



OPEN ACCESS

EDITED BY

Attia El-Fergany,
Zagazig University, Egypt

REVIEWED BY

Yan Sun,
Beijing Forestry University, China
Mack Shelley,
Iowa State University, United States

*CORRESPONDENCE

Qing Shao
✉ shaoqing2002@126.com

RECEIVED 02 April 2025

ACCEPTED 20 August 2025

PUBLISHED 03 September 2025

CITATION

Jiang A, Shao Q and Zhang S (2025) Did urban agglomeration development planning policies accelerate urban population decline? A quasi-natural experiment based on urban agglomeration development planning policies in China.
Front. Sustain. Cities 7:1604569.
doi: 10.3389/frsc.2025.1604569

COPYRIGHT

© 2025 Jiang, Shao and Zhang. This is an open-access article distributed under the terms of the [Creative Commons Attribution License \(CC BY\)](https://creativecommons.org/licenses/by/4.0/). The use, distribution or reproduction in other forums is permitted, provided the original author(s) and the copyright owner(s) are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms.

Did urban agglomeration development planning policies accelerate urban population decline? A quasi-natural experiment based on urban agglomeration development planning policies in China

Aiqing Jiang, Qing Shao* and Songlin Zhang

Business School of Shaoxing University, Shaoxing, China

Introduction: To promote integrated development of large, small, and medium-sized cities, Chinese governments have successively implemented urban agglomeration development planning policies (UADPPs). However, UADPP may intensify the siphoning effect of big cities on smaller peers within urban agglomeration (UA), accelerating population decline in small and medium-sized cities (SMCs) and undermining integration goals. This study investigates the relationship between UADPP and population decline of SMCs in UA, uncovers the logical mechanisms driving this relationship, and conducts heterogeneity analysis to explore the variations from urban types, urban agglomeration types and regions.

Methods: Using prefecture-level city data (2011–2022), this study employs a quasi-natural experiment based on the Chinese State Council-approved UADPPs, using a difference-in-differences (DID) approach to identify the relationship between UADPP and population decline of SMCs in UA. This paper uses the urban population decline rate to reflect the extent of urban population decline. The core explanatory variable of this paper is represented by whether the UADPP where the city is located has been approved by the Chinese State Council. The control variables include Built-up area (lnarea), Economic development (gdpr), Wage (lnwage), Governmental intervention (gov), and younger workers (stud).

Results: Results show that UADPPs strengthen the agglomeration effect of large cities, which triggers the siphoning of resources from surrounding SMCs. Meanwhile, UADPP, facilitating free flow of production factors, drives population migration from SMCs to large ones and accelerates the population decline in SMCs. Robustness tests confirm the validity of this conclusion. Additionally, the heterogeneity analysis reveals that the effect of UADPPs on accelerating urban population decline varies across different city types, urban agglomeration types, and regions. This effect is notably more pronounced and statistically significant in small cities, urban agglomerations characterized by low population agglomeration, and the central regions.

Discussion: These results highlight that the UADPP will accelerate the population decline of SMCs in UA. Policy implications include mitigating the administrative hierarchy-driven siphoning effects, leveraging local resources to cultivate characteristic industries and optimize talent ecosystems in SMCs, actively integrating into global value chains and constructing the agglomeration-economy-driven urban development model.

KEYWORDS

urban agglomeration development planning policy, agglomeration effect, urban population decline, siphoning effect, urban agglomeration

1 Introduction

Since the reform and opening-up, Chinese urbanization has experienced rapid development (Wang et al., 2021). The urbanization rate rose from 17.92% to 65.22% between 1978 and 2022.¹ Against the backdrop of rapid urbanization in China in recent years, large-scale population mobility has given rise to the population agglomeration effect in some cities, while triggering population outflow problems in others. Some have faced population decline, an overall slowdown in economic growth, and spatial changes characterized by “urban shrinkage” (He et al., 2023). Research on urban population decline dates back to early theoretical explorations. As early as the 1980s, German scholars Häußermann and Siebel (1988) first identified the term “shrinking cities” to describe the phenomenon of urban population decline. This concept laid the foundation for subsequent cross-national studies. Since the 1990s, population decline has become a global phenomenon: over a quarter of cities with populations exceeding 100,000 worldwide have experienced a decline (Wang and Fukuda, 2019). Developed and developing nations alike face varying degrees of this challenge, but this problem appear later in developing countries (Richardson and Nam, 2014). In China, academic research has also increasingly focused on this issue (Hu et al., 2021; Long and Gao, 2019), noting that most cities exhibit mild decline but the number of shrinking cities is growing steadily (Chen et al., 2022).

The urban population decline is predominantly caused by the low birth rate in developed countries (Hospers and Reverda, 2015; Sobotka, 2004). In contrast, developing nations face a distinct dynamic: population migration emerges as a primary catalyst (Hartt, 2016; Mallach et al., 2017; Jaroszevska and Strykiewicz, 2020). Großmann et al. (2016) further emphasize that small towns in these contexts often shrink as residents migrate to large cities. Chinese studies align with this migration-centric framework. Deng et al. (2019) demonstrate that the high-speed railway has systematically drawn populations from SMCs to metropolises, accelerating SMC population decline. This logic suggests that populations may increasingly migrate from SMCs to large cities within UAs, accelerating demographic decline in smaller urban centers.

The UADPP is a strategic policy tool designed to promote economic integration across large, medium, and small cities in the UA and play a pivotal role in advancing regional economic coordination while addressing disparities in urban development efficiency (Hu et al., 2024). And multiple UADPPs were laid down by Chinese government to foster integrated development among large, medium, and small cities in recent years. Yet, two critical questions remain underexplored: does the UADPP influence the urban population decline? What are the

underlying logical and causal mechanisms? Some literature highlights that the UADPP promotes regional factor mobility and efficient agglomeration, significantly facilitating cross-provincial flows of technology, capital, and labor (Lu et al., 2024). However, the policy may also intensify the one-way siphoning of the population from smaller cities to large ones (Yao and Luo, 2024). Other studies either focus on the single city (Deng et al., 2019; Hu et al., 2021) or the specific agglomeration (Shan et al., 2020; Ma et al., 2020) to probe into the problem of urban population decline. However, no study has systematically analyzed whether the UADPP influences the urban population decline, nor explored the underlying logical and causal mechanisms. As mentioned earlier, the UADPP is designed to foster integrated development among large, medium, and small cities in the UA. However, if the UADPP inadvertently triggers population decline in SMCs without adequate policy intervention, the core objectives of balanced development will be undermined.

To address this paradox, this study employs a quasi-natural experiment based on the Chinese State Council-approved UADPPs, using a difference-in-differences (DID) approach to identify the relationship between UADPP and population decline in SMCs, uncover the logical mechanisms driving this relationship, and conduct heterogeneity analysis to explore regional variations. Drawing on empirical findings, the study will propose targeted policy recommendations to mitigate population decline in SMCs within UAs, ensuring the UADPP aligns with the original objectives of inclusive urban development.

In contrast to previous researches, this paper has three contributions as follows. First, at the theoretical mechanism level, most studies focus on the positive effects of UADPPs on economic growth or factor agglomeration. In contrast, this study reveals that UADPPs accelerate population decline in SMCs and the empirical analysis confirms this conclusion.

Second, in terms of research scope and methodology, previous studies were either confined to case studies of specific urban agglomerations or lacked systematic investigations into population decline. This study, by contrast, takes all urban agglomerations across China as samples and constructs a quasi-natural experiment using the difference-in-differences (DID) method. It validates the impact of UADPPs on population decline and conducts heterogeneity analyses from multiple dimensions, including urban population size, heterogeneity across urban agglomeration types and regional disparities.

Third, in the sphere of policy implementation, drawing on robust empirical evidence, this study integrates international urban theories and comparative urbanism methodologies and puts forward tailored policy recommendations aimed at easing the problem of population decline in SMCs from some critical dimensions including resource reallocation and inter-jurisdictional policy alignment.

Other parts of this paper are as follows. Section 2 presents the theoretical analysis and research hypothesis, including a literature review, the logical mechanism of UADPP accelerating the population decline of SMCs in UA, and research hypothesis. Section 3 is identification methods and results of urban population decline the methods. Section 4 shows the difference-in-differences (DID) model,

¹ The data comes from the Statistical Yearbook of Urban Construction released by China's Ministry of Housing and Urban-Rural Development.

Abbreviations: UADPP, urban agglomeration development planning policy; UA, urban agglomeration; SMCs, small- and medium-sized cities.

variable definitions, and data descriptive statistics. Section 5 discusses empirical results, including robustness tests, heterogeneity analyses, and discusses. Section 6 synthesizes the core findings and proposes policy recommendations to mitigate population decline in SMCs.

