International Core Journal of Social Sciences
ISSN: 3080-8774 (Print), ISSN: 3080-8782 (Online) | Vol. 1, No. 1, 2026

Spatial-Temporal Evolution and Multidimensional Structural Analysis of Population rowth -Decline Differentiation in the Sichuan-Chongqing Region of China

Hongshu He[1, *], Yongfei Zhang[2], Yixuan Yang[1], Ziqing Xu[1], Yijun Zhuo[1], Yuxin Deng[1]

[1] School of Economics, Sichuan University, Chengdu 610065, China
[2] School of Light Industry Science and Engineering, Sichuan University, Chengdu 610065, China
[*] **Corresponding author Email:** 2023141010173@stu.scu.edu.cn

Abstract: This study focuses on the Sichuan-Chongqing region of China, systematically analyzing the spatiotemporal evolution characteristics and multi-dimensional structural mechanisms of population growth and decline differentiation during 2000—2023. The results reveal a prominent "core-periphery" pattern: the core urban areas of Chengdu and Chongqing maintain positive population growth as regional agglomeration hubs, while most peripheral areas face dual pressures of declining natural growth rates and continuous outflow, with negative growth regions expanding. Using hierarchical clustering, the region is classified into six types, and a two-way fixed effects model explores population change drivers. Findings show: urbanization rate inhibits natural growth rate, while social security expenditure has a positive impact; per capita GDP, population density, and social security expenditure negatively drive net migration rate; total population growth is constrained by economic factors and agglomeration costs, with no significant direct effects of urbanization rate or social security expenditure. Correspondingly, this study proposes differentiated fertility support, optimized regional development, improved social security, high-quality urbanization, and regional collaborative governance to promote long-term balanced population development and spatial coordination in the region.

Keywords: Sichuan-Chongqing Region; Population Growth-Decline Divergence; Spatial-Temporal Evolution of Population Distribution; Driving Factors of Population Change.

1. Introduction

Against the backdrop of overlapping collisions of urban-rural transformation, economic restructuring and social upheaval in the era of globalization, population growth and decline differentiation has become a focal issue in interdisciplinary research. Urban-rural dual differentiation is one of its important manifestations. Remote areas in developed countries, such as inland municipalities in Spain [1], rural towns in South Korea [2] are all facing population loss. China, in particular, is a typical example of an urban-rural dual economy, where the continuous migration of population from rural to urban areas constitutes an important feature of population structure change [3]. Regions such as Lanxi [4] are generally facing the problem of population outflow to core cities. From the perspective of inter-provincial and inter-county population mobility, core cities are more likely to attract inter-provincial migrants, while secondary node cities tend to draw inter-county migrants [5]. In terms of the composition of mobile populations, highly educated groups [6] are also more inclined to move to core cities.

Population growth and decline differentiation is the result of the superposition of multiple factors such as economic drivers, social structures, and spatial conditions. The imbalance of regional development is widespread in both developed and developing countries [7]. A region's economic structure determines the trend of population inflow or outflow [8]. Young laborers are gradually migrating to cities with more employment opportunities [9]. Areas with population outflow are often those with poor socio-economic conditions and weak infrastructure. Due to tight public finances, these regions struggle to improve public services and related facilities, further expanding regional population differentiation [10]. This "Matthew effect" means that economically prosperous areas will attract more people to flow in, while impoverished areas will continue to lose population, becoming the initial driving force for regional differentiation. Meanwhile, after 2010 in China, the impact of economic drivers on population has gradually weakened [11], and population migration decisions have shifted from focusing solely on economic benefits to emphasizing quality-of-life benefits [12]. Non-economic factors have become increasingly important in influencing population growth and decline.

In summary, existing literature has comprehensively explored the driving factors, spatial characteristics, and policy tools of population growth and decline differentiation, providing a theoretical foundation for this study. However, current research has paid insufficient attention to the Sichuan-Chongqing region, making it difficult to support the region's population development needs. As an important strategic fulcrum and economic growth pole in western China, the Sichuan-Chongqing region is also the core area of the national "Chengdu-Chongqing Twin-City Economic Circle" strategy. Its population change pattern exerts a profound impact on the process of Western Development, regional coordinated development, and urban-rural integration. Based on this, this study will, drawing on the current situation of population growth and decline differentiation in the Sichuan-Chongqing region, reveal the dynamic laws of natural growth, population mobility, and total population changes in the region, and systematically explore the influence mechanisms of population growth and decline differentiation. It aims to provide policy implications for exploring paths to high-quality population development and realizing the coordination of human-land relations under the background of Chinese-style modernization.

