The Impact and Mechanism of Population Growth-Decline Differentiation on Urban Economic Resilience in the Lanzhou-Xining Urban Agglomeration: Postprint

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Abstract

In the process of accelerating the construction of a new development pattern and promoting high-quality development, human capital has become a core element of inter-city competition. In recent years, the Lanxi urban agglomeration has experienced severe population loss and insufficient human capital competitiveness, directly affecting its urban economic resilience. This study selects six typical cities in the Lanxi urban agglomeration as the research area and employs a linear mixed-effects model to explore the impact and pathways of population increase-decrease differentiation on urban economic resilience in 2010, 2015, and 2020. The results indicate: (1) From 2010 to 2020, the urban economic resilience of major cities in the Lanxi urban agglomeration showed an overall upward trend, forming a "core-periphery" structure with Lanzhou City and Xining City as the core and other cities as the periphery. (2) Population increase-decrease differentiation directly affects the urban economic resilience of major cities in the Lanxi urban agglomeration, with population inflow having positive externalities on urban economic resilience. (3) The degree of industrial structure rationalization does not alter the intensity of the impact of population change on urban economic resilience. For population-outflow cities in the Lanxi urban agglomeration, initial population loss can, to a certain extent, promote industrial structure rationalization, but this industrial adjustment model is not sustainable. (4) Population change affects local informatization levels, which in turn influences urban economic resilience to a certain degree. Increases in population size facilitate improvements in urban informatization levels, thereby enhancing urban economic resilience. Based on the research conclusions, efforts should be made to enhance the urban economic resilience of major cities in the Lanxi urban agglomeration by promoting coordinated regional development, emphasizing human capital accumulation, accelerating industrial structure transformation and

upgrading, and prioritizing the coordinated advancement of population policies and informatization construction.

Full Text

Impact and Pathways of Population Growth-Decline Differentiation on Urban Economic Resilience in the Lanzhou-Xining Urban Agglomeration

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Abstract

As China accelerates the construction of a new development pattern and promotes high-quality development, human capital has become a core element of intercity competition. In recent years, the Lanzhou-Xining urban agglomeration has experienced severe population loss and insufficient human capital competitiveness, directly affecting its urban economic resilience. This study selects six typical cities in the Lanzhou-Xining urban agglomeration as the research area and employs a linear mixed-effects model to explore the impact and pathways of population growth-decline differentiation on urban economic resilience from 2010 to 2020. The results indicate: (1) The urban economic resilience of major cities in the Lanxi urban agglomeration showed an overall upward trend, forming a "core-periphery" structure with Lanzhou and Xining as the core cities and the remaining cities as the periphery. (2) Population growth-decline differentiation directly affects the urban economic resilience of major cities in the Lanxi urban agglomeration, with population inflows exerting positive externalities on urban economic resilience. (3) The degree of industrial structure rationalization does not alter the intensity of the impact of population change on urban economic resilience. For cities experiencing population loss in the Lanxi urban agglomeration, initial population outflows can promote industrial structure rationalization to some extent, but this adjustment model is not sustainable. (4) Population change influences local informatization levels, which in turn affects urban economic resilience. Population growth facilitates improvements in urban informatization, thereby enhancing urban economic resilience. Based on these findings, policy recommendations focus on promoting coordinated regional development, emphasizing human capital accumulation, accelerating industrial transformation and upgrading, and emphasizing the coordinated advancement of population policy and informatization construction to enhance the urban economic resilience of major cities in the Lanzhou-Xining urban agglomeration.

Keywords: population change; urban economic resilience; influence pathways; Lanzhou-Xining urban agglomeration

Introduction

China' s economy has transitioned from a high-speed growth phase to a high-quality development stage. In this new era, General Secretary Xi Jinping has clearly stated that China' s economic development has entered a "new normal" characterized by changing speed, structural optimization, and power conversion. In the process of accelerating the construction of a new development pattern and promoting high-quality development, human capital serves as an important source and lasting driver of economic growth. As China' s urbanization enters its mid-to-late stage, large populations and resources are rapidly concentrating in eastern regions, particularly in major cities. This phenomenon has caused many cities, especially numerous western cities, to face significant population loss pressure. Insufficient local labor force and high-tech talent have become important factors constraining the sustained and healthy socio-economic development of some western cities, while also hindering industrial upgrading and creating a clear "bottleneck" effect.

