

Analysis of Spatiotemporal Variations and Influencing Factors of Human Resources in Xinjiang Counties (Post-Print)

Authors: Sun Jiming

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Abstract

Based on data from the fifth and sixth national population censuses, and employing regional human resource measurement methods, multiple linear regression, and geographic detector research methods, this study analyzes the spatiotemporal distribution differences and influencing factors of human resources at the county level in Xinjiang. The results show that: (1) From 2000 to 2010, the total human resources in Xinjiang increased by 54.89%, characterized by dispersed distribution and increasing spatial disparities; the per capita human resources level increased by 30.71%, with regional disparities mainly manifested as differences between southern and northern Xinjiang, showing a pattern of low-value clustering and high-value dispersion. (2) After excluding the cumulative effect of educational investment in human resources, counties (cities, districts) with increased total human resources in Xinjiang from 2000 to 2010 were mainly concentrated in southern Xinjiang, while northern and eastern Xinjiang experienced mainly decreases, and the improvement in per capita human resources in southern Xinjiang was significantly higher than that in northern and eastern Xinjiang. (3) The spatiotemporal distribution differences of per capita human resources in Xinjiang are influenced by multiple factors; apart from educational factors, employees in secondary and tertiary industries, per capita gross domestic product (GDP), local fiscal revenue, and the number of personnel engaged in health and social security are relatively significant driving factors. The findings of this study can provide references for narrowing regional human resource development disparities in Xinjiang in the new era.

Full Text

Spatial and Temporal Variations and Influencing Factors of Human Resources at the County Level in Xinjiang

SUN Jiming^{1, 2}, LI Jiangang^{1, 2}, LEI Jun^{1, 2}, YANG Zhen³, DUAN Zuliang¹

¹Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, Urumqi 830011, Xinjiang, China

²College of Resources and Environment, University of Chinese Academy of Sciences, Beijing 100049, China

³School of Geography, Geomatics and Planning, Jiangsu Normal University, Xuzhou 221116, Jiangsu, China

Abstract

This study utilizes data from the fifth and sixth national population censuses of Xinjiang to estimate regional human resources based on education fund investment. Due to the cumulative nature of education investment, we developed a calculation method for human resource changes that excludes the accumulation of education investment, enabling analysis of spatiotemporal characteristics both with and without this adjustment. The influencing factors of human resource distribution across Xinjiang's counties are examined using multiple linear regression and geographical detector techniques. The findings provide references for improving human resource quality, optimizing spatial allocation, and supporting regional economic development and social stability in Xinjiang. The results indicate: (1) Without excluding accumulated education investment, Xinjiang's total human resources increased by 54.89% from 2000 to 2010, showing characteristics of dispersed distribution and increasing spatial disparity. Per capita human resources rose by 30.71% during the decade, with regional differences primarily manifested as north-south Xinjiang contrasts, exhibiting low-value clustering and high-value dispersion. (2) After excluding education investment accumulation, counties with increased total human resources were concentrated mainly in southern Xinjiang, while northern and eastern Xinjiang experienced decreases. The improvement in per capita human resources was significantly more pronounced in southern Xinjiang than in northern and eastern regions. (3) Multiple factors influence spatiotemporal differences in per capita human resources. Besides education, significant drivers include employment in secondary and tertiary industries, per capita gross domestic product, local fiscal revenue, and the number of health and social security workers.

Keywords: human resources; county level; influencing factors; Xinjiang

1 Study Area Overview

Xinjiang is located in northwestern China at the heart of the Eurasian continent, serving as a critical node on the Eurasian Land Bridge. The region covers a total

area of $166 \times 10^4 \text{ km}^2$ and comprises 14 prefecture-level administrative units (4 prefecture-level cities, 5 autonomous prefectures, and 5 prefectures), which are geographically divided into southern Xinjiang, northern Xinjiang, and eastern Xinjiang. The study area includes 98 counties (cities and districts), with 42 in northern Xinjiang, 48 in southern Xinjiang, and 8 in eastern Xinjiang. It should be noted that due to administrative boundary changes, this study uses the 2010 Xinjiang county-level vector map as the base map. Newly established cities such as Aral, Huyanghe, Kunyu, and Khorgos are excluded due to missing data.