2. Research Methods

Natural growth and net migration are the components of regional total population change, and influencing factors such as economy, education, and medical care affect regional total population change through these two factors. To explore the influencing factors of regional total population change in depth, this paper uses a two-way fixed effects model to analyze the influencing factors of regional total population change, natural growth, and net migration in the Sichuan-Chongqing region over more than 20 years from 2000 to 2023. The constructed econometric model is as follows:

Define that: A_{ij} is urbanization_rate$_i$, B_{ij} is public_universities$_i$, C_{ij} is gdp_per_capita$_i$, D_{ij} is elevation$_i$, E_{ij} is population_density$_i$, F_{ij} is social_security_expenditure$_i$.

$$natural\_growth\_rate_{it} = \beta_0 + \beta_1 A_{it} + \beta_2 B_{it} + \beta_3 C_{it} + \beta_4 D_{it} + \beta_5 E_{it} + \beta_6 F_{it} + u_i + v_t + \varepsilon_{it} \tag{1}$$

$$migration\_rate\_analysis_{it} = \beta_{19} + \beta_7 A_{it} + \beta_8 B_{it} + \beta_9 C_{it} + \beta_{10} D_{it} + \beta_{11} E_{it} + \beta_{12} F_{it} + u_i + v_t + \varepsilon_{it} \tag{2}$$

$$pop\_growth_{it} = \beta_{20} + \beta_{13} A_{it} + \beta_{14} B_{it} + \beta_{15} C_{it} + \beta_{16} D_{it} + \beta_{17} E_{it} + \beta_{18} F_{it} + u_i + v_t + \varepsilon_{it} \tag{3}$$

In the equation, natural_growth_rateit, migration_rate_analysisit, and pop_growthit are the dependent variables, representing the natural population growth rate, net migration rate, and total population growth rate of city i in the Sichuan-Chongqing region in year t, respectively.

urbanization_rateit, public_universitiesit, gdp_per_capitait, elevationit, population_densityit, and social_security_expenditureit are the independent variables, which stand for the urbanization rate, number of public undergraduate universities, per capita GDP, average elevation, population density, and government social security expenditure of city i in the Sichuan-Chongqing region in year t, respectively.

Here, β denotes the model parameters, ui is the individual effect, vt is the time effect, and εit is the error term after eliminating individual and time effects.

This paper uses per capita GDP and urbanization rate to measure a city's economic level, the number of public undergraduate universities to measure its educational level, average elevation to measure its geographical conditions, population density to measure its spatial crowding degree, and government social security expenditure to measure its welfare level. Through these five dimensions, this paper explores the influencing factors of the differentiation in regional population growth and decline in the Sichuan-Chongqing region.

To eliminate the individual and time effects in the model, the author transformed the model. The following section will take the natural growth rate as an example to explain the transformation process. For Equation (2):

First, the author calculated the time-wise average to obtain Equation (5);

Next, the individual-wise average (by city) was calculated to obtain Equation (6);

Then, the individual-wise average of Equation (5) or the time-wise average of Equation (6) was computed to obtain Equation (7);

Finally, Equation (2) was subtracted by Equation (5), then subtracted by Equation (6), and added by Equation (7), resulting in Equation (8) with individual and time effects eliminated.

The model parameters can be solved by directly conducting OLS regression on Equation (8).

$$\overline{natural\_growth\_rate_i} = \beta_0 + \beta_1 \bar{A}_i + \beta_2 \bar{B}_i + \beta_3 \bar{C}_i + \beta_4 \bar{D}_i + \beta_5 \bar{E}_i + \beta_6 \bar{F}_i + u_i + \bar{v} + \bar{\varepsilon}_i \tag{4}$$

$$\overline{natural\_growth\_rate_t} = \beta_0 + \beta_1 \overline{A_t} + \beta_2 \overline{B_t} + \beta_3 \overline{C_t} + \beta_4 \overline{D_t} + \beta_5 \overline{E_t} + \beta_6 \overline{F_t} + \bar{u} + v_i + \bar{\varepsilon}_t \tag{5}$$

