PREDICTION AND ANALYSIS OF RURAL POPULATION IN SHAANXI PROVINCE BASED ON POPULATION DEVELOPMENT EQUATION MODEL

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ABSTRACT

Based on the sixth census data of Shaanxi Province, this paper established the model of rural population in Shaanxi Province. On the basis of extrapolation of the fertility mode function and the mortality function of the sex and age and according to the total fertility rate. Three schemes are designed, which are high, medium and low, and then using the dynamic population development equation model established the model of rural population in Shaanxi province and predicted the population of rural areas in Shaanxi province, and analyzed the relevant population indexes. The results showed that, within the next 15 years, Shaanxi province rural elderly dependency ratio increased, the total dependency ratio rising, the proportion of the labor force declining.

Keywords: Population development equation; growth pattern; total fertility rate; population index; prediction.

INTRODUCTION

Population forecast is based on current demographic situation and consider the various factors affecting the development of the population, according to the scientific method, estimates of population size the levels and trends in the future some time, population forecast not can provide important information for the socio-economic development ,but can provide theoretical basis for the government to develop population policy planning to the relevant departments and provide a reference to development strategies. Based on the relevant population data of Shaanxi Province in the sixth national census, this paper uses the concept and method of population control to study the development process of population state variables, analyzes the rural population in Shaanxi Province and forecasts the future population status and its development trend.

Basic Principles of Population Forecasting Model

If the population of a certain year is sex-disaggregated by age, the annual distribution of the female population, the male population and the total population from the age of 0 to the largest age can be obtained. Different sexes of different ages of the population, according to their respective mortality rate decreased year by year [1-2]. Clearly, t to t + 1 in the above state distribution of the population can use the following model representation

$$x_{r+1}^{W}(t+1)=[1-d_r^{W}(t)]x_r^{W}(t)\ r=0,1,2,\cdots,m-1 \quad (1)$$

$$x_{r+1}^{M}(t+1)=[1-d_r^{M}(t)]x_r^{M}(t)\ r=0,1,2,\cdots,m-1 \quad (2)$$

which： $d_r^{W}(t)$ —Mortality r-year-old female population in year t;

$x_r^{W}(t)$ —Quantityr-year-old female population in year t；

$d_r^M(t)$—Mortality r-year-old male population in year t;

$x_r^M(t)$—Quantityr-year-old male population in year t;

m—The maximum age people

The above model is a recursive model, which can be passed on to any later year. This is a constant process of transfer. When the 0-year-old population to t + 1 years after the adult population, there are t to t + 1 year newborn less than 1 year old baby $x_0(t+1)$ joined the ranks of the population, the calculation model is:

$$x_0(t+1) = [1 - d_{00}(t)]B(t+1) \quad (3)$$

which: $d_{00}(t)$—The infant mortality rate in year t;

$B(t+1)$—The total number of live-born babies born t to t + 1 year can be calculated by the following formula:

$$B(t+1) = J(t)\sum_{r=r_1}^{r_2} h_r(t)x_r^W(t) \quad (4)$$

In the formula: $J(t)$—The average number of children born to each person for the total fertility rate of women under the fertility level in the whole childbearing age in year t;

r_1—Age lower limit for women of childbearing age, international take $r_1 = 15$ years;

r_2—Age upper limit for women of childbearing age, international take $r_2 = 49$ years;

$h_r(t)$—r-year-old women's fertility patterns indicate the fertility rates of women in different age groups in t year, meet the normative conditions $\sum_{r=r_1}^{r_2} h_r(t) = 1$。

According to the above-mentioned population fertility and state transition principle ,which can establish the state transition model of the population transfer mathematical model ,that is

（1）Newborn live births

Total: $$B(t+1) = J(t)\sum_{r=r_1}^{r_2} h_r(t)x_r^W(t) \quad (5)$$

Baby girl: $$B^W(t+1) = kB(t+1) \quad (6)$$

Baby boy: $$B^M(t+1) = (1-k)B(t+1) \quad (7)$$

In the formula: k—The proportion of female children to the total number of infants.