2 Theoretical analysis and research hypothesis

2.1 Literature review

As the most advanced spatial form of urban development in its mature stage, UA inherently exhibits strong agglomeration effect (Chung et al., 2021). This agglomeration effect can generate dual effects: the spillover effect and the siphoning effect. Core cities within UAs drive development in surrounding and outlying cities through knowledge, technology, and capital diffusion via a spillover mechanism (Chen et al., 2023). Conversely, core cities attract economic and social resources from surrounding areas, particularly accelerated by transportation network upgrades via a siphoning mechanism (Jiao et al., 2024). Not limited to the situation that population agglomeration in central cities leads to a population siphoning effect in surrounding cities (Zheng et al., 2024). UAs demonstrate strong siphoning effects on non-agglomeration areas (Leonardi and Moretti, 2023), driving population migration from non-agglomerations to agglomerations. Concurrently, the siphoning effect induces population mobility that may trigger population decline, primarily affecting SMCs within agglomerations, which often experience latent population decline (He et al., 2023). As an innovative institutional design for regional integration and breaking administrative barriers, UADPPs exhibit dual impacts. One is about the factor flow and market integration. UADPPs significantly facilitate cross-provincial mobility of technological, capital, and population factors, fostering a unified regional market system and enabling free flow and efficient agglomeration of resources (Sun et al., 2022). However, this process intensifies the unidirectional “siphoning” of the population toward core cities (Yang et al., 2024). Another is about equity enhancement and structural upgrading. UADPPs elevate regional average income levels and narrow development gaps between central and non-central cities (Hu et al., 2024). Through technological innovation, industrial restructuring, and optimized resource allocation, UADPPs promote high-quality urban economic growth while mitigating the “agglomeration shadow” effect within agglomerations (Yao and Luo, 2024).

In conclusion, existing literature has extensively examined the economic effects of UAs, the spatial distribution of population, and population agglomeration within UAs. Some studies have noted that the siphoning effect of central cities in UAs may induce population decline in surrounding smaller peers. However, these studies often overlook the underlying mechanisms and take only a single agglomeration as an example. Research on UADPPs has predominantly centered on their economic impacts. While some studies mention that UADPPs intensify unidirectional population siphoning, they do not explicitly address population decline or investigate the logical mechanisms linking UADPP to this phenomenon.

Consequently, few studies have directly analyzed how UADPPs influence population decline and its logical mechanism. Although UAs undeniably boost regional economic growth, population decline, particularly in SMCs, represents an urgent and non-negligible reality.

Thus, the study on “whether UADPPs accelerates population decline in SMCs” is substantially and practically significant to UAs.

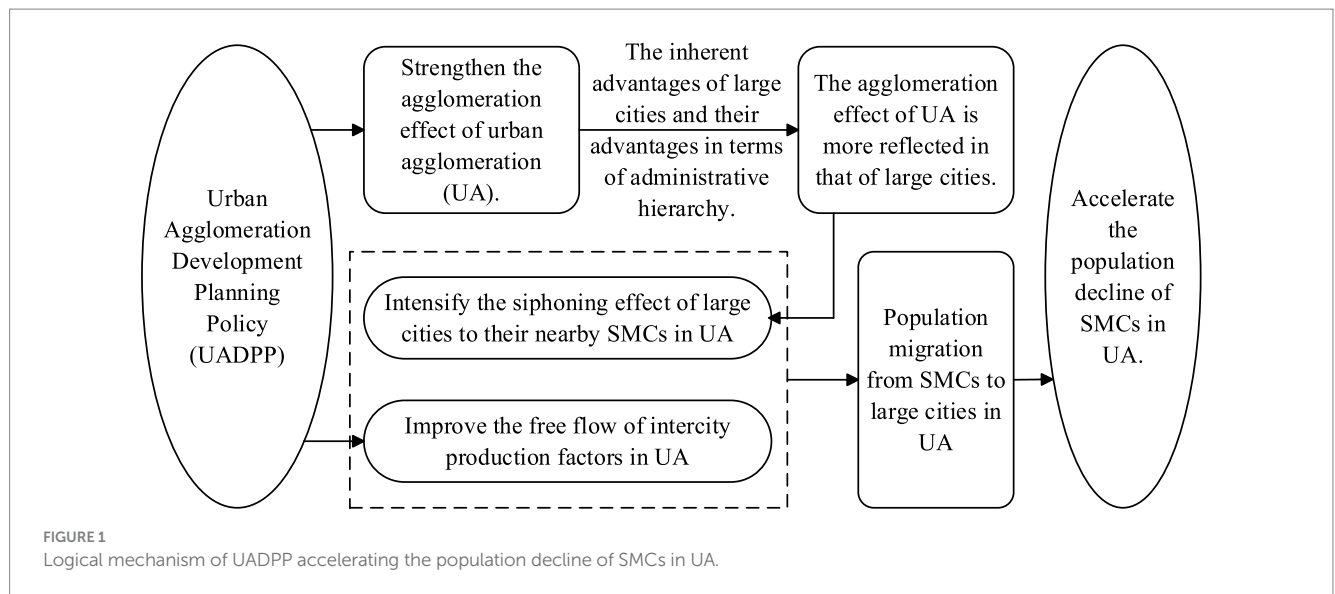
2.2 Logical mechanism of UADPP accelerating the population decline of SMCs in UA

Unbalanced regional development widely exists globally, nationally, and even within cities (Peck et al., 2023). UA development aims to narrow regional disparities and foster coordinated regional growth (Feng et al., 2023). Regional integration policies effectively foster the establishment of unified market systems and well-structured division-of-labor frameworks, enabling the free flow of production factors on a larger scale and enhancing economies of scale (Camagni et al., 2016). As a policy design to transcend administrative boundaries, the UADPP promotes inter-city cooperation and specialization. By optimizing the spatial allocation of production factors across agglomerations, the UADPP generates enhanced divisional and scale benefits, thereby strengthening agglomeration effects. Indeed, Meijers et al. (2016) demonstrate that organizing urban systems around agglomerations as basic spatial units amplifies agglomeration effects through intra-agglomeration factor allocation efficiency.

Large cities often serve as regional central hubs and spatial drivers of economic growth in UA. They attract and consolidate production factors (e.g., materials, human capital, and capital) from surrounding areas to fuel their economic expansion (Wang et al., 2023). Empirical evidence shows that the UADPP exerts a more pronounced growth-promoting effect on large- and medium-sized cities than small ones (Kong et al., 2022). Consequently, the agglomeration effect of UAs is predominantly from the large cities within the agglomeration.

The possible reasons are as follows. (i) Large cities have greater agglomeration power because of their larger geographical space and more powerful economic power. (ii) In the context of administrative hierarchy, large cities often have advantages from administrative resources, infrastructure, and public services (Dalmazzo, 2010), which are conducive to attracting various production factors. (iii) Under the existing political performance-assessment system, there is competition among the cities, which sometimes vehemently compete for some core resources. Large cities can further enhance their agglomeration advantages by leveraging their robust competitive edges to compete for additional resources, thereby intensifying the siphoning effect on surrounding SMCs. This siphoning effect draws investment and talents from SMCs within the agglomeration to large cities, thereby creating an agglomeration shadow that hampers the development of less-developed regions (Meijers et al., 2016; Wu et al., 2024). Thus, while the UA aims to promote the free flow of production factors among member cities, the intensified siphoning effect of large cities further induces population migration from SMCs, leading to population decline in these SMCs. Empirically, population decline in Chinese cities predominantly occurs in SMCs (Yang, 2019; Jin et al., 2022).

Figure 1 illustrates the logical mechanism by which the UADPP accelerates population decline. By breaking down administrative division barriers, UADPP fulfills two core roles: on one hand, it facilitates the free intercity flow of production factors within UA; on the other hand, it enhances the agglomeration effect by optimizing the spatial allocation of these factors across the entire UA. However, this effect becomes disproportionately concentrated in major



cities—largely due to their intrinsic locational advantages, administrative hierarchy, and other structural factors. Consequently, this concentration amplifies the siphoning effect on surrounding SMCs. Against the backdrop of population mobility, this siphoning effect further spurs population migration from SMCs to major cities, thereby accelerating population decline in the former.

2.3 Research hypothesis

Based on the above logical mechanism, the following analysis will focus on these three aspects: population size, population concentration within the urban agglomeration, and regional differences, and consecutively propose corresponding research hypotheses.

2.3.1 The impact of population size

Agglomeration is a defining characteristic of cities and urbanization (Strumsky et al., 2023), with UAs representing the regions where population agglomeration is most pronounced. The higher the development level of a UA, the greater the degree of population agglomeration (Cao et al., 2023). Consequently, the agglomeration effect of UAs is manifested predominantly as the agglomeration effect of large cities within the agglomeration. Ceteris paribus, an increase in urban population size facilitates the strengthening of agglomerative forces and enhances agglomeration advantages. Conversely, the smaller the urban population, the weaker its agglomeration forces and comparative advantages. As the urban population in China has not reached a 'saturated' state (Li et al., 2020), there remains a trend of population migration from SMCs to large cities. When UADPP promotes the free flow of intercity production factors within the agglomeration, the agglomeration effect will inevitably render smaller cities more susceptible to population outflow.

