes have occurred in the pattern of China’s economic development. One crucial characteristic is the rapid transformation of population and labor from low mobility to high mobility. This shift has facilitated the continuous optimization of spatial allocation of population, realizing mutual influence between population mobility and economic development (Haas, 2010). Local population represents the potential development of cities. Typically, the increase in population comes from natural population growth and net population inflow. As the natural population growth rate gradually slows down in recent years, understanding the changes in population inflows and outflows becomes crucial.

In the past, scholars mainly focused on rural-to-urban migration or long-distance migration from inland to coastal provinces. However, it is important to recognize that the patterns of population migration in China have become increasingly diverse in the last decade. According to the latest national census data in 2020, internal population mobility in China is

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becoming increasingly active, with a scale of 376 million people.¹ Compared to the sixth national census in 2010, the mobile population has increased by 154 million people, representing a growth of 69.73%.² In 2020, the number of intra-provincial migrants nationwide was 251 million, an increase of 85.7% over the past 10 years. The number of inter-provincial migrants was 125 million, an increase of 45.37% over the same period. It is evident that intra-provincial migration has been more active compared to inter-provincial migration.

The data from the Seventh National Census validates the well-known “hypothesis of the mobility transition (Zelinsky, 1971)”. As urbanization in China advances, the scale of long-distance migration between urban and rural areas and regions are expected to decline. However, migration within the same province or same city will become dominant and remain at a high level. Therefore, changes in inter-city and intra-city population movements will become key factors influencing the overall dynamics of population migration in China. Besides, influenced by factors such as the continuous decline in the birth rate and the further deepening of aging, China experienced negative population growth for the first time in 2022. China has abundant human resources to promote its rapid economic development over the past 40 years. The declining population growth may imply that China will gradually lose its demographic advantage. Therefore, it is important to examine the population dynamics in the last decade.

In China, county is the basic geographical unit for economic activities. Besides cities, counties are also important growth regions for China’s economic development. In 2020, the population in China’s counties reached 721 million, accounting for 51.13% of the total national population. The substantial population size serves as a crucial driving force for sustainable economic development, urbanization, and urban-rural integration. From 2010 to 2020, changes in the population of Chinese counties were relatively gradual, with the characteristic of a slow outflow of population. Considering the rapid urbanization that led to frequent administrative changes such as county reclassification and city-county mergers, and the occasional adjustment of administrative boundaries, it is more appropriate to measure population changes using counties where the boundaries did not change during our research period. The population in these counties decreased from 732 million in 2010 to 698 million in 2020, with a modest change of only 4.64%.³

Figure 1 illustrates the general scenario of China’s county-level regions in the year 2020. Color-filled areas represent the 1,709 counties that remained unchanged, while dotted areas indicate the exclusion of 167 counties from the study. With increasing grayscale, counties with a net outflow of population gradually transition to those with a net inflow. Specifically, there are 140 counties with a net outflow population exceeding 100,000, and 1,041 with a net outflow population below 100,000. Simultaneously, there are 60 counties with a net inflow population surpassing 100,000, and 468 with a net inflow population below 100,000. According to Figure 1, we could find that population changes in the majority of Chinese counties are relatively modest, with net population changes generally staying below 100,000

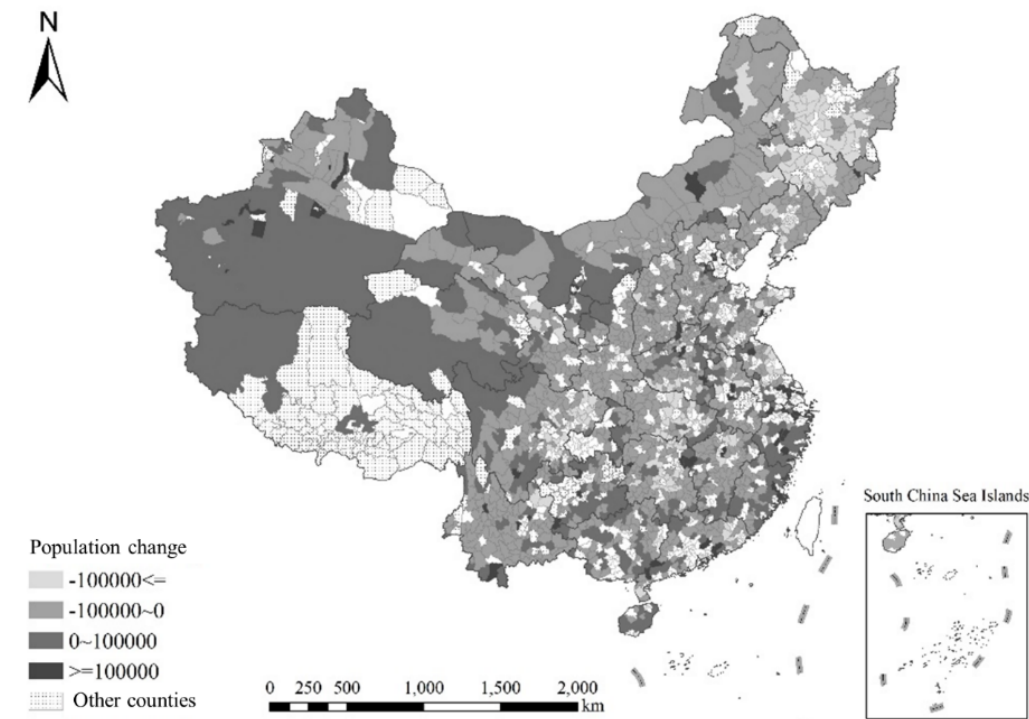
¹The latest monitoring data of population mobility in each province indicates that the scale of internal population mobility in China reached 385 million people in 2021.