The concept of "resilience" originates from the Latin word "resilio," meaning "to bounce back." As a branch of resilience, economic resilience is defined as "the unique ability of an economic system to maintain stability and further drive recovery to a more robust development stage when facing and adapting to various uncertain shocks." Reggiani et al. creatively proposed the concept of urban economic resilience based on this definition, describing it as "the ability of a region' s economic system to recover to its pre-disturbance state after experiencing disruption or damage." Population growth-decline differentiation has a significant impact on urban economic resilience. Current domestic and international research on the relationship between population change and urban economic resilience is still in its infancy, with most existing studies focusing on theoretical analysis and fewer conducting dynamic research or regional analyses.

Previous studies have examined how population agglomeration affects urban economic resilience. For instance, Jiang Jing used data from 280 Chinese cities to investigate the impact of population concentration on urban economic resilience, finding that population agglomeration enhances urban economic resilience by stimulating consumer demand and promoting technological innovation. Other research has constructed theoretical frameworks and measurement models to study the impact of population agglomeration on urban economies, demonstrating that population concentration within cities promotes economic growth and strengthens urban economic resilience, making cities more stable when facing various challenges. Researchers have further found that compared to economic recovery capacity, urban population growth and shrinkage have a more pronounced impact on risk resistance capacity. Additionally, industrial structure

configuration and human capital levels play a positive moderating role in the relationship between population change and urban economic resilience. While a positive correlation exists between urban economic resilience and population growth, there are also cases where they diverge, allowing Chinese cities to be categorized into four types: population expansion with strong resilience, population expansion with weak resilience, population contraction with strong resilience, and population contraction with weak resilience.

The upper reaches of the Yellow River refer to the Yellow River basin area above Tuoketuo County, Hohhot City, Inner Mongolia Autonomous Region. Compared with the middle and lower reaches, the upper Yellow River region features numerous ethnic groups, relatively backward economies, and complex and severe ecological environmental problems, with exceptionally prominent contradictions between ecological protection and economic development. The Lanzhou-Xining urban agglomeration represents an important growth pole for economic development in the upper Yellow River region. However, due to unbalanced regional development and population concentration in eastern China, most cities in the Lanzhou-Xining urban agglomeration have become typical "population outflow areas." Local population outflow leads to substantial human capital loss, directly affecting industrial transformation and high-quality economic development in the Lanzhou-Xining urban agglomeration. Therefore, this study selects six typical cities in the Lanzhou-Xining urban agglomeration—Lanzhou, Xining, Baiyin, Dingxi, Haidong, and Hainan Tibetan Autonomous Prefecture—as the research area to assess the degree of population loss and its impact on urban economic resilience, aiming to provide theoretical support and policy recommendations for enhancing urban economic resilience and achieving high-quality economic development in the Lanzhou-Xining urban agglomeration.

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1 Study Area Overview

The Lanzhou-Xining urban agglomeration is centered around Lanzhou City and Xining City, encompassing prefecture-level cities and autonomous prefectures including Dingxi, Haidong, Linxia Hui Autonomous Prefecture, and Baiyin. It represents an important cross-provincial economic and cultural center in western China. The development of the Lanzhou-Xining urban agglomeration influences the economic growth of Gansu and Qinghai provinces while also driving economic growth in neighboring Tibet and Xinjiang. This plays a crucial role in promoting ethnic unity, strengthening national security in western China, and stabilizing development in southwestern regions.

Referring to the "Lanzhou-Xining Urban Agglomeration Development Plan" and considering data availability, this study selects six cities (prefectures) in the Lanzhou-Xining urban agglomeration—Lanzhou, Xining, Baiyin, Dingxi, Haidong, and Hainan Tibetan Autonomous Prefecture—as the research area (Fig. 1) to analyze the impact mechanisms of population change on urban

economic resilience in this region, providing policy optimization and support for local efforts to curb population loss, attract talent, and facilitate industrial transformation.

[Figure 1: see original paper]

2 Data and Methods

2.1 Data Sources

The primary data for this study are derived from the "Gansu Statistical Yearbook" and "Qinghai Statistical Yearbook" series from 2010 to 2020. Additionally, this research integrates multi-source information including economic census data at the municipal (prefecture) and county levels, government annual reports, and special survey data provided by statistical departments.