Figure 1 Schematic diagram of study area (Note: This figure is based on the standard map GS(2019)1825 downloaded from the National Administration of Surveying, Mapping and Geoinformation's standard map service website, with no modifications to boundary lines. The same applies below.)

2.1 Data Sources

Considering data availability and accuracy, this study employs data from Xinjiang's fifth and sixth national population censuses. Educational attainment is categorized into seven levels: no schooling, primary school, junior high school, senior high school (including technical secondary school), junior college, bachelor's degree, and postgraduate. The population count (p) for each educational stage is calculated. To account for price factors in education funding and ensure consistency with county-level population data, while maintaining comparability across time points and better reflecting human resource changes, we uniformly adopt the number of students enrolled in regular primary schools, junior high schools, senior high schools (including technical secondary schools), and regular institutions of higher education (with education expenditures for junior college, bachelor's, and postgraduate levels all calculated according to regular higher education institutions' annual expenditures) from the *Xinjiang Statistical Yearbook 2011*. This allows calculation of per capita education expenditure (e) for each educational stage. The education expenditure for the population with no schooling is set at 0.

2.2.1 Regional Human Resource Calculation Method

Human resources refer to the sum of knowledge and labor skills possessed by the working-age population in a region, reflecting both quantitative and qualitative characteristics such as knowledge, skills, and health. Common methods for measuring regional human resource quality include average education years and education expenditure approaches. The average education years method offers good data availability and precision but overlooks knowledge accumulation effects, whereas the education expenditure method accounts for knowledge accumulation.

Human resource quality investment plays a crucial role in promoting social and economic development, encompassing investments in education, training,

healthcare, and employment. Education investment yields the highest returns, strongest practicality, and is relatively easy to quantify with strong regional comparability. Based on education expenditure and following the regional human resource calculation method by Xu Zening et al. [14,24], this approach considers that different educational groups receive varying education investments and knowledge levels, reflecting both educational attainment and investment quantity. The method is as follows:

$$hr = \sum_{i=1}^7 \sum_{j=1}^7 p_i \times e_j$$

where hr represents the total human resources of each Xinjiang county (city, district) in monetary terms; i and j denote educational stages including the seven categories from no schooling to postgraduate; p is the population aged 15 and above who completed educational stage i ; and e is the per capita education expenditure for stage j (in yuan). This model calculates the total human resources for each county, representing the monetized expression of the population's overall knowledge and skill levels.

To reflect average population quality, per capita human resources are defined as the ratio of total human resources to the population aged 15 and above:

$$\text{average}(hr) = \frac{hr}{\sum_{i=1}^7 p_i}$$

2.2.2 Method for Calculating Human Resource Changes Excluding Educational Investment Accumulation

Due to the annual accumulation of education investment, both total and per capita human resources increase with overall education investment growth. The difference between two time points cannot objectively reflect relative change differences without removing the accumulated human resource investment from the first year. Therefore, to better reflect net growth changes, this study designs a calculation method for relative human resource changes. First, we calculate the overall human resource change rate (r) for Xinjiang's counties from 2000 to 2010, then compute the expected human resource level in 2010 based on this rate $[(hr_{2010})]$. The difference between the actual 2010 value (hr_{2010}) and the rate-calculated value $[(hr_{2010})]$ represents the human resource change value (Δhr) after excluding accumulation effects:

$$\Delta hr_i = hr_{i2010} - (1 + r) \times hr_{i2000}$$

where r is the human resource change rate, hr_{2010} and hr_{2000} are the actual human resource values for county i in 2010 and 2000 respectively, and Δhr is the human resource change value after excluding accumulation effects.

2.2.3 Multiple Linear Regression Method

Multiple linear regression is a mature and widely used method in geography. To explore statistical relationships between per capita human resource spatial differentiation and various influencing factors, we employ a multiple linear regression model to quantitatively examine each factor's impact. Collinearity diagnostics were performed to obtain a linear model relating each factor to per capita human resource spatial differentiation.

2.2.4 Geographical Detector Analysis Method

Geodetector is a tool for detecting and utilizing spatial stratified heterogeneity. The model is immune to multicollinearity among multiple independent variables, provides specific detection power values, can test the spatial differentiation of single variables, and identifies factor determinacy strength. The formula is:

$$P_{D,U} = 1 - \frac{1}{n\sigma_U^2} \sum_{i=1}^m n_{D,i} \sigma_{U,D,i}^2$$

where $P_{D,U}$ represents the explanatory power of determinant factor D on per capita human resources U ; n and σ^2 are the regional sample size and variance respectively; σ^2 is the variance of regional per capita human resources; m is the number of subregions; $n_{D,i}$ is the sample size of subregion i ; and $\sigma_{U,D,i}^2$ is the variance of subregion i . Assuming $\sigma_{U,D,i}^2 \neq 0$, the model holds. $P_{D,U}$ ranges from $[0,1]$. When $P_{D,U} = 0$, human resources are randomly distributed. Larger $P_{D,U}$ values indicate greater influence of a factor on per capita human resources.

3.1.1 Spatiotemporal Changes of Total Human Resources Without Excluding Educational Investment Accumulation

From 2000 to 2010, Xinjiang's total human resources increased significantly from 2133.56×10^8 yuan to 3304.62×10^8 yuan, a growth of 54.89%. The Global Moran's I index for county-level human resources was 0.548 in 2000 and 0.548 in 2010 ($p < 0.01$), indicating that human resources exhibit significant spatial autocorrelation while showing characteristics of dispersed distribution and increasing regional spatial differences.

In 2000, most counties had relatively low total human resources, with higher-value areas scattered discontinuously, primarily in Urumqi's districts (Tianshan, Shayibake, Xinshi), Shihezi, Aksu, and Hami cities (Figure 2). By 2010, high-value areas showed concentrated and contiguous distribution, mainly in the Tianshan North Slope urban agglomeration, Korla, Yining, Hami, and surrounding regional central cities. Low-value areas were predominantly located in peripheral counties (Figure 2).

3.1.2 Spatiotemporal Changes of Total Human Resources Excluding Educational Investment Accumulation

After excluding educational investment accumulation, distinct regional differences emerged in human resource changes from 2000 to 2010. Northern and eastern Xinjiang experienced mainly decreases, while southern Xinjiang saw increases. Overall, counties with reduced human resources were concentrated in northern border areas, eastern border regions, and most counties in the Tianshan North Slope urban agglomeration. Counties with increased human resources were primarily in southern Xinjiang (Figure 3). In terms of magnitude, the largest decreases occurred in Urumqi County and Shihezi City in northern Xinjiang, while the most significant increases were in Urumqi's Xinshi, Shuimogou, and Tianshan districts (Figure 3).

3.2.1 Spatiotemporal Changes of Per Capita Human Resources Without Excluding Educational Investment Accumulation

Xinjiang's per capita human resources demonstrated significant spatial autocorrelation, with Global Moran's I values of 0.153 in 2000 and 0.155 in 2010 ($p < 0.01$), showing weakening agglomeration and increasing spatial differences. In 2000, per capita human resources exhibited low-value clustering and high-value dispersion, with low values concentrated in southern Xinjiang and high values scattered in Urumqi and Karamay cities (Figure 4). By 2010, high-value clustering became prominent, concentrated in the Tianshan North Slope urban agglomeration, Yining, Korla, Hami, and surrounding areas. Low values were relatively concentrated in counties such as Hotan, Pishan, Moyu, Yutian in Hotan Prefecture, and Bachu, Shufu, Jiashi in Kashgar Prefecture (Figure 4).

With continuous education investment and accumulation, county-level per capita human resources improved overall from 1.66×10^4 yuan to 1.27×10^5 yuan, though regional disparities remained evident.

3.2.2 Spatiotemporal Changes of Per Capita Human Resources Excluding Educational Investment Accumulation

After excluding educational investment accumulation, per capita human resource changes showed significant regional differences. From 2000 to 2010, 59.18% of Xinjiang's counties (cities, districts) experienced per capita human resource increases, while 40.82% saw decreases. The improvement magnitude in southern Xinjiang counties was significantly higher than in eastern and northern Xinjiang. The most substantial increases occurred in Taxkorgan Tajik Autonomous County, Moyu County, Akto County, and Minfeng County in southern Xinjiang, while the most notable decreases were in Urumqi and Karamay cities (Figure 5).

