Prediction of Population Aging Based on an Improved Markov Matrix

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ABSTRACT

Grasping the population aging from the perspective of long-term development has certain guiding significance of formulating national economic development plan and social strategic goals in China. Based on the Markov matrix and the population process reflected by Leslie matrix, an improved Markov matrix is constructed in this paper to predict the aging tendency of China's population. The prediction process takes full account of age-specific fertility rate, age-specific survival rate, male-to-female birth ratio and age-specific male-to-female ratio, which makes it have strong fault tolerance. It turns out that China's population will reach a peak of 1.42337 billion in 2027, and the proportion of the aging population will reach a maximum of 34.35% in 2060 and then begin to decline slightly, which can be traced to the second baby boom in Chinese history. But the proportion will remain above 25% until 2220. China's population aging is a long-term and non-cyclical process, and its deepening is mainly caused by the population structure not adapting to the population fertility pattern and life style under the background of the new era. Therefore, improving the population aging in China needs time to push forward the evolution of population structure. At the same time, China should develop a long-term sustainable aging economy to prepare for confronting the aging war and the "turning point".

Keywords*: Population Prediction, Improved Markov Matrix, Population Aging, Leslie Matrix, Turning Point.*

1. INTRODUCTION

With the rapid development of social economy, continuous breakthroughs in science and technology and steady improvement of people's living standards since the reform and opening-up, China's population situation has also turned a corner. One of the major issues that has attracted special attention is the increasing degree of population aging. According to *the Bulletin of the Seventh National Population Census*, the total number of aging people over 65 years old in China accounted for 13.50% in 2020, an increase of 4.63% compared with 2010, approaching the standard of aging coefficient of 14% in the stage of deep aging. At present, some scholars try to construct a new combination model [1-3] on the basis of the original models, such as population-development-environment model [4], grey system model [5], neural network model [6-7], gene expression method [8], Bayesian hierarchical model [9], etc. Although the prediction accuracy has been improved, these models still ignore the reproduction process of the populations. In fact, whether it is population size, population structure, fertility rate or survival rate, these demographic characteristics are related to the whole population process, and they are also interrelated and influence each other. Therefore, based on the Markov matrix and Leslie matrix, this paper attempts to construct an improved Markov matrix that fits the population process so as to study the development tendency and characteristics of population aging in China, and interpret the current population aging from the perspective of history and future.

2. IMPROVED MARKOV MATRIX

Markov matrix dosen't need to seek the mutual rule from the complex influence factors and consequence, but only considers the evolution characteristics of the historical conditions of the event, and uses the state transition probability to predict the tendency of the future state [10]. It can roughly estimate the variation tendency of population size and population structure, but cannot reflect other population characteristics more, such as sex ratio, age-specific fertility rate, etc.

Leslie matrix is an effective means of predicting the evolution of population size and age structure, so it has always been concerned by scholars in population research [11]. But Leslie matrix only takes women into account

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and assumes that all people over 90 will die one year later. However, with the improvement of people's living quality, the number of people over 90 years old is also increasing, becoming a large group that can not be ignored.

Markov matrix and Leslie matrix have advantages and disadvantages respectively which are both special transition matrixes in essence. Based on the Markov matrix and the thought of population process reflected by Leslie matrix, we create an improved Markov matrix by multiplying the Markov matrix representing survival state and the Markov matrix representing fertility state. The matrix contains 183 states, recording 0 years old of non-pregnancy, 0 years old of pregnancy, ..., over 90 years old non-pregnancy, over 90 years old pregnancy and death as the 1st, 2nd, ..., 181st, 182nd, 183rd states.

2.1 Basic Assumptions of Matrix

(1) Affected by fertility rate, it is assumed that the research object of matrix is only female;

(2) It is assumed that pregnant women must experience childbirth in addition to the causes of death, and miscarriage and abortion are not considered;

(3) The number of pregnant women beyond the age of 14 to 48 is defined as 0 due to the pregnancy lasting approximately one year;

(4) Female deaths in every age group are uniformly classified as death state without specific distinction.

