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Predicting China population structure under population aging

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ABSTRACT

Population aging problem becomes increasingly severe in the process of economic and social development in China. In this paper, urban people's death rates are estimated by age and gender respectively, then the women's birth rates are predicted using Grey-Models. Furthermore, Chinese urban population structure is predicted. From the results and analysis, it can be clearly seen that the population aging in China is becoming more and more severe under our current policies. That a sharply decline for the population of labor force would affect the development of Chinese economy.

KEYWORDS

Death rate; Birth rate; Population aging; Predicting.

INTRODUCTION

Nowadays, Chinese population aging is becoming more and more severe, which is different from other developed countries, for it comes before a developed market economy, i.e. aging comes before richness. It would have heavy influences to Chinese society and economy. On one hand, population aging will result in a decline of supply of labor force, which might drive a disadvantage of higher price of labor force. On the other hand, there will be more and more aging people, which might lead to a lot of problems of supporting old people, such as the balance of pension fund, medical insurance and so on.

Predicting the future urban population structure of China reasonably, computing the advantage of demographic dividend and disadvantage of population aging in China, are very significant for Chinese sustainable development, which contains medical treatment and public health, education and so on.

As for population structure prediction methods, queue factor models gain their popularity. They could be classified to 2 types depending on the methods of estimating death rate and birth rate. One is Demographic Scenarios Forecast Methods (DSFM), such as the United Nations predicting the problems of population aging and decline of population of industrialized countries in 2000[1]. The other is Demographic Probabilistic Forecast Methods (DPFM), for example, Lutz and his group predicted that the population in world will be 7.4 - 10.4 billions in 2050 by the probability of 80%[2]. They also did a lot of work on population's probability forecast for European Union countries and other countries in world[2-4].

Taking the exactness into consideration, we refer to the actuarial models, predict China urban people's death rates by age and gender respectively, then predict the women's birth rates, and at last get China population structure.

DATA AND MODELING

TABLE 1: Center death rate data by gender and age group respectively (‰)

Age Group	Year 1990		Year 1995		Year 2000		Year 2005		Year 2010	
	Male	Female	Male	Female	Male	Male	Female	Male	Female	Male
0-4	6.11	6.61	6.71	8.32	5.25	6.98	2.99	3.64	1.31	1.27
5-9	0.85	0.61	0.73	0.58	0.65	0.44	0.53	0.29	0.36	0.23
10-14	0.67	0.50	0.62	0.46	0.50	0.33	0.49	0.27	0.37	0.22
15-19	1.08	0.87	1.11	0.79	0.77	0.47	0.87	0.44	0.52	0.25
20-24	1.41	1.17	1.68	1.23	1.21	0.72	1.26	0.51	0.70	0.30
25-29	1.40	1.12	1.79	1.17	1.36	0.84	1.41	0.60	0.84	0.37
30-34	1.72	1.29	1.96	1.18	1.66	0.98	1.73	0.79	1.11	0.50
35-39	2.25	1.60	2.35	1.46	2.15	1.18	2.18	1.06	1.59	0.71
40-44	3.29	2.30	3.30	2.02	3.05	1.70	2.98	1.29	2.37	1.11
45-49	5.02	3.50	4.97	3.07	4.33	2.57	4.32	2.20	3.50	1.68
50-54	8.04	5.52	7.61	5.02	6.71	4.19	5.86	3.27	5.48	2.81
55-59	13.10	8.54	12.64	7.88	10.57	6.63	8.85	5.20	8.04	4.29
60-64	22.38	14.37	21.46	12.56	17.92	11.43	14.29	8.95	13.02	7.49
65-69	35.99	23.26	34.58	21.75	29.59	19.06	23.70	15.14	21.26	13.06
70-74	59.15	39.75	56.51	38.87	51.03	34.11	39.19	26.07	37.01	24.36
75-79	86.79	60.51	86.44	61.42	79.89	55.70	63.02	45.33	59.13	40.89
80-84	136.42	99.16	138.60	103.81	133.28	97.48	100.56	75.95	98.56	73.98
85-89	190.52	145.73	201.24	154.64	188.75	145.36	155.25	118.51	146.53	115.29
90+	271.13	231.61	316.08	259.44	264.44	245.18	239.61	202.17	216.19	193.30

Note：Data resource：Chinese Population Census Data in 1990, Chinese Population Census Data in 2010, Sample Survey Data of 1% of the whole Population in 1995, Sample Survey Data of 1% of the whole Population in 2005.

Based upon the maximum likelihood estimation (MLS), the parameters of α_x , β_x and κ_t can be estimated.