²The 7th national census.

³After data cleaning, there are 1,709 counties where the boundaries did not change during 2010-2020. We will discuss in detail in later section.

people.

Figure 1: Population changes of counties in China



Given the current population changes in China, Chinese government started to place greater emphasis on optimizing the population structure. In 2022, the National Development and Reform Commission (NDRC) of China issued the “Opinions on Urbanization Construction with Counties and Towns as Important Carriers,” which specifically emphasized county population mobility. It proposed to remove restrictions on household registration in counties, aiming to promote the optimization of population resource allocation and the transformation of counties. In the same year, the Chinese government introduced the “Opinions on Accelerating the Construction of a Unified National Market,” explicitly supporting counties to integrate into nearby large cities. This further promotes the construction of urban-rural relationships in counties. These policies indicate that population changes in counties are also significantly influenced by cities.

Existing research on county-level population changes in China is abundant. However, current studies still have some limitations. Firstly, many existing studies include all county-level administrative units, lacking a specific focus on the spatial aspects of counties. Secondly, some studies tend to adopt a case study, so the conclusion is not general. Thirdly, the relationship between counties and cities are not well examined.

To investigate how population growth of counties is affected by the large cities in China, this study utilizes data from the sixth and seventh national censuses to analyze the factors influencing county-level population changes in China from 2010 to 2020 under the framework of new economic geography. Our study shows that county population is positively affected by near prefecture-level cities, provincial capitals, and large cities, which exhibit spread effect

on population growth. Such spread effect primarily strengthens the economy by constructing industrial chains between counties and cities, driving the development of county industries and enterprise investments, and creating job opportunities for the labor force.

The innovations and contributions are as follows. Firstly, this paper investigates the relationship between large cities and counties in China from the perspective of population, integrating ideas from new economic geography and central place theory to clarify the heterogeneity of different tier cities' effects on county development. Secondly, from the industrial structure perspective, this study explores the mechanism of "spread backwash" effects on county development. Thirdly, the data used in this paper is comprehensive and detailed. Specifically, we use the census data to reflect the specific changes in county populations from 2010 to 2020 and Amap Open Platform Road data to verify the mechanism of urban spillover effects.

2. LITERATURE REVIEW

This paper is primarily related to two strands of literature. The first is the theoretical and empirical analysis of the spread-backwash effect, and the second is the driving factors of county-level population changes.

2.1. Spread/Backwash effects

The "core-periphery" economic pattern forms the basis for the application of the "spread-backwash" effect. The economic core acts as the driving force for economic development, dominated by advanced industries, surrounded by supporting industries and various related sectors, thereby forming the economic periphery. The continuous drive from the economic center ensures that the "spread and backwash" effect promotes the joint development of both the center and the periphery. This concept has received widespread support (Boudeville, 1966; Friedmann, 1972; Myrdal, 1957; Richardson, 1976).

Market potential serves as a simplified tool to empirically test the theoretical concept of the "spread-backwash" effect. From the perspective of economies of scale and profit maximization, For instance, Krugman (1991) pointed out that enterprises tend to locate their production facilities in areas with higher market potential. Areas with high market potential imply a larger market size and higher market demand, making it easier for enterprises to maximize profits through increased sales. This, in turn, encourages enterprises to cluster in high market potential areas.

Evidence of the spread-backwash effect has been investigated in many countries, but the conclusions are mixed. For developed countries, such as the United States and European countries, municipal growth in the United States would generate a spread effect on employment in nearby regions (Boarnet, 1994). However, the effect may vary across various types of counties in the United States (urban, rural, and mixed counties). The employment growth in highly urbanized counties had a spread effect on employment growth in nearby rural counties, while employment growth in mixed counties had a backwash effect on rural counties (Feser and Isserman, 2005). In Europe, the spread effect of urban growth is a key

factor in population growth in rural communities (Henry et al., 1999). And European integration expanded the coverage of urban spread effects, attracting labor migration within and between EU member states to areas with higher spread effects (Kancs, 2011).

For developing countries like China, Brazil, etc., the results are more complicated. In Brazilian cities, the spread and backwash effects also exist, and areas with high spread effects had higher wage levels and labor inflows, while areas with high backwash effects experienced significant labor outflows (Hering and Paillacar, 2008). In China, the spread and backwash effects exhibited different patterns in different areas. For some specific regions, urban growth generates spread effects on interprovincial labor mobility in Yangtze River Delta urban agglomeration (Zhang et al., 2016). Additionally, suburbs within metropolitan areas exhibited both spread and backwash effects in Beijing and Shanghai (Chiang, 2018), and the greater the disparity between the city and its suburbs, the weaker the spread effect and the stronger the backwash effect. Besides, the administrative hierarchy in China also matters. County-level cities exhibited a spread effect on GDP and employment growth, while there was a backwash effect on rural areas (Ke and Feser, 2010). Specifically, using city-county consolidations in China as an example, such urban-led policy may cause a strong backwash effect on nearby rural areas. (Deng et al., 2022).

Therefore, we propose the following hypotheses.

Hypothesis 1: Urban growth may produce spillover effects (spread and backwash effects) on population changes in counties.

Hypothesis 2: The spillover effect (spread and backwash effects) of large cities on counties is reflected by market potential.

2.2. Counties' Development and Population in China

The second strand of the literature mainly focuses on the development of counties in China. Due to the administrative hierarchy in China, county is the basic economic jurisdiction. Therefore, we need to investigate the driving factors of counties' growth. Currently, research on county-level development primarily focuses on three areas: industrial structure, income levels, and public services. This paper will analyze these three aspects from the perspective of county populations.