2.2 Specific Construction of Matrix

Define the transfer matrix from the nth year to the $(n+1)$th year as $\mathbf{M}_n$. In the nth year, the element $\mathbf{M}_n(i,j)$ in the ith row and jth lie represents the rate of the transition from the jth state to the ith state, the ratio of the pregnant women at the age of i in the nth year entering the pregnancy state again in the $(n+1)$th year is $a_i(n)$, the ratio of non-pregnant women at the age of i entering the pregnancy state in the next year is $b_i(n)$, the fertility rate of women at the age of i is $\delta_i(n)$, and the ratio of women at the age of i surviving to the next year is $p_i(n)$, thus:

$$
\mathbf{M}_n = \begin{pmatrix}
0 & 0 & \cdots & 0 & 0 & 0 \\
0 & 0 & \cdots & 0 & 0 & 0 \\
p_0(n)(1-b_0(n)) & p_0(n)(1-a_0(n)) & \cdots & 0 & 0 & 0 \\
p_0(n)b_0(n) & p_0(n)a_0(n) & \cdots & 0 & 0 & 0 \\
0 & 0 & \cdots & 0 & 0 & 0 \\
0 & 0 & \cdots & 0 & 0 & 0 \\
\vdots & \vdots & \ddots & \vdots & \vdots & \vdots \\
0 & 0 & \cdots & p_{90}(n)(1-b_{90}(n)) & p_{90}(n)(1-a_{90}(n)) & 0 \\
0 & 0 & \cdots & p_{90}(n)b_{90}(n) & p_{90}(n)a_{90}(n) & 0 \\
1-p_0(n) & 1-p_0(n) & \cdots & 1-p_{90}(n) & 1-p_{90}(n) & 1
\end{pmatrix}_{183\times183}
$$

$$
= \begin{pmatrix}
0 & 0 & 0 & 0 & \cdots & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & \cdots & 0 & 0 & 0 & 0 & 0 \\
p_0(n) & 0 & 0 & 0 & \cdots & 0 & 0 & 0 & 0 & 0 \\
0 & p_0(n) & 0 & 0 & \cdots & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & p_1(n) & 0 & \cdots & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & p_1(n) & \cdots & 0 & 0 & 0 & 0 & 0 \\
\vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots & \vdots \\
0 & 0 & 0 & 0 & \cdots & p_{89}(n) & 0 & p_{90}(n) & 0 & 0 \\
0 & 0 & 0 & 0 & \cdots & 0 & p_{89}(n) & 0 & p_{90}(n) & 0 \\
1-p_0(n) & 1-p_0(n) & 1-p_1(n) & 1-p_1(n) & \cdots & 1-p_{89}(n) & 1-p_{89}(n) & 1-p_{90}(n) & 1-p_{90}(n) & 1
\end{pmatrix}_{183\times183}
$$

$$
\times \begin{pmatrix}
1-b_0(n) & 1-a_0(n) & 0 & 0 & \cdots & 0 & 0 & 0 & 0 & 0 \\
b_0(n) & a_0(n) & 0 & 0 & \cdots & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1-b_1(n) & 1-a_1(n) & \cdots & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & b_1(n) & a_1(n) & \cdots & 0 & 0 & 0 & 0 & 0 \\
\vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots & \vdots \\
0 & 0 & 0 & 0 & \cdots & 1-b_{89}(n) & 1-a_{89}(n) & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & \cdots & b_{89}(n) & a_{89}(n) & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & \cdots & 0 & 0 & 1-b_{90}(n) & 1-a_{90}(n) & 0 \\
0 & 0 & 0 & 0 & \cdots & 0 & 0 & b_{90}(n) & a_{90}(n) & 0 \\
0 & 0 & 0 & 0 & \cdots & 0 & 0 & 0 & 0 & 1
\end{pmatrix}_{183\times183} \tag{1}
$$

The specific assignment methods of each parameter are as follows:

$a_i(n)$: According to the survey of Beijing Population Research Institute, it takes 3.97 years on average for families to have a second child without the influence of policy factors. Meanwhile, according to the survey data of fertility intention of urban residents in Hebei province, almost 100% of families spend more than two years to give birth to their first and second children [12]. Very few

families have had two children in succession within two years, but considering that families like this do exist, we approximate a_i to 0.001 when it is not zero. That is:

$$a_i(n) = \begin{cases} 0, i = 0,1,\ldots,13 \text{ or } i = 48,49,\ldots,90 \\ 0.001, i = 14,15\ldots,47 \end{cases} \quad (2)$$

$b_i(n)$: The number of pregnant women in the $(n+1)$th year is mostly reflected by the number of newborns in the $(n+2)$th year. Because the increase and decrease of pregnant women reflected in $\mathbf{M}_n$ is actually related to the birth rate in the $(n+2)$th year, $b_i(n)$ is approximated as fertility rate $\delta_{i+2}(n+2)$. That is:

$$b_i(n) = \begin{cases} 0, i = 0,1,\ldots,12 \text{ or } i = 48,49,\ldots,90 \\ \delta_{i+2}(n+2), i = 13,14,\ldots,47 \end{cases} \quad (3)$$

$p_i(n)$: The influence of pregnancy and non-pregnancy on female survival rate is not considered in this paper, so $p_i(n)$ is uniformly taken as the overall survival rate of women at the age of i in the nth year.