Poisson Log-bilinear model

Death numbers could be seen as a counting process, suppose that it submit to the Poisson distribution[5]:

$$D_{xt} \sim Poisson\left(E_{xt}\mu_x\left(t\right)\right), \ \mu_x\left(t\right) = \exp\left(\alpha_x + \beta_x\kappa_t\right) \quad \textbf{(1)}$$

where $\sum_t \kappa_t = 0$ and $\sum_x \beta_x = 0$, i.e.

$$\ln \mu_x(t) = \alpha_x + \beta_x \kappa_t \tag{2}$$

Prediction of Urban Population Death Rate

In this paper, we use the broader respondents i.e. the national census and survey data[6-9] in large sample of actual population condition. We list our data in TABLE 1.

From the estimation model, we can get the estimated values of α_x and β_x by male and female respectively, as well as estimated values of κ_t, in TABLE 2-4.

TABLE 2: Estimated value of α_x and β_x in male

Age Group	α_x	β_x	Age Group	α_x	β_x
0-4	-5.599657	0.150555	50-54	-5.000818	0.035193
5-9	-7.425451	0.087105	55-59	-4.551327	0.046037
10-14	-7.590586	0.057767	60-64	-4.037611	0.051530
15-19	-7.153255	0.072226	65-69	-3.550274	0.050685
20-24	-6.819452	0.070913	70-74	-3.019348	0.045829
25-29	-6.722785	0.053717	75-79	-2.586117	0.039169
30-34	-6.500469	0.046423	80-84	-2.093613	0.035625
35-39	-6.213302	0.036409	85-89	-1.735067	0.029538
40-44	-5.839079	0.032959	90+	-1.375947	0.025013
45-49	-5.455860	0.033306			

TABLE 3: Estimated value of α_x and β_x in female

Age Group	α_x	β_x	Age Group	α_x	β_x
0-4	-5.474921	0.111507	50-54	-5.496986	0.043805
5-9	-7.795474	0.067549	55-59	-5.050793	0.045713
10-14	-7.994234	0.056227	60-64	-4.514296	0.043426
15-19	-7.609534	0.089497	65-69	-4.002110	0.038575
20-24	-7.299224	0.094956	70-74	-3.424246	0.032987
25-29	-7.224706	0.078339	75-79	-2.948926	0.027546
30-34	-7.031170	0.065557	80-84	-2.401315	0.022145
35-39	-6.781100	0.053842	85-89	-1.993190	0.018240
40-44	-6.397218	0.046663	90+	-1.483793	0.017248
45-49	-5.989152	0.046177			

TABLE 4: Estimated values of death rate κ_t in different gender

Year	κ_t	
	Male	**Female**
1990	3.692872	5.029911
1995	3.942539	5.545960
2000	1.422896	2.405613
2005	-2.884598	-3.935165
2010	-6.173709	-9.046318

Taking advantage of OLS to predict the death rate κ_t by gender in future years, we can get the predicted values，which are listed in TABLE 5:

TABLE 5: Predicted values of κ_t

Year	κ_t		Year	κ_t	
	Male	**Female**		**Male**	**Female**
2011	-6.704909	-9.798998	2026	-14.672909	-21.089198
2012	-7.236109	-10.551678	2027	-15.204109	-21.841878
2013	-7.767309	-11.304358	2028	-15.735309	-22.594558
2014	-8.298509	-12.057038	2029	-16.266509	-23.347238
2015	-8.829709	-12.809718	2030	-16.797709	-24.099918
2016	-9.360909	-13.562398	2031	-17.328909	-24.852598
2017	-9.892109	-14.315078	2032	-17.860109	-25.605278
2018	-10.423309	-15.067758	2033	-18.391309	-26.357958
2019	-10.954509	-15.820438	2034	-18.922509	-27.110638
2020	-11.485709	-16.573118	2035	-19.453709	-27.863318
2021	-12.016909	-17.325798	2036	-19.984909	-28.615998
2022	-12.548109	-18.078478	2037	-20.516109	-29.368678
2023	-13.079309	-18.831158	2038	-21.047309	-30.121358
2024	-13.610509	-19.583838	2039	-21.578509	-30.874038
2025	-14.141709	-20.336518	2040	-22.109709	-31.626718

TABLE 6: Predicted center death rate values $\mu_x(t)$ (‰) (Male, partly)