2.2 Research Methods

This study employs three scenario simulations to analyze the impact and pathways of population growth-decline differentiation on urban economic resilience in the Lanzhou-Xining urban agglomeration (Fig. 2).

Scenario 1: Focuses on analyzing the direct impact of population change on urban economic resilience. In this process, population growth may enhance the risk resistance capacity of the economic system, while population decline may weaken the adaptability and recovery capacity of the economic system.

Scenario 2: Focuses on analyzing the impact of regional industrial structure rationalization on urban economic resilience. Population change affects the supply scale and skill structure of the labor force, influencing the allocation efficiency of production factors and industrial matching. Therefore, the degree of industrial structure rationalization is affected, which may subsequently impact urban economic resilience.

Scenario 3: Focuses on analyzing how population change affects urban economic resilience under changing regional informatization levels. Informatization reflects the level of social development and the effectiveness of social progress. Higher informatization levels help reduce innovation costs and optimize resource allocation efficiency, potentially enhancing urban economic stability.

[Figure 2: see original paper]

2.2.1 Calculation of Urban Economic Resilience Current methods for calculating urban economic resilience can be broadly categorized into single-variable indicator methods and multi-variable indicator methods. Although the single-variable indicator method is relatively intuitive and yields concise results, it cannot directly reflect and characterize urban economic resilience. Therefore,

this study constructs an urban economic resilience evaluation system based on four dimensions: economic stability, economic innovation, economic recovery, and economic circulation, as shown in Table 1. The indicator system references frameworks summarized in previous research, incorporates indicator architectures related to "shock recovery capacity," and includes indicators of economic circulation, ultimately establishing 12 secondary indicators to comprehensively measure the urban economic resilience of six major cities (Lanzhou, Xining, Baiyin, Dingxi, Haidong, and Hainan Tibetan Autonomous Prefecture) in the Lanzhou-Xining urban agglomeration.

Economic Stability: A city' s economic stability relates to the coordinated development between its aggregate demand and aggregate supply. When a city' s aggregate demand and supply are relatively coordinated, urban economic resilience remains relatively stable and can exert strong self-coordination capabilities. Therefore, internal stability factors such as stable development of the urban economic system, low inflation and unemployment rates, and minimal economic fluctuations contribute to maintaining good economic stability. This study selects inflation rate, fiscal deficit rate, urban registered unemployment rate, and the ratio of net exports to GDP as four secondary indicators to measure the economic stability of major cities in the Lanzhou-Xining urban agglomeration. Among these, the inflation rate reflects the speed of currency purchasing power decline—lower inflation indicates better economic stability. As a positive indicator, per capita GDP is an important measure of urban economic development. The urban registered unemployment rate reflects the vitality and stability of urban economic development—lower unemployment indicates better economic stability. A higher ratio of net exports to GDP indicates better economic stability. The fiscal deficit rate reflects the stability of the internal economic system—lower fiscal deficits indicate better economic stability.

Economic Innovation: Economic innovation is a core driver of urban economic development. A city' s level of economic innovation is mainly reflected in education funding input, scientific and technological R&D investment, and innovation output. Improving economic innovation levels helps enhance urban economic resilience. From the perspective of local education investment, increased education funding can improve education quality, cultivate more high-quality labor with professional knowledge and skills to meet the needs of industrial upgrading, enhance industrial competitiveness, and strengthen urban economic resilience. Additionally, higher education funding can attract and retain talent, creating talent agglomeration effects and knowledge spillover effects that enhance urban economic risk resistance. Second, increased scientific and technological R&D investment plays an important role in transforming traditional industries, cultivating emerging industries, promoting innovation achievement transformation, and enhancing enterprise competitiveness, representing a key approach to strengthening urban economic resilience. Meanwhile, increased urban innovation output can promote innovation capacity, enabling stable urban economic development even when facing external shocks such as economic crises or market competition. Therefore, this study selects education funding input,

scientific and technological R&D investment, and innovation output as three secondary indicators to measure urban economic innovation.