（2）Total population state transfer formula

$$x_0(t+1) = [1 - d_{00}(t)]B(t+1)$$

$$x_1(t+1) = [1 - d_0^W(t)]x_0^W(t) + [1 - d_0^M(t)]x_0^M(t)$$

$$x_2(t+1) = [1 - d_1^W(t)]x_1^W(t) + [1 - d_1^M(t)]x_1^M(t)$$

$$x_m(t+1) = [1 - d_{m-1}^W(t)]x_{m-1}^W(t) + [1 - d_{m-1}^M(t)]x_{m-1}^M(t)$$

Extrapolation of population model function

Extrapolation of future fertility model function

Fertility pattern $h_i(t)$ represents the fertility level of women of childbearing age at different birth ages. The value of $h_i(t)$ indicates that the fertility level is high at the age of i age, in contrast, it will indicate low fertility level. $h_i(t)$ meets the normalization conditions:

$$\sum_{i=a_1}^{a_2} h_i(t) = 1 \quad (8)$$

After reference to a lot of regional demographic data, It can be found that the normalized fertility pattern t can be more accurately approximated by the Gamma distribution density curve in statistics.Assuming that a_1 and a_2 are the minimum and maximum fertility ages of women of childbearing age, then, for fixed age t, $h(a,t)$ can be expressed as:

$$h(a,t) = \begin{cases} \dfrac{(a-a_1)^{\alpha-1} e^{-\frac{a-a_1}{\theta}}}{\theta^{\alpha}\Gamma(\alpha)}, & a > a_1 \\ 0 & a \le a_1 \end{cases} \quad (9)$$

In the formula：α、θ is a parameter that more than zero. $\Gamma(\alpha)$ is a gamma function:

$$\Gamma(\alpha) = \int_0^{\infty} e^{-x} x^{\alpha-1} dx \quad (10)$$

Let this function reach the maximum value of a is the fertility peak age, denoted as $a_{\max}$:

$$a_{\max} = a_1 + \alpha\theta - \theta \quad (11)$$

Statistical data on fertility in rural Shaanxi Province, the use of matlab programming process,get $\alpha = 9.28$， $\theta = 1.06$.So the fertility pattern of rural areas in Shaanxi Province is

$$h_i(t) = \begin{cases} \dfrac{(\alpha-15)^{9.28} e^{\frac{\alpha-15}{1.06}}}{126660} & \alpha > 15 \\ 0 & \alpha \le 15 \end{cases} \quad (12)$$

Corresponding peak birth age is:

$$\alpha_{\max} = 15 + 9.28 * 1.06 - 1.06 = 23.78 \quad (13)$$

The fertility pattern determined by the formula (12) is shown in table 1.This mode is calculated using the number of newborns and the actual number of newborns out statistical difference of 549 people, The relative error of 0.25%, the actual fertility data approximation accuracy is quite high. In the prediction of rural labor force population will be based on this fertility model.

Table 1 Rural women's fertility model in Shaanxi Province

age	Calculated	age	Calculated	age	Calculated	age	Calculated
16	0	25	0.1203	34	0.005	43	0
17	0.0004	26	0.1031	35	0.003	44	0
18	0.0042	27	0.0825	36	0.0017	45	0
19	0.0175	28	0.0623	37	0.001	46	0
20	0.0433	29	0.0448	38	0.0006	47	0
21	0.0762	30	0.0309	39	0.0003	48	0
22	0.1064	31	0.0205	40	0.0002	49	0
23	0.1251	32	0.0132	41	0.0001		
24	0.1291	33	0.0082	42	0.0001		

Extrapolation function mortality

The mortality function is a quantitative description of the death factors in the process of

population development. This function is usually estimated from the statistics. The more accurate the estimation, the more accurate the quantitative calculation of the population development process.

For each fixed age t_0, the mortality function $u(a,t_0)$ is a Bathtub curve that can be approximated by a function. For the convenience, the age range can usually be divided into three sections. Infant stage（$0 \le a \le 5$）,young adults stage（$5 \le a \le 50$）,old stage（$a \ge 50$）,and it was fitted with different curves.

$$u(a,t+1)=\begin{cases}[1-\varepsilon_1(t)]u(a,t), & 0 \le a \le 5\\ [1-\varepsilon_2(t)]u(a,t) & 5 \le a \le 50\\ [1-\varepsilon_3(t)]u(a,t) & 50 \le a \le 100\end{cases} \quad (14)$$

In the population forecasting, the use of Subsection weighting method to gradually transition the population mortality to an ideal state, the design of different weight function, so that the mortality function in the infancy, adult and old age at different rates of decline. The average life expectancy is an important demographic in dynamic index, and the average life expectancy and mortality has a close relationship. Estimating the trend of average life expectancy, we can also estimate the trend of mortality; calculate the average life expectancy formula is:

$$S_0=\sum_{j=0}^{100} e^{-\sum_{i=0}^{j} u_{(i)}} \quad (15)$$

In the formula：

S_0——Average life expectancy；

$u_{(i)}$——i-year-old population mortality rate.