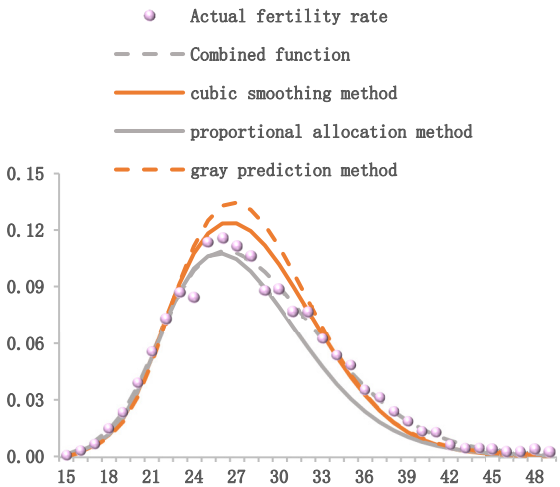

Figure 1. Age-specific fertility rate fitting image in 2018

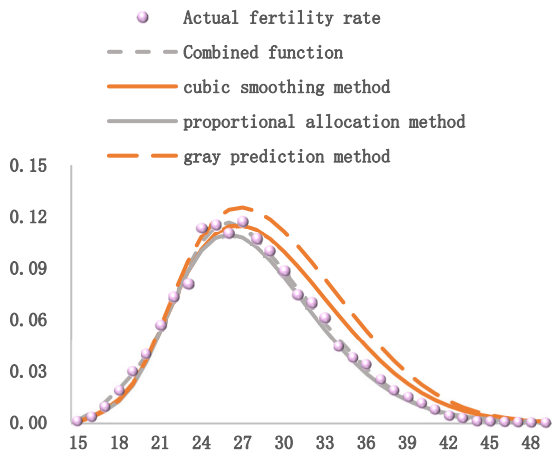

Figure 2. Age-specific fertility rate fitting image in 2019

3. POPULATION PREDICTION MODEL BASED ON THE IMPROVED MARKOV MATRIX

Define the initial year as the 0th year and the corresponding state vector of the n th year as $\mathbf{S}_n = (s_{n,1}, s_{n,2}, \ldots, s_{n,182}, s_{n,183})^T$, where $s_{n,i}(i = 1,3\ldots181)$ represents the number of non-pregnant females at the age of $\frac{i-1}{2}$ in the n th year, $s_{n,i}(i = 2,4,\ldots,182)$ represents the number of pregnant females at the age of $\frac{i-2}{2}$ in the nth year, $s_{n,183}$ is the number of female deaths in the nth year, $\mathbf{F}_n = (f_{ij})_{183\times183}$ is an auxiliary matrix, and ε_n represents the proportion of female births in the n th year. $\mathbf{S}_n$ can be obtained according to the recursive formula

$$\mathbf{S}_n = \mathbf{M}_{n-1}\mathbf{S}_{n-1} + \mathbf{F}_n\mathbf{S}_{n-1} \quad (4)$$

where

$$f_{ij} = \begin{cases} \varepsilon_n, i = 1 \text{ and } j = 30,32,34,\ldots,98 \\ 0, \text{others} \end{cases} \quad (5)$$

After obtaining the state vector $\mathbf{S}_n$ in the nth year, we can calculate the population number and population structure of China only according to the number of females and the ratio of males to females at different ages. Next, we make predictions for four indicators: age-

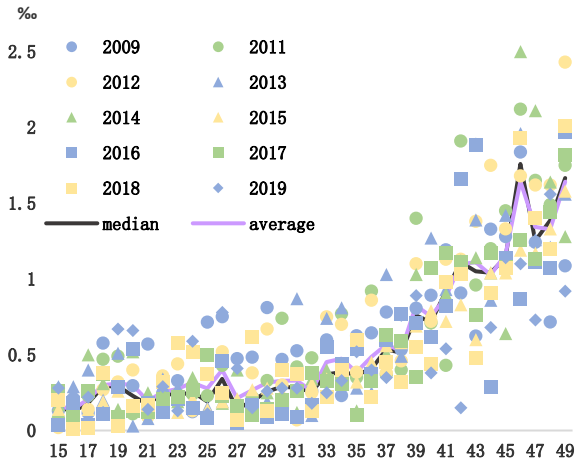

Figure 3. Age-specific mortality rate of females at childbearing age in China after smoothing treatment