Economic Recovery: The resilience of an urban economic system depends not only on its stability and innovation but also on its shock resistance and recovery capacity when facing new environments. When encountering "black swan" events such as financial crises or COVID-19, an urban economic system' s ability to resist shocks and achieve recovery growth represents the direct manifestation of strong urban economic resilience. In urban economic systems, investment scale, investment structure, consumption levels, and economic structure affect shock resistance and recovery capacity. From the perspective of investment scale and structure, expanded investment scale and optimized investment structure can promote healthy future economic and social development and help resist unknown risks. Increased consumption levels can stimulate investment growth and become a new driver of economic growth. Diversified economic structures can also enhance the stability and recovery capacity of urban economic systems. Therefore, this study selects per capita fixed asset investment, per capita retail sales of consumer goods, tourist numbers, GDP development level, and the proportion of private enterprise and self-employed employment as indicators to measure regional economic recovery capacity. Among these, per capita fixed asset investment represents investment scale—larger values indicate stronger urban economic recovery capacity. Increased per capita retail sales of consumer goods indicate expanded consumption demand and enhanced economic activity, which strengthen urban economic recovery capacity. Increased tourist numbers can expand consumption expenditure, promote investment activities, optimize economic structure, and increase government fiscal revenue, thereby enhancing urban economic recovery capacity. Higher GDP development levels indicate better economic foundations and stronger urban economic recovery capacity. A higher proportion of private enterprise and self-employed employment indicates stronger urban innovation, adaptability, and market vitality, which facilitate recovery growth.

Economic Circulation: Economic circulation is an important support for urban economic systems to resist shocks and achieve resilient recovery. When responding to shocks, strong capital absorption capacity forms the foundation of urban economic system circulation, mainly reflected in the scale of financial institution loan balances. Under effective risk control, higher loan balances not only reflect a city' s capacity to bear market demand but also enhance absorption capacity through capital circulation, ultimately improving the circulation efficiency of the economic system. Therefore, this study selects financial institution loan balances to measure urban economic circulation. Additionally, freight volume, as an indicator of urban logistics scale, can reflect both urban transportation infrastructure levels and economic activity. Thus, this study selects freight volume to measure urban economic circulation—higher freight volume indicates higher material circulation efficiency and better urban economic circulation.

2.2.2 Measurement of Population Change Considering the consistency between local resident population and registered population statistics and their uniform statistical 口径, this study uses the difference between local resident population and registered population to measure population growth and loss. Registered population refers to citizens who have registered their permanent household with local public security authorities at their usual place of residence, reflecting the de jure population within the local jurisdiction. Resident population refers to individuals who actually reside in a region for more than half a year, including both registered population and eligible non-registered residents. The difference between registered and resident population reflects whether a locality has experienced population shrinkage. The calculation formula is:

$$S_{it} = pop_{it}^{\text{hukou}} - pop_{it}^{\text{resident}}$$

where pop_{it}^{hukou} is the registered population of city i in year t; $pop_{it}^{\text{resident}}$ is the resident population of city i in year t; and S_{it} is the degree of population change in city i in year t. If $S_{it} > 0$, it indicates population loss; if $S_{it} < 0$, it indicates population growth.

2.2.3 Linear Mixed-Effects Model This study uses a linear mixed-effects model to examine the impact of population change in major cities of the Lanzhou-Xining urban agglomeration on urban economic resilience. Mixed-effects models generally include fixed effects and random effects, where fixed effects capture the influence of systematic variables such as population change, and random effects capture nested structures within urban agglomerations and non-systematic influencing factors. The general form of the linear mixed-effects model is:

$$Y_i = \text{Intercept} + \sum \beta x_i + \sum b_i z_i + \varepsilon_i$$

where Y_i is the urban economic resilience of city i; β represents fixed effects; x_i are fixed-effect variables; b_i represents random effects; z_i are random-effect variables; Intercept is the model intercept; and ε_i is the individual residual term. Based on existing research, this study adds the degree of industrial structure rationalization and local informatization level as mediating variables to analyze the impact mechanisms on top of the population change effect.