According to the statistics of the sixth census data in Shaanxi Province in 2010, the average life expectancy of rural population in Shaanxi Province can be calculated as 72.54 years for males and 76.80 years for females, and the average life expectancy of developed countries has reached the average life expectancy level. The United Nations population department analyzes a large number of life tables in various regions of the world and presents a model of average life expectancy [3], which provides a reference for population development and estimated average life expectancy. Based on the empirical data provided by this model, the possible life expectancy of male and female population in Shaanxi Province in the next 50 years can be calculated, as shown in Table 2.

Table 2 Forecast of average life expectancy of male and female population in rural areas of Shaanxi Province from 2010 to 2050

years	2010	2015	2020	2025	2030
male	72.54	72.74	72.94	73.14	73.34
female	76.8	77.5	77.7	77.9	78.1
years	2035	2040	2045	2050	
male	73.54	73.74	73.94	74.14	
female	78.3	78.5	78.7	78.9	

It can be seen from Table 2, the average life expectancy of the male population in Shaanxi rural areas increased by 0.2 years on average in the next 40 years, and the average life expectancy of the female population increased by 0.26 years on average. Therefore, according to the average life expectancy of male and female population, the mortality

reduction function of the future forecast period is divided into segments, and the mortality function of male population is:

$$u(i,t)=\begin{cases} u_{(i,2010)}-0.000013 & 0\le i\le 5 \\ u_{(i,2010)}-0.00005 & 5\le i\le 50 \\ u_{(i,2010)}-(t-2010)*0.0001 & 50\le i\le 100 \end{cases} \quad (16)$$

The female population's mortality function is

$$u(i,t)=\begin{cases} u_{(i,2010)}-0.00002 & 0\le i\le 5 \\ u_{(i,2010)}-0.00004 & 5\le i\le 50 \\ u_{(i,2010)}-(t-2010)*0.00016 & 50\le i\le 100 \end{cases} \quad (17)$$

In the formula： t ——years； $u(i,t)$ ——the age of i population mortality rate in t years.

Future population migration

Population migration is a complex population phenomenon; the definition of migrant in different countries is also different. With the accelerated pace of modernization in China, the further development of market economy and the release of urban and rural surplus labor. Under the strict household registration management system leads to the formation of a large number of family separation populations. Therefore, the sixth census in 2010 will live in the province more than six months, accounts in other provinces, as well as living in the province less than half a year, leaving the registration of more than six months of population are counted as migrant population. As the gender structure of the population moving and moving out is very complex, it is very different from the local resident population. At the same time, due to the lack of population migration data, which have increased the difficulty of predicting future population migration. According to the census data, in the city of Harbin, a total of 154,677 people were relocated in 2000. For the sake of convenience, the population migration for the future forecast period is set at 155,000, and the age distribution of the population is the same as that of the local resident population [3].

Total fertility rate

The total fertility rate has a general character that reflects the fertility level of the population for a certain period [4-5]. The sum of fertility which is an important indicator of demographics rates is directly related to the size and speed of population growth. The total fertility rate is derived from the total fertility level of women of reproductive age in a given age group. According to the total fertility rate, the birth sex ratio is different and set high, medium and low three kinds of plan to forecast the rural population in Shaanxi Province.
High program: In the case of liberalization of the two-child policy, it is assumed that the rural total fertility rate in Shaanxi Province changes from 1.22 in 2010 to 2.1 in 2030, and the population changes to a more appropriate level of replacement, and then remain unchanged at this level.

Intermediate program: Assuming that the total fertility rate in rural areas of Shaanxi Province changes from 1.22 in 2010 to 1.6 in 2020 and then to 1.8 in 2030, the level has been maintained since then.
Low program: According to the existing fertility level has remained unchanged.

Prediction results and analysis

Based on the above forecast or assumptions, the population of rural population and the rural working age population can be predicted according to Song Jian separated population forecasting model.

The overall size of the future population

According to the established dynamic population forecasting model, the total rural population in the future is shown in Table 3.

Table 3 Total number of rural population in 2010-2030

Age	Total population		
	High program	Intermediate program	Low program
2010	20268042	20268042	20268042
2011	20407239	20266231	20337466
2012	20557110	20383007	20413993
2013	20713495	20504970	20494303
2014	20871604	20627851	20574721
2015	21026348	20747145	20651368
2016	21172961	20893993	20720684
2017	21305585	21026776	20777949
2018	21421032	21142346	20821013
2019	21515756	21237166	20847177
2020	21587335	21308829	20854600
2021	21675528	21356212	20842409
2022	21736161	21379271	20810498
2023	21769956	21378463	20758996
2024	21780581	21357053	20690632
2025	21770728	21317256	20606941
2026	21744707	21262871	20510978
2027	21705707	21196601	20404675
2028	21656866	21121068	20289953
2029	21601008	21038615	20168539
2030	21541052	20951500	20042369

It can be seen from Table 3 that the population of Shaanxi Province in the next 15 years is in a trend of rising and then descending under the population forecast of these three schemes .Under the low program, China's rural areas in Shaanxi will reach a population peak of 20.8546 million in 2020.Under the Intermediate program, China's rural areas in Shaanxi will reach a population peak of 2137.93 million in 2023.Under the High program, China’s rural areas in Shaanxi will reach a population peak of 2178.06 million in 2024.

The child’s dependency ratio

The child’s dependency ratio is the proportion of children aged 0-14 and working age. As shown in Figure 1.

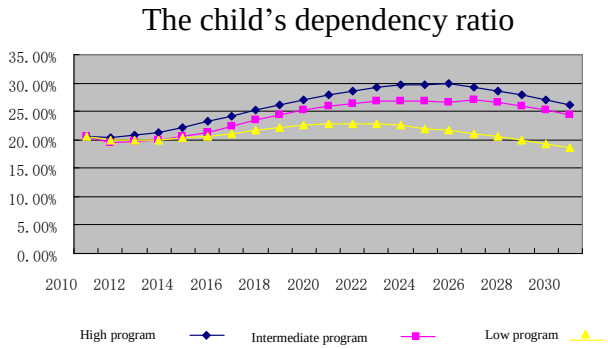

Figure 1 Trends in the three programs of child support ratios

From the general trend of the dependency ratio, the various programs have shown a trend of rising first and then declining. In the low program, it falls below 20% in 2028.In the Intermediate program, in 2027 has been in an upward trend, and then began to decline. In the High program, in 2025 will reach the peak of29.87%, then began to decline, but has been higher than 25%.

Old age dependency ratio

The old age dependency ratio is the proportion of the elderly population aged 65 and the proportion of children's age population. Figure 2 is the trend of the elderly dependency ratio.

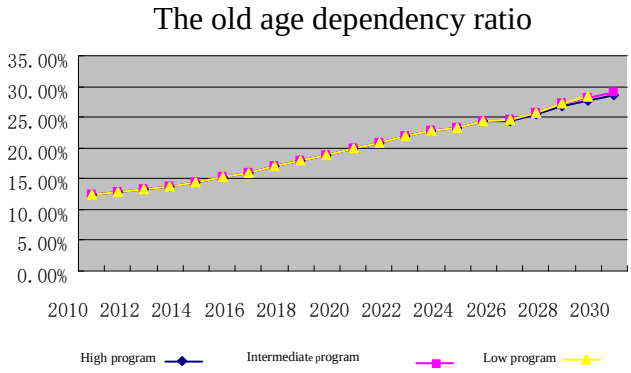

Figure 2 The trend of the elderly dependency ratio.

It can be seen from Figure 2, under different programs, the next 15 years, Shaanxi rural elderly dependency ratio has similar to the same trend.In 2020, the rural old-age dependency ratio in Shaanxi was more than 20%. In 2030, the rural old-age dependency ratio in Shaanxi was more than 29%.It can be seen that regardless of which kind of program, Shaanxi rural elderly dependency ratio is in the growth trend. The aging degree is accelerated, so the rural labor force population burden will become more and more heavier.

Total dependency ratio

The total dependency ratio is the proportion of non - labor and working - age population. According to the established population forecasting model, the older dependents are available as shown in Figure 3.