Regarding the industrial structure, scholars have systematically studied counties with sustained economic development and identified commonalities in their industrial sectors. On one hand, thanks to strong external policy support and an increasingly robust market system, many counties have made significant progress in developing main industries. These industries have facilitated nearby employment for a substantial portion of the rural labor force (Tang and Tan, 2021). On the other hand, some migrant workers who have accumulated funds, technology, and social capital outside their hometowns have started returning to start businesses. They have used local relationships to bring back fellow townsmen who were working elsewhere (Wang et al., 2018). However, declining counties generally suffer from insufficient industrial development and low efficiency in traditional industries, making past development paths unsustainable and leading to a lack of job opportunities. Furthermore, the transformation and development of traditional industries are hindered by a shortage of innovative talent and financial constraints. This situation results in a detrimental cycle of

“delayed industrial development—massive loss of labor—further delayed industrial development” (Wang and Sun, 2023).

Income level is another important driver of population change. County populations generally migrate towards regions and industries with higher income and more employment opportunities. Young industrial workers and service industry groups primarily constitute the population moving from counties to central cities. In contrast, those moving between counties or within the same county are typically individuals with the lowest education levels and unstable incomes. Those moving from central cities to counties tend to be more specialized professionals (Xiao, 2016). According to Su et al. (2017), significant wage differences, large population sizes, and rapid employment growth rates are the main reasons cities attract rural migrant workers. This pattern also exists in other countries. For example, skilled workers in small cities are more likely to migrate to large cities in Spain (Roca, 2017). Additionally, due to having lower skills than the residents of their destination areas, migrants often experience low-income levels and high unemployment rates.

In terms of public services, the choice of destination for the migrant population depends not only on employment opportunities and income levels in the destination but also on the abundance and availability of urban public and commercial services. This is especially crucial for migrants who plan to reside long-term, making it an important factor in their selection of target cities. However, there is a common mismatch between the permanent population and public resources in Chinese counties, which may further exacerbate the loss of the labor force. Current provincial fiscal funds for county construction in China are allocated based on registered population, leading to a mismatch between public resources and the actual population capacity (Zhao et al., 2023). Moreover, rapid urbanization has caused a large influx of rural populations into county towns. However, due to financial constraints, many county towns have relatively limited basic public services, such as healthcare, education, and elderly care, which cannot fully meet the public service needs of the migrating agricultural population (Wu and Liu, 2021).

The existing literature provides insights for investigating the potential mechanism. Given the data availability, we will mainly examine the channel of industrial structure; thus, we propose the following hypothesis.

Hypothesis 3: The channels through which urban development affects county populations may be industrial structure.

3. EMPIRICAL STRATEGY

3.1. Conceptual Framework

We follow Partridge et al. (2007) and Rappaport (2004) to use population change as part of an adjustment for long-term equilibrium transition. The model assumes that, given a certain population density level, each region initially resides in a steady state, with population density reflecting the actual preferences of a representative household. In the model, the change in population density of city i in year t (PD_{it}) relative to the population density in year 0 (PD_{i0}) depends on the combination of the actual population density in year 0 and

regional characteristics (X_{i0})⁴. Therefore, the county population density can be modeled as follows:

$$PD_{it} - PD_{i0} = \lambda\beta X_{i0} - \lambda PD_{i0}, \quad (0 \leq \lambda \leq 1) \quad (1)$$

If the area of the region remains unchanged from year 0 to year t, the left side of the equation can be replaced with the percentage change in population. Therefore, we can use market potential as a proxy variable for the extent of spread and backwash effect on counties exerted by large cities. The model can then be further expressed as follows:

$$\% \Delta POP_{i(t-0)} = f(MP_{i0}, Econ_{i0}, Society_Amen_{i0}, Nature_Amen_{i0}, X_{i0}) \quad (2)$$

where MP_{i0} is the market potential of city i in year 0, $Econ_{i0}$ is the economic development level of city i in year 0, $Society_Amen_{i0}$ and $Nature_Amen_{i0}$ are the social amenities and natural amenities of city i in year 0, respectively. X_{i0} includes other control variables.

3.2. Baseline Empirical Model

Following prior studies (Partridge et al., 2007; Chen and Partridge, 2013), this paper constructs an econometric model as follows:

$$\begin{aligned} \% \Delta POP_i = & \vartheta + \iota MP_i + \kappa Econ_i + \lambda Society_Amen_i \\ & + \mu Nature_Amen_i + \nu X_i + \xi Prov_i + o_i \end{aligned} \quad (3)$$

where the dependent variable $\% \Delta POP_i$ is the change in the resident population of the i-th county between the sixth and seventh population censuses. Regarding the main explanatory variables, we construct market potential to examine the spillover effects of these central cities on county populations. MP_i represents the estimated market potential of a county in relation to the nearest prefecture-level city, provincial capital, and megacity (Harris, 1954), which is given below.

$$MP_i = \sum_{j=1}^J \frac{GDP_j}{DIS_{ij}^\alpha} \quad (4)$$

The GDP data is from 2011⁵. Due to the unavailability of early road mileage data, the distance (DIS) uses real-time road mileage data from October 1, 2023, as a proxy for the base-period road mileage, with α set to 2. Recent work by Davis et al. (2025) provides annual GIS measures of China's surface transport network from 1993 to 2020, which could further

⁴See Partridge et al. (2007) for details.

⁵Concerning the choice of economic data: since the sixth population census occurred between November 2010 and April 2011, the economic variables for the concluding year are treated as the base-year variables, specifically, 2011. Likewise, for the fifth population census conducted from November 2000 to June 2001, the base year for economic variables is established as 2001. Remarkably, the seventh population census data spans from November 2020 to December 2020, consequently, the economic variables are designated for the year 2020.

improve the historical measurement of transport accessibility. However, the construction of county-level points/access measures is not fully consistent with our current county-level measurement strategy. We leave the incorporation of these data for future research.

