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China's Future Population: Predictions and Prospects

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Abstract

Based on the 1949 – 2004 statistics, models of grey increment and grey growth rate are used to predict the population of China up to the year 2050. Evidence shows that at the end of 2005, 2010, 2020, 2030, 2040 and 2050 the total population will reach 1.3068, 1.336, 1.372, 1.391, 1.401 and 1.406 billion, respectively. In the last decade the annual increase is predicted to be less than 460,000 people, showing an almost zero growth.

Keywords

China's population, grey model establishment, model of grey increment, model of grey growth rate, prediction of population size and growth

I. Course of the Development of China's Population

China has the largest population in the world, with 1299.88 million at the end of 2004 (NBS 2005). China's population makes up one fifth of the world's total population. China's huge population is the leading factor influencing and controlling the socio-economic development of the nation. During the 55 years after the founding of the People's Republic of China, the population experienced a twenty-two year high followed by a thirty-three year low. 1949 to 1970 was a stage of high birth and low mortality rates. The period prior to 1949 was characterized by high birth and high mortality rates. Thus, 1949 to 1970 was characterized by a sharp drop in crude mortality and a high birth rate >30‰ to 37‰ (see Table 1), where the sharp fluctuation is an exception in 1959 to1961 for natural disaster-hit years. The yearly increment of Chinese population reached a first population peak of 23.21 million in 1970, when the yearly growth rate was 28.77‰. The period from 1970 to the present is one dominated by birth rate, with mortality reduced to < 7‰. During this period the fast increase in population is suppressed, leading to a significant decrease in the birth rate and natural growth rate. The total birth-giving rate of women was consistently below the level of replacement.

The second stage is divided into three sub-stages. The first sub-stage, 1971–1980, represents a period of sharp drop in birth rate, from 30.65‰ to 18.21‰. In 1980, the yearly net increment dropped to what is was when the PRC was founded. The second sub-stage, 1981–1990 denotes a stage of maintenance of high birth rate, with the birth rate kept above 20‰ and mortality at 6.7‰, for the effect of high birth-rate during the two decades (1950s and 1960s). The yearly net increment rose year by year and formed a second population peak of 17.93 million in1987. The third sub-stage, 1991 to present, signifies a stage during which the birth rate was kept at a low level, declining slowly from 19.68‰ in 1991 to 12.29‰ in 2004. The yearly average increment rate of total population was 11.23‰ during 1991–1997. By comparison, it was 7.20‰ during 1998–2004.

At the end of the 1990s, the reproduction of population reached a stage of low birth rate, low mortality rate, and low augmentation rate. This was an eventful demographic change that took slightly more than 20 years to transpire. In comparison, it took nearly 200 years for the same change to occur in most other foreign countries. During this 20-year interval, China launched a planned birth policy that reduced the total birth size by more than 0.3 billion. This laid the foundation for modernization and a better quality of life. The resulting decrease in population numbers also contributed to the world's population growth and control. Nevertheless, in spite of an effective birth control policy, China's large population continues to increase. The average annual net increase was 13 million in the 1990s. During 2000-2004, the average annual net increase was more than 8.4 million. This increase in population numbers may consume as much as thirty to forty percent of yearly GDP increment. Economists estimate that people's living standard can be maintained only when GDP increases by 3% for every 1% increase in population. Population growth, therefore, exerts great pressure on the social and economic factors that influence the nation. Like all countries,