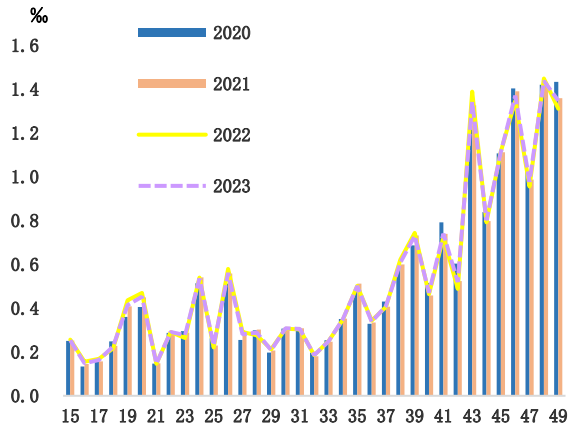

Figure 4. Age-specific mortality rate of women of childbearing age in China from 2020 to 2023

specific fertility rate, age-specific mortality rate, male-to-female birth ratio and age-specific male-to-female ratio.

3.1 Prediction of the Age-Fertility Rate

Lognormal distribution model, Poisson distribution model and Weber distribution model are widely used in the study of age-specific fertility rate by scholars at home and abroad. Liping Yu et al. [13] proposed the first combined model by combining lognormal distribution model and Poisson distribution model, whose results were better than the model fitting alone. Changwei Li et al. [14] proposed the second combined model by combining lognormal distribution model and Weber distribution model, which worked better than the first combined model.

Table 1. RMSE comparison of three parameter prediction methods

	Cubic Smoothing	Proportional Allocation	Gray Prediction
2015	0.009533	0.011308	0.013848
2016	0.006138	0.005552	0.007461
2017	0.017000	0.015772	0.017663
2018	0.007948	0.008183	0.011827
2019	0.008020	0.004442	0.013945

We take the age-specific fertility rate from 2009 to 2019 as an example (lack of data in 2010 because of census), and use the combined formula of lognormal distribution and Weber distribution proposed by Changwei Li et al. [14] and the least square method to estimate the parameters. In Equation (6), k is the overall scale transformation factor, λ is the weight factor of the lognormal distribution model, σ and μ determine the shape of age-specific fertility curve, α and β reflect the fertility pattern [15], and $x_0 = 14$.

$$f(x) = k \times [\lambda \times \frac{1}{\sigma(x-x_0)\sqrt{2\pi}} e^{\frac{-(ln(x-x_0)-\mu)^2}{2\sigma^2}} + (1 - \lambda) \times \frac{\beta}{\alpha}\left(\frac{x-x_0}{\alpha}\right)^{\beta-1} e^{-\left(\frac{x-x_0}{\alpha}\right)^{\beta}}] \quad (6)$$

After fitting the age-specific fertility rate from 2009 to 2019, it can be observed that the value range of parameters is relatively stable. Therefore, we use three methods, namely cubic smoothing method, 1:2:3:4:5 proportional allocation method and gray prediction method to predict parameters from 2015 to 2019. The root mean square error (RMSE) is shown in Table 1. Figure 1 and Figure 2 respectively take 2018 and 2019 as examples to demonstrate the fitting results. Because the combined function is highly consistent with the actual fertility rate, and the three methods of parameter prediction are based on the combined function fitting, the errors are all within an acceptable range. We use proportional allocation method whose fitting effect is best to predict the parameters and substitute them into the combination formula. The fertility rates obtained are given in Table 2.

Table 2. Fertility rates for women aged 30-40 in 2020-2025

	30	31	32	33	34	35	36	37	38	39	40
2020	0.0904	0.0788	0.0671	0.0559	0.0455	0.0362	0.0282	0.0214	0.0159	0.0115	0.0082
2021	0.0920	0.0804	0.0687	0.0575	0.0470	0.0376	0.0294	0.0224	0.0167	0.0121	0.0086
2022	0.0918	0.0806	0.0693	0.0583	0.0480	0.0388	0.0306	0.0236	0.0178	0.0131	0.0094
2023	0.0915	0.0801	0.0685	0.0575	0.0472	0.0379	0.0298	0.0228	0.0171	0.0125	0.0089
2024	0.0915	0.0800	0.0684	0.0573	0.0470	0.0377	0.0295	0.0226	0.0169	0.0123	0.0088
2025	0.0916	0.0801	0.0686	0.0575	0.0471	0.0378	0.0297	0.0227	0.0170	0.0124	0.0089