Regarding the other control variables, they are primarily categorized into economic variables $Econ_i$, social amenities $Society_Amen_i$, natural amenities $Nature_Amen_i$, and other control variables X_i . $Econ_i$ comprises the county's 2011 GDP, the proportion of the added value of the secondary and tertiary industries to the 2011 GDP, and the general public budget expenditure in 2011. $Society_Amen_i$ involves the count of high school students, hospital and health center bed capacity, and social welfare stations in the county in 2011. $Nature_Amen_i$ covers the county's average annual precipitation, January temperature, standardized vegetation index⁶, and PM2.5 concentration from 2011 to 2020. Precipitation and temperature indicators are sourced from the China Research Data Service Platform (CNRDS), NDVI data is derived from MOD13A3 data within the MODIS dataset, and PM2.5 concentration indicators originate from the National Meteorological Science Data Sharing Service Platform. Four counties have missing values in NDVI and PM2.5 concentration indicators, and this paper addresses the gaps by incorporating data from adjacent counties. X_i includes county-level population density and average education levels from the Sixth National Population Census; dummy variables for the three batches of new-type urbanization pilots from 2014 to 2016; a dummy variable for the policy of converting counties into districts; and a dummy variable indicating whether high-speed rail was introduced between 2010 and 2020. These variables aim to control the impact of non-economic factors on county-level population changes, such as the household registration (*hukou*) system, policy pilots, administrative division adjustments, and new transportation investments. Additionally, we control for provincial fixed effects, and all estimated models use robust standard errors.

4. DATA

4.1. Sample and Statistics

In China, county-level administrative divisions include districts, counties, autonomous counties, banners, and autonomous banners. In 2010, a total of 2,000 jurisdictions were recorded, consisting of 370 counties, 1,461 counties, 117 autonomous counties, 49 banners, and 3 autonomous banners. By 2020, the count reached 1,876, comprising 387 counties, 1,318 counties, 117 autonomous counties, 50 banners, 3 autonomous banners, and 1 administrative committee. Owing to rapid urbanization in China during the past decade, there have been frequent administrative adjustments, including county-to-district conversions, development zone construction, and city-county mergers. Given the data availability, this study exclusively examines counties with unchanged administrative codes and names. Furthermore, the study utilizes geographical area indicators from the "China County Statistical Yearbooks" of 2011 and 2020, in conjunction with GIS data, counties with area changes exceeding 20% are excluded. After data cleaning, the study's sample size is 1,709.

Regarding prefecture-level cities, the dataset includes 328 administrative units across the 31 provinces in mainland China. For megacities, following Ho and Li (2010) to consider city

⁶Normalized difference vegetation index, NDVI.

size and administrative level, we choose six super-first-tier cities and directly administered municipalities: Beijing, Shanghai, Guangzhou, Shenzhen, Tianjin, and Chongqing.

The original population data for this study are obtained from the “China Population Census – County-level Data” for the years 2010 and 2020. Economic data are extracted from the “China Urban Statistical Yearbook” and “China County Statistical Yearbook” for the respective years. Geographic data involve calculating straight-line distances between cities using GIS, complemented by collecting the latest road mileage information through the path planning feature of the Amap Open Platform⁷. Data on the opening of high-speed rail lines was compiled using information from the official website of the China State Railway Group, supplemented by reports from local news websites.

To address the impact of extreme values, all continuous variables are winsorized at 1% from both tails. Consequently, the statistical description of the main variables is presented in Table 1.

4.2. Description of County-Level Economy and MP

To more clearly reflect the significant differences between cities and display the hierarchical classification of different cities, this paper compares the average values of counties, prefecture-level cities, provincial capitals, and megacities, as shown in Table 2. The population ratios of prefecture-level cities, provincial capitals, and megacities to counties are approximately 2 times, 10 times, and 36 times, respectively. The GDP ratios are approximately 4 times, 28 times, and 102 times. The market potential of prefecture-level cities is roughly 3 times that of provincial capitals and 4 times that of megacities. There are significant differences in both city size and market potential between counties, prefecture-level cities, provincial capitals, and megacities.

5. RESULTS

5.1. Baseline Results

Table 3 reports the benchmark results for including “spread-backwash” effects of nearest prefecture-level cities, provincial capitals, and megacities, respectively. In columns 1 to 3, the market potential between counties and their nearest prefecture-level cities, provincial capitals, and megacities is significantly positive. This implies that the spillover effects of large cities will enhance the attractiveness of counties to the overall population, consistent with the findings of Bian et al. (2021). In Column 4, using the percentage change in the county-level urban population as the dependent variable, the results indicate that the spillover effects from large cities significantly promote the migration of rural populations to county towns, thereby accelerating the intra-county urbanization process. Column 5 keeps only the main explanatory variables and provincial fixed effects from Equation 3 to check the robustness, and we find the main results are unchanged.

⁷As of October 1, 2023.