2.3.2 The impact of population agglomeration in UAs

Due to the intricate interplay of geographical endowments, economic structures, policy interventions, and demographic traits, distinct urban agglomerations exhibit pronounced heterogeneity in

terms of population scale, spatial distribution, driving mechanisms, and dynamic evolution. The core-periphery theory (Friedman, 1966) posits that population mobility is fundamentally shaped by regional economic disparities, transportation accessibility, and policy incentives, underscoring that population agglomeration is not uniform but manifests significant variations across spatial scales and urban hierarchies.

Empirical evidence confirms a robust link between the developmental stages of urban agglomerations and their population aggregation patterns. In mature agglomerations, core cities experience decelerated population growth as peripheral cities assume roles in industrial transfer. Developing agglomerations remain dominated by core-centric aggregation, with persistent out-migration from the periphery. Studies (Zhang and Wang, 2020) reveal that urban agglomerations have long served as the epicenter of China's spatial population concentration, with eastern developed clusters sustaining rapid population growth, while central-western and northeastern clusters have seen declining population shares.

Spatially, the functional division within agglomerations has a more significant positive impact on central cities and large- and medium-sized ones. A recent analysis (Zheng et al., 2024) highlights that with the deepening of spatial functional division of labor in urban clusters (SFDL), population distribution within agglomerations increasingly gravitates toward core nodes, and SFDL demonstrates a promotive effect on urban population size compared to other agglomeration development models. It collectively underscores the heterogeneous impacts of different agglomeration types on population aggregation, rooted in their structural and developmental disparities.

2.3.3 The impact of regional disparities

Due to China's vast territory and unbalanced regional development, the UA in different regions shows a gradient distribution pattern. Generally, eastern UA possesses the highest competitiveness, followed by central and western ones (Fang, 2015). This paper further examines the heterogeneous impacts of UADPP on urban population decline across regions. Eastern UA has become the primary destination for floating populations due to the developmental and institutional advantage (Hong and Su,

2019). Eastern UADPP promotes population migration from SMCs to large ones and probably accelerates population decline in SMCs. The inflow of national migrant populations mitigates this decline, as such mobility stems from the strengthened agglomeration effect of the UADPP. Notably, eastern agglomerations more easily attract floating populations from central regions due to their geographic proximity compared to western and northeastern areas. In contrast, under the free flow of production factors promoted by UADPP, central-regional UA experiences dual population outflows: internal migration from SMCs to central cities, and external migration to eastern UA. Consequently, the UADPP exerts a more pronounced effect on the population decline in central regions.

Based on the above analysis, this study proposes the following hypotheses.

Hypothesis 1: The UADPP accelerates the population decline of SMCs in UA.

Hypothesis 2: The acceleration effect of UADPP on urban population decline shows heterogeneity in urban types, and that effect is more obvious in small cities.

Hypothesis 3: The acceleration effect of UADPP on urban population decline shows heterogeneity in UA types, that effect is more pronounced in those with low population agglomeration levels.

Hypothesis 4: The impact of UADPP on urban population decline varies across regions, with central-regional UADPP exhibiting a more pronounced acceleration effect on urban population decline.

3 Identification methods and results of urban population decline

Academic consensus on quantitative criteria for identifying urban population decline remains elusive. A prevailing approach defines population decline by selecting two temporal nodes and using negative population growth as the benchmark (Hu et al., 2021; Großmann et al., 2016; Deng and Ma, 2015). Building on this framework and drawing from studies by Wang et al. (2021) and Hu et al. (2021), this paper classifies cities as experiencing population decline if their total urban population—including temporary residents—exhibited negative growth between 2011 and 2022.

The choice of 2011 as the baseline observation year is rooted in China's demographic shift to an urban-majority society in that year (Wang et al., 2021). Considering the majority of UADPPs were approved in 2016, we decompose population decline dynamics into two subperiods: 2011–2016 and 2017–2022. This temporal division enables a nuanced analysis of population trend dynamics of policy rollout. Figure 2 illustrates the results. Bar chart displays quantities and proportions for time periods 2011–2022, 2011–2016, and 2017–2022. The values are as follows: 36, 38, and 69 for quantities and 12.632, 13.333, and 24.211 for proportions.

The results indicate the population decline in China's prefecture-level and above cities. Spatially, this decline demonstrates pronounced regional disparities. Spatially, this decline demonstrates pronounced regional disparities. Specifically, 80.56% of cities experiencing population decline are concentrated in China's central and western regions, whereas the eastern region accounts for 19.44%. In terms of urban administrative hierarchy, cities experiencing population decline generally belong to lower administrative levels. Notably, no population decline has appeared in central municipalities, provincial capitals,

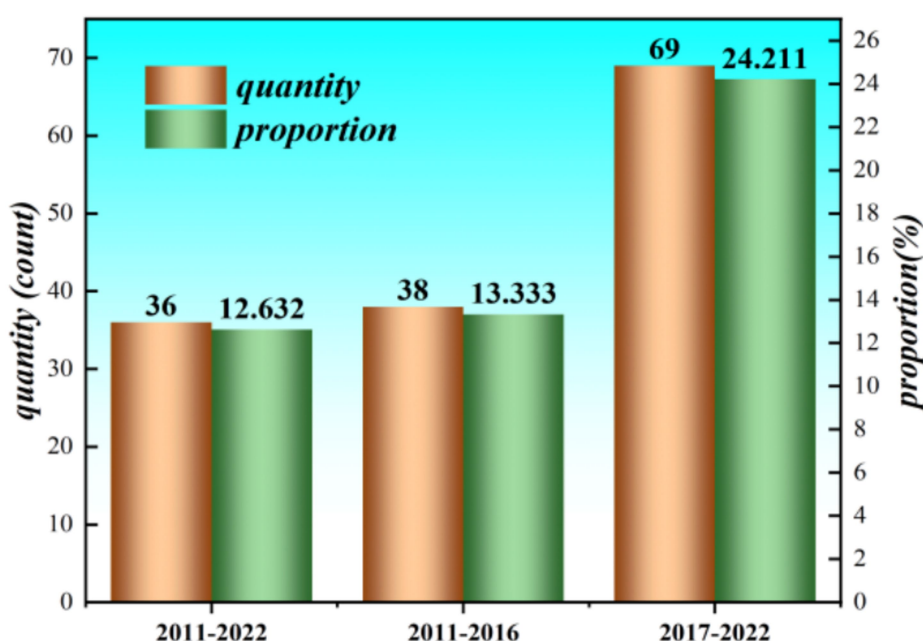


FIGURE 2

The population decline across 285 prefecture-level and above cities in China. The number of population-decline cities refers to the count of cities with negative population change rates between two time points (e.g., 2011 and 2022); the proportion of population-decline cities denotes the ratio of such cities to the total 285 prefecture-level and above cities.

sub-provincial cities, or other higher-tier administrative cities. The findings indicate that urban population decline is predominantly concentrated in SMCs rather than large ones, which aligns with prior theoretical frameworks. Notably, this trend coincides with the Chinese State Council's successive issuance of multiple UADPPs starting in 2015–2016 (Li et al., 2022). Due to the lag in policy implementation, the impact of urban agglomeration development plans is primarily evident in the second temporal phase. Paradoxically, however, the phenomenon of population decline worsened during this stage. Despite this apparent contradiction, preliminary analysis suggests that these plans may play a significant role in mitigating urban population decline.

4 Methods and data

4.1 Methods

Guided by the research hypotheses, this paper centers on examining whether UADPP accelerates population decline in intra-agglomeration small- and medium-sized cities. Therefore, by referring to related researches of Li et al. (2022) and Restuccia and Rogerso (2013), this paper employs the progressive difference-in-differences (DID) method for empirical analysis. We designate the UADPPs approved by the State Council of China as a quasi-natural experiment, with the implementation of these UADPPs specified as the treatment variable. Compared to traditional difference models, this approach is less susceptible to confounding factors, as the probability of unobserved factors and policy conflicts exhibiting identical distributions across different years is extremely low (Benjamin, 2012). Thus, the baseline estimation model is specified as follows:

$$popsr_{it} = \alpha + \beta_1 \times did_{it} + \gamma \times X_{it} + \mu_i + \varepsilon_{it} \quad (1)$$

Hereinto, subscripts “*i*” and “*t*” represent city and year respectively; “*popsr*” is the dependent variable of the urban population decline rate; “*did*” as the core explanatory variable of this paper, namely the UADPP; “*X*” represents a set of control variables; “ μ_i ” stands for city fixed effect; “ ε_{it} ” is the random error term; “ α ” is a constant term, and “ β_1 ” & “ γ ” are model estimation parameters. If the estimated value “ β_1 ” is significantly positive, it shows that the UADPP accelerates the population decline of SMCs.

4.2 Data

4.2.1 Sample selection and data sources

This paper designates the research period as 2011–2022. Because of being focused on the influence of UADPP on urban population decline, at the same time to ensure all sample cities have the potential characteristics of population decline (Wang et al., 2021), this paper only uses small- and medium-sized cities as samples in the empirical study, excluding large cities composed of directly governed municipalities, provincial capitals, and sub-provincial cities. The city's annual CPI data is from the city's local yearbook, statistical bulletin, and Wind database. The remaining data are from the city-district statistics in the China City Statistical Yearbook.