2.2.4 Mediating Variables This study introduces two mediating variables (degree of industrial structure rationalization and local informatization level) to analyze the mechanisms through which population change affects urban economic resilience. Following Li Yan' s research methodology, the degree of industrial structure rationalization is represented by the balance and coordination of inter-industry proportions, expressed as:

$$R_{it} = \sum_{i} \left(\frac{Y_{ijt}}{M_{it}} \ln \frac{Y_{ijt}/M_{it}}{P_{ijt}/P_{it}} \right)$$

where R_{it} is the degree of industrial structure rationalization in city i during period t; Y_{ijt} is the added value of industry j in city i during period t; M_{it} is the gross regional product of city i during period t; P_{ijt} is the employment in industry j in city i during period t; and P_{it} is the total employment in city i during period t.

The local informatization level is measured by the proportion of mobile phone users and internet users in the urban population, expressed as:

$$I_{it} = \frac{M_{it}}{P_{it}} + \frac{N_{it}}{P_{it}}$$

where I_{it} is the informatization level of city i during period t; M_{it} is the number of mobile phone users in city i during period t; N_{it} is the number of internet users in city i during period t; and P_{it} is the total population of city i during period t. This indicator comprehensively reflects regional informatization development levels through the sum of proportions of these two user groups.

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3 Results and Analysis

3.1 Evolutionary Characteristics and Spatial Patterns of Urban Economic Resilience

The urban economic resilience data for major cities in the Lanzhou-Xining urban agglomeration from 2010 to 2020 (Table 2) show that urban economic resilience generally increased during this period, though significant differences exist among cities. Lanzhou and Xining, as the core cities of the agglomeration, exhibited particularly notable growth in urban economic resilience, with Lanzhou' s resilience increasing nearly fourfold from 0.14 to 0.54. In contrast, other cities experiencing population loss showed slower growth in urban economic resilience. Hainan Tibetan Autonomous Prefecture had relatively high urban economic resilience in 2010, but its growth rate was particularly slow thereafter. Although its urban economic resilience level rebounded noticeably in 2020, it remained at a relatively low level overall.

Using the natural breaks method, the 2020 data were divided into three categories (high, medium, and low) for analysis (Fig. 3). The results show that the two core cities, Lanzhou and Xining, demonstrate significant advantages in urban economic resilience, exhibiting stronger stability and innovation. Meanwhile, population loss cities such as Haidong, Baiyin, and Dingxi generally have lower levels of economic resilience. The urban economic resilience of major

cities in the Lanzhou-Xining urban agglomeration is roughly symmetrically distributed, forming a distinct "core-periphery" structure. The dual-core polarization effect of Lanzhou and Xining is particularly prominent, with urban economic resilience showing significant gradient characteristics that decrease from the dual-core center to surrounding areas.

Among these, Hainan Tibetan Autonomous Prefecture had relatively high urban economic resilience in 2010, but its subsequent growth was relatively flat, and its economic position gradually became marginalized. The economic development trajectory of Hainan Tibetan Autonomous Prefecture exhibits significant phased characteristics. During the 2010-2015 period, Hainan Tibetan Autonomous Prefecture demonstrated strong urban economic resilience in its early development stage, relying on mineral resource development, agricultural and pastoral foundations, and tourism industries. However, in recent years, as ecological protection efforts on the Qinghai-Tibet Plateau have continued to advance, Hainan Tibetan Autonomous Prefecture faces multiple constraints in mineral resource development and grassland utilization. The transformation pressure of this development model directly affects the improvement of its urban economic resilience level.

In summary, urban economic resilience in different cities of the Lanzhou-Xining urban agglomeration shows significant spatial heterogeneity, reflecting the unbalanced development within the region. The urban economic resilience in this region has formed a distinct "core-periphery" structure during its dynamic evolution.

3.2 Impact Effect Identification of Population Change on Urban Economic Resilience

The impact of population change on urban economic resilience can be analyzed through two main aspects. On one hand, population and talent inflows directly increase urban human capital stock, expand labor supply, and bring valuable resources such as knowledge and skills, thereby enhancing local industrial technology levels and innovation capacity, which improves urban economic stability and innovation. On the other hand, population outflows lead to human capital loss, creating a vicious cycle of "population loss → local industrial development constraints → economic structural unemployment → continued labor outflow" that affects urban economic stability and recovery capacity. However, for some population outflow areas, although labor and human capital loss pose challenges, income transfers from migrant workers (such as remittance effects) may relatively improve local residents' income levels and social welfare. This capital 回流 not only helps narrow income gaps among local residents but may also alleviate regional economic development imbalances through consumption-driven effects.