Table 1: Summary Statistics

Variable	Description	N	Mean	SD	Min	Max
<i>Dependent Variable</i>	Change in total population 2010–2020 (%)	1709	-0.0484	0.1693	-0.5552	3.6797
	Change in urban population 2010–2020 (%)	1709	0.4216	0.4703	-0.6165	6.3193
<i>Core Ind Variables</i>	Market potential of nearest prefecture-level city (¥100 million/km)	1709	0.3833	1.4223	0.0004	12.1150
	Market potential of nearest provincial capital (¥100 million/km)	1709	0.1365	0.2512	0.0007	1.6394
	Market potential of nearest megacity (¥100 million/km)	1709	0.0868	0.1938	0.0006	1.3891
<i>Econ</i>	ln(GDP) of counties, 2011	1709	4.2328	1.0458	1.3609	6.5542
	Share of secondary and tertiary industries in GDP, 2011	1709	0.7722	0.1187	0.4056	0.9810
	ln(General fiscal expenditures), 2011	1709	2.6697	0.5165	1.3699	3.9787
<i>Society Amen.</i>	ln(Number of middle school students), 2011	1709	9.7761	0.9398	5.7236	11.5526
	ln(Hospital and health clinic beds), 2011	1709	6.7941	0.8293	2.9957	8.4523
	ln(County-level urban social welfare institutions), 2011	1709	2.3526	0.9002	0.6931	4.3820
<i>Nature Amen.</i>	Average precipitation 2011–2020 (mm)	1709	970.1246	431.4524	63.1894	2274.4720
	Average Jan. temperature 2011–2020 (°C)	1709	0.7199	8.8552	-21.4608	18.0152
	Average NDVI 2011–2020	1709	0.7225	0.1556	0.1204	0.8830
	Average PM2.5 2011–2020 ($\mu\text{g}/\text{m}^3$)	1709	40.9442	17.3716	3.9708	91.8955
<i>Control Variables</i>	Population density, 2011	1709	212.5119	205.2020	0.5984	1054.8640
	Average years of education, 2011	1709	8.2165	0.9206	4.6700	10.0700
	County-to-district conversion: nearest prefecture-level city, 2011–2020	1709	0.2926	0.4551	0.0000	1.0000
	County-to-district conversion: nearest provincial capital, 2011–2020	1709	0.6881	0.4634	0.0000	1.0000
	New-type urbanization pilot county	1709	0.2592	0.4383	0.0000	1.0000
	High-speed rail operation, 2010–2020	1709	0.2101	0.4075	0.0000	1.0000

Table 2: County-Level Economic and Market Potential Indicators

	Counties	Nearest Prefecture Cities	Provincial Capital	Megacity
Average urban resident population, 2011	428,235	992,817	4,164,751	15,417,810
Average urban GDP, 2011 (¥100 million)	116.68	493.44	3,177.75	11,527.17
Market potential, 2011 (¥100 million/km)	–	0.38	0.14	0.09
Average straight-line distance (km)	–	63.46	214.61	618.70
Average highway distance (km)	–	89.20	286.46	1,010.45
No. of Counties	1,709	1,709	1,709	1,709

5.2. Endogeneity

To mitigate endogeneity concerns between population changes at the county level and the market potential of the nearest major cities, we adopt the instrumental variable construction approach similar to (Galvao, 2011). We employ the GDP of the nearest prefecture-level cities, provincial capitals, and megacities in 2001 as the numerator, while the straight-line distance from county towns to these cities as the denominator. The calculation is as below:

$$IVGDP_MP_i = \sum_{j=1}^J \frac{GDP_2001_j}{ST_DIS_{ij}^2} \quad (5)$$

Valid instrumental variables need to satisfy relevance and exogeneity conditions. Our instrumental variable used the lagged 10-year value of GDP, due to historical reasons, there exists a temporal autocorrelation. Regarding exogeneity, as the instrumental variable is derived from lagged variables, it is determined by previous information. Therefore, the exogeneity assumption also holds.

Table 4 reports the results of instrumental variables. The main results are consistent with the baseline models. The first-stage F-statistic is greater than the critical value of 13.94, as proposed by Stock and Yogo (2005). This test could mitigate the risk of weak instrument bias.

5.3. Robustness Checks

Since the measurement of market potential varies, we test the sensitivity of market potential measures. First, using 2023 highway distances to approximate conditions around 2010 may still overestimate early accessibility. Therefore, we substitute straight-line distances for highway distances in model (5). Secondly, following Lin (2017), Donaldson (,2018) and Simonovska and Waugh (2014), we change the parameter α to 3.6 and 4. The results are reported in Table 5.

Table 3: Baseline Results

Variables	(1) % Δ POP	(2) % Δ POP	(3) % Δ POP	(4) % Δ POP_Urban	(5) % Δ POP
MPC	0.0191*** [5.5529]	0.0176*** [5.1079]	0.0180*** [5.1904]	0.0170*** [2.7026]	0.0217*** [4.8982]
MPP		0.0553*** [3.2059]	0.0497*** [2.8089]	0.2218*** [4.7566]	0.0494*** [2.8755]
MPM			0.0696*** [2.7151]	0.0992** [2.0464]	0.0907*** [3.5774]
Econ	YES	YES	YES	YES	NO
Society_AMEN	YES	YES	YES	YES	NO
Nature_AMEN	YES	YES	YES	YES	NO
Control Variables	YES	YES	YES	YES	NO
Province Effect	YES	YES	YES	YES	YES
Adjusted R ²	0.326	0.331	0.335	0.377	0.303
No. of Counties	1709	1709	1709	1709	1709

Note: t-statistics in brackets. The 1%, 5%, and 10% levels of significance are given as ***, **, and *, respectively.

5.4. Heterogeneous Analysis

5.4.1. Eastern, Central, and Western Regions

Since the economic conditions are various across China, the “spread-backwash” effects in the eastern, central, and western regions may also be different. Thus, we conduct heterogeneous effect analysis. The results are reported in Table 6. The eastern region shows significant spread effects from the nearest megacities; the central region shows significant spread effects from the nearest provincial capitals and megacities; and the western region shows significant spread effects from the nearest prefecture-level cities and provincial capitals. However, the backwash effect associated with the nearest megacity is significant.