Year	Age Group				
	70-74	**75-79**	**80-84**	**85-89**	**90+**
2025	25.541	43.281	74.466	116.160	177.341
2026	24.927	42.390	73.070	114.351	175.000
2027	24.328	41.517	71.701	112.571	172.691
2028	23.743	40.662	70.357	110.818	170.411
2029	23.172	39.825	69.038	109.093	168.162
2030	22.614	39.005	67.743	107.395	165.942
2031	22.070	38.202	66.474	105.723	163.752
2032	21.540	37.415	65.227	104.077	161.590
2033	21.022	36.645	64.005	102.457	159.458
2034	20.516	35.890	62.805	100.861	157.353
2035	20.023	35.151	61.628	99.291	155.276
2036	19.541	34.427	60.472	97.745	153.226
2037	19.071	33.718	59.339	96.224	151.204
2038	18.612	33.024	58.226	94.726	149.208
2039	18.165	32.344	57.135	93.251	147.239
2040	17.728	31.678	56.064	91.799	145.295

TABLE 7: Predicted center death rate value $\mu_x(t)$ (‰) (Female, partly)

According to the equation $\ln \mu_x(t) = \alpha_x + \beta_x \kappa_t$, we can get the center death rate value $\mu_x(t)$ in future years, which are listed in TABLE 6-7：

Year	Age Group				
	70-74	**75-79**	**80-84**	**85-89**	**90+**
2025	16.246	29.309	56.793	92.750	157.625
2026	15.848	28.708	55.854	91.485	155.591
2027	15.459	28.119	54.931	90.238	153.585
2028	15.080	27.542	54.023	89.007	151.604
2029	14.710	26.977	53.130	87.794	149.648
2030	14.349	26.423	52.252	86.597	147.718
2031	13.997	25.881	51.388	85.416	145.813
2032	13.654	25.350	50.538	84.251	143.932
2033	13.319	24.830	49.703	83.102	142.075
2034	12.993	24.320	48.881	81.969	140.243
2035	12.674	23.821	48.073	80.852	138.434
2036	12.363	23.332	47.279	79.749	136.648
2037	12.060	22.853	46.497	78.662	134.886
2038	11.764	22.385	45.729	77.589	133.146
2039	11.476	21.925	44.973	76.531	131.429
2040	23.577	40.001	72.925	113.958	191.512

Predicting Chinese birth rate

Given observed data

$$x^{(0)} = \left\{ x^{(0)}(1), x^{(0)}(2), \cdots, x^{(0)}(N) \right\} \quad \textbf{(3)}$$

after added for once:

$$x^{(1)} = \left\{ x^{(1)}(1), x^{(1)}(2), \cdots, x^{(1)}(N) \right\} \quad \textbf{(4)}$$

Assume $x^{(1)}$ satisfies First-order differential equation:

$$\frac{dx^{(1)}}{dt} + ax^{(1)} = u \quad \textbf{(5)}$$

In which, a is a constant, i.e. developmental gray number; u is a constant input for the system as a endogenous control gray number[10, 11]. Initial condition is $x^{(1)} = x^{(1)}(t_0)$.

Make use of the average birth rate of urban fertile woman (age 15-49) in 2001-2010[7], work out estimated values of a and u, where $\hat{a} = -0.00183$, and $\hat{u} = 27.70819$. Thus，the predicting model for average birth rate of urban fertile woman (age 15-49) could be written as：

$$\hat{x}^{(1)}(k+1) = 15132.41e^{0.00183k} - 15105.72 \quad \textbf{(6)}$$

According to the results，the average birth rate of urban fertile woman（age 15-49）in 2011-2040 in China can be foreseen in TABLE 8：

TABLE 8: Predicted birth rate （unit：‰）

Year	Birth Rate	Year	Birth Rate	Year	Birth Rate
2011	29.07599	2021	30.05320	2031	30.97003871
2012	29.16350	2022	30.14365	2032	31.06324728
2013	29.25127	2023	30.23437	2033	31.15673637
2014	29.33931	2024	30.32536	2034	31.25050683
2015	29.42761	2025	30.41663	2035	31.3445595
2016	29.51617	2026	30.50817	2036	31.43889524
2017	29.60501	2027	30.59999	2037	31.5335149
2018	29.69411	2028	30.69209	2038	31.62841932
2019	29.78348	2029	30.78446	2039	31.72360938
2020	29.87311	2030	30.87711	2040	31.81908592

RESULT AND DISSCUSS

Assumptions

1) The effects of population migration are not taken into consideration.
2) Suppose the birth rate of the urban fertile woman will not change a lot in following decades.
3) Suppose the gender proportion of the new born is 1：1.