3.2.1 Impact of Population Change on Urban Economic Resilience

By adjusting the random effects parameter structure, six linear mixed-effects models were fitted (Table 3). Models 5 and 6 have the same corrected Akaike

information criterion and log-likelihood, but Model 6 includes both city and year random effects. Model 6 explains 88.9% of the variance, indicating that population change has cross-city and cross-temporal heterogeneity in its impact on urban economic resilience. Meanwhile, residual diagnostics of the fitting results show that the residuals of this linear mixed-effects model conform to normal distribution assumptions. Therefore, Model 6 was selected for comprehensive consideration.

The results show that all model parameters pass significance tests at the 0.001 level (Table 4). The model' s technical results indicate that the regression coefficient of the population change variable is negative, showing a significant negative association with urban economic resilience. In cities with population growth, such as Lanzhou and Xining, larger population growth rates more clearly promote urban economic resilience. In other cities experiencing population loss, as the degree of loss increases, their urban economic resilience gradually declines. The between-group variance is at the same magnitude as the population change amplitude, reflecting significant differences among cities in the explanatory power of random effect terms on the dependent variable, which is related to factors such as different cities' economic development levels, industrial structure characteristics, and resource-environment foundations.

3.2.2 Mechanism Analysis of Population Change Impact on Urban Economic Resilience Based on the scenario simulation analysis above, the impact of population change on urban economic resilience mainly operates through the degree of industrial structure rationalization and informatization level. To verify the effectiveness of these mediating mechanisms, this study constructed a dual-mediation effects model for testing (results shown in Table 5). The data show that in the baseline model without mediating variables, the direct effect value of population change on urban economic resilience is -0.18 ($p < 0.001$), confirming a direct negative association between population loss and urban economic resilience. Notably, when mediating variables are included, the regression coefficient of the core explanatory variable decreases to -0.11, a reduction of 38.9% compared to the baseline model, which proves the existence of mediating effects as expected.

Mediation effect test results (Table 6) show that the mediating role of industrial structure rationalization does not pass significance tests, indicating that introducing the degree of industrial structure rationalization does not change the estimated impact of population change on urban economic resilience. These two explanatory variables act independently in the model but both contribute significantly to explaining urban economic resilience. For Lanzhou and Xining, population growth is a significant factor directly promoting increased urban economic resilience, while changes in industrial structure rationalization cannot significantly demonstrate its promoting effect in the short term. For other cities, population loss is significantly negatively correlated with urban economic resilience, consistent with Lu Fenggang' s research findings. However, unlike

that study, for cities in the Lanzhou-Xining urban agglomeration experiencing population loss, a certain degree of population loss promotes their industrial structure rationalization. This occurs because population loss prompts local industrial enterprises to undergo structural adjustments to adapt to the new environment with reduced population, and these adjustments develop toward more efficient, lower-energy, and lower-cost directions, temporarily improving industrial structure rationalization. However, this population-loss-driven industrial restructuring lacks sustainability and cannot directly resist the negative impacts caused by population loss.

According to test results (Table 6), informatization level plays a partial mediating role between population change and urban economic resilience, but its explanatory power is relatively limited (contribution rate of 29.63%). This indicates that population change leads to changes in local informatization levels, which in turn affect urban economic resilience within a certain range. For cities with population growth, increased population promotes improved informatization, thereby enhancing urban economic resilience. Conversely, for cities experiencing population loss in the urban agglomeration, population reduction leads to decreased information flow and exchange, further weakening cities' ability to respond to changes and shocks. The decline in informatization levels makes urban economic resilience more vulnerable.

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4 Conclusions and Implications

4.1 Conclusions

1) The six typical cities in the Lanzhou-Xining urban agglomeration showed an overall upward trend in urban economic resilience from 2010 to 2020. However, significant differences in urban economic resilience exist among cities, forming a "core-periphery" structure with population growth cities —Lanzhou and Xining—as the core, while other population loss cities remain relatively peripheral. Among these population loss cities, Hainan Tibetan Autonomous Prefecture' s urban economic resilience growth rate is particularly slow, facing an obvious "growth bottleneck" problem.