Table 1. **Statistics of China's population in 1949-2004**

year	total pop (10^4)	birth rate (‰)	mortality (‰)	natural growth (‰)	net increase(10^4)	increase rate (‰)
1949	54,157	36.00	20.00	16.00	----	----
1950	55,196	37.00	18.00	19.00	1,029	19.00
1951	56,300	37.80	17.80	20.00	1,104	20.00
1952	57,482	37.00	17.00	20.00	1,182	20.99
1953	58,796	37.00	14.00	23.00	1,314	22.86
1954	60,266	37.97	13.18	24.79	1,470	25.00
1955	61,456	32.60	12.28	20.32	1,190	19.75
1956	62,828	31.90	11.40	20.50	1,372	22.32
1957	64,653	34.03	10.80	23.23	1,825	29.05
1958	65,994	29.22	11.98	17.24	1,341	20.74
1959	67,207	24.78	14.59	10.19	1,213	18.38
1960	66,207	20.86	25.43	-4.57	-1,000	-14.88
1961	65,859	18.02	14.24	3.78	-348	-5.26
1962	67,295	37.01	10.02	26.99	1,436	21.80
1963	69,172	43.37	10.04	33.33	1,877	27.89
1964	70,499	39.14	11.50	27.64	1,327	19.18
1965	72,538	37.88	9.50	28.38	2,039	28.92
1966	74,542	35.05	8.83	26.22	2,004	27.63
1967	76,368	33.96	8.43	25.53	1,826	24.50
1968	78,534	35.59	8.21	27.38	2,166	28.36
1969	80,671	34.11	8.03	26.08	2,137	27.21
1970	82,992	33.43	7.60	25.83	2,321	28.77
1971	85,229	30.65	7.32	23.33	2,237	26.95
1972	87,177	29.77	7.61	22.16	1,948	22.86
1973	89,211	27.93	7.04	20.89	2,034	23.33
1974	90,859	24.82	7.34	17.48	1,648	18.47
1975	92,420	23.01	7.32	15.69	1,561	17.18
1976	93,717	19.91	7.25	12.66	1,297	14.03
1977	94,974	18.93	6.87	12.06	1,257	13.41
1978	96,259	18.25	6.25	12.00	1,285	13.53
1979	97,542	17.82	6.21	11.61	1,283	13.33
1980	98,705	18.21	6.34	11.87	1,163	11.92
1981	100,072	20.91	6.36	14.55	1,367	13.85
1982	101,654	22.28	6.60	15.68	1,582	15.81
1983	103,008	20.19	6.90	13.29	1,354	13.32
1984	104,357	19.90	6.82	13.08	1,349	13.10
1985	105,851	21.04	6.78	14.26	1,494	14.32
1986	107,507	22.43	6.86	15.57	1,656	15.64
1987	109,300	23.33	6.72	16.61	1,793	16.68
1988	111,026	22.37	6.64	15.73	1,726	15.79
1989	112,704	21.58	6.54	15.04	1,678	15.11
1990	114,333	21.06	6.67	14.39	1,629	14.45
1991	115,823	19.68	6.70	12.98	1,490	13.03
1992	117,171	18.24	6.64	11.60	1,348	11.64
1993	118,517	18.09	6.64	11.45	1,346	11.49
1994	119,850	17.70	6.49	11.21	1,333	11.25
1995	121,121	17.12	6.57	10.55	1,271	10.60
1996	122,389	16.98	6.56	10.42	1,268	10.47
1997	123,626	16.57	6.51	10.06	1,237	10.11
1998	124,761	15.64	6.50	9.14	1,135	9.18
1999	125,786	14.64	6.46	8.18	1,025	8.22
2000	126,743	14.03	6.45	7.58	957	7.61
2001	127,627	13.38	6.43	6.95	884	6.97
2002	128,453	12.86	6.41	6.45	826	6.47
2003	129,227	12.41	6.40	6.01	774	6.03
2004	129,988	12.29	6.42	5.87	761	5.89

Note: The 2003 and 2004 data are taken from PRC National Statistics Bureau, 2003, 2004 and others from the "China Statistical Yearbook". The two columns on the right side are based on integrative treatment by the writers.

China's modernization requires a level of population increase that is sustainable in terms of its impact on the economy and environment. In order to create the conditions that will result in continued improvements to Chinese society, the current and most important tasks are to control population size, improve the quality and structure of populations, redistribute populations, and stabilize birth rates at a low level. Scientific predictions of the future population are, therefore, of great importance and significance to the strategic decision-making related to the socio-economic development of China.

II. Establishment of grey-increment model

Grey System Theory (Deng 1990; Liu et al. 1999) is designed to research uncertain systems–systems where information is partially known and partially unknown–with small samples and poor information. The research is undertaken mainly by extracting useful information from the generation and developing the known part. The correct understanding and viable control of the system's operation pattern can then be realized. The reproduction of a population consists of many factors that are inter-influencing and inter-controlling, such as birth, death, diseases, environmental quality, and other social and economic factors. Consequently, with only a few indices, many elements cannot be elucidated. We are not able to accomplish precise calculation of the potential and complicated effects upon the increase of population. As a result, the population system has a distinct grey scale. Because of this, the grey model is suitable to dig out and understand the inherent law which is contained in synthesized grayness factors of primitive time-series. Grey prediction is the prediction based on GM (1, 1) model. The model is a dynamic first-order univariate differential equation. It is formally a single-sequence prediction, but, in reality, all-element (Deng 1990; Liu et al. 1999).