In summary, as one moves from coastal to inland areas in China, urban sizes gradually decrease, and the distance between counties and large cities gradually increases. Consequently, owing to the westward shift of the geographical location, there is a phenomenon of county population changes being influenced by both spread effects from lower-tier cities and backwash effects from higher-tier cities.

5.4.2. Counties with High-Speed Rail Access

Transportation infrastructure was a major driving force behind population mobility and county-level development in China between 2010 and 2020. Notably, high-speed rail (HSR) construction—characterized by its large investment scale, high transport capacity, and rapid operational speeds—emerged as a crucial factor in significantly improving transportation conditions at the county level. Based on whether a county is connected to the HSR network, this paper divides the research sample into two groups to analyze the differential impacts of market potential on county-level population changes under varying conditions of transport accessibility.

Table 4: IV Results

Variables	IVGDP			
	(1) MPC	First-stage (2) MPP	(3) MPM	Second-stage (4) % Δ POP
IV_MPC	3.1856*** [24.27]	-0.0029 [-0.58]	-0.0027** [-2.24]	
IV_MPP	-0.0321 [-0.09]	2.6531*** [37.38]	0.0091 [1.07]	
IV_MPM	0.4046* [1.94]	0.2088*** [5.00]	3.2215*** [50.71]	
MPC				0.0193*** [4.91]
MPP				0.0527*** [3.00]
MPM				0.0771*** [2.89]
Econ	YES	YES	YES	YES
Society_Amen	YES	YES	YES	YES
Nature_Amen	YES	YES	YES	YES
Control Variables	YES	YES	YES	YES
Province Effect	YES	YES	YES	YES
First-stage F-statistic MPC	212.43	583.793	1360.83	
Shea's adjusted partial R ²	0.8981	0.9058	0.9425	
Minimum Eigenvalue Statistic				4875.98
No. of Counties	1709	1709	1709	1709

Note: t-statistics in brackets. The 1%, 5%, and 10% levels of significance are given as ***, **, and *, respectively.

As shown in Table 7, Column 1 indicates that counties with HSR access exhibit a significant spread effect, primarily originating from neighboring prefecture-level cities, provincial capitals, and megacities, with the magnitude of this effect increasing multiplicatively. In contrast, Column 2 shows that counties without HSR access are only subject to spread effects from neighboring prefecture-level cities and provincial capitals. These results indicate that improvements in transport accessibility help to expand the spatial reach of the economic spread effects from higher-tier cities, thereby enhancing the capacity of surrounding counties to attract population.

6. MECHANISM DISCUSSIONS

As we discussed in the literature review, the potential mechanisms could be industrial structures, income levels, and public services. Given the data availability, we specifically check the industrial structure mechanisms in this section.

Large cities have agglomeration advantages in many areas such as technological innovation, transportation hubs, and policy support. These advantages continually increase the demand for primary industrial products, processing materials, and various goods and services. This trend naturally encourages surrounding counties to actively integrate into the urban industrial chain. Counties take their own advantages to develop local industries and

Table 5: Robustness Checks

Variables	MP Line			MP Road		
	(1)	(2)	(3)	(4)	(5)	(6)
	$\alpha = 2$	$\alpha = 3.6$	$\alpha = 4$	$\alpha = 2$	$\alpha = 3.6$	$\alpha = 4$
MPC	0.0105*** [4.9722]	0.0564*** [5.2690]	0.0858*** [5.3177]	0.0180*** [5.1904]	0.1384*** [5.1901]	0.2290*** [5.0173]
MPP	0.0312*** [3.2085]	17.1687*** [5.1849]	75.5268*** [5.2740]	0.0497*** [2.8089]	39.0690*** [4.9679]	181.6917*** [5.0275]
MPM	0.0441*** [2.9640]	59.8555*** [3.7881]	346.7628*** [3.9207]	0.0696*** [2.7151]	152.8577*** [3.6063]	986.5162*** [3.7022]
Econ	YES	YES	YES	YES	YES	YES
Society_Amen	YES	YES	YES	YES	YES	YES
Nature_Amen	YES	YES	YES	YES	YES	YES
Control variables	YES	YES	YES	YES	YES	YES
Province effects	YES	YES	YES	YES	YES	YES
Adjusted R^2	0.339	0.343	0.343	0.335	0.338	0.338
No. of Counties	1,709	1,709	1,709	1,709	1,709	1,709

Note: t-statistics in brackets. The 1%, 5%, and 10% levels of significance are given as ***, **, and *, respectively.

attract enterprises. The investment and construction activities of enterprises create numerous job opportunities locally, attracting incoming populations to settle. Therefore, we first examine this channel.

We build the following model:

$$\begin{aligned} \Delta CORP_i = & a_0 + a_1 MP_i + a_2 Econ_i + a_3 Society_Amen_i \\ & + a_4 Nature_Amen_i + a_5 X_i + a_6 Prov_i + \varpi_i, \end{aligned} \quad (6)$$

where $\Delta CORP_i$ is the change of the number of firms in county i . The other variables keep the same meanings as the benchmark model.

We collect the information on newly registered enterprises in all counties nationwide from 2011 to 2020. The data are from the Tianyancha website⁸, and the sample includes over 80 million enterprises. Figure 2 shows the categories with an average of more than 50 new enterprises per county per year. The first column presents the situation for the primary industry, the second and third columns reflect the secondary industry, and the fourth to eighth columns cover the tertiary industry. As seen in the figure, most new enterprises in counties are concentrated in the tertiary industry.