4.2.2 Variables and measurement

(i) Urban population decline rate (*popsr*). This paper uses the urban population decline rate to reflect the extent of urban population decline, referring to the research of Hu et al. (2021) and Kimisato et al. (2018). The specific calculation formula is

$$popsr_t = 1 - urbanpop_t / urbanpop_{t-1},$$

here “*t*” represents the year and “*urbanpop*” is the number of urban populations.

(ii) Urban agglomeration development planning policy (*did*). The UADPP approved by the Chinese State Council is prior to the one of non-national urban agglomeration at the institutional level (Wei et al., 2022). Following Li et al. (2022), this paper uses the core explanatory variable of this paper is represented by whether the UADPP where the city is located has been approved by the Chinese State Council. Specifically speaking, if “*i*” city is approved to implement the UADPP at “*t*” year, the planning “*did*” is assigned the value 1, otherwise 0.

(iii) Control variables. To minimize potential errors arising from omitted variables, this paper followed previous studies in controlling for several variables (Beauregard, 2009; Li et al., 2022). The detailed motivations for adopting these control variables and their respective measures are as follows. ① Built-up area (*lnarea*). The built-up area reflects a city's spatial utilization over a specific period. A larger built-up area typically implies more infrastructure, commercial zones, and residential areas, which may influence urban population mobility and spatial distribution. (Pan et al., 2023). Therefore, this paper has incorporated the logarithm of the built-up area as one of the control variables in the analysis. ② Economic development (*gdpr*). Economic development. Prior research has established a link between economic growth and population dynamics (Patterson, 2023). Therefore, this paper uses the GDP growth rate as an indicator to measure the level of economic development and control its potential effect on urban population decline. ③ Wage (*lnwage*). As argued by Rosero-Ceballos and Mendoza-Cota (2024), the wage of labor is one of the important factors affecting population migration. In this context, this paper employs the logarithm of total on-the-job employee wages to measure wage levels, thereby mitigating the interference of wage disparities on urban population decline. ④ Governmental intervention (*gov*). Acknowledging Beunen et al. (2020) proposition that a correlation exists between governmental intervention and population decline, governmental intervention is also included as a control variable, measured using the ratio of local government general budgetary revenue to regional gross domestic product. ⑤ Younger workers (*stu*). According to McCann (2017), there is a link between age structure and urban population decline, with the outflow of younger workers, in particular, contributing significantly to this trend. Based on this, we use the number of college students per capita to measure the younger worker level, controlling for the potential impact of age structure on urban population decline. Table 1 presents the descriptive statistics of the variables.

5 Empirical results and analysis

5.1 Basic estimation results

Table 2 presents the regression results examining the impact of UADPP on urban population decline, with control variables

TABLE 1 Descriptive statistics of variables.

Variable	Mean	SD	Min	Max	N
<i>popsr</i>	−0.027	0.096	−1.598	0.577	2,739
<i>did</i>	0.315	0.465	0.000	1.000	2,739
<i>lnarea</i>	4.405	0.632	2.342	7.085	2,739
<i>gdpr</i>	0.071	0.043	−0.206	1.090	2,739
<i>lnwage</i>	14.229	0.765	7.292	17.634	2,739
<i>gov</i>	0.073	0.023	0.023	0.204	2,739
<i>s</i>	0.013	0.013	0.000	0.120	2,739

SD represents the standard deviation.

TABLE 2 The impact of UADPP on urban population decline.

Variables	(1)	(2)	(3)	(4)
	<i>popsr</i>			
<i>did</i>	0.023*** (0.005)	0.019*** (0.005)	0.019*** (0.005)	0.018*** (0.005)
<i>lnarea</i>	−0.042** (0.017)	−0.056*** (0.019)	−0.059*** (0.019)	−0.062*** (0.019)
<i>gdpr</i>		−0.158** (0.063)	−0.143** (0.062)	−0.139** (0.062)
<i>lnwage</i>		0.005 (0.011)	0.004 (0.011)	0.004 (0.011)
<i>gov</i>			−0.344** (0.148)	−0.329** (0.148)
<i>stu</i>				0.580 (0.511)
Constant	0.151** (0.074)	0.149 (0.143)	0.201 (0.143)	0.214 (0.144)
Observations	2,739	2,739	2,739	2,739
R-squared	0.008	0.012	0.014	0.014

***, **, *, respectively represent significant at the significance level of 1%, 5%, and 10%, while the value in parentheses represents the robust standard errors adjusted for city-level clustering. The following tables are the same.

introduced sequentially according to Equation 1. Column (1) controls for the effect of built-up area. The results show that the DID regression coefficient is 0.023, significant at the 1% significance level. It suggests that the UADPPs accelerate population decline in SMCs. In Column (2), economic control variables are added to the model specified in Column (1), including economic development and wage. Column (3) presents the results after adding the degree of government intervention based on Column (2). Column (4) includes all control variables. The regression results in Columns (2)–(4) show that the DID regression coefficient remains significantly positive. All estimation results consistently demonstrate that UADPPs accelerate population decline in SMCs. This result confirms Hypothesis 1. Although UADPPs enhance the agglomeration effect of UAs, this effect is predominantly manifested in large cities within the UA, thereby amplifying the

siphoning effect on surrounding SMCs. With the free flow of intercity production factors within the agglomeration—promoted by UADPPs—this siphoning effect further drives population migration from SMCs to large ones, thus accelerating population decline.

5.2 Parallel trend test

The premise of adopting a multi-period DID model is that the treatment and control groups maintain consistent change trends before the policy shock. In this study, it is necessary to ensure that the difference in urban population decline between the treatment and control groups remains relatively stable before the official approval of urban agglomeration development plans, i.e., a parallel trends test is required. To this end, this paper

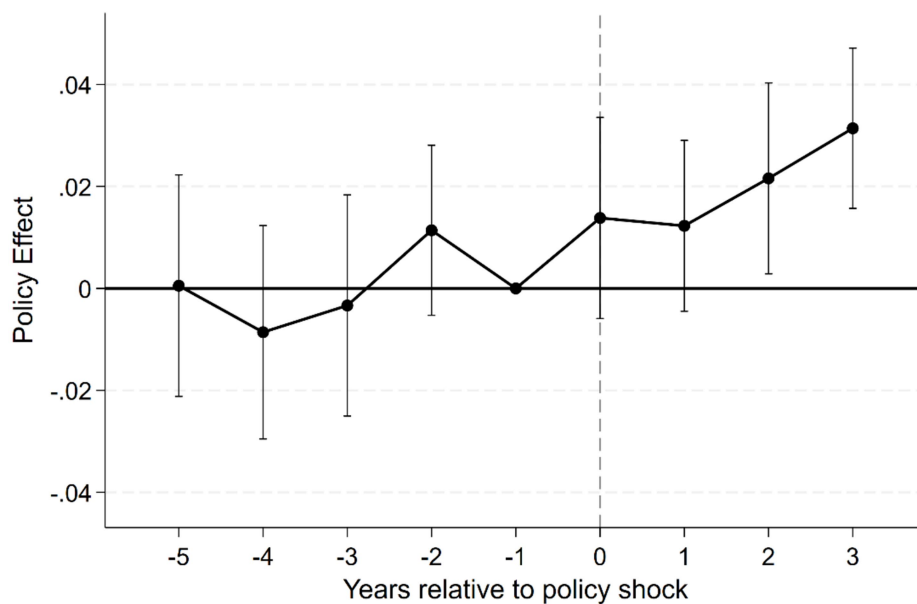


FIGURE 3
Results of the parallel trend test.

employs an event study method to conduct the test following Huang et al. (2025), and the model is specified as follows:

$$\begin{aligned} pops_{it} = & \alpha + \eta_1 \times did_{it}^{-5} + \eta_2 \times did_{it}^{-4} + \dots \\ & + \eta_9 \times did_{it}^3 + \gamma \times X_{it} + \mu_i + \varepsilon_{it} \end{aligned} \quad (2)$$

Here, $did_{it}^{\pm k}$ ($k = -5, -4, -3, \dots, 3$) represents a dummy variable for the approval of the UADPP at $\pm k$ year. Specifically, for cities in the treatment group, when it is in the $\pm k$ year after the approval of UADPPs, the value of $did_{it}^{\pm k}$ is 1, or it is 0. To mitigate pre-policy noise, this study adopts the standard methodology in the literature (Li et al., 2016) by applying winsorization to relative policy timing. The event study window is set as five periods before policy implementation and three periods after policy implementation. The year before implementation is regarded as the benchmark. Furthermore, to more rigorously address potential pre-treatment trends, this study follows the methodology of Beck et al. (2010). Specifically, we first compute pre-treatment means values, then demean the regression coefficients and confidence intervals across all periods.