Assume the output of the population system to be a non-negative time-series

$$Z^{(0)} = [\, Z^{(0)}(1), Z^{(0)}(2), \ldots, Z^{(0)}(n) \,]$$

To contribute the economic increment information as much as possible to economic growth and still get higher prediction accuracy, the authors do not construct a predicting model based on the total population sequence shown in Table 1, but a special treatment of the raw series, i.e., a first-order accumulative subtraction operator, for the purpose of separating the increment part.

$$X^{(0)}(t) = \Delta Z^{(0)}(t+1) = Z^{(0)}(t+1) - Z^{(0)}(t)$$

This is followed by first-order accumulative addition of the increment time-series $x^{(0)}$ through 1-AGO (accumulating generation operator). A newly generated sequence $x^{(1)}$ is formed , namely,

$$X^{(1)}(k) = \sum_{i=1}^{k} x^{(0)}(i) \quad (k = 1, 2, \ldots, n)$$

with which to make a general GM (1, 1) prediction model

$$\frac{dx^{(1)}}{dt} + ax^{(1)} = b$$

where a and b are coefficients to be determined, called a development coefficient and grey action quantity, respectively. Coefficient a has its valid limits (-2, 2) and is obtained from the following expression using the least squares method:

$$\hat{a} = (a,b)^T = (B^T B)^{-1} \cdot B^T \cdot Y_n$$

in which

$$B = \begin{pmatrix} -1/2(x^{(1)}(1) + x^{(1)}(2)), & 1 \\ -1/2(x^{(1)}(2) + x^{(1)}(3)), & 1 \\ \Lambda & \Lambda \\ -1/2(x^{(1)}(n-1) + x^{(1)}(n)), & 1 \end{pmatrix}$$

$$Y_n = [\, x^{(0)}(2),\ x^{(0)}(3),\ \ldots,\ x^{(0)}(n) \,]$$

the solution, also the time response function, is as follows:

$$\begin{cases} \hat{x}^{(1)}(k+1) = (x^{(0)}(1) - \frac{b}{a}) \cdot e^{-ak} + \frac{b}{a} \\ \hat{x}^{(0)}(k+1) = \hat{x}^{(1)}(k+1) - \hat{x}^{(1)}(k) \end{cases}$$

The result is then retrieved to the total by means of $z^{(0)}(t+1) = z^{(0)}(t) + x^{(0)}(t)$. The model presented here is subject to the treatment, and we call it a grey increment model as contrasted with its general kind. Likewise, the GM (1, 1) model, built on the natural growth rate of population to find the total, is named a grey growth rate model. On the basis of these models, predictions will be made for short- and extended-range as follows.

Not all raw data are used for establishing a grey model. Different dimension (or length) produces different values of a and b, leading to different predictions. They constitute a predictive grey interval. According to grey modeling theory, one-step prediction precision is above 98% and two to five step are above 97% as $|a| \le 0.3$, while one to two step prediction precisions are above 90% and ten-step is above 80% as $0.3 < -a \le 0.5$ (Liu et al. 1999) . Thus, to improve the prediction accuracy, we have to select a grey model of suitable dimension. In addition, we can construct an equal-dimension metabolism model where predicting values $z^{(0)}(n+1)$ obtained from the model based on primitive series z (0) = [$z^{(0)}(1)$, $z^{(0)}(2)$, …, $z^{(0)}(n)$] are put into the series as newest information. It replaces old information $z^{(0)}(1)$ for keeping the length unchanged. In this way we can establish a group of GM (1, 1). The metabolism model makes full use of the newest information carried by data to reveal the development trend of the system. Thus, in general, higher precision can be gained.

III. Prediction and analysis of the future population of China

1. Testing Prediction of the Population in 2003 and 2004

(1) General prediction model and test

Following the statistics given in Table 1, we prepare the following trend extrapolation models using nonlinear least squares fitting method (Xu and Hu 1998; Wang 2000):

Gompertz model (1991–2002): $y = 144055.5 \times 0.7926^{[\exp(t*\ln 0.9423)]}$ (1)

Logistic model (1991–2002): $y = 142556.6 / (1 + 0.2483\, e^{-0.0686t})$ (2)

Triple multinomial model (all data):

$$y = 53911 + 745.935193t + 33.49486t^2 - 0.403292t^3 \qquad (3)$$

The predictions of the 2003 population total of China, derived from the above models, are listed in Table 2. Table 3 shows the predictions for 2004, also derived from the above models.

Table 2 Comparison of various models -based predictions for China's total population for 2003

(Units: 10,000 persons)

model	statistics	prediction	residual difference	relative error (‰)
Gompertz	129227	129393.5	166.5	1.29
Logistic	129227	129387	160	1.24
Triple linear	129227	129162	65	0.50
GM (1, 1)	129227	129464	237	1.83
gray increment	129227	129209	18	0.14
gray growth rate	129227	129204	23	0.18

Table 3 Comparison of various models -based predictions of China's total population for 2004

(Units: 10,000 persons)

model	statistics	prediction	residual difference	relative error (‰)
Gompertz	129988	130043	55	0.42
Logistic	129988	130031	43	0.33
Triple linear	129988	129899	89	0.68
GM (1, 1)	129988	130164	176	1.35
gray increment	129988	129945	43	0.33
gray growth rate	129988	129943	45	0.35

(2) Grey model and its test

To select a suitable model for experimental prediction of the total population of our country, we single out short series of 5–9 dimensions to construct models of general-type GM (1, 1) and grey increment and grey growth rate. Tests show that the 6-dimension or 7-dimension models give the closest result. It can, therefore, be used with the values from all the grey prediction models summarized in Table 2 and 3.

Comparison of tests of table 2 and 3 indicates that grey increment and grey increment rate models have higher first and second-step predicting accuracy than other models. Furthermore, it is superior to other models because: high predicting accuracy is maintained in mid- and long-range predictions; no large quantities of data are demanded in collection (four to eight samples can be chosen for modeling which is useful when data are difficult to obtain); and it is flexible in model operations with small calculations. Consequently, the grey increment model is a useful new tool for population prediction.

2. Population prediction and analysis for the following 50 years in China

From the above comparison, we prepare a grey increment model and a grey growth rate model on a 7-dimension basis using data from 1998 to 2004 separately.

$$\hat{x}^{(1)}(k+1) = -16374.86\, e^{-0.0640527k} + 17509.86 \qquad (5)$$

$$\hat{x}^{(1)}(k+1) = -0.1183\, e^{-0.0713k} + 0.1274 \qquad (6)$$

Tests show C = 0.096, P = 1, the mean fitting precision q = 98.77%, mean square deviation S = 13.22 for Model (5), C = 0.088, P = 1, the means fitting precision q = 98.74%, mean square deviation S = 0.0001 for Model (6).

The two models satisfy first-grade accuracy requirement. It can, therefore, be used for the extended and long-range prediction of China's total population, with the predictions shown in Table 4, and 5, respectively. In the 2005–2010 predictions the results are very close and the errors are less than 0.1 million between related predictions. But in 2020–2050 predictions of Table 5 are smaller than those of Table 4, differing from 1.6 million to 5.7 million of individuals.

Predictions of the total from the grey increment metabolism models, based on 1998–2004 annual increments, are summarized in Table 6. The figures are roughly

Table 4 Grey increment model-based predictions of China population for 2005─2050

(Units: 10000 persons

Year	2005	2006	2007	2008	2009	2010	2015
total	130680	131329	131937	132508	133043	133545	135626
net increase	692	649	609	571	535	502	365
growth rate (‰)	5.32	4.97	4.64	4.33	4.04	3.77	2.70
year	2020	2025	2030	2035	2040	2045	2050
total	137137	138233	139030	139607	140027	140332	140553
net increase	265	192	139	101	74	53	39
growth rate (‰)	1.94	1.39	1.00	0.72	0.53	0.38	0.28

Table 5 Grey growth rate model –based predictions of the population for 2005─2050

(Units: 10000 persons)

Year	2005	2006	2007	2008	2009	2010	2015
total	130678	131324	131928	132493	133022	133516	135539
net increase	690	646	604	565	529	494	351
growth rate (‰)	5.31	4.94	4.60	4.28	3.99	3.71	2.60
Year	2020	2025	2030	2035	2040	2045	2050
total	136976	137992	138707	139208	139561	139809	139984
net increase	249	175	123	86	61	43	29
growth rate (‰)	1.82	1.27	0.89	0.62	0.44	0.31	0.21

identical to those of Table 4, indicating the feasibility of the models used. Therefore, we can utilize the combination of the three tables to indicate the total population in a relevant year, i.e. putting the values of Table 4 as basic solution, that of Table 6 as the upper limit, and Table 5 as the lower limit. The predicting values form a bell-mouthed grey interval by 240–1200 (viz. approximate ±1‰ – ±4‰) from 2015 to 2050.

It must be stated that the natural growth rate in Table 1 equals the annual net-increase of individuals divided by yearly averaged total population (the births minus deaths in the involved year), and the increase rates in Tables 4–6 are acquired approximately by the prediction of net growth in a year divided by the total number of the preceding year.

Table 6 Grey increment metabolism model-based predictions of China population for 2005–2050

(Units: 10000 persons)

Year	2005	2006	2007	2008	2009	2010	2015
total	130680	131333	131953	132539	133091	133605	135779
net increase	692	653	620	586	552	514	384
growth rate (‰)	5.32	5.00	4.72	4.44	4.16	3.86	2.84
Year	2020	2025	2030	2035	2040	2045	2050
total	137391	138584	139468	140121	140604	140960	141222
net increase	285	211	156	115	85	63	46
growth rate (‰)	2.08	1.52	1.12	0.82	0.61	0.45	0.33

IV. Conclusion and discussion

From the above discussion and analysis, we can conclude that grey increment and growth rate models are able to strengthen increment information prominence, weaken disturbing factors and reveal the operational law of the system, thus higher precision can be gained. Under the normal operation of the present population system, the following conclusions are available. First, the natural growth rate of the population on a yearly basis is expected to decline to 6.02‰ during 2001–2005, compared to 11.56‰ during 1990–1995 and 9.08‰ during 1996–2000 respectively. Second, the natural growth rate will be lowered to about 3.88‰ in 2010 and 2.5‰ in 2016 (equivalent to the figure in developed countries). Third, the annual net increase of population in China is expected to decline from 7.6 to 5 million during 2004–2010, about 1.4×10^6 persons in 2030, and less than 400,000 in 2050, when the growth of the population will approximate zero. Fourth, the population will reach 1.3068 billion at the end of 2005 and 1.3133 billion at the end of 2006. Consequently, the target set by the PRC State Council in the White Book "Population and Its Development for the 21st century in China," and an associated target of the total to be kept inside 1.33 billion at the end of 2005 with annual natural growth rate of 9‰ during 2001–2005, will be met. The targets will be fulfilled keeping the total within 1.4 billion as set in the White Book, compared to <1.336 billion at the end of 2010. At the end of 2020, 2030, 2040 and 2050 the total will reach 1.372, 1.391, 1.401 and 1.406 billion, respectively. It can be asserted that, with the persistent and efficient implementation of a Planned Birth Policy, the continuance of China's markedly prosperous socio-economic situation, and significantly improved qualification in the future for national citizenship, the total population will not exceed 1.45 billion persons.

From Table 1 we come to the conclusion that the present stage of population development is in the third interval of the second period (1970 to present). This stage is characterized by a slow decline of birth rate leading towards a stabilized low birth rate stage. With a rapidly advancing economy, raised standard of living and improvement of health care, the crude death rate in China will decline to the bottom limit of 6.2‰. It will then be maintained at 6.2‰-6.3‰. A chief factor that will determine the growth during the next 50 years is birth rate. Consequently, decision-makers must implement policies that maintain strict control of birth rate because maintaining a low birth rate is a long-term and strategic goal. Though difficult, it is advisable that low birth rates be maintained for at least 40 to 50 years. To stabilize at lower birth rate level, it will be necessary to insert population growth control into the overall planning of the sustainable development of China. This will create an enabling environment that will maintain lower birth rates by accelerating the conversion of the governmental management system and method. In essence, the problem of population concerns national development. As shown by the thematic slogan for Day of World's Population 1999, current birth policies have a profound impact on the quality of life in the future. The best policy for dropping and maintaining birth rates is economic prosperity and growth.

Currently, the structure of the population is almost becoming as important an issue as population numbers. Besides vast numbers of people, China is facing such problems as a serious imbalance in the sex ratio at birth, with males far exceeding females. The proportion of invalids in the overall population is increasing. The percentage of the elderly is increasing. In addition, floating populations and ex- and immigration populations (Liang et al. 2004) are on the rise, leading to social problems related to employment, the spread of disease (including HIV/AIDS), personal security and crime. Given the above, greater emphasis should be placed on bettering the population's structure, establishing systems of sound child rearing, and social security. Through these efforts and more, the overall quality of the population can be raised. The entire society should work towards an integrative solution to the population problem that will lead to a convivial integration of population, natural resources and economy.

As noted by Mr. Zhang Weiqing, Director of the National Committee of Population and Planned Birth, during the next 20 – 30 years China will experience three major demographic events: 1) the number of people entering the labor market will peak, 2) the number of people reaching old age will peak, and 3) the total population size will peak. These demographic milestones will ensure that the study of China's population will remain an interesting and challenging task well into the 21st century.

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