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Research on Prediction of China's Population Development from 2008 to 2050

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Abstract

Population system is a typical grey system. In this paper, we establish two new grey models of population prediction: discrete grey increment model(DGIM) and grey increment model with new initial value(NGIM). By contrasting, we did simulation and test prediction through utilizing a large amount of data. The results indicate that the two new models prove more accurate than GM(1, 1) model and other models. According to the latest statistical data of China's population from 1949 to 2007, we predict the population development of China up to the year 2050 based on the two new models. Evidence shows that at the end of 2008, 2010, 2020, 2030, 2040 and 2050 the total population will reach 1.32789, 1.3403, 1.3917, 1.428, 1.454 and 1.472 billion, respectively.

Keywords: China's population, Discrete grey increment model(DGIM), Grey increment model with new initial value(NGIM), Prediction of population

1. Introduction

China has the largest population in the world, reaching 1.32129 billion at the end of 2007(except Hongkong, Macao and Taiwan), which makes up one fifