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COMMENTARY

Demographic transition and population dynamics in Xinjiang, China

Jianxin Li[1] · **Liya Qiu**[1]

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Abstract
This study is based on census data, statistical yearbooks, and research materials related to the population in Xinjiang, providing a comprehensive analysis and description of population changes and development in the region. The research findings indicate that the population changes in Xinjiang follow general demographic patterns. With the concurrent development of socio-economic factors, the implementation of institutional regulations, and shifts in attitudes toward marriage and childbearing, the fertility in Xinjiang is inevitably declining.

Keywords Xinjiang · Demographic transition · Total fertility rate · Cohort indicators

1 Demographic transition in Xinjiang

Whether it is the Western countries that led industrialization in the mid-eighteenth century or the developing countries (including China) after the mid-twentieth century, the history of demographic transition proves that it is a universal phenomenon. This transition refers to the shift from a state of high birth and death rates in pre-industrial societies to low birth and death rates in industrial societies (Kirk, 1996). This pattern of change has been summarized in demographic studies as the theory of demographic transition.

Since the 1930s, various theories have emerged to describe and explain demographic transitions, including the three-stage theory (Notestein, 1945), the four-stage theory (Notestein, 1953), and the five-stage theory (Blacker, 1947). In the 1980s, European scholars Lesthaeghe and van de Kaa (1986) proposed the Second Demographic Transition theory. They argued that after the completion of the classical demographic transition, widespread use of contraception methods led to a decline in

✉ Jianxin Li
ljx@pku.edu.cn

Liya Qiu
qiuly33@pku.edu.cn

[1] Sociology Department, Peking University, Beijing, China

fertility rates below replacement levels,[1] which is the core characteristic of the second demographic transition (Van De Kaa, 1987, 1994). Although the driving forces behind the decline in fertility rates are different in the two demographic transitions, with social and economic development and changing values, fertility levels tend to decline, making low fertility a global trend.

Examining the demographic changes in China, it follows the universal patterns of demographic transition but exhibits several significant characteristics compared to the classical demographic transition. Firstly, the decline in death and birth rates is rapid, and the entire demographic transition cycle is relatively short, exhibiting temporal compressibility (Li, 2005). For example, the time it takes for the birth rate to decrease by 50%, even in later-developing countries where the decline in fertility rates occurs later, is typically around 30 years, whereas China accomplished this in less than 20 years. Secondly, there are internal differences in demographic transition. On the one hand, this is manifested in regional disparities between the eastern, central, and western regions (Li, 2000; Li & Chang, 2016). On the other hand, it is evident between the Han ethnic group and minority ethnic groups, and, of course, within minority ethnic groups, particularly in terms of changes in fertility levels (Duan et al., 2021; Huang, 2009; Li & Qiu, 2022; Xiao et al., 1991). Thirdly, in terms of the analysis of the reasons for the decline, China's population policies have played a crucial role in the demographic transition, especially in the changes in fertility levels. This is the result of the combined effects of the external push of the family planning policy and the intrinsic driving force of economic and social development.

Xinjiang, as an area with a concentration of minority ethnic populations, exhibits characteristics of population change that both follow general demographic transition patterns and possess certain distinct features such as relative lag, structural differences, and volatility. Relative lag refers to the fact that the transition in fertility rates in Xinjiang occurs later compared to the national average. Since 1949, the demographic transition in Xinjiang started with high birth and death rates. The death rate began to fall first, while the fertility rate exhibited relative lag and slower decline. However, there was still a downward trend, and the natural growth rate showed a trend of first rising and then falling. By 2018, Xinjiang had completed its demographic transition, achieving a balance with low levels of birth rates, death rates, and natural growth rates (see Fig. 1). However, compared to the national average, Xinjiang's demographic transition was relatively delayed. For instance, while the natural growth rate of the national population dropped to single digits (per thousand) in the early twenty-first century, Xinjiang reached a similar level after 2018.

Structural differences refer to variations in the demographic transition processes among different regions, ethnic groups, and localities within Xinjiang (Li

[1] The replacement level refers to maintaining a fertility rate that keeps the population stable, with births equaling deaths over generations. In demographic terms, it is represented by a net reproduction rate of 1 or, in the context of low mortality levels, a total fertility rate of 2.1–2.3.

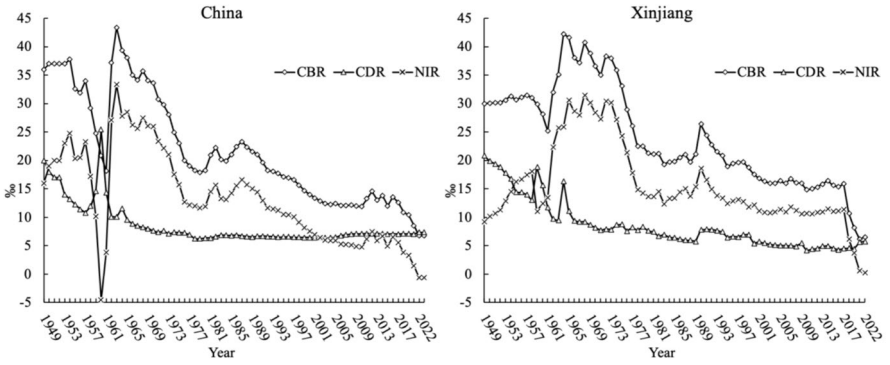

Fig. 1 Birth rate, death rate, and rate of natural increase in China and Xinjiang. 1949–2022. Data source: China Statistical Yearbook of 1990, 2005, 2017, 2023; Xinjiang Statistical Yearbook of 1990, 2005, 2017, 2021; Statistical Bulletin of National Economic and Social Development of Xinjiang Uygur Autonomous region in 2022

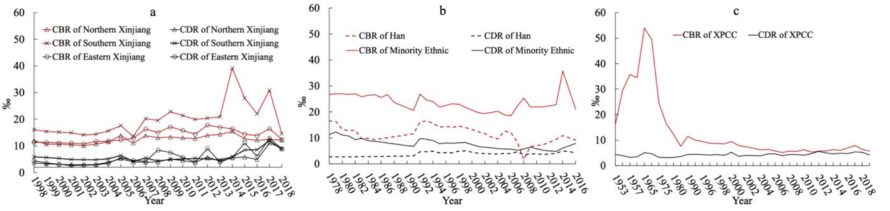

Fig. 2 Population changes in Xinjiang by region and ethnicity groups, 1980–2018. Data source: Xinjiang Statistical Yearbook of 1990, 2005, 2017, 2021; Statistical Yearbook of Xinjiang Production and Construction Corps

et al., 2019). The demographic transition in southern Xinjiang[2] is relatively slow, with fertility levels consistently higher than those in northern and eastern Xinjiang (see Fig. 2a), which is related to the level of socio-economic development in the region. Among different ethnic groups, the fertility reduction among minority ethnic populations is significantly smaller, with a higher natural growth rate, indicating a relatively slow demographic transition (see Fig. 2b). This is associated with differences in family planning policies and regulations and varying perspectives on marriage and childbirth. The population of Xinjiang Production and Construction Corps (XPCC) completed the demographic transition earlier (see Fig. 2c). In the 1980s,

[2] Xinjiang can be divided into Northern Xinjiang, Southern Xinjiang, and Eastern Xinjiang. Northern Xinjiang is the region between the northernmost Altai Mountains and Tian Shan, including areas such as Urumqi, Altay, Tacheng, Changji, Yili, and Bortala. Southern Xinjiang is situated between the Tian Shan and Kunlun Mountains, encompassing places like Bayingolin Prefecture, Kashgar, Hotan, Aksu, and the Kizilsu Kyrgyz Autonomous Prefecture. Eastern Xinjiang mainly refers to the regions of Hami and Turpan and serves as a crucial transportation hub connecting to the inland.

Table 1 Maternal, infant and under-five mortality, 2010–2020

	Maternal mortality (per 100 thousand live births)		Infant mortality (‰)		under-five mortality (‰)	
	2010	2020	2010	2020	2010	2020
National	30.0	16.9	13.10	5.40	16.40	7.50
Xinjiang	43.41	17.89	26.58	6.75	31.95	10.91

Data source: 2011 China Health Statistics Yearbook; "White Paper on Population and Development in Xinjiang 2021"; The press conference of the State Information Office, https://difang.gmw.cn/2021-09/28/content_35197567.htm

birth, death, and natural growth rates had already entered a low-level stage. In 1975, Xinjiang first implemented the family planning policy among the Han population, leading to a rapid decline in birth rates. This is linked to the higher proportion of Han population in the XPCC and the unique system of the XPCC.

Volatility mainly refers to significant fluctuations in fertility rates among minority ethnic populations during the process of fertility decline, which is associated with the significant underreporting of the population in Uyghur-populated areas of southern Xinjiang in the past decade. In 2014, during an investigation conducted by the author in a Uyghur regiment in southern Xinjiang, it was found that the cumulative underreporting rate of population registration conducted by the team in 2014 reached as high as 15% to 20%, mainly among the population of infants and young children aged 0 to 9 years. This indicates a significant underreporting of the population in Uyghur-populated areas of southern Xinjiang in the past decade. The number of births in years of significant fluctuations in fertility rates is the sum of all the underreported infants and young children discovered during these data rechecks over the past few years, leading to an unreasonable level of birth rates (Li & Chang, 2016).

What has caused the demographic transition in Xinjiang, particularly the decline in fertility rates? Previously, we established an explanatory framework for the changes in fertility levels and patterns based on China's demographic transition practices and drawing from traditional population transition theories such as the Modernization Process Fertility Transition Theory proposed by American scholar Easterlin and Crimmins (Easterlin & Crimmins, 1985). This framework is composed of demographic factors (such as mortality), socio-economic development (factors like living standards and education), institutional regulations (family planning policies), and cultural beliefs (Li, 2006; Li & Qiu, 2022).

Firstly, demographic factors- in Xinjiang, infant mortality, child mortality under the age of 5, and maternal mortality have significantly decreased (see Table 1). The proportion of early marriages in the Xinjiang has decreased, shortening the reproductive cycle. According to census data and 1% population sample survey data, in 1990, among the 15–19 year-old female population in Xinjiang, the percentage with ever married was 13.8%. This percentage decreased to 7.3% in 2000 and remained at 7.8% in 2010 and 2015.

Secondly, socio-economic development factors- statistical facts in Table 2 indicate that the per capita GDP in Xinjiang has rapidly increased, doubling in the decade from 2010 to 2020. The basic living security level of the people has continuously improved, with the per capita disposable income of residents increasing from less than 10,000 RMB in 2010 to 23,845 RMB in 2020. The level of social security has gradually increased, and the conditions for guaranteeing the right to health have significantly improved. The rights to work and education have been effectively protected (State Council Information Office of the People's Republic of China, 2020). In the last decade, the number of university students per ten thousand population, the number of health technical personnel per thousand population, and the number of hospital beds per thousand population have all significantly increased (see Table 2).

The third factor is related to fertility policies. In southern Xinjiang, areas such as Kashgar and Hotan have long experienced inadequate implementation of family planning policies, leading to a phenomenon of lax control and unauthorized births. In 1981, Xinjiang Government issued the "Interim Provisions on Several Issues Concerning Family Planning," followed by the "Interim Provisions on Family Planning for Ethnic Minorities in Xinjiang Uygur Autonomous Region" in 1988 and 1992, as well as the "Measures for Family Planning in Xinjiang Uygur Autonomous Region" in 1992 (Peng, 1997; The Policy & Regulations Department of the National Population & Family Planning Commission of the People's Republic of China, 1992; Xu, 1995). Subsequently, the Standing Committee of the Xinjiang Autonomous Region People's Congress revised these regulations in 2004, 2006, and 2010. These family planning policies specifically addressed the fertility of ethnic minority populations in Xinjiang. Ethnic minority couples are allowed to have two children in urban areas and three children in rural areas; Han Chinese couples are generally permitted to have one in urban areas and two children in rural areas. It was not until the revision of regulations in 2017 that a unified policy, regardless of ethnicity, was implemented. The policy stipulated that "urban couples are allowed to have two children, and rural couples are allowed to have three children." (Regulations Publishing Center of the People's Republic of China, 2004; Xinjiang Daily, 2010, 2022). Since 2017, Xinjiang has comprehensively implemented family planning policies through legal governance, strengthened propaganda, and the provision of contraceptive and family planning services. This has significantly reduced unintended pregnancies and frequent childbirth among women of all ethnicities (State Council Information Office of the People's Republic of China, 2021; Xinjiang Philosophy & Social Science Network, 2020).

The fourth factor is related to attitudes towards marriage and childbirth. In recent years, modern attitudes toward marriage and childbirth have fundamentally changed the marital and reproductive behavior of local women, including a decrease in the phenomenon of having multiple children in quick succession and an increase in inter-ethnic marriage rates. On one hand, in recent years, Xinjiang has effectively curbed the intervention of religious extremism in administrative, judicial, educational, marital, and medical fields, alleviating the traditional religious influences on the reproductive age population of ethnic minorities and promoting the modernization of their attitudes towards marriage and childbirth. On the other hand,

Table 2 Changes of socio-economic indicators in Xinjiang, 2010–2020

	GDP per capita (RMB)	Per capita disposable residents income (RMB)	Number of college students per 10,000 population	Health technicians per thousand population	Number of beds in medical institutions per thousand population
2010	25,057	8243*	115.14	5.63	5.37
2015	39,959	16,859	129.12	6.80	6.37
2016	40,020	18,355	133.39	7.06	6.54
2017	45,476	19,975	141.55	7.10	6.85
2018	51,238	21,500	150.78	7.13	7.19
2019	53,542	23,103	169.22	7.40	7.39
2020	53,593	23,845	188.25	7.39	7.02

Data source: Xinjiang Statistical Yearbooks and China Health Statistics Yearbooks of related years

*The per capita residents disposable income in 2010 is the weighted average of the per capita net income of rural households and that of urban households

opportunities for women of all ethnicities in Xinjiang to receive higher education and participate in socio-economic activities have been continuously increasing. For example, the proportion of female teachers and female university students has been steadily growing, reaching 66.5% and 55.6%, respectively, in 2018. In 2019, there were 480,900 new urban jobs, of which 228,100 were filled by women, accounting for 47.43% of the total (State Council Information Office of the People's Republic of China, 2021; Xinjiang Philosophy & Social Science Network, 2020).

2 Xinjiang population dynamics in the twenty-first century

In recent years, Xinjiang has experienced a slowdown in population growth, a more rational population structure, and a continuous improvement in population quality. These trends are in sync with the overall socialist development in China and the socio-economic progress in Xinjiang.

In terms of population size, Xinjiang has experienced continuous growth in the twenty-first century, although the rate of growth has slowed down. From the year 2000 to 2010, the population of Xinjiang increased from 18.46 million to 21.82 million. Since the strict implementation of family planning policies in 2018, the birth rate has decreased from 15.88‰ in 2017 to 5.6‰ in 2021, with a relatively small change in the death rate. The natural population growth rate has declined from 11.4‰ to 0.56‰, completing the process of demographic transition and reaching a low-level equilibrium in birth, death, and natural population growth rates. However, the overall population of Xinjiang continues to grow, reaching 25.85 million in 2020 and 25.89 million in 2021. The population of ethnic minorities also continues to grow, with 10.97 million in 2000, 12.99 million in 2010, and 14.93 million in 2020. Among them, the Uygur population was 8.52 million in 2000, 10.17 million in 2010, and 11.62 million in 2020. The trend in population changes for ethnic minorities aligns with the overall population of Xinjiang and exceeds the average growth rate of ethnic minorities in the entire region.

From the perspective of age and gender structure (see Fig. 3), data from the seventh national population census in China in 2020 reveals that Xinjiang has an aging population. In comparison with other provinces, the population distribution in Xinjiang shows that individuals aged 0–14 account for 22.46%, and those aged 65 and above constitute 7.76%. This makes Xinjiang's population relatively younger, second only to Tibet in terms of 0–14 years old. In 2020, the gender ratio at birth in Xinjiang was 105.89, and the overall gender ratio in the population was 106.85, indicating normal levels. As 98.72% of the Uygur population resides in Xinjiang, national Uygur population data is used here to represent the Uygur population in the region The Uygur population is characterized by a younger age structure, with individuals aged 0–14 making up 30.23%, while those aged 65 and above constitute only 5.59%. The gender ratio at birth for the Uygur population is 106.28, indicating a normal distribution across different age groups.

The health level Xinjiang's population has reached is its highest level since the founding of the People's Republic of China. According to Table 1, in 2020, Xinjiang's infant mortality rate, mortality rate for children under 5, and maternal

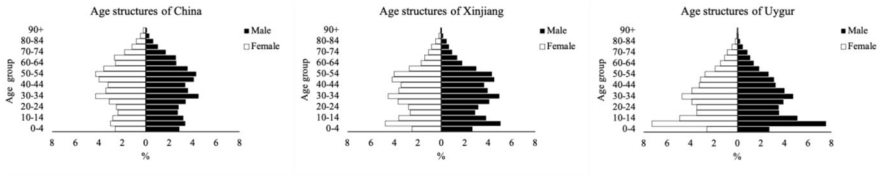

Fig. 3 Age structures of different population groups, 2020. Data source: the 2020 National Population Census results

mortality were at their lowest since 1949. The differences with the national average level further decreased, indicating a significant improvement in the health of Xinjiang's population. In terms of changes, according to the China Health Yearbook, Xinjiang's average life expectancy increased from 62.59 in 1990 to 67.41 in 2000, and further increased to 72.35 in 2010. In 2020, it had reached 74.42,[3] narrowing the gap with the national average life expectancy, which reduced from nearly 6 years in 1990 to around 3 years in 2020. For the Uygur population (of China), the average life expectancy has continuously improved, rising from 63.43 in 1990 to 68.14 in 2000 and further to 72.59 in 2010 (Huang & Zhao, 2004; Xu et al., 2014), it is higher than the average level of the Xinjiang population.

Xinjiang's population has made significant progress in education, with a further reduction in educational disparities among different ethnic groups. In 2020, the education level of Xinjiang's population was relatively high, with the proportion of individuals aged 15 and above who had received high school education or above exceeding the national average. Compared to 1990, Xinjiang's human resource level has further improved. In terms of ethnic differences, from 1990 to 2010, the Han population in Xinjiang had a higher level of education than the ethnic minority population. For the Uygur population in Xinjiang, their education level was lower than that of the overall ethnic minority population from 1990 to 2010. By 2020, the education level of the Uygur population still showed some disparity with the overall population in Xinjiang, but it had reached the highest level since the founding of the People's Republic of China.

According to the 2020 Population Census data, individuals aged 15 and above in the Uygur population in Xinjiang had an average education duration of 9.19 years, higher than the 7.06 years in 2000. For every 100,000 people, 8944 had a university-level education, an increase of 6540 from 2000. The overall average education duration for Xinjiang's total population in 2020 was 10.11 years, with 16,500 people per 100,000 having a university-level education.

Xinjiang's population has seen a more modernized composition in terms of industries and occupations, with significant changes observed in the Uygur population. According to Table 3, in 2020, the percentage of the population engaged in the primary industry and the percentage of workers in agriculture, forestry,

[3] Data source: "The average life expectancy of residents in Xinjiang has reached 74.42 years", Tianshannet, http://news.ts.cn/system/2021/02/10/036576343.shtml.

Table 3 Changes of socio-economic indicators, 1990–2020 (%)

Items	Population groups	Year			
		1990	2000	2010	2020
Education: Secondary education and above	National Total	10.88	15.76	24.55	36.99
	Xinjiang	17.63	19.00	24.35	38.23
	Han in Xinjiang	26.44	28.83	37.55	–
	Minority in Xinjiang	10.84	12.05	14.70	–
	Uygur in Xinjiang	9.79	10.57	12.63	–
Industry: Share of first industry	National Total	72.24	64.38	48.36	20.56
	Xinjiang	66.31	61.44	61.31	25.29
	Han in Xinjiang	41.00	37.32	32.72	–
	Minority in Xinjiang	83.19	78.46	80.16	–
	Uygur in Xinjiang	85.31	80.60	82.86	–
Occupation: Proportion of agriculture workers	National Total	70.58	64.46	48.31	20.53
	Xinjiang	64.35	61.10	60.91	25.69
	Han in Xinjiang	38.06	36.77	31.94	–
	Minority in Xinjiang	81.88	78.26	80.12	–
	Uygur in Xinjiang	84.14	80.51	83.01	–
Proportion of urban population	National Total	20.23	36.92	50.27	63.89
	Xinjiang	28.51	33.84	42.79	56.53
	Han in Xinjiang	–	53.62	70.28	–
	Minority in Xinjiang	–	20.34	24.10	–
	Uygur in Xinjiang	–	19.21	21.97	34.97

Data source: National Population Census of 1990, 2000, 2010, and 2020

"–" represent data not available

animal husbandry, and fisheries were 25.29% and 25.69%, respectively. Both indicators were above 60% from 1990 to 2010. The trend towards modernization in both industry and occupation populations became more apparent, especially with a much higher rate of change between 2010 and 2020 compared to the previous two decades. Looking at ethnic differences, from 1990 to 2010, there was a significant disparity in the industry and occupation composition between the Han and ethnic minority populations in Xinjiang. The former's percentage was generally below 40%, steadily decreasing, while the latter's percentage remained around 80%. For the Uygur population in Xinjiang, the proportion engaged in the primary industry in 2020 was 37.60%, higher than the overall Xinjiang population but significantly lower than the proportions for the Uygur population from 1990 to 2010. From 2010 to 2020, there was a noticeable acceleration in the modernization of the industry and occupation composition of the Uygur population.

Xinjiang's population urbanization has reached its highest level, with the process accelerating for the Uygur population. In 2020, the urban population in Xinjiang accounted for 56.53%, still lagging behind the national average. However,

the urban population has increased by 32.11% in the past decade, surpassing the growth rates of the two previous decades (18.69% and 26.45%).

Looking at ethnic differences, from 2000 to 2010, the urban population among the Han population in Xinjiang was higher than that of the ethnic minority population. In 2020, the urban population ratio for the Uygur population in Xinjiang reached 34.97%, showing a disparity with the overall Xinjiang population but significantly higher than the percentages of 19.21% in 2000 and 21.97% in 2010. In terms of growth rate, the increase from 2010 to 2020 exceeded 59%, surpassing the growth rate of 14.37% from 2000 to 2010.

The population in Xinjiang, especially among the young ethnic minorities, is gradually adopting modern marriage and childbirth concepts along with lifestyle changes. In July–August 2022, the author's research team conducted a survey in W Community, Atushi City, Kizilsu Kirghiz Autonomous Prefecture. The ethnic composition of W Community mainly consists of Uygurs, Han, Kirghiz, and other ethnic groups, accounting for 54.4%, 28.8%, 11.4%, and 5.4% respectively. The changing views on marriage and childbirth among reproductive-age women in this community are a typical example of the increasing modernization of marriage and childbirth values and beliefsamong Uygur women, especially in southern Xinjiang. Through interviews and observations, new characteristics are emerging in the marriage and childbirth values and beliefs of ethnic minority women in southern Xinjiang:

Firstly, the traditional notion of early marriage and early childbirth is gradually diminishing. Among the interviewees from the post-1990s generation, there is no evidence of early marriage and early childbirth. Most of them gave birth between the ages of 21 and 23. For women born in the 2000s, the desire for early marriage and childbirth is notably postponed, occurring around the ages of 27 to 28. As women with new childbirth concepts become the main group of reproductive-age women, this influence is expected to become even more pronounced.

Secondly, the preference for having many children and having them closely spaced is diminishing. For women in southern Xinjiang, especially those with higher education and full-time jobs, there is a need to effectively allocate time between work and childcare, balancing self-realization and family responsibilities. They are also increasing their investment in their children's resources, requiring a balance between the quantity and quality of children. As the educational level of Uygur women increases, the opportunity cost of childbirth rises. The current trend isevolving towards prioritizing the quality of children over quantity, thereby diminishing the traditional preference for having many children and having them closely spaced.

Thirdly, the likelihood of interethnic marriage is increasing. With the growing interaction between Uygurs and other ethnic groups, enhanced proficiency in the national language, and increased cultural inclusivity, Uygur women in southern Xinjiang have a more diverse range of ethnic choices for spouses. In the new generation of Uygur women, there is a more widespread acceptance, respect, and appreciation for the cultures of other ethnicities.

3 Understanding and interpreting the changes in rate of natural increase in southern Xinjiang population

Since 2018, there has been a rapid transformation in the reproductive patterns in the minority population areas of Xinjiang, leading to a sharp decline and even negative natural population increase rate in some places (Table 4). While this change is somewhat related to the implementation of family planning policies, it does not necessarily mean that the lifelong fertility of local women fall below replacement level. As mentioned earlier, in recent years, Xinjiang, especially southern Xinjiang, has been in a phase of comprehensive and rapid development. This includes the development of the Uygur population, particularly in women's development, such as the increased women's employment, universal secondary education, and changes in marriage and childbearing opinions. These transformations and developments directly impact the patterns of marriage and childbirth. As the shift from early marriage, early childbirth, having many children, and closely spaced births rapidly moves towards a new model of marrying and having children later, and emphasizing healthy childbirth, corresponding demographic indicators such as fertility and natural growth rates are inevitably experiencing a rapid transition from high to low or from positive to negative.

We give an abstract and simplified example to illustrate the transition from positive to negative changes in fertility rate in southern Xinjiang during this period. Assume that in 2017, there was a traditional reproductive pattern where each reproductive-age woman gave birth to her first child at the age of 18, the second child at 21, the third child at 24, and the fourth child at 27. This would mean that a woman could have four children before reaching the age of 30. Now, in the following year of 2018, a transition occurs as the effect of multiple factor changes mentioned above. The new reproductive pattern shifts to women giving birth at the age of 20 to the first child, 24 to the second child, and 28 to the third child. In this scenario, we would observe the following changes: in the second year (2018), newly entering 18-year-old women would not marry and give birth to their first child as was the case in the past. Newly entering 20-year-old women could give birth to their first child, but they may have already had a child at the age of 18, under the previous reproductive pattern. Newly entering 24-year-old women could give birth to their second child, but they may have already had two children by the age of 21 under

Table 4 Natural growth rate in Han and ethnic minority areas in Xinjiang, 2013–2018 (‰, %)

Areas in Xinjiang	2013	2014	2015	2016	2017	2018
Xinjiang Han regions	7.74	7.71	5.16	6.58	0.26	2.44 (7.42)
Xinjiang minority regions	15.44	14.60	12.34	11.06	8.32	4.06 (−0.25)
Hotan prefecture	19.07	17.83	17.51	15.79	11.80	2.96 (3.08)
Hotan City	12.26	12.40	14.32	11.11	12.08	4.13 (16.39)
Yutian County	25.84	22.85	21.87	12.74	10.35	−0.49 (−3.82)

Data source: Zenz, 2020; Xinjiang Statistical Yearbook of related years (Table 3–6 and 3–7)

Note: The data in parenthesis under 2018 are the population increase rates between 2017 and 2018

Table 5 Period indicators in a population with rapid childbearing pattern change

Age specific birth rate	2017	2018 (if there is no transition)	2018 (after transition)
15–19	21.93	21.93	7.31
20–24	144.35	144.35	48.12
25–29	147.60	147.60	49.20
30–34	103.35	103.35	34.45
35–39	41.09	41.09	13.70
40–44	17.09	17.09	5.70
45–49	4.59	4.59	1.53
Total fertility	2.40	2.40	0.80
Crude birth rate	20	20	7
Crude death rate	7.5	7.5	7.5
Rate of natural increase	12.5	12.5	−0.5

Data source: Estimated from the 2010 Yutian County population census data

the previous pattern. Similarly, newly entering 28-year-old women could give birth to their third child, but they may have already had three children by the age of 24 under the previous pattern. As a result, the possibility of having four children may have diminished due to changing reproductive attitudes or other factors. This shift in reproductive patterns can lead to a negative change in demographic indicators, reflecting a decrease in the natural population growth rate of the specific year.

Therefore, in the above-mentioned period of rapid transformation of childbearing patterns, there may be situations where there are few or no women who meet the new childbirth conditions. Consequently, both the total fertility and the birth rates would be very low, even approaching zero in a period. Meanwhile, due to the consistently low level of mortality, the natural population growth rate in that area would inevitably be zero or negative. The demographic changes among the Uygur population in southern Xinjiang are indeed in the midst of such a transformative process. Table 5 illustrates our simulation of fertility changes using Yutian County data, where demographic indicators shift from positive to negative. If there is no transformation in the fertility pattern, then the age-specific fertility rates in 2018 would be similar to those in 2017, with little difference, as shown in the second column of Table 5. If there is a drastic transformation in the fertility pattern, then the fertility circumstancesof women of childbearing age in 2018 would be as described above, and their age-specific fertility rates would consequently change, as shown in the third column of Table 5. Specifically, the natural population growth rate in Yutian County equaled to -0.5‰ in 2018 after the rapid transition. However, in terms of cohort indicators, the total fertility rate for women in these regions remains around 3 children, meaning that the fact each woman gives birth to three children in her lifetime has not changed. From the perspective of population reproduction, having a total fertility rate of three children is higher than the replacement level. Therefore, the southern Xinjiang region still falls into the category of a growing population

reproduction type. While the natural population growth rate becomes negative during the transitional period, it does not necessarily imply a reduction in population.

However, there are some misunderstanding and incorrect interpretation from some of the research's arguments and conclusions. Firstly, they disregard the rules of demographic transition and forcibly assume that maintaining a high fertility among the ethnic minority populations in Xinjiang is normal. As analyzed earlier, during the process of demographic transition, a decline in fertility leading to a sustained lower level is a trend in common. The demographic transition in Xinjiang is accompanied by progress and development in various social and economic aspects, and the decline in fertility rates is inevitable and a consequence of development.

Secondly, solely retroactively attributing presumed causes based on statistical data results completely overlooks other crucial factors influencing the reproductive transition. As discussed earlier in the analysis of the demographic transition and its causes in Xinjiang, the fertility changes in the Uygur population are motivated by declining mortality, decreasing early marriage, socio-economic development, implementation of institutional regulations, and shifts in cultural perspectives and opinions. Those important factors cannot be ignored.

Thirdly, the misuse of demographic indicators measuring fertility would leading to incorrect conclusions. Indicators reflecting population changes are categorized into period indicators and cohort indicators. Period indicators used to measure population fertility and changes include birth rate, total fertility rate, and rate of natural population growth. Indicators measuring cohort fertility levels include lifetime fertility rate. The period indicators, such as the total fertility rate, and the cohort indicators, such as the lifetime fertility rate, generally align when the population state, such as marriage and fertility patterns, remains relatively stable. However, during periods of rapid transition in factors like marriage and fertility patterns, period indicators may not accurately reflect the actual cohort fertility levels, let alone the long-term trend of population change. The misuse of period population indicators and misunderstanding of period indicators could result in wrongful conclusions without any supportive evidence.

4 Critiques of the population projection of southern Xinjiang: corrections to some misleading inferences

The misuse of demographic indicators and misunderstanding about demographic transition in Xinjiang lead to wrong population projections about Xinjiang's population. Typical example is Zenz's misinterpretation of the fertility trends of ethnic minority women (see Table 4) in Xinjiang (Zenz, 2021). Firstly, the rule of demographic transition was disregarded and forcibly assuming that maintaining a high growth rate among the Uygur population in future Xinjiang is considered normal, as discussed above.

Secondly, Zenz (2021) completely distorts the fact that the ethnic groups population is preferential in population policy, and ethnic minorities implement more relaxed family planning regulations, especially in Xinjiang. As already outlined in the preceding text, whether in urban or rural areas, ethnic minority couples were

allowed a greater birth quota compared to the local Han population until 2017. The policy differences between Han and minority ethnic groups were only abolished in 2017. The revision of regulations in 2017 that "urban couples are allowed to have two children, and rural couples are allowed to have three children." As of 2022, the Standing Committee of the Xinjiang Autonomous Region People's Congress has once again revised the regulation, aligning the policy with the national standard, allowing a couple to have three children. Therefore, from the initiation of family planning policies targeting ethnic minority populations in the 1980s until now, the family planning policies in Xinjiang concerning ethnic minority populations have generally been more lenient, allowing for the birth of 2–4 children, higher than the replacement level.

Thirdly, the population projection about ethnic minorities in Xinjiang by Zenz is not convincing due to inadequate knowledge and incorrect methodology. The current prevailing method for demographic predictions is the cohort component projection. This method is based on the current age and gender structure of the population. It then uses assumed parameters for birth, death, and migration to forecast and estimate future populations. Typically, three scenarios are presented for birth levels: low, medium, and high, assuming stable and low mortality rates without considering migration factors. Taking the United Nations population projections as an example, countries or regions are classified based on the fertility transition process. Existing empirical data from vital statistics, censuses, and surveys are utilized in a Bayesian hierarchical model (BHM) to obtain fertility parameters (United Nations, 2022). Some literatures about population projections for Xinjiang have been published, such as Huo et al. (2020) assuming low scenario of total fertility 1.8 and high scenario of total fertility of 3.3 for the Hotan area. However, Zenz's scenario faces an initial problem related to the set parameters, specifically the "rate of natural population growth" parameter. Zenz's use of the rate -5‰ to 5‰ to estimate the minority population natural increase in southern Xinjiang over the next 20 years is flawed. As mentioned earlier, the minority population in Xinjiang is in a phase of rapid fertility transition, and Zenz's population projection completely overlook this crucial premise. Instead, he directly employs an unstable natural growth rate parameter influenced by structural factors. The use of population phenomena during the transition period as the basis for long-term predictions indicates a lack of knowledge in population forecasting.

In the long run, on the one hand, Xinjiang maintains the existing fertility policy, that is, the three-child policy, and the type of population reproduction of ethnic minorities is still in a growth pattern. There is still room for three children in the fertility trend of the minority population in Xinjiang and the lifetime fertility rate of women in southern Xinjiang. On the other hand, the population of Xinjiang, including the Uygur population, follows the common pattern of demographic transition, and it is inevitable to move towards low fertility and low growth, which is the inevitable result of the pursuit of all-round development and a better life by the people of all ethnic groups in Xinjiang. The most crucial point is that the logic of negative growth hypothesis by Zenz is not caused by fertility transformation, but the result of the Chinese government's compulsory family planning, while the logic behind fertility decline hypothesis by Huo et al. (2020) is the rule of fertility transformation.

5 Conclusion

Since the founding of People's Republic of China, the demographic transition and development of Xinjiang, including ethnic minorities in southern Xinjiang, is the inevitable result of economic and social development and the inevitable result of industrialization and modernization. The population of Xinjiang is developing healthily, the population size is growing continuously, the quality of life is improving continuously, and the life expectancy is increasing steadily. Among them, the Uygur population in Xinjiang continues to grow, and the population size has increased from 3.6 million in 1953 to 11.6 million in 2020, always maintaining a high level of growth.

With the acceleration of China's modernization process and the continuous development of state aid to Xinjiang, the development of various undertakings in Xinjiang is also accelerating. Since the Work Conference of 19 provinces and cities on aid to Xinjiang was held in 2010, the state has gradually increased its efforts to aid Xinjiang. Since the 18th CPC National Congress, 19 provinces and cities have invested more than 170 billion RMB in aid to Xinjiang.[4] By the end of 2020, there were more than 12,000 industrial cooperation projects, 15,000 cadres and talents, invested more than 80 per cent into grass-roots units and people's livelihood, and helped more than 3 million rural people out of poverty.[5] It has promoted the all-round development of public management, culture, education and social economy in Xinjiang. Kashgar, Hotan and Kizilsu Kirgiz Autonomous Prefecture in the south of Xinjiang are the key areas for counterpart assistance to Xinjiang. Take Kashgar as an example, since 2019, four provinces and cities of Shanghai, Guangdong, Shandong and Shenzhen have invested a total of 19.872 billion yuan in aid to Xinjiang and implemented 827 aid projects in Kashgar, and seven state own enterprises have invested 590 million RMB in 8 designated aid counties. The implementation of 115 aid projects and the selection of cadres to work in the recipient areas[6] have promoted the all-round economic and social development and the rapid modernization in Xinjiang.

Under this background, even if the state gives enough space for fertility policy, the development and change of Xinjiang's population, including Uygur population, will follow the rule of demographic transition, and the population will certainly move towards the status of low birth, low death and low growth, which is the inevitable result of human development and the pursuit of all-round development and a better life by the people of all ethnic groups in Xinjiang.

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[4] Data source: "China These Ten Years: Xinjiang", Tianshannet, https://www.ts.cn/xwzx/szxw/202208/t20220827_8634341.shtml.

[5] Data source: "Harmoniously Pursuing Dreams and Sketching the 'Jiang'—Overview of the New Round of National Support for Xinjiang Action", Xinhuanet, http://www.xinhuanet.com/politics/2021-07/20/c_1127673836.htm.

[6] Data source: "Kashgar Region Holds Twinning Support for Xinjiang Work and Project Promotion Meeting", China Kashgar Net, http://www.zgkashi.com/c/2021-09-20/648746.shtml.

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Declarations

Conflict of interest All authors declare that there are no financial or non-financial interests that are directly or indirectly related to this work.

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Jianxin Li is a professor in Sociology Department, Peking University, Beijing, P.R. China. His research interests include social demography, ethnic minority population studies, and aging studies

Liya Qiu is a Ph.D. candidate in Sociology Department, Peking University, Beijing, P.R. China. Her main fields of interest are ethnic minority population studies, fertility and health