Table 3. Proportion of female births in 2020-2049

Year	Proportion of Female Births	Year	Proportion of Female Births	Year	Proportion of Female Births
2020	0.468861317	2030	0.468167911	2040	0.467728013
2021	0.468967331	2031	0.468016578	2041	0.467750312
2022	0.469502398	2032	0.467971864	2042	0.4677859
2023	0.468973426	2033	0.46788937	2043	0.467827425
2024	0.468630939	2034	0.467768973	2044	0.46786259
2025	0.469185782	2035	0.467765035	2045	0.467904008
2026	0.468404232	2036	0.467680869	2046	0.467935318
2027	0.468914455	2037	0.467709205	2047	0.467969231
2028	0.468313215	2038	0.467692796	2048	0.467997392
2029	0.468324221	2039	0.467706779	2049	0.468021462

3.2 Prediction of the Age-Specific Mortality

The overall female mortality rate of China has not changed much in recent years, which is mainly due to the relative balance of the mortality rate caused by the gradual improvement of China's medical level, the environmental impact brought by economic development, and people's own living habits. To further study the age-specific mortality rate, we collated the age-specific mortality rate data for females from 2009 to 2019 and performed simple smoothing on the points with large variation, as shown in Figure 3.

The closer mortality rates are to a given year, the more valuable they are to the given year regardless of emergencies. In combination with the mortality rate of the previous three years, we predict the mortality rate of the current year with the reference value of 1:2:3. The result is shown in Figure 4 with 2020-2023 as an example.

3.3 Prediction of the Ratio of Male to Female Births

Since there are many influence factors of sex ratio at birth, and it is difficult to find an accurate calculation formula according to their corresponding influence factors, and the value is relatively stable [16], it is suitable to adopt the grey model GM (1,1) for prediction [17]. The figure below shows the comparison between the actual proportion of female born in China and the grey predicted from 2009 to 2019. Except for the large error of initial value, the fitting degree of other years is excellent.

The predicted proportion of female births from 2020 to 2049 is shown in Table 3. We find that in the process of forecast, development index a has been between-0.002 and -0.0004, meeting $|a| < \varepsilon$ (ε is a sufficiently small normal number) [18]. Combined with the successful

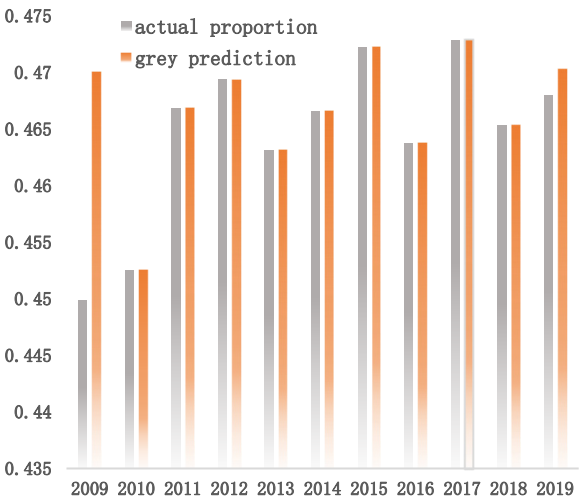

Figure 5. Proportion of female births in China

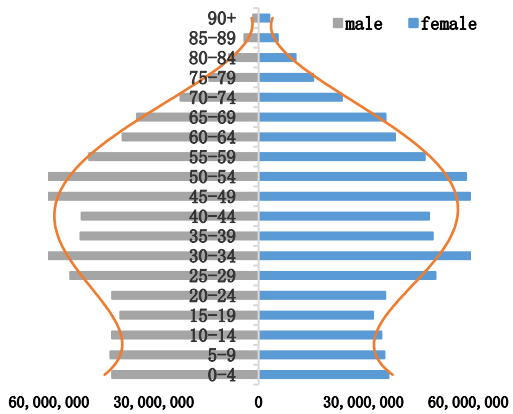

Figure 6. China's population pyramid in 2020

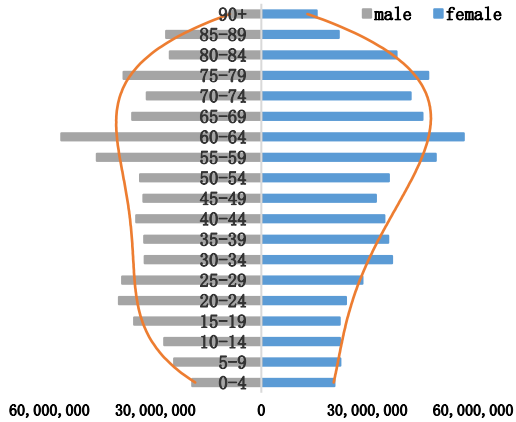

Figure 7. China's population pyramid in 2050

experience of grey prediction, ε can be regarded as sufficiently small at 0.06 [19], which fully demonstrates that our prediction results are relatively accurate. In the same method we predicted 0-4, 5-9, ..., 85-89, 90+ age groups of women.