Prediction Results

Based on the initial population data by age and gender respectively from *China Population Statistic Yearbook*, we can get an accurate distribution of population by age and gender respectively from 2012 to 2040, with the specific formulas:

$$P_{0,t}^{M} = P_{0,t}^{F} = 1/2(\sum_{k=15}^{49} P_{k,t}^{F})\,\delta_t : x = 0;$$
$$P_{x,t}^{M} = P_{x-1,t-1}^{M} - \hat{D}_{x-1,t-1}^{M} : x \ge 1, t \ge 1;$$
$$P_{x,t}^{F} = P_{x-1,t-1}^{F} - \hat{D}_{x-1,t-1}^{F} : x \ge 1, t \ge 1. \quad (7)$$

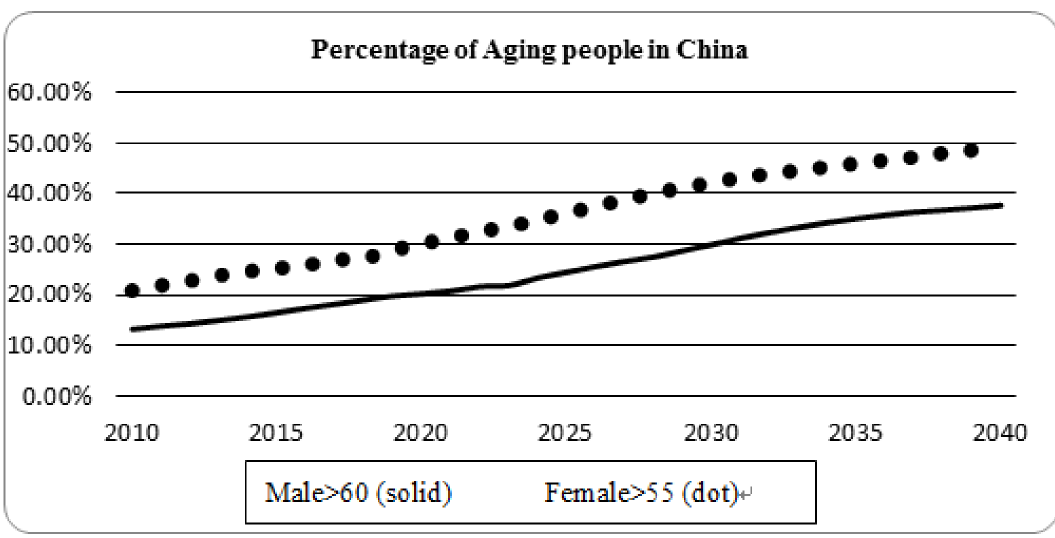

Figure 1: Percentage and trend of China aging people in the next 3 decades

where δ_t is the predicted value of birth rate in year *t*, $\hat{D}^M_{x,t}$, $\hat{D}^F_{x,t}$ are predicted values of dead population numbers in their *x* (age) in year t by gender, $P^M_{0,t}$ is population of the newly born boy baby in year *t*, $P^F_{0,t}$ is population of newly born girl baby in year *t*, $P^M_{x,t}$ is population of male in their *x* (age) in year *t*, and $P^F_{x,t}$ is population of female in their *x* (age) in year *t*.

Based upon the results above, we can get the percentage of the aging people (male >60, female >55) in the next 3 decades, as shown in Figure 1.

From Figure 1, it could be clearly seen that, population of aging male (>60) will increase from 10.2% in 2012 to 35.8% in 2040, meanwhile, population of aging female (>55) will increase from 21.7% in 2012 to 56.2% in 2040. The data indicate that population aging is becoming more and more severe, which might lead to a decrease of labor force and an increase of retired workers. On one hand, serious population aging convert Chinese demographic dividend in past years into population burden, decrease in young labor force making labor's cost increasing so fast as to the sustainable increase will be hindered. On the other hand，population aging will also bring much burden to the medical care and provision for the old.

CONCLUSIONS

In this paper, we combine econometrics methods and actuarial methods, predict Chinese population structure. We predict Chinese urban people's death rates by age and gender respectively using Poisson Log-bilinear model, then predict Chinese women's birth rates using a gray model, and based on above results, we obtain China population structure.

With the demographic structure of China being predicted, it can be learned that population aging has been an emerging problem. Population of aging male (>60) will increase from 10.2% in 2012 to 35.8% in 2040, meanwhile, population of aging female (>55) will increase from 21.7% in 2012 to 56.2% in 2040. The amount of young laborers is reducing and the demographic dividend is disappearing, bringing with a lot of population aging problems such as in education, pension, and healthcare and so on.

According to the report on the Trend of China's Ageing Population Prediction, china has entered the aging society in 1990. At present, population of senior citizens in china is one fifth of the world, in other words, china maintain the largest aging population in the world. Under such complex context, the central government should attach more attention to this problem and corresponding measures should be introduced to meet this challenge. It is a promising start to deliver some relative loose two-child fertility policy recently.

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