Based on Equation 2, Figure 3 shows a line graph of the coefficient with a 95% confidence interval in this paper. The results show that the annual dummy variables are all insignificant and close to zero before the official approval of UADPPs. It indicates that the difference in urban population decline between experimental and control group cities was relatively stable, that is, the parallel trends test is satisfied. But the regression coefficients are significant and increase year by year after the official approval, which suggesting that the policy begins to accelerate urban population decline. The above analysis confirms that the multi-period difference-in-differences (DID) method is suitable for evaluating the impact of UADPPs on urban population decline.

5.3 Robustness checks

To further validate the reliability of the main findings from the baseline regressions, this section conducts additional robustness checks. First, since the approval policy for UADPPs is not a natural experiment in the strict sense, a selection bias may persist in the analysis of research data. To mitigate this effect, this paper employs propensity score matching (PSM) to match suitable control groups for the treatment group, followed by difference-in-differences (DID) estimation.

Table 3 presents the results of the sample balance test before and after PSM. Before PSM, most paired variables showed significant differences between the treatment and control group samples, while after PSM, no paired variables showed statistically significant differences between the two groups. Column (1) of Table 4 reports the regression results using propensity score matched samples. The DID regression coefficient post-matching continues to exhibit a significant positive value at the 1% significance level, consistent with the baseline regression results, further confirming the robustness of the findings.

Second, one concern regarding the main findings is the potential bias that may arise from other confounding factors or trends inherent in the data. Therefore, following Lu and Yu (2015), this paper alters the time window by moving the approval year of UADPPs forward by 4 years and conducts a placebo test. The results of the placebo test reported in Column (2) of Table 4 show that the regression coefficient of DID4 is insignificant, which validates the robustness of the baseline regression results in this paper.

Third, considering the complexity of real-world problems, some unobservable variables may be omitted. This paper employs the method proposed by Oster (2019) to analyze the potential impact of omitted variable issues on the estimation results of core variables in this study. Oster proposes two methods to test whether omitted variables affect empirical results. First, given the ratio δ (typically set

TABLE 3 The results of the PSM balance test.

Variable	Unmatched	Mean		%bias	% reduct	t-test	
	Matched	Treated	Control			t	p > t
<i>lnarea</i>	U	4.535	4.231	49.2		12.80	0.000
	M	4.535	4.549	−2.4	95.1	−0.67	0.505
<i>gdpr</i>	U	0.075	0.067	18.0		4.80	0.000
	M	0.075	0.073	3.5	80.4	1.21	0.225
<i>lnwage</i>	U	14.400	13.997	55.1		14.14	0.000
	M	14.408	14.411	−0.4	99.3	−0.12	0.907
<i>gov</i>	U	0.073	0.074	−5.1		−1.33	0.184
	M	0.073	0.072	1.4	72.2	0.43	0.665
<i>st</i>	U	0.014	0.011	25.3		6.51	0.000
	M	0.014	0.014	3.8	85.0	1.02	0.306

TABLE 4 The results of PSM-DID and Placebo test.

Variables	(1)	(2)
	<i>popsr</i>	
	PSM match	Placebo
<i>did</i>	0.014***	
	(0.005)	
<i>did4</i>		0.004
		(0.009)
Control variable	Yes	Yes
Constant	0.043	0.114
	(0.119)	(0.148)
Observations	2,736	2,739
R-squared	0.018	0.011

TABLE 5 Robustness test for omitted variables.

Test method	(1)	(2)	(3)
	Criteria	Results	Approved or not
(1)	$\beta \in (0.008, 0.028)$	0.020	yes
(2)	$\delta > 1$	11.093	yes

to 1) of the correlation between omitted variables and the dependent variable to the correlation between observable variables and the dependent variable, as well as the maximum goodness of fit $R_{\max}$ of the model including omitted variables, the coefficient estimator β^* of the independent variable is simulated. If β^* falls within the 95% confidence interval of the β estimator in the baseline regression results, it indicates that the regression results are robust.

Third, given the goodness of fit $R_{\max}$ of the model including omitted variables and assuming $\beta = 0$ for the independent variable, we calculate δ . If $\delta > 1$, it suggests that the omitted variable problem is not severe, and vice versa. The specific results are shown in Table 5. Row 1 presents the estimated β^* when setting $\delta = 1$, and the results show that β^* falls within the 95% confidence interval of the baseline regression estimator, passing the robustness test. Row 2 shows the

estimated δ value when setting $\beta = 0$, with $\delta = 11.093$, which is far greater than 1, indicating that omitted variables do not affect the significance of the baseline regression results. In summary, the findings presented earlier can be considered reliable.

Fourth, a key consideration is that the effect of UADPPs on urban population decline might be subject to confounding from simultaneous policies and exogenous events, which could potentially bias the study's core conclusions. It is particularly relevant for other agglomeration-related policies or those targeting urban population decline. To exclude this interference, this paper adds two dummy variables to the baseline regression model: (1) *ifhsr*, indicating whether high-speed railway was launched in the current year (assigning a value of 1 to the year of high-speed railway launch and all subsequent years, and 0 to other years); and (2) *ifdig*, indicating whether the city was a

pilot city of the Broadband China policy in the current year (coding a value of 1 for pilot cities and 0 for non-pilot cities).

Columns (1) and (2) of Table 6 present the results of controlling for these two policies. Notably, after accounting for these potential confounding policies, the DID regression coefficient remains significantly positive, indicating that UADPPs do significantly accelerate urban population decline. Moreover, the COVID-19 pandemic that occurred in 2020 had a major impact on various fields of the economy and society, restricting population mobility. This exogenous shock might influence the development of urban agglomerations and the decline of urban populations. To exclude the impact of the COVID-19 pandemic, this paper reselected samples from 2019 and earlier years for regression, and the findings are presented in Column (3) of Table 6. The test results show that the coefficient of the core explanatory variable DID is significantly positive, which verifies the robustness of the estimation results once again.

Fifth, to avoid the impact of special samples on baseline regression results, this paper employs the following three methods for exclusion.

First, the regression analysis excludes samples from the Yangtze River Delta Urban Agglomeration. Although this paper primarily examines the impact of UADPPs on urban population decline, the Yangtze River Delta Urban Agglomeration had already undergone multiple expansions and initiated explorations into integrated urban agglomeration development before the explicit approval of such UADPPs, which may affect the research results. To assess the robustness of baseline regression results, this study reruns the regression analysis excluding samples from the Yangtze River Delta Urban Agglomeration. The results are reported in Column (1) of Table 7.

Second, the regression analysis excludes samples of shrinkage resource-based cities. Given that shrinkage resource-based cities exhibit notable limitations in economic development, population mobility, among other aspects, urban population decline could stem from UADPPs or be attributable to the intrinsic traits of these cities. Therefore, this paper identifies shrinkage resource-based cities according to the list published in the Notice of the Chinese State Council on Issuing the National Sustainable Development Plan for

TABLE 6 Excluding interference from other policies and unexpected events.

Variables	(1)	(2)	(3)
	<i>popsr</i>		
	Controlling for the impact of high-speed railway launch	Controlling for the impact of the Broadband China policy	Excluding the impact of the COVID-19 pandemic
<i>did</i>	0.014*** (0.005)	0.017*** (0.005)	0.015** (0.006)
<i>ifhsr</i>	0.024*** (0.008)		
<i>ifdig</i>		0.007 (0.007)	
Control variables	yes	yes	yes
Constant	0.303** (0.147)	0.227 (0.146)	0.110 (0.172)
Observations	2,739	2,739	1992
R-squared	0.020	0.015	0.022

TABLE 7 The test results of excluding the influence of special samples.

Variables	(1)	(2)	(3)
	<i>popsr</i>		<i>popsr_w</i>
	Excluding Yangtze River Delta	Excluding shrinkage resource-based cities	Winsorization
<i>did</i>	0.018*** (0.006)	0.018*** (0.005)	0.013*** (0.004)
Control variables	yes	yes	yes
Constant	0.234 (0.160)	0.278** (0.137)	0.070 (0.101)
Observations	2,343	2,486	2,739
R-squared	0.014	0.014	0.018

Resource-based Cities (2013–2020), and then performs baseline regression after excluding these cities. The results are shown in Column (2) of Table 7.

Third, to mitigate the influence of extreme outliers on baseline regression outcomes, this paper winsorizes the research samples at the 1% level (both upper and lower tails) and re-conducts regression analysis, with results shown in Column (3) of Table 7. As can be seen from the results in Columns (1)–(3), after excluding the influence of special samples, the DID regression coefficients remained significantly positive, confirming the robustness of the baseline regression results.

5.4 Heterogeneity analysis

The baseline regression results reveal that UADPPs significantly accelerate urban population decline, and findings from robustness checks further validate the consistency of this conclusion. However, the acceleration effect of this policy on urban population decline is likely to exhibit heterogeneity across city typologies, agglomeration configurations, and regional contexts. Therefore, this section will carry out heterogeneity tests on the baseline regression results.