4. ANALYSIS OF PREDICTIONS

This paper will analyze the future development trend of aging in China from three aspects. Firstly, this paper studies the changes of population size and population structure in China from 2020 to 2050 to analyze the impact of population aging on society. Secondly, based on the original model, the prediction time is extended to 2220 years to study the duration and cycle characteristics of aging in China. Finally, this paper calculates the final stable state of a specific transition matrix and studies whether the population transition reflected by the matrix is reasonabe.

4.1 Analysis of Demography from 2020 to 2050

Taking the number of females in 2019 as our initial state, we can calculate the number of females at different ages by substituting it into the population prediction

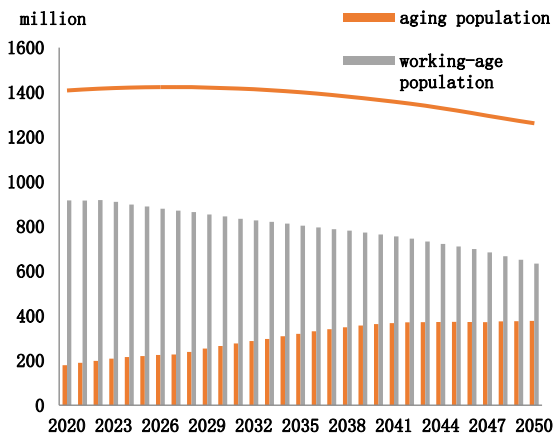

Figure 8. Changes of the numbers of population, aging population and working-age population in China from 2020 to 2050

model based on the improved Markov matrix, and then we can get the number of males at different ages by using the predicted ratio of males to females at different ages. Taking 2020 and 2050 as examples, the population pyramids are as follows.

As can be seen from the figure above, the number of children will be significantly smaller than the number of working population in 2020, which indicates the reduction of the working population and the aging trend of the population in the future. In 2050, the population pyramid will get wider at the top and narrower at the bottom, meaning that there will be fewer children and more elderly people.

Figure 8 shows the prediction results of relevant population in China from 2020 to 2050. It can be seen that the total population of China will reach the maximum value of 1.42337 billion at the turning point in 2027, and

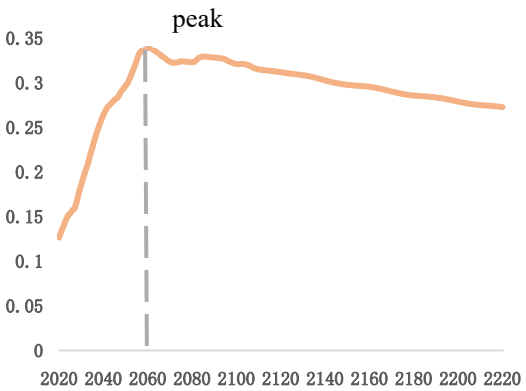

Figure 9. Proportion trend of the elderly population in China from 2020 to 2220

the total population is expected to decrease to 1.26156 billion in 2050 when the aging population accounts for about 29.89% and the working-age population accounts for only 50.19%, which means that for every 100 working people, the number of pensioners has increased from 19 to 59. As the traditional family pension function is greatly weakened and the social pension system is not yet mature, how the elderly themselves, the family, the society and the government work together to deal with the increasingly prominent problems of the elderly has become a major livelihood issue and challenge in the new era [20].

4.2 Study on Aging Duration

Based on the model established above, we extend the prediction time from 2050 to 2220. With the extension of the prediction period, the error of the model will certainly increase, but the overall trend of change still has a certain reference value. The proportion of the elderly population shows a steady decline after crossing the turning point