Table 8 shows the correlation between the number of new enterprises in the past 10 years and market potential. The first column presents the situation of new enterprises nationwide,

⁸Website: <https://www.tianyancha.com>

Table 6: Heterogeneous Effects across Regions

Variables	(1) % Δ POP_ East region	(2) % Δ POP_ Central region	(3) % Δ POP_ West region
MPC	0.0038 [0.6007]	0.0089 [1.3551]	0.0212*** [5.0194]
MPP	-0.0071 [-0.2437]	0.0875*** [3.0468]	0.1055*** [3.1389]
MPM	0.1025*** [4.0407]	0.4203*** [2.8144]	-0.2245** [-2.3734]
Econ	YES	YES	YES
Society_Amen	YES	YES	YES
Nature_Amen	YES	YES	YES
Control Variables	YES	YES	YES
Province Effect	YES	YES	YES
Adjusted R ²	0.455	0.504	0.248
No. of Counties	446	552	711

Note: t-statistics in brackets. The 1%, 5%, and 10% levels of significance are given as ***, **, and *, respectively.

indicating that the spillover effects of large cities have indeed driven the growth in the number of new enterprises.

The second column presents the overall situation of the primary industry, indicating that the number of new enterprises in the primary industry in counties is not significantly related to large cities and may even be affected by the backwash effects of megacities. This directly illustrates that the industrial development mechanism is not applicable to agriculture.

The third column presents the overall situation of the secondary industry, indicating that large cities help increase the number of industrial enterprises. The fourth and fifth columns show the categories of manufacturing and construction industries, with prefecture-level cities and megacities exhibiting spillover effects on both, while provincial capitals only show spillover effects on the construction industry. The sixth column reports changes in the number of industrial enterprises above a designated size. Similar to new manufacturing enterprises, the spillover effects of prefecture-level cities and megacities also promote an increase in the number of large enterprises. These results indicate that the spillover effects of large cities can promote county population growth through the development of the secondary industry. Specifically, county manufacturing enterprises may be more inclined towards types such as product export and processing of imported materials, while construction enterprises are more likely related to policy issues.

From Table 9, it can be seen that the increase in the number of new enterprises in the tertiary industry is also closely related to the spillover effects of cities. The first column shows the overall situation of the tertiary industry, with results indicating that the spillover effects of large cities can increase the number of enterprises. Columns 2-6 report on five categories: wholesale and retail trade, accommodation and food services, resident services, repairs and other services, leasing and business services, and transportation, warehousing, and postal services. The findings show that the spillover effects of prefecture-level cities are very robust, generally affecting each category, while the spillover effects of provincial capitals and megacities only influence the accommodation and food services and resident

Table 7: Heterogeneous Effects in High-Speed Rail Operation

Variables	(1) Operational	(2) Not operational
MPC	0.0130*** [2.8542]	0.0190*** [4.3936]
MPP	0.0448* [1.8925]	0.0509** [2.0753]
MPM	0.1020*** [2.7840]	0.0474 [1.3739]
Econ	YES	YES
Society_Amen	YES	YES
Nature_Amen	YES	YES
Control Variables	YES	YES
Province Effect	YES	YES
Adjusted R ²	0.541	0.319
No. of Counties	359	1350

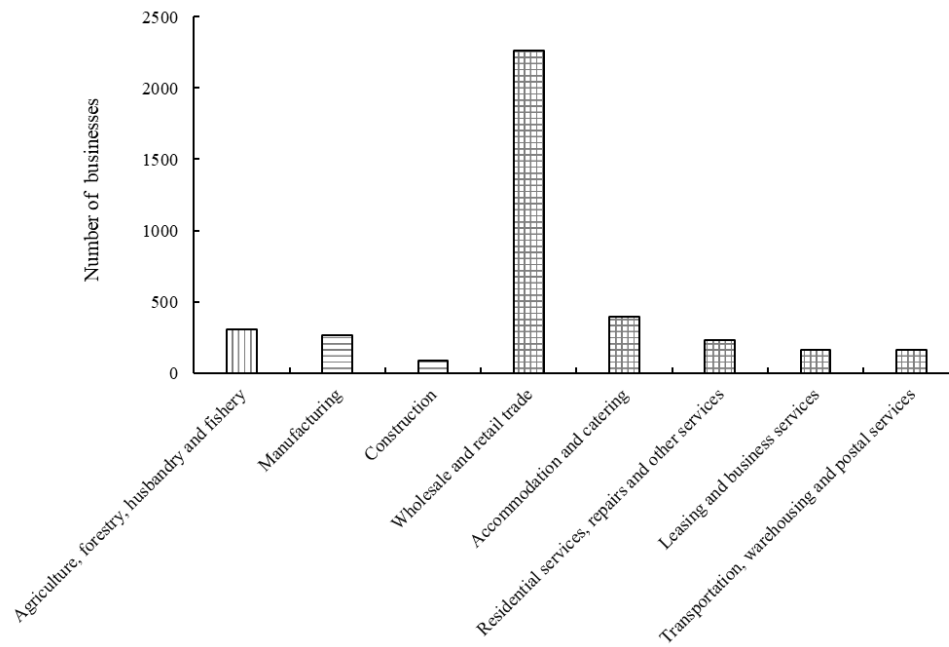
Figure 2: The Annual Number of New Businesses in a County.