$$\overline{natural\_growth\_rate} = \beta_0 + \beta_1 \bar{A} + \beta_2 \bar{B} + \beta_3 \bar{C} + \beta_4 \bar{D} + \beta_5 \bar{E} + \beta_6 \bar{F} + \bar{u} + \bar{v} + \bar{\varepsilon} \tag{6}$$

$$\begin{aligned} natural\_growth\_rate_{it} &- \overline{natural\_growth\_rate_i} - \overline{natural\_growth\_rate_i} + \overline{natural\_growth\_rate} \\ &= \beta_1 (A_{it} - \bar{A}_i - \overline{A_t} + \bar{A}) + \beta_2 (B_{it} - \bar{B}_i - \overline{B_t} + \bar{B}) \\ &+ \beta_3 (C_{it} - \bar{C}_i - \overline{C_t} + \bar{C}) + \beta_4 (D_{it} - \bar{D}_i - \overline{D_t} + \bar{D}) \\ &+ \beta_5 (E_{it} - \bar{E}_i - \bar{E}_t + \bar{E}) + \beta_6 (F_{it} - \bar{F}_i - \bar{F}_t + \bar{F}) + (\varepsilon_{it} - \bar{\varepsilon}_i - \bar{\varepsilon}_t + \bar{\varepsilon}) \end{aligned} \tag{7}$$

3. Results

To explore the spatiotemporal evolution of population growth and decline differentiation in the Sichuan-Chongqing region, this paper conducts a characteristic analysis based on the evolution maps of the spatial patterns of total population growth, natural growth, and net migration in various areas of the Sichuan-Chongqing region over four time periods in the past 20 years.

3.1. Data Sources

In this study, data related to population, economy, and education were obtained from the Sichuan Statistical Yearbook and Chongqing Statistical Yearbook. The number of Grade A tertiary hospitals was counted using data from the Sichuan Provincial Health Commission, Chongqing Municipal Health Commission, and the official websites of individual Grade A tertiary hospitals. The average elevation of each region was sourced from the topographic map website (topographic-map.com). Additionally, for partially missing data, the author used interpolation and regression methods for estimation.

To explore the influencing factors of regional population growth-decline differentiation in the Sichuan-Chongqing Region, this study conducted regression analysis. To avoid multicollinearity among variables, the correlation coefficients between variables were calculated, and variables with high correlation coefficients were eliminated. Pearson correlation coefficient has significant advantages in analyzing linear relationships. Compared with Spearman correlation coefficient, it can more accurately quantify the strength and direction of the linear association between two variables, and is particularly suitable for continuous data with an approximate normal distribution. When the data meet the linear assumption, Pearson's results have stronger statistical interpretability. Furthermore, it is more sensitive to weak linear signals, whereas Spearman, which relies solely on rankings, may obscure the details of actual linear patterns. Therefore, this study chose to calculate the Pearson correlation coefficient. Using Formula (1), the author derived the Pearson correlation coefficients between various variables and obtained the correlation coefficient matrix shown in Figure 1.

$$r_{xy} = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2} * \sqrt{\sum_{i=1}^{n}(y_i - \bar{y})^2}} \tag{8}$$