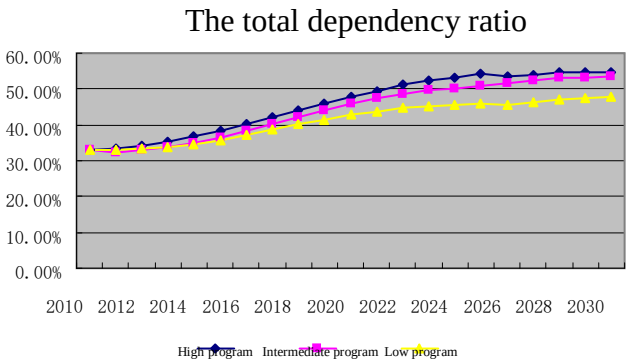

Figure 3 The total dependency ratio trends

As can be seen from Figure 3, under different programs Shaanxi rural total dependency ratio is increasing in the next 15 years. From a numerical point of view, under the low program the total dependency ratio in 2018 reach 40%, reaching 47% by 2030.In the Intermediate program, the total dependency ratio reach 40% in 2017 , by 2030 the total dependency ratio reach 53%.In the High program, the total dependency ratio reached 40% in 2016 , by 2030 the total dependency ratio reached 54%.It can be seen that in the next 15 years, Shaanxi rural total dependency ratio will be more than 50%, the working age population burden increased, also shows that the "demographic dividend" will gradually disappear.

Working Age Population Percentage

The working age population is 15-64 years old. Figure 4 is the working age of the proportion of the total population trend.

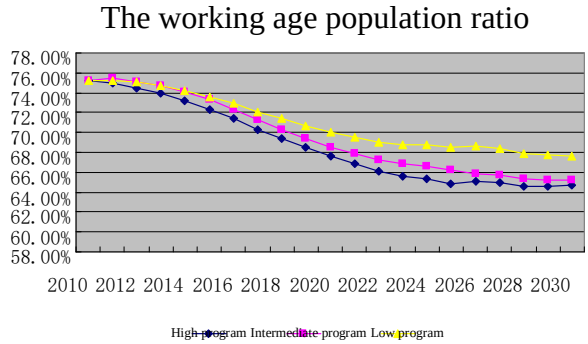

Figure 4 Various programs Labor Age Population ratio

It can be seen from Figure 4, the rural population in rural areas in the proportion of the total population is declining in the next five years under various programs.From 2010 to 2030, the proportion of working age population in low, medium and high programs decreased by 7.58%, 10.06% and 10.56% respectively.The high program fell below 14 million in 2029, and the Intermediate program and the low program fell below 14 million in 2027.

Older population ratio

The older population is the proportion of the elderly population (65 years and above) to the total population. Figure 5 shows the trend of rural elderly population in Shaanxi Province.

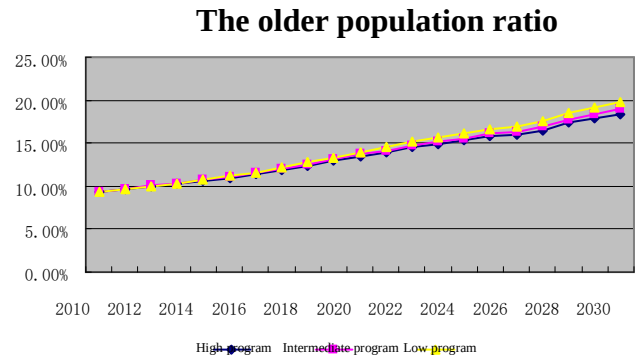

Figure 5 Elderly population trend

It can be seen from Figure 5, the proportion of rural population in Shaanxi Province has been rising in the next 15 within a variety of programs. Under the low program, the degree of aging reached 19.79% in 2030.Under the Intermediate program it reached 18.93% in 2030.Under the High program it reached 18.93% in 2030.From the total population point of view, in these three programs under 2030 elderly population exceeded 396.65 million people

CONCLUSIONS

In this paper, the effect of fertility model on fertility level was considered and the mortality function of sub-sex age scale was fitted. Using the high, medium and low schemes, the dynamic population growth equation model was used to establish the rural population Prediction model. From the forecast results, we can see that in the next 15 years, the proportion of rural elderly population in Shaanxi Province increased , the old age dependency ratio increased , the total dependency ratio increased and the proportion of labor force decreased, Therefore, we should rationally control the population age structure and fundamentally solve the problem of population development.

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