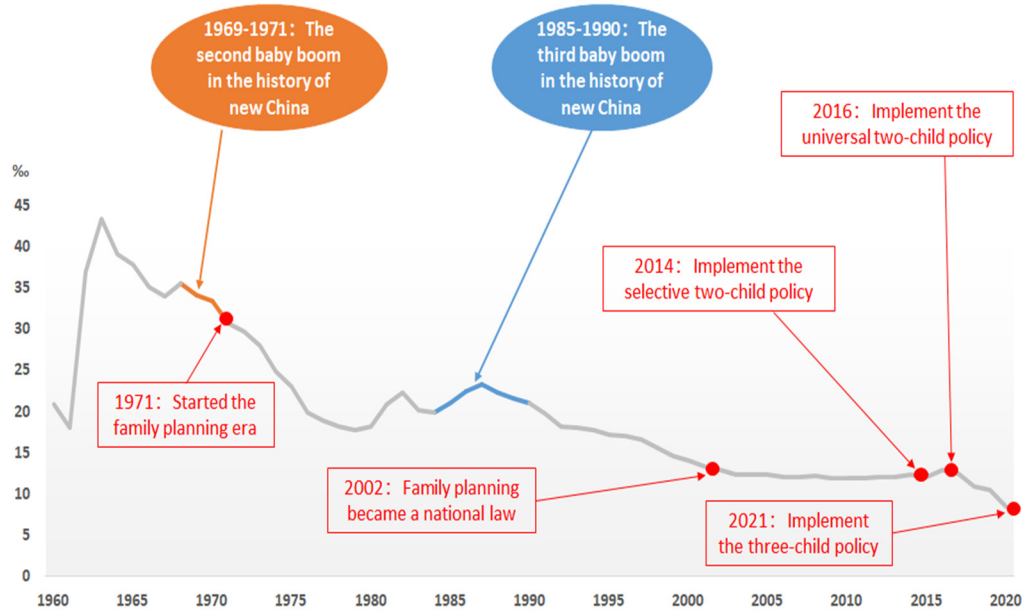

Figure 10. China's historical birth rate and policies from 1960 to 2021

in 2060 in the Figure 9, but will keep on the proportion above 25% until 2220, which shows that China's population aging is not a short-term or cycle phenomena [21]. On the contrary, long-lasting, large-scale and high proportion of elderly population will be the inevitable result of our society [22]. Therefore, China's policies should focus on the long-term development of the aging society and stimulate the growth of the population with the corresponding fertility policy on the basis of the comprehensive implementation of pension policies.

According to our country's history and the future proportion of elderly population, we find that these old people who successively enter the state of death around 2060 happen to correspond to the babies born between the second baby boom in 1962 and the reform and opening-up in 1978. China has also experienced the third baby boom again in 1985-1990, but compared to the previous baby boom, it has a shorter duration and a smaller fluctuation range of fertility rate. The babies born in this period will become the old population in 2060, which is far from making up for the number of babies born in the second baby boom who will enter the state of death in 2060, resulting in a retarding of aging population. The aging of our country's population is an inevitable trend, but it is also a predictable fact that it will slow down in a few years.

4.3 Study on Population Transition Matrix

The health status of the population is defined as less than 7% of the population aged over 65. If the final stable state corresponding to the current population transition matrix is healthy, we need to focus our policy making on present and overcome the short-term pressures of population aging. If it is unhealthy, the policy formulation should focus on the long-term sustainable development of the aging economy, and even consider changing the standard of the aging society to keep up with the process of the new era in time [22]. We still take female as the research object. Taking the improved Markov matrix $\mathbf{M}_{2019}$ as an example, suppose that the corresponding state vector of 2019 is $\mathbf{S}_{2019}$ and the final stable state is $\mathbf{F}_{2019}$, then:

$$\mathbf{M}_{2019}\mathbf{f}_{2019} + \mathbf{F}_{2020}\mathbf{f}_{2019} = \lambda\mathbf{f}_{2019} \tag{7}$$

That is:

$$(\mathbf{M}_{2019} + \mathbf{F}_{2020})\mathbf{f}_{2019} = \lambda\mathbf{f}_{2019} \tag{8}$$

Therefore, $\mathbf{f}_{2019}$ is the eigenvector of $\mathbf{M}_{2019} + \mathbf{F}_{2020}$, and the proportion of each age can be obtained by standardizing $\mathbf{f}_{2019}$, as shown in Figure 11. Figure 12 plots the change of the proportion of the aging population calculated using $\mathbf{M}_{2019} + \mathbf{F}_{2020}$ and $\mathbf{S}_{2019}$, where the state vector in the nth year is

$$\mathbf{S}_n = (\mathbf{M}_{2019} + \mathbf{F}_{2020})^{n-2019}\mathbf{S}_{2019} \tag{9}$$

In this paper, according to the classification standard of age structure in *Population Geography* written by Yujiang Li [23], we can know that $\mathbf{f}_{2019}$ is a young type by calculation of relevant indicators, which indicates that the population transfer situation in 2019 is reasonable. Under the situation that all conditions remain unchanged, China will end the aging society at the turning point in 2075. The population structure will stabilize around 2200, when the proportion of the aging population above 65 years old is only 4.49%.