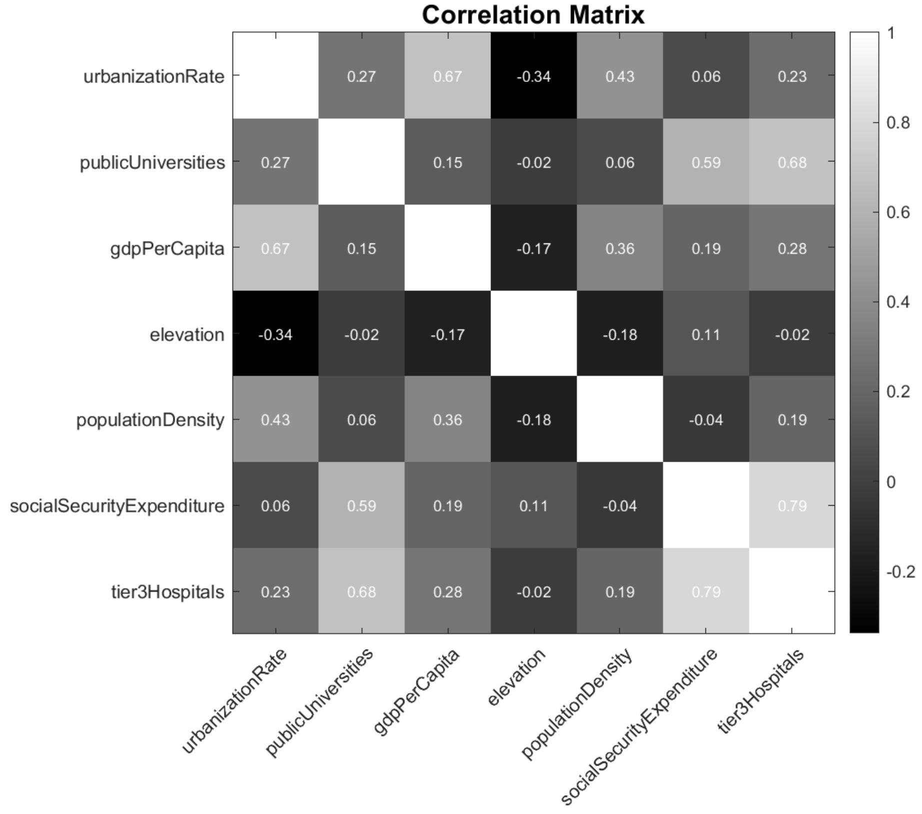


Figure 1. Correlation Coefficient Matrix

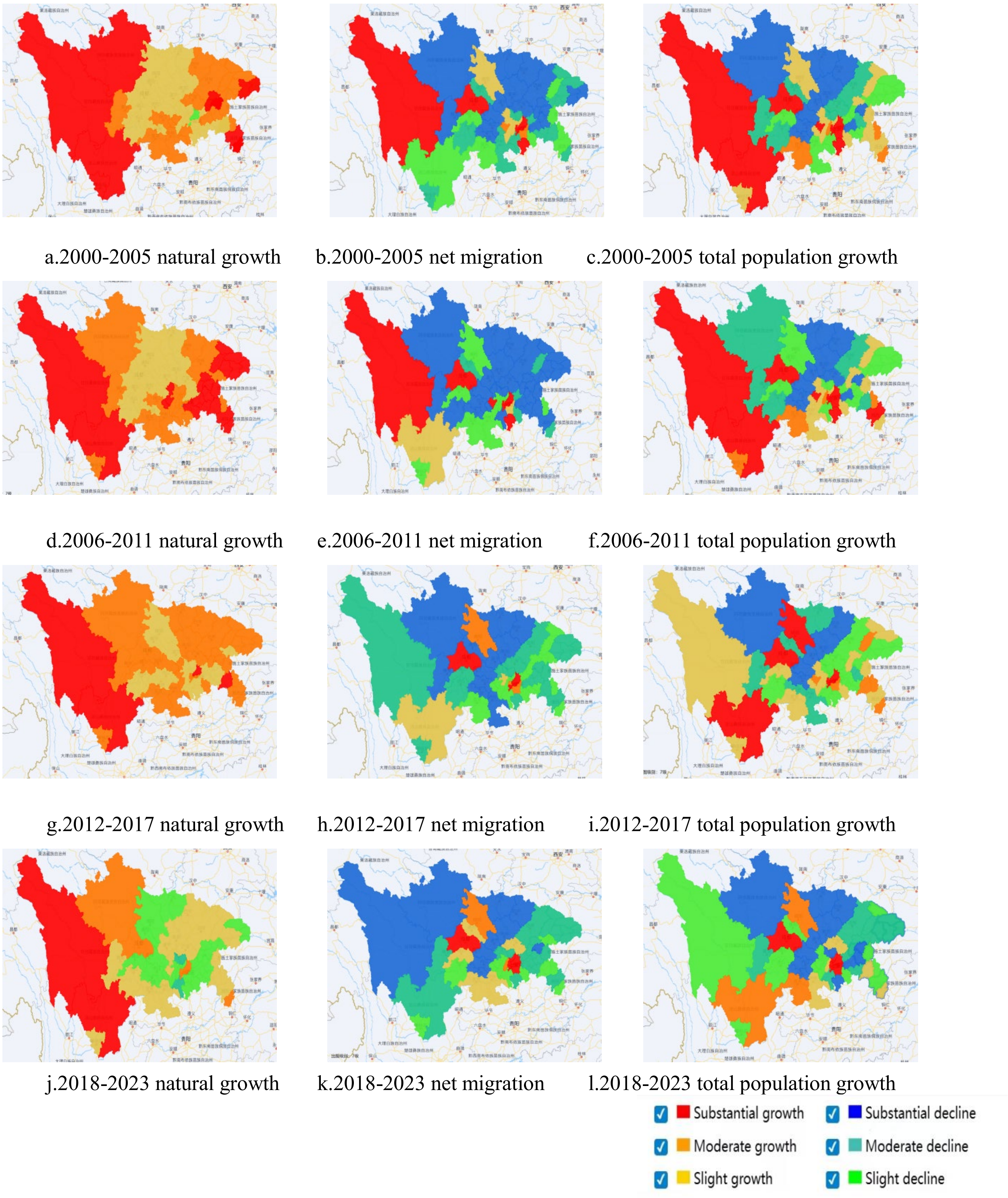
A correlation coefficient greater than 0.7 is generally considered to indicate a strong correlation between two variables. As can be seen from the correlation coefficient matrix diagram, the correlation coefficients between the number of Grade A tertiary hospitals and both social security and employment expenditure, as well as the number of public undergraduate institutions, are relatively high. Therefore, the author excluded the variable "number of Grade A tertiary hospitals".