5.4.1 Urban type

This study classifies research samples into LMCs and small cities following the list of 70 large- and medium-sized cities (LMCs) issued by the Chinese National Bureau of Statistics. Table 8 presents the regression results for the two types of samples, with the regression model specified identically to the baseline regression. In Column (1), the DID regression coefficient is positive but insignificant, while in Column (2), the DID coefficient is significantly positive at the 1% level. It indicates that, compared with the 70 large- and medium-sized cities, UADPPs have a more pronounced acceleration effect on population decline in small cities, confirming Hypothesis 2. This outcome stems from the fact that UADPPs enhance the agglomeration effect within urban agglomerations, particularly manifesting in the intensified agglomeration of large cities within the cluster. This amplified agglomeration in large cities further exacerbates the

siphoning effect on surrounding smaller cities, thereby driving population migration from SMCs to metropolises.

5.4.2 Urban agglomeration type

The heterogeneity of the “weak-city population decline” effect in urban agglomerations manifests at both the intra-agglomeration and inter-agglomeration levels. First, this study measures the population agglomeration level of urban agglomerations by drawing on the methodology of Zheng et al. (2024), aiming to capture variations in population agglomeration capacity across different urban agglomerations. Then, according to whether the population agglomeration of UAs is higher than the average population agglomeration of all UAs, the samples are divided into two groups: low-density UAs and high-density UAs. Finally, these variables are included separately in the baseline regression model, with the regression results presented in Columns (3) and (4) of Table 8.

The regression results of the two types of samples show that the DID regression coefficients are both significantly positive. However, in comparison, both in terms of significance and the magnitude of the regression coefficients, the acceleration effect of UADPPs on urban population decline is more significant in low-density UAs, thus verifying Hypothesis 3.

5.4.3 Regional type

Marked regional heterogeneities in China could give rise to spatial variations in how UADPPs influence urban depopulation across different territorial scales. Therefore, this paper divides the research samples into two groups based on their regions: the Eastern Regions and the Central and Western Regions, and incorporates them into the baseline regression model separately.

Columns (5) and (6) of Table 8 report the regression results for the Eastern Regions and the Central and Western Regions, respectively. The results show that the DID estimated coefficient for the Central and Western Regions is significantly positive at the 1% significance level, while the coefficient for the Eastern Regions is not significant. It indicates that the impact of UADPPs on urban population decline exhibits significant regional heterogeneity, with a more pronounced acceleration effect in the Central and Western Regions, thus verifying

TABLE 8 The results of heterogeneity analysis.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	<i>popsr</i>					
	Urban type		Urban agglomeration type		Regional type	
	70 cities	Other cities	Low	High	Eastern regions of China	Central and Western Regions of China
<i>did</i>	0.001 (0.008)	0.023*** (0.006)	0.024*** (0.008)	0.016* (0.009)	0.014 (0.011)	0.019*** (0.005)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Constant	0.108 (0.274)	0.224 (0.152)	0.560** (0.276)	0.418 (0.287)	0.112 (0.207)	0.201 (0.161)
Observations	759	2,376	964	609	924	1815
R-squared	0.014	0.015	0.027	0.028	0.014	0.018

Hypothesis 4. Within the theoretical framework of this study, this phenomenon may stem from the Eastern Regions' edge in natural resource endowments, human capital, and physical capital accumulation over their Central and Western counterparts—with such advantages originating from geographical predispositions and earlier developmental trajectories. These capital factors are conducive to attracting mobile populations at the national level, thereby offsetting the adverse impact of UADPPs on accelerating urban population decline.

6 Conclusion and policy recommendations

6.1 Conclusion and discussion

This study utilizes small- and medium-sized cities with population decline between 2011 and 2022 as the sample, employs the difference-in-differences (DID) approach, and adopts the UADPPs approved by the Chinese State Council as a quasi-natural experiment to systematically examine their impact on urban population decline and the underlying logical mechanisms. The research confirms that UADPPs significantly accelerate population decline in SMCs, and this effect is realized through an “agglomeration-siphoning” transmission pathway. The agglomeration effects of UAs are intensified by the UADPPs. Moreover, this effect is predominantly manifested in large cities, attributable to their advantages in terms of scale and administrative hierarchy. Driven by policies promoting the free flow of production factors among cities in the UAs, this advantage further amplifies the siphoning effect on surrounding SMCs, prompting accelerated population migration to large cities and ultimately worsening population loss in SMCs.

Heterogeneity analysis reveals a more complex situation. First, urban scale differences significantly moderate policy impacts, with population decline driven by UADPPs being notably more severe in small cities than in medium and large cities. This indicates that UADPPs may result in the bipolarization of urban systems in resource allocation. Second, the impact of UADPP transcends the geographical boundaries of urban agglomerations, as population siphoning effects are also evident between agglomerations, confirming that regional development imbalances may be intensified at a larger spatial scale. Third, in urban agglomerations with low population agglomeration levels, the population decline effects triggered by UADPPs are more pronounced, reflecting that the “Matthew Effect” of resource factors is more significant in regions with weak foundations. Fourth, the central regions are most negatively affected by UADPPs, which is closely related to the “sandwiched” position of central cities in the national economic landscape and their insufficient capacity to absorb resources.

6.2 Policy recommendations

Population decline undoubtedly exerts multiple adverse impacts on urban development. For instance, it results in a shrinkage of the workforce, especially an exodus of high-quality young and middle-aged labor. It decelerates the transformation of urban industrial structures and significantly erodes technological innovation capabilities, plunging cities into an aging crisis (Ohashi and Phelps, 2020). Additionally, it

directly causes a surge in vacant residential properties and underutilized public service facilities, when reducing local government fiscal revenue and escalating operational costs and deficit risks (Slach et al., 2019). Furthermore, it contributes to rising urban crime and unemployment rates, deteriorating environmental and hygiene conditions, and thus erodes overall resident welfare (Delken, 2008). The UADPP aims to foster urban integration. However, this study contends that the policy exacerbates population decline in SMCs. Thus, it is imperative to deliberate appropriate policy recommendations to address this challenge.

First, mitigating the administrative hierarchy-driven siphoning effects. Efforts should focus on weakening the competitive advantages of large cities derived from administrative hierarchies to reduce the “siphoning effect” on population. This study shows that large cities' preferential access to resources via administrative ranks intensifies the siphoning effect on surrounding SMCs. While the UADPP promotes free flow of production factors—intensifying this siphoning effect in population mobility—ideal population decline should result from the natural adjustment of the economic system, such as factor flows driven by endogenous advantages of large cities in industrial clustering and innovation capacity. In addition, Harper (2012) argues that the formulation and implementation of spatial planning necessitate collaborative efforts among multiple stakeholders. Therefore, it is crucial to contain administrative resource misallocation within reasonable bounds. When formulating UADPPs, policymakers should strengthen market-led agglomeration effects while breaking down factor flow barriers, and gradually reduce administrative hierarchy's intervention in resource allocation through policy combinations, including cross-regional allocation of public service resources, incentive mechanisms for cross-city talent mobility, and so on.

Second, leveraging local resources to cultivate characteristic industries and optimize talent ecosystems in SMCs. SMCs in the UA should leverage local resource endowments to cultivate characteristic industries and optimize supporting infrastructure and services for talent development. Rational industrial division and collaboration can promote coordinated intercity development within agglomerations, directly influencing population mobility patterns. This study confirms that the UADPP accelerates the population decline in SMCs, with the effect intensifying as city size decreases. While urbanism theory (Knox and Taylor, 1997) posits that no two cities worldwide share identical developmental trajectories or characteristics and each city embodies a unique path shaped by historical, cultural, and socioeconomic contexts, rendering universal planning models inadequate. Thus, these cities must define distinct positioning within the agglomeration's industrial system and develop specialized economic niches to enhance population attraction and mitigate decline pressures. Conversely, ambiguous industrial positioning and competitiveness deficits place SMCs at a disadvantage in industrial competition with large cities, accelerating population outflows. The urban spatial equilibrium theory (Roback, 1982) posits that intercity population agglomeration patterns arise from regional disparities in income, living costs, and urban livability. Therefore, SMCs should continuously upgrade talent-supporting infrastructure and enhance livability to counteract these disparities.

Third, actively integrating into global value chains and constructing the agglomeration-economy-driven urban development model. It is essential to actively integrate into the global value chain, construct a city development model driven by the agglomeration economy of urban clusters, and promote integrated development among large, medium,

and small cities. With the evolution of the spatial economy, UAs—rather than individual cities—have become the basic spatial units for global competition (Hospers, 2014). At the same time, the scholars of Gereffi et al. (2005) highlight in the theory of global value chain (GVC) that value chains—comprising global organizational and spatial arrangements—ultimately form networked production systems. Thus, as the UADPP is put into practice, the agglomeration economy of UA will eventually replace that of individual cities as the primary driver of urban development. Therefore, the UADPP should be oriented from global value chains, establishing a symbiotic industrial division system, such as formulating inter-agglomeration industrial collaboration plans and cross-city industrial alliances, promoting upstream-downstream industrial chain collaboration, guiding the gradient transfer of excess production capacity in core cities to smaller ones, and jointly developing industrial parks to narrow intercity economic disparities, thereby mitigating population flow from SMCs to large cities.