5. CONCLUSIONS

In this paper, an improved Markov matrix is obtained by combining the Markov matrix and idea of Leslie matrix based on the phenomenon of increasing aging degree in China, and a population prediction model

suitable for China's reality is constructed. The conclusions are as follows:

(1) The total population of China will reach its peak in 2027 and continue to decrease until 2050, while the total number of the aging population will remain in a

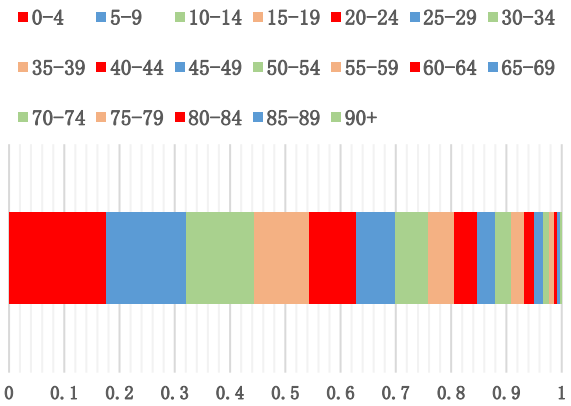

Figure 11. Population structure in the final stable state

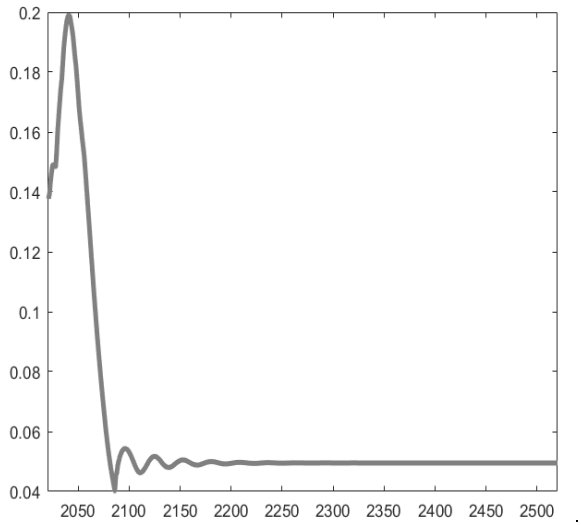

Figure 12. Schematic diagram of the change of the proportion of the aging population

period of growth in a short time. As the population aging deepens and the size of the labor force shrinks, the burden on the working-age population, society and the government of supporting elderly and raising children will inevitably increase. We should also note that with the support of policies, the elderly population with rich knowledge, skills and productive experience could become a valuable resource for social and economic development and an indispensable force for social construction.

(2) China's population aging is a long-term and non-cyclical process. The proportion of the elderly population will reach its peak in 2060, and will remain in a stable and declining state until 2220 with aging moderated but still at a high aging level. Combined the phenomenon that "two-child policy" which is gradually implemented in 2014 has not fundamentally solved the problem of population development in our country or brought the fourth baby boom [24], we can conclude that improving the population aging in our country under the background of the new ear not only needs the support of population policy, but also needs time to push forward the evolution of China's population structure.

(3) This paper takes 2019 as an example. Under the premise that the transfer situation remains unchanged, the proportion of the elderly population in China will undergo a turning point in the next 20 years, and then decline steeply-slope in the next 50 years which makes the population structure return to the young type. It can be boldly speculated that the deepening of China's aging is primarily caused by the population structure not adapting to the fertility pattern and survival state. When the population structure adapts to it for a period of time, China's aging will rapidly slow down and recover to the normal level.

This paper mainly studies the population aging in China. The prediction method is relatively innovative, and the combination and application of Markov matrix and Leslie matrix are successfully realized. In terms of the analysis of the prediction results, this paper analyzes from the short-term and long-term perspectives, and explains that China's population aging is a serious but will slow down, long-term but not cyclical process, and the growth of the proportion of the aging population will be finite. At the same time, this paper also creatively analyzes the causes of aging from the historical dimension and correctly views the current population situation from the limit dimension, which provides a new idea for the academic community to study population aging. From an optimistic point of view, aging will not continue to deepen and there is a high probability that China will go back to non-aging at some point in the future, but it is still a long way to overcome the problem of population aging. How to formulate policies according to the actual population situation in China is a new requirement for China's policy-makers in the new era.

Table 4. Classification standards of age structure types

Type	Young Type	Adult Type	Senile Type	f_{2019}
Proportion of Population Aged 0-14	≥40%	30%-40%	≤30%	44.26%
Proportion of Population Aged over 65	≤4%	4%-7%	≥7%	4.49%
Ratio of Old to Young	≤15%	15%-30%	≥30%	10.14%
Median Age	≤20	20-30	≥30	17.28

AUTHORS' CONTRIBUTIONS

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