3.2. Spatiotemporal Evolution of Population Growth and Decline Differentiation in the Sichuan-Chongqing Region

It can be seen from Figure 2 that during 2000—2005, the natural growth in the Sichuan-Chongqing Region showed the characteristic of "stronger growth in the west and slower growth in the east", with the three autonomous prefectures in western Sichuan serving as the core of growth; during 2018—2023, the overall natural growth narrowed, the gap between the eastern and western regions widened, the three autonomous prefectures in western Sichuan remained the concentrated growth areas, Deyang and Mianyang in the Chengdu Plain shifted to a slight decrease, and the natural growth of the Sichuan-Chongqing Region has officially entered a narrowing phase.

The net population migration pattern has gradually evolved from "dual-core agglomeration and peripheral differentiation" to "dual-core stable agglomeration and local return": during 2000—2005, the core areas of Chengdu and Chongqing continued to experience population inflow, while most peripheral regions saw population outflow; during 2018—2023, the core areas of Chengdu and Chongqing still maintained net population inflow but with a contracted growth rate, Mianyang has become a regional secondary growth pole, Guangan shifted from moderate outflow to slight inflow, and the population outflow rate in northeastern Chongqing and southeastern Chongqing slowed down.

The total population growth has transitioned from "rapid growth in core areas and uneven growth in peripheral areas" to "stable growth only in core areas and overall contraction": during 2000—2005, the core regions experienced significant population growth, while some peripheral regions saw a decrease; during 2018—2023, only a few core urban areas of Chengdu and Chongqing still maintained population growth, Yibin in southern Sichuan and Liangshan in Panxi Region achieved moderate growth, most regions experienced population decrease, and the "Matthew effect" of population agglomeration towards core regions has become increasingly prominent.



a.2000-2005 natural growth b.2000-2005 net migration c.2000-2005 total population growth

d.2006-2011 natural growth e.2006-2011 net migration f.2006-2011 total population growth

g.2012-2017 natural growth h.2012-2017 net migration i.2012-2017 total population growth

j.2018-2023 natural growth k.2018-2023 net migration l.2018-2023 total population growth

Figure 2: Evolution of Spatial Patterns of Total Population Growth, Natural Growth, and Net Migration Across Various Regions in the Sichuan-Chongqing Region Over the Past 20 Years (Across Four Time Periods)

3.3. Solution and Analysis of the Two-Way Fixed Effects Model

The two-way regression model constructed in this paper is used for solution. As shown in Table 1, the urbanization rate has a stable negative impact on the natural growth rate, and the number of public universities shows a significant positive impact in Models 2 to 5. However, after introducing the variable of social security expenditure, the coefficient of Model 6 reverses. Although this paper calculates the Pearson correlation coefficient between variables, the correlation coefficient between the two variables is 0.56, which is still relatively large.