Table 8: Mechanism Discussion: Agglomeration of the Secondary Industry

Variables	(1) ln(All new businesses added) in counties from 2011 to 2020	(2) ln(New businesses added in the primary industry) in counties from 2011 to 2020	(3) ln(New businesses added in the secondary industry) in counties from 2011 to 2020
MPC	0.0184*** [4.2218]	-0.0135 [-1.3368]	0.0261*** [4.4188]
MPP	0.035 [1.1047]	0.0532 [0.9245]	0.0748* [1.9343]
MPM	0.0383 [0.8481]	-0.4681*** [-6.5061]	0.3384*** [4.4255]
Econ	YES	YES	YES
Society_Amen	YES	YES	YES
Nature_Amen	YES	YES	YES
Control Variables	YES	YES	YES
Province Effect	YES	YES	YES
Adjusted R ²	0.908	0.741	0.875
No. of Counties	1709	1709	1709

Variables	(4) ln(New businesses of manufacturing) in counties from 2011 to 2020	(5) ln(New businesses of construction) in counties from 2011 to 2020	(6) Change number of large-scale industrial enterprises in counties from 2011 to 2020
MPC	0.0148** [2.2755]	0.0518*** [7.2780]	1.5555* [1.7176]
MPP	-0.0157 [-0.3351]	0.2656*** [5.4257]	8.4286 [0.8708]
MPM	0.3429*** [3.3630]	0.3790*** [5.8176]	54.8492*** [4.6785]
Econ	YES	YES	YES
Society_Amen	YES	YES	YES
Nature_Amen	YES	YES	YES
Control Variables	YES	YES	YES
Province Effect	YES	YES	YES
Adjusted R ²	0.842	0.834	0.419
No. of Counties	1709	1709	1709

services, repairs, and other services categories. This indicates that the spillover effects of large cities can also increase county populations through the development of the tertiary industry. Categories such as wholesale and retail trade are more sensitive to city proximity and may be more inclined to serve the local market. Categories represented by accommodation and food services are likely tied to travel-related consumption and are more dependent on transportation facilities.

7. CONCLUSION

This paper aims to explore the impact of the spread and backwash effects of large cities on the population growth of counties in China. Within the framework of new economic geography theory, a market potential variable was constructed, and its influence mechanisms were thoroughly examined. The main findings of this study are as follows:

Firstly, the spread effects generated by prefecture-level cities, provincial capitals, and megacities can significantly increase county populations. Secondly, there are heterogeneous effects on county population changes across the eastern, central, and western regions. Moving from the coast inland, the size of Chinese cities gradually decreases, and the distance between counties and large cities gradually increases; changes in county populations are influenced by the spread effects of lower-level cities and the backwash effects of higher-level cities. Furthermore, transport accessibility is a crucial factor influencing inter-city spillover effects. Particularly following the introduction of high-speed rail, counties along the routes are better positioned to absorb the economic spillovers from higher-tier cities. Finally, the core mechanism of county development lies in the spread effects of cities driving the overall development of secondary and tertiary industries in counties and the investment and establishment of enterprises, thereby increasing labor demand and attracting a permanent influx of migrants.

From a theoretical perspective, the functional decentralization of central cities has led to a significant increase in the number of enterprises in surrounding counties serving central cities. On one hand, counties promote the development and establishment of local industrial enterprises by building an industrial chain division of labor with cities and attracting labor to serve external demands. On the other hand, as the economic influence of cities expands further, county residents' demand for goods and services becomes increasingly diversified, which has also spurred the establishment of numerous tertiary industry enterprises.

One limitation of this study is that the market-potential measure relies on current road mileage to proxy earlier transport accessibility. Future research could use the annual GIS transport network developed by Davis et al. (2025) to construct historically consistent measures of county-city accessibility and examine how changes in transport networks shape the spread and backwash effects of large cities.

We find that the spread effects of large cities on surrounding areas outweigh the backwash effects. This indicates that the strategy of central cities driving surrounding development is effective. Therefore, regional central cities play a crucial role in the development of surrounding areas. To promote the overall development of the regional economy, the government should continue to strengthen the development of regional central cities by providing policy

Table 9: Mechanism discussion: agglomeration of the tertiary industry

Variables	(1) ln(New businesses added in the tertiary industry) in counties from 2011 to 2020	(2) ln(New businesses of wholesale and retail trade) in counties from 2011 to 2020	(3) ln(New businesses of accommodation and catering) in counties from 2011 to 2020
MPC	0.0196*** [4.3149]	0.0141*** [2.9987]	0.0237*** [4.3262]
MPP	0.0341 [1.0438]	0.0009 [0.0266]	0.0633* [1.7989]
MPM	0.0172 [0.3650]	-0.0221 [-0.4190]	0.2016*** [4.0889]
Econ	YES	YES	YES
Society_Amen	YES	YES	YES
Nature_Amen	YES	YES	YES
Control Variables	YES	YES	YES
Province Effect	YES	YES	YES
Adjusted R ²	0.901	0.896	0.821
No. of Counties	1709	1709	1709

Variables	(4) ln(New businesses of residential services, repairs and other services) in counties from 2011 to 2020	(5) ln(New businesses of leasing and business services) in counties from 2011 to 2020	(6) ln(New businesses of transportation, warehousing and postal services) in counties from 2011 to 2020
MPC	0.0179*** [3.8256]	0.0487*** [6.2319]	0.0175 [1.4951]
MPP	0.023 [0.6329]	0.1371*** [2.9923]	0.2500*** [3.3817]
MPM	0.1372*** [3.0035]	0.2360*** [3.4827]	-0.2393** [-2.5709]
Econ	YES	YES	YES
Society_Amen	YES	YES	YES
Nature_Amen	YES	YES	YES
Control Variables	YES	YES	YES
Province Effect	YES	YES	YES
Adjusted R ²	0.876	0.856	0.727
No. of Counties	1709	1709	1709

support and infrastructure construction. Meantime, the government should also guide enterprises to effectively distribute their geographic locations and avoid excessive concentration in central cities. Moreover, increasing industrial support for surrounding counties is also importance, because it can improve their industrial competitiveness and promote industrial upgrading to achieve coordinated regional development.

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