4 Analysis of Influencing Factors on Spatiotemporal Differences in Per Capita Human Resources

Regional human resource differences are influenced by multiple factors. Following principles of scientificity, rationality, and data availability, we establish a multiple linear regression model with per capita human resources as the dependent variable. Three dimensions—population base, socioeconomic base, and social security base—are examined through 13 indicators (Table 1).

Population base: Population constitutes the foundation of human resources. Total human resources correlate closely with regional population size [1,6,14-15,25,32-35]. We select total population and natural growth rate to measure county-level population conditions. Population migration represents a necessary pathway for rational human resource allocation and optimization [14,24], so we include the proportion of different migration types to characterize migration's impact on per capita human resource distribution.

Socioeconomic base: Regional economic development level is the dominant factor affecting human resource spatial differences [15,32]. Per capita GDP reflects regional economic development potential, employment opportunities, and living standards [1,6,14-15,25,32-35]. Local fiscal revenue largely indicates economic development potential, job opportunities, and living comfort [15,32]. Average wages of employed staff directly influence job satisfaction and attractiveness [1,6,14-15,25,32-35]. Urbanization provides opportunities for human resource agglomeration, measured by urban population proportion [14,24]. The proportion of secondary and tertiary industry employees and total retail sales of consumer goods reflect the market economic environment attracting human resources [1,6,14-15,25,32-35].

Social security base: Effective healthcare and pension security mechanisms promote human resource investment accumulation [1,6,14-15,25,32-35]. We select hospital/health center beds, social welfare institution beds, number of social welfare institutions, and health/social security personnel to measure county-level social security levels.

To avoid multicollinearity, we conduct significance testing ($p < 0.05$) and variance inflation factor analysis ($VIF < 5$), ultimately selecting five significant variables (Table 2). Model goodness-of-fit reaches 87.6% for 2000 and 74.5% for 2010, both highly significant, with coefficients matching expected directions.

The 2000 model shows: (1) Total population, natural growth rate, and population migrating within the province are significantly negatively correlated with per capita human resources, indicating that population base changes affect per capita human resource levels. (2) Higher urbanization rates and proportions of secondary/tertiary industry employees correlate with better market economies that attract human resources, leading to more obvious per capita human resource improvements. This suggests that spatial distribution differences in Xinjiang's per capita human resources were mainly influenced by population base

changes and market environments attracting human resources.

Compared with 2000, the 2010 model shows that besides the proportion of secondary/tertiary industry employees, per capita GDP, local fiscal revenue, and health/social security personnel significantly influence county-level per capita human resources, indicating that counties with better economic development and healthcare conditions had higher per capita human resource levels.

For the four significant factors identified in the 2010 regression, we apply natural breaks classification and use Geodetector to calculate each factor's decisive power on Xinjiang's county human resource levels ($P D, U$) (Table 3). Factor detection results show that in 2000, urbanization rate, proportion of secondary/tertiary industry employees, proportion of intra-provincial migrants, and natural growth rate significantly drove per capita human resource spatial distribution differences, with decisive powers of 0.412, 0.386, 0.271, and 0.185 respectively. In 2010, secondary/tertiary industry employee proportion, per capita GDP, local fiscal revenue, and health/social security personnel passed significance tests, with decisive powers of 0.446, 0.382, 0.314, and 0.287 respectively, further confirming the regression analysis results.