As shown in Table 2, the VIF (Variance Inflation Factor) of each variable is less than 5, indicating that there is no serious multicollinearity issue. Therefore, the author argues that social_security_expenditure is a suppressing variable, which masks the true effect of public_universities. After controlling for this variable, the relationship between the number of public colleges and universities and the natural growth rate turns negative. This suggests that the continuous expansion of higher education may crowd out social security resources, leading to the emergence of more implicit costs. Secondly, this shift reveals the dual-mechanism of higher education resources on population growth.

The coefficient of the gdp_per_capita variable is negative but not significant in Models 3 and 4, while it is positive but also not significant in Models 5 and 6. This indicates a relatively complex non-linear relationship between economic development and population growth. The VIF of the gdp_per_capita variable is 2.05, which excludes the interference of multicollinearity and confirms that there is no serious multicollinearity in the entire model group.

Table.1. Regression Model Parameter Table for Natural Growth Rate

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
urbanization_rate	-0.0831***	-0.0746***	-0.0832***	-0.0832***	-0.0802***	-0.0818***
	(-4.50)	(-3.93)	(-4.40)	(-4.40)	(-4.46)	(-4.49)
public_universities		0.7231***	0.6917***	0.6906***	0.5578***	-0.4989**
		(3.34)	(3.23)	(3.22)	(2.62)	(-2.04)
gdp_per_capita			-0.1183	-0.1189	0.0798	0.1122
			(-1.36)	(-1.37)	(0.98)	(1.38)
elevation				-0.0057**	-0.0050**	-0.0046*
				(-2.31)	(-2.01)	(-1.85)
population_density					0.0016***	0.0017***
					(3.25)	(3.41)
social_security_expenditure						0.0495***
						(7.22)
Constant	7.1938***	6.2021***	7.0418***	11.6372***	8.8336***	8.5177***
	(8.05)	(6.40)	(6.75)	(4.95)	(3.59)	(3.46)
Observations	1,416	1,416	1,416	1,416	1,416	1,416
R-squared	0.465	0.468	0.469	0.469	0.479	0.492

Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table.2. Variance Inflation Factor (VIF) of Model Variables

VARIABLES	VIF
urbanization_rate	2.44
public_universities	2.11
gdp_per_capita	2.05
elevation	1.16
population_density	1.38
social_security_expenditure	3.21

In Models 4 to 6, elevation shows a significant negative impact, indicating that terrain remains an important geographical constraint affecting natural population growth. The population_density variable exhibits a significant positive impact in Models 5 and 6, suggesting that higher population density is conducive to increasing the number of births. The social_security_expenditure variable shows a significant positive impact in Model 6, with a coefficient of 0.0495 (statistically significant).

Table.3. Regression Model Parameter Table for Net Migration Rate

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
urbanization_rate	0.1259**	0.0396	0.0162	0.0162	0.0070	0.0112
	(2.16)	(0.65)	(0.23)	(0.23)	(0.10)	(0.17)
public_universities		-7.3824***	-7.4682***	-7.4683***	-7.0587***	-4.2052
		(-2.81)	(-2.84)	(-2.84)	(-2.70)	(-1.27)
gdp_per_capita			-0.3229	-0.3229	-0.9354***	-1.0228***
			(-1.24)	(-1.24)	(-3.07)	(-3.30)
elevation				-0.0002	-0.0024	-0.0034
				(-0.03)	(-0.35)	(-0.51)
population_density					-0.0049***	-0.0051***
					(-5.24)	(-5.34)
social_security_expenditure						-0.1338*
						(-1.83)
Constant	-7.6325***	2.4911	4.7829	4.9441	13.5889*	14.4419*
	(-2.58)	(0.61)	(0.96)	(0.62)	(1.66)	(1.79)
Observations	1,416	1,416	1,416	1,416	1,416	1,416
R-squared	0.405	0.415	0.416	0.416	0.419	0.422

For the regression on the net migration rate, Table 3 shows that the relationship between the urbanization rate and the net migration rate presents phased characteristics. In the basic model, the impact of the urbanization rate on the net migration rate is relatively obvious. From Models 2 to 6, it can be concluded that the effect of the urbanization rate on the net migration rate is affected by multiple factors. At the same time, the change in coefficients also indicates that when the socio-economic level reaches a certain stage, the marginal effect of urbanization on population migration due to economic, political and other factors will show a decreasing trend.