6.3 Limitations and future research directions

The theoretical value of this study lies in revealing the non-equilibrium effects of UADPPs on population mobility, providing a new perspective for policy evaluation, and filling the research gap on the impact of regional development policies on population spatial distribution. At the practical level, the findings warn policymakers to pay attention to the “scale bias” in the implementation of plans to avoid accelerating the hollowing-out of SMCs. Future research can further integrate factors such as the digital economy and transport infrastructure to deeply explore how to optimize resource allocation mechanisms within urban agglomerations and build a new pattern of collaborative development among large, medium, and small cities. Meanwhile, as this study only selected samples of population-decline cities, follow-up research can expand the sample scope to comprehensively evaluate the differentiated impacts of UADPPs on cities at different development stages.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

References

- Beauregard, R. A. (2009). Urban population loss in historical perspective: United States, 1820–2000. *Environ. Plan. A* 41, 514–528. doi: 10.1068/a40139a
- Beck, T., Levine, R., and Levkov, A. (2010). Big bad banks? The winners and losers from bank deregulation in the United States. *J. Finan.* 65, 1637–1667. doi: 10.1111/j.1540-6261.2010.01589.x
- Benjamin, M. (2012). Productivity losses from financial frictions: can self-financing undo capital misallocation? *Am. Econ. Rev.* 104, 3186–3221. doi: 10.1257/aer.104.10.3186
- Beunen, R., Meijer, M., and de Vries, J. (2020). Planning strategies for dealing with population decline: experiences from the Netherlands. *Land Use Policy* 93:104107. doi: 10.1016/j.landusepol.2019.104107
- Camagni, R., Capello, R., and Caragliu, A. (2016). Static vs. dynamic agglomeration economies. Spatial context and structural evolution behind urban growth. *Pap. Reg. Sci.* 95, 133–158. doi: 10.1111/pirs.12182
- Cao, Y. W., Zhang, R. R., Zhang, D. H., and Zhou, C. S. (2023). Urban agglomerations in China: characteristics and influencing factors of population agglomeration. *Chin. Geogr. Sci.* 33, 719–735. doi: 10.1007/s11769-023-1368-7
- Chen, Q., Zheng, L., Wang, Y., Wu, D., and Li, J. (2023). Spillover effects of urban form on urban land use efficiency: evidence from a comparison between the Yangtze and yellow Rivers of China. *Environ. Sci. Pollut. Res.* 30, 125816–125831. doi: 10.1007/s11356-023-30976-w
- Chen, S., Zheng, L., and Gao, Y. (2022). Educational divergence among urban residents and migrant workers: evidence from China. *Chin. J. Popul. Resour. Environ.* 3, 295–306. doi: 10.3969/j.issn.1004-2857.2022.03.011
- Chung, E. C., Lee, B. S., and Cho, C. (2021). Determinants of agglomeration in Korean manufacturing industries. *Singapore Econ. Rev.* 66, 1293–1319. doi: 10.1142/S0217590818500169

Author contributions

AJ: Formal analysis, Investigation, Writing – review & editing. QS: Conceptualization, Methodology, Writing – original draft. SZ: Methodology, Supervision, Writing – original draft, Writing – review & editing.

Funding

The author(s) declare that financial support was received for the research and/or publication of this article. This paper is supported by the Chinese National Funding of Social Sciences “Research on the Mechanism and Policy of Spatial Agglomeration in Urban Agglomerations Promoting Economic Growth” (Grant number: 22BJL070).

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The authors declare that no Gen AI was used in the creation of this manuscript.

Any alternative text (alt text) provided alongside figures in this article has been generated by Frontiers with the support of artificial intelligence and reasonable efforts have been made to ensure accuracy, including review by the authors wherever possible. If you identify any issues, please contact us.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