2) Population change is one of the important factors affecting the urban economic resilience of major cities in the Lanzhou-Xining urban agglomeration. The impact of population change on urban economic resilience can be analyzed through two aspects: on one hand, population inflow brings positive externalities to urban economic resilience, helping to improve urban economic stability and innovation; on the other hand, population outflow creates negative externalities for urban economic resilience, exerting significant pressure on urban economic stability, innovation, and recovery capacity.

3) As a mediating variable, the degree of industrial structure rationaliza-

tion does not reach a significant level of impact. This indicates that the degree of industrial structure rationalization and population change independently affect urban economic resilience as important factors. Therefore, introducing the degree of industrial structure rationalization does not change the intensity of population change' s impact on urban economic resilience. Additionally, in cities within the Lanzhou-Xining urban agglomeration that experience population loss, initial population loss can promote industrial structure rationalization to some extent, driving industrial enterprises toward more efficient, lower-energy, and lower-cost development. However, this population-loss-driven industrial restructuring lacks sustainability and cannot effectively resist the negative impacts of population loss.

4) Informatization level has a certain mediating effect on urban economic resilience, but this mediating effect is relatively weak. Changes in regional population cause fluctuations in informatization levels, thereby affecting urban economic resilience within a certain range. When population numbers increase, informatization levels improve, which to some extent enhances urban economic resilience. Conversely, population reduction leads to decreased information flow and exchange, weakening cities' ability to respond to various changes and shocks. Meanwhile, reduced informatization levels further make urban economic resilience more vulnerable.

4.2 Policy Implications

1) **Promote coordinated regional development according to local conditions.** For Lanzhou and Xining, excessive resource concentration should be avoided to prevent the "siphon effect" from exacerbating the difficulties of peripheral cities. These core cities need to strengthen industrial synergy with surrounding cities, such as jointly building industrial parks and sharing upstream and downstream industrial chain resources, to drive industrial development in peripheral cities and help them break through the "growth bottleneck." For population loss cities, particularly Hainan Tibetan Autonomous Prefecture, attention should be paid to cultivating characteristic and advantageous industries under the premise of ecological protection, such as developing tourism industries based on local ethnic cultures and creating distinctive agricultural product brands to enhance urban economic resilience and gradually narrow the gap with core cities, promoting the overall coordinated development of the Lanzhou-Xining urban agglomeration.

2) **Emphasize talent attraction, cultivation, utilization, and retention, focusing on human capital accumulation.** For population inflow cities like Lanzhou and Xining, efforts should continue to optimize the business environment to attract high-end talent and innovative enterprises, strengthen the supply of public services such as education and healthcare, and enhance urban carrying capacity to further improve eco-

nomic stability and innovation capacity. For population loss cities like Hainan Tibetan Autonomous Prefecture and Dingxi, it is necessary to deeply analyze outflow reasons such as insufficient employment opportunities and low income levels, and formulate corresponding policies. By developing characteristic industries and strengthening regional cooperation, measures should be taken to promote cross-regional labor mobility and employment to alleviate population outflow pressure and enhance urban economic resilience.

3) **Accelerate industrial transformation and upgrading to promote healthy and sustainable urban economic development.** In terms of industrial structure adjustment, cities in the Lanzhou-Xining urban agglomeration experiencing population loss should avoid over-reliance on the short-term industrial structure rationalization brought by population loss. The government should introduce policies to guide enterprises toward sustainable industrial upgrading, such as providing technical transformation subsidies and encouraging enterprise R&D innovation, to enhance enterprise competitiveness and resist the negative impacts of population loss.

4) **Emphasize the coordinated advancement of population policy and informatization construction.** On one hand, optimize population policies to attract talent inflows and increase human capital, providing a human resource foundation for informatization development. On the other hand, increase investment in informatization infrastructure to improve informatization levels and enhance urban economic resilience. Simultaneously, attention should be paid to informatization construction in population loss areas of the Lanzhou-Xining urban agglomeration to avoid informatization level decline caused by population loss, which would further weaken urban economic resilience. Only in this way can major cities in the Lanzhou-Xining urban agglomeration become more resilient when facing various changes and shocks, achieving sustainable development.

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Note: Figure translations are in progress. See original paper for figures.