The number of public universities shows a stable negative impact in Models 2 to 5. Factors such as the high cost of living in areas with concentrated universities will reduce the number of incoming migrants. The impact of per capita GDP shows very obvious phased characteristics: the coefficients of per capita GDP in Models 3 and 4 fail the significance test; after adding population density, the coefficients of per capita GDP in Models 5 and 6 are -0.9354 and -1.0228, respectively, and both are significant at the 1% level. This turning point indicates that the impact of economic development on migration does have a significant threshold effect.

The variable of elevation is statistically insignificant, indicating that with the rapid development of various types of infrastructure, the role of traditional geographical barriers that previously hindered peoples mobility has been relatively weakened. The population density variable shows a significant negative effect in Models 5 and 6, which is in sharp contrast to the expectations of Chinas traditional agglomeration economy theory, and also reveals the particularity of Chinas urbanization. The social security expenditure variable shows a significant negative impact in Model 6, and this empirical result reflects the regional differences in Chinas social security system.

4. Conclusions

Demographic evolution in the Sichuan–Chongqing region has crystallized into a core–periphery schism, with metropolitan cores sustaining growth against widespread peripheral decline. Empirical evidence establishes that urbanization significantly constrains natural population growth, while social security expenditure exerts a positive moderating effect; net migration responds negatively to per capita GDP, population density, and social security spending—reflecting rational mobility under high-cost constraints; total population growth is jointly shaped by agglomeration benefits and carrying costs, with no significant direct effects from urbanization or social security expenditure.

Policy imperatives demand spatial differentiation: urban centers require cost-sharing mechanisms to alleviate reproductive constraints, while western regions need healthcare enhancements to sustain natural increase. Future research will integrate micro-level individual behavior data and develop dynamic simulation models to enhance the precision and timeliness of policy interventions, thereby transforming structural divergence into sustainable regional integration.

References

[1] L. A ,V. B ,N. R , et al. Drivers of depopulation and spatial interdependence in a regional context[J]. Cities, 2021, 114.

[2] Seo J, Yoon S, Kim J, et al. Regional Youth Population Prediction Using LSTM[J]. Sustainability, 2025, 17(15): 6905-6905.

[3] LiJianwei. Research and judgment on the trend of China's population development and its impact on future economic development [J]. reform, 2025, (08): 11-34.

[4] WangYifei, KongDezhen, luoYuxuan, et al. The impact and path of population growth and decline differentiation on the urban economic resilience of Lanxi urban agglomeration [J]. geography of arid areas, 2025,48 (06): 1020-1030

[5] WangLucang, ZhaoDanxiao, YangYunxian.Study on temporal and spatial differentiation of floating population in urban agglomerations in the upper reaches of the Yellow River [J]. Western China, 2022, (01): 27-35.

[6] Xu Shuning Response to Regional Population Differentiation Based on High Quality Population Development: A Case Study of Zhejiang Province [C]// China Urban Planning Society, Hefei Municipal People's Government Beautiful China, Co construction, Co governance and Sharing - Proceedings of the 2024 China Urban Planning Annual Conference (12 Urban and Rural Governance and Policy Research). Zhejiang Development Planning Research Institute; , 2024: 630-638.

[7] Lim J ,Kwon D ,Ha J S . Revisiting the growth poles: regional disparity and population redistribution policy[J]. The Annals of Regional Science, 2025, 74 (1): 22-22.

[8] ROOS GALJAARD, LEO VAN WISSEN and KIM VAN DAM. European Regional Population Decline and Policy Responses: Three Case Studies[J]. Built Environment (1978-), 2012, 38(2): 293-302.

[9] Hartt D M . How cities shrink: Complex pathways to population decline[J]. Cities, 2018, 7538-49.

[10] Yang Ge. Regional population growth and decline differentiation and population aging in Japan [J]. research on Japan, 2023,37(06): 51-61.

[11] Lou Fan, Li Xiaojian, Bai Yanfei. Analysis of the transition of China's coastal and inland economic pattern since 1978 [J]. China population, resources and environment, 2021, 31(05): 1-11

[12] Hou Li. aruhan Spatio temporal evolution and driving factors of regional population increase and decrease in China [J]. population journal, 2025,47 (03): 1-18.