5.1 Discussion

This study's comparison of results with and without excluding education investment accumulation reveals different outcomes. Without exclusion, Xinjiang's human resource changes were influenced by both education investment accumulation and population migration. Compared with migration, the continuous accumulation of education investment for all educational levels across Xinjiang played a dominant role in human resource changes. After excluding education investment accumulation, population migration significantly impacted human resource changes. Most counties in the Tianshan North Slope urban agglomeration experienced decreases in both total and per capita human resources, likely due to: (1) As the core city of the Tianshan North Slope Economic Belt, Urumqi holds clear advantages in economic and social development indicators [36]. Since the proposal of the "Urumqi Metropolitan Circle" and "Urumqi-Changji Integration," human resources from surrounding counties have continuously flowed into Urumqi's districts, causing noticeable human resource reductions in other municipal and county areas. (2) Consistent with existing research on Xinjiang's brain drain [19,23], Xinjiang's relatively lagging economic and social development has led to outflow of highly educated populations to inland areas, creating difficulties in attracting outstanding talents from other provinces while losing local talent, with outflows far exceeding inflows. (3) In 2010, Xinjiang's population migration was dominated by inter-provincial net inflow [37], with migrants primarily from northwestern, southwestern, and central-south China. Most inflows consisted of populations with medium-to-low education levels, resulting in low-quality population expansion and obvious per capita human resource decreases.

The implementation of national poverty alleviation programs has strengthened education investment in impoverished counties across southern Xinjiang, achieving full coverage of 12-year compulsory education and significantly improving human resource quantity and quality. By 2020, all national-level poverty counties in southern Xinjiang had been lifted out of poverty. Further structural analysis of education investment is needed to explore the sustainable impact of human resources on poverty alleviation effectiveness. Additionally, due to data availability and comparability limitations, this study only uses the fifth and sixth census data. Future research should incorporate the seventh census data for more comprehensive analysis. The regional human resource calculation method does not include family education investment, neglecting regional and inter-annual differences in education investment, and the indicator system requires further enrichment.

5.2 Conclusions

Based on education investment calculations of regional human resources and accounting for the cumulative nature of education investment, this study compares spatiotemporal changes with and without excluding education investment accumulation. The findings reveal:

- (1) Without excluding education investment accumulation, Xinjiang's county-level total human resources and per capita human resources improved significantly, with increases of 54.89% and 30.71% respectively. After excluding education investment accumulation, changes in both total and per capita human resources showed regional patterns, with decreases dominating in northern and eastern Xinjiang and increases in southern Xinjiang.
- (2) The spatial distribution of total human resources shifted from high-value dispersion to a pattern of low-value dispersion embedded with high-value concentration. North-south and east-west differences in per capita human resources were significant and widening.
- (3) In 2000, spatiotemporal distribution differences in per capita human resources were mainly influenced by urbanization rate, proportion of secondary/tertiary industry employees, proportion of intra-provincial migrants, and natural growth rate. In 2010, secondary/tertiary industry employee proportion, per capita GDP, local fiscal revenue, and health/social security personnel had significant impacts.

These conclusions indicate that Xinjiang's human resource development exhibits regional differences primarily influenced by economic development level, industrial structure, and social security factors. Therefore, future priorities for Xinjiang's regional human resource development should include: (1) Focusing on the core area construction of the Silk Road Economic Belt to cultivate new economic growth drivers and promote high-quality development, particularly by strengthening economic development in underdeveloped areas such as southern Xinjiang and border regions to enhance overall economic levels and

narrow regional development gaps. (2) Using the Silk Road Economic Belt's core area medical service center construction as an opportunity to advance Healthy Xinjiang initiatives, improve the medical service system, actively promote national-level regional medical centers, enhance medical service capacity, and better meet people's basic medical needs and diversified, multi-level health demands to continuously improve urban and rural residents' health levels. (3) Implementing diversified talent policies, intensifying talent recruitment, optimizing talent development environments, and providing special incentive policies to encourage and guide talent flow to remote, border, and grassroots areas.

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Figure 2 Spatial distributions of total human resources at county level in Xinjiang in 2000 and 2010

Figure 3 Spatial pattern of the total amount of human resources change at county level in Xinjiang after excluding the accumulation of human resources education investment in 2000 and 2010

Figure 4 Spatial distributions of per capita human resources at county level in Xinjiang in 2000 and 2010

Figure 5 Spatial pattern of per capita human resources change at county level in Xinjiang after excluding the accumulation of human resources education investment in 2000 and 2010

Table 1 Influencing factors of spatial distribution differences of per capita human resources at county level in Xinjiang

Table 2 Estimated results of influencing factors of spatial distribution differences of per capita human resources at county level in Xinjiang

Table 3 Decisive powers and dynamic changes of the influencing factors on the spatial distribution of per capita human resources at county level in Xinjiang

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

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