- Dalmazzo, A. G. (2010). Amenities and skill-biased agglomeration effects: some results on Italian cities. *Pap. Reg. Sci.* 90, 503–527. doi: 10.1111/j.1435-5957.2010.00327.x
- Delken, E. (2008). Happiness in shrinking cities in Germany. *J. Happiness Stud.* 9, 213–218. doi: 10.1007/s10902-007-9046-5
- Deng, C., and Ma, J. (2015). Viewing urban decay from the sky: a multi-scale analysis of residential vacancy in a shrinking U.S. city. *Landsc. Urban Plan.* 141, 88–99. doi: 10.1016/j.landurbplan.2015.05.002
- Deng, T., Wang, D., Yang, Y., and Yang, H. (2019). Shrinking cities in growing China: did high speed rail further aggravate urban shrinkage. *Cities* 86, 210–219. doi: 10.1016/j.cities.2018.09.017
- Fang, C. L. (2015). CL important progress and future direction of studies on China's urban agglomerations. *Geogr. Sci.* 25, 1003–1024. doi: 10.1007/s11442-015-1216-5
- Feng, Y., Lee, C. C., and Peng, D. Y. (2023). Does regional integration improve economic resilience? Evidence from urban agglomerations in China. *Sustain. Cities Soc.* 88:104273. doi: 10.1016/j.scs.2022.104273
- Friedman, J. (1966). Regional development policy. Cambridge, USA: MIT Press.
- Gereffi, G., Humphrey, J., and Sturgeon, T. (2005). The governance of global value chains. *Rev. Int. Polit. Econ.* 12, 78–104. doi: 10.1080/09692290500049805
- Großmann, K., Haase, A., Bernt, M., Mykhnenko, V., and Rink, D. (2016). Varieties of shrinkage in European cities. *Eur. Urban Reg. Stud.* 23, 86–102. doi: 10.1177/0969776413481985
- Harper, T. L. (2012). The Ashgate research companion to planning theory: conceptual challenges for spatial planning. *J. Reg. Sci.* 52, 709–712. doi: 10.1111/j.1467-9787.2012.007845.x
- Hart, M. D. (2016). How cities shrink: complex pathways to population decline. *Cities* 75, 38–49. doi: 10.1016/j.cities.2016.12.005
- Häußermann, H., and Siebel, W. (1988). Die Schrumpfende Stadt und die Stadtsoziologie. Opladen: Westdeutscher Verlag, 78–94.
- He, Q. S., Yan, M., and Wu, J. Y. (2023). Characteristics of population shrinkage in inner urban China and correlations with urban growth patterns. *Appl. Spat. Anal. Policy* 16, 1317–1343. doi: 10.1007/s12061-023-09511-4
- He, X. J., Guan, D. J., Zhou, L. L., He, X., Guan, D., Zhou, L., et al. (2023). Quantifying spatiotemporal patterns and influencing factors of urban shrinkage in China within a multidimensional framework: a case study of the Yangtze River Economic Belt. *Sustain. Cities Soc.* 91:104452. doi: 10.1016/j.scs.2023.104452
- Hong, W. Y., and Su, M. (2019). Influence of rapid transit on accessibility pattern and economic linkage at urban agglomeration scale in China. *Open Geosci.* 11, 804–814. doi: 10.1515/geo-2019-0062
- Hospers, G. J. (2014). Policy responses to urban shrinkage: from growth thinking to civic engagement. *Eur. Plan. Stud.* 22, 1507–1523. doi: 10.1080/09654313.2013.793655
- Hospers, G. J., and Reverda, N. (2015). Managing population decline in Europe's urban and rural areas. Berlin Germany: Springer International Publishing.
- Hu, P. P., Huang, Y. J., He, Q. K., and Zhang, G. C. (2024). Can urban agglomeration policies promote regional economic agglomeration? Evidence from the Yangtze River Economic Belt in China. *Environ. Plan. B* 52, 1335–1352. doi: 10.1177/23998083241293217
- Hu, Y. K., Wang, Z. Y., and Deng, T. T. (2021). Expansion in the shrinking cities: does place-based policy help to curb urban shrinkage in China? *Cities* 113:103188. doi: 10.1016/j.cities.2021.103188
- Huang, Y., Xiong, N., and Liu, C. K. (2025). Smart city policies and corporate renewable energy technology innovation: insights from patent text and machine learning. *Energy Econ.* 148:108612. doi: 10.1016/j.eneco.2025.108612
- Jaroszewska, E., and Strykiewicz, T. (2020). Drivers, scale, and geography of urban shrinkage in Poland and policy responses. *J. Urban Plann. Dev.* 146:0502021. doi: 10.1061/(ASCE)UP.1943-5444.0000601
- Jiao, J. J., Zhao, H. Y., and Lyu, G. (2024). How does high-speed rail affect off-site investments? Evidence from the Yangtze River Delta, China. *Transp. Res. A Policy Pract.* 181:103978. doi: 10.1016/j.tra.2024.103978
- Jin, Z. X., Wang, C. X., Yu, S. K., Jin, Z., Wang, C., Yu, S., et al. (2022). Spatiotemporal evolution and influencing factors of urban shrinkage in the Yellow River Basin, China. *PLoS One* 17:e0264236. doi: 10.1371/journal.pone.0264236
- Kimisato, O., Christoph, D. R., Kazuaki, T., and Steven, R. M. (2018). Urban agriculture as a sustainability transition strategy for shrinking cities? Land use change trajectory as an obstacle in Kyoto City, Japan. *Sustainability* 10:1048. doi: 10.3390/su10041048
- Knox, P. L., and Taylor, P. J. (1997). World cities in a world-system. Cambridge: Cambridge University Press.
- Kong, F. C., Zhang, H. K., Meng, X. Y., Kong, F., Zhang, H., Meng, X., et al. (2022). Can the policy of national urban agglomeration improve economic and environmental gains? Evidence from quasi-natural experiments with 280 cities in China. *Int. J. Environ. Res. Public Health* 19:7596. doi: 10.3390/ijerph19137596
- Leonardi, M., and Moretti, E. (2023). The agglomeration of urban amenities: evidence from Milan restaurants. *Am. Econ. Rev. Insights* 5, 141–157. doi: 10.1257/aeri.202200011
- Li, K., Qu, J. Y., Wei, P., Qu, J., Ai, H., and Jia, P. (2020). Modelling technological bias and productivity growth: a case study of China's three urban agglomerations. *Technol. Econ. Dev. Econ.* 26, 135–164. doi: 10.3846/tede.2020.11329
- Li, L., Ma, S. J., Zheng, Y. L., and Xiao, X. Y. (2022). Integrated regional development: comparison of urban agglomeration policies in China. *Land Use Policy* 114. doi: 10.1016/j.landusepol.2021.105939
- Li, P., Lu, Y., and Wang, J. (2016). Does flattening government improve economic performance? Evidence from China. *J. Dev. Econ.* 123, 18–37. doi: 10.1016/j.jdeveco.2016.07.002
- Long, Y., and Gao, S. H. Q. (2019). Shrinking cities in China. Singapore: Springer.
- Lu, Y., Xie, D., Liu, H., and Zhong, Z. (2024). Impact of urban agglomeration development planning policy on the promotion of efficiency of urban economic development: empirical evidence from 283 cities in China. *J. Urban Plann. Dev.* 150:150. doi: 10.1061/JUPDDM.UPENG-4872
- Lu, Y., and Yu, L. (2015). Trade liberalization and markup dispersion: evidence from China's WTO accession. *Am. Econ. J.: Appl. Econ.* 7, 221–253. doi: 10.1257/app.20140350
- Ma, Z. P., Li, C. G., and Zhang, J. (2020). Understanding urban shrinkage from a regional perspective: case study of Northeast China. *J. Urban Plann. Dev.* 146, 1–14. doi: 10.1061/(ASCE)UP.1943-5444.0000621
- Mallach, A., Haase, A., and Hattori, K. (2017). The shrinking city in comparative perspective: contrasting dynamics and responses to urban shrinkage. *Cities* 69, 102–108. doi: 10.1016/j.cities.2016.09.008
- McCann, P. (2017). Urban futures, population ageing and demographic decline. *Camb. J. Reg. Econ. Soc.* 10, 543–557. doi: 10.1093/cjres/rsx009
- Meijers, E. J., Burger, M. J., and Hoogerbrugge, M. M. (2016). Borrowing size in networks of cities: city size, network connectivity and metropolitan functions in Europe. *Pap. Reg. Sci.* 95, 181–199. doi: 10.1111/pirs.12181
- Ohashi, H., and Phelps, N. A. (2020). Diversity in decline: the changing suburban fortunes of Tokyo metropolis. *Cities* 103:102693. doi: 10.1016/j.cities.2020.102693
- Oster, E. (2019). Unobservable selection and coefficient stability: theory and evidence. *J. Bus. Econ. Stat.* 37, 187–204. doi: 10.1080/07350015.2016.1227711
- Pan, F., Sun, Y. J., Jiang, N., Sun, Y., Jian, Z., Mei, Y., et al. (2023). Analysis of the coordination of built-up area expansion and population growth in the Shandong peninsula urban agglomeration. *Sustainability* 15:7763. doi: 10.3390/su15107763
- Patterson, A. C. (2023). Is economic growth good for population health? A critical review. *Can. Stud. Popul.* 50:1. doi: 10.1007/s42650-023-00072-y
- Peck, J., Werner, M., Jones, M., and Turok, I. (2023). A dialogue on uneven development: a distinctly regional problem. *Reg. Stud.* 57, 1392–1403. doi: 10.1080/00343404.2022.2116417
- Restuccia, D., and Rogerson, R. (2013). Misallocation and productivity. *Rev. Econ. Dyn.* 16, 1–10. doi: 10.1016/j.red.2012.11.003
- Richardson, H. W., and Nam, C. W. (2014). Shrinking cities: a global perspective. NY: Routledge.
- Roback, J. (1982). Wages, rents, and the quality of life. *J. Polit. Econ.* 90, 1257–1278. doi: 10.1086/261120
- Rosero-Ceballos, E. L., and Mendoza-Cota, J. (2024). Incident factors in the wage gaps between the Colombian and US immigrant population. *Pap. Poblac.* 29, 99–123. doi: 10.22185/24487147.2023.118.29
- Shan, J. C., Liu, Y. L., Kong, X. S., Shan, J., Liu, Y., Kong, X., et al. (2020). Identifying city shrinkage in population and city activity in the middle reaches of the Yangtze River, China. *J. Urban Plann. Dev.* 146:04020027. doi: 10.1061/(ASCE)UP.1943-5444.0000593
- Slach, O., Bosák, V., Krtička, L., Nováček, A., and Rumpel, P. (2019). Urban shrinkage and sustainability: assessing the nexus between population density, urban structures and urban sustainability. *Sustainability* 11:4142. doi: 10.3390/su11154142
- Sobotka, T. (2004). Is lowest-low fertility in Europe explained by the postponement of childbearing? *Popul. Dev. Rev.* 30, 195–220. doi: 10.1111/j.1728-4457.2004.010_1.x
- Strumsky, D., Bettencourt, L., and Lobo, J. (2023). Agglomeration effects as spatially embedded social interactions: identifying urban scaling beyond metropolitan areas. *Environ. Plann. B* 50, 1964–1980. doi: 10.1177/23998083221148198
- Sun, X. Y., Yan, S., Liu, T., and Wang, J. Y. (2022). The impact of high-speed rail on urban economy: synergy with urban agglomeration policy. *Transp. Policy* 130, 141–154. doi: 10.1016/j.tranpol.2022.11.004

- Wang, R. L., Wang, C. X., Zhang, S., and Ding, X. M. (2021). A study on the spatial and temporal evolution of urban shrinkage and its influencing factors from a multidimensional perspective: a case study of resource-based cities in China. *PLoS One* 16, 1–19. doi: 10.1371/journal.pone.0258524
- Wang, Y. P., and Fukuda, H. (2019). Sustainable urban regeneration for shrinking cities: a case from Japan. *Sustainability* 11:1505. doi: 10.3390/su11051505
- Wang, Z. L., Wang, L., Zhao, B., and Pei, Q. (2023). Analysis of spatiotemporal interaction characteristics and decoupling effects of urban expansion in the Central Plains urban agglomeration. *Land* 12:772. doi: 10.3390/land12040772
- Wei, G. D., Li, X. Y., Yu, M. Y., Wei, G., Li, X., Yu, M., et al. (2022). Influence mechanism of transportation integration on industrial agglomeration in urban agglomeration theory—taking the Yangtze River Delta urban agglomeration as an example. *Appl. Sci.* 12:8369. doi: 10.3390/app12168369
- Wu, T., Xu, W. X., and Kung, C. C. (2024). The impact of data elements on urban sustainable development: evidence from the big data policy in China. *Technol. Soc.* 81:102800. doi: 10.1016/j.techsoc.2024.102800
- Yang, J., Ko, W., and Cho, Y. (2024). Modeling the United Oscillation and Wave of economic policy and urban planning employing spatial population dynamics. *PLoS One* 19:e0305465. doi: 10.1371/journal.pone.0305465
- Yang, Z. (2019). Sustainability of urban development with population decline in different policy scenarios: a case study of Northeast China. *Sustainability* 11, 1–17. doi: 10.3390/su11226442
- Yao, L., and Luo, R. Y. (2024). Decoding China's urban agglomerations policies: a scientific evaluation and exploration of economic benefits. *Habitat Int.* 152:103159. doi: 10.1016/j.habitatint.2024.103159
- Zhang, Y. J., and Wang, X. X. (2020). Research on the spatial distribution of China's population from the perspective of urban agglomerations (in Chinese). *Popul. Econ.* 3, 1–13. doi: 10.3969/j.issn.1000-4149.2020.00.024
- Zheng, H. Q., Hsiao, C. Y. L., Ho, H. W., Zheng, H., Hsiao, C. Y.-L., Ji, C., et al. (2024). How the spatial functional division of labor in urban clusters affects urban population size? Evidence from 19 urban clusters in China. *Humanit. Soc. Sci. Commun.* 11, 1–12. doi: 10.1057/s41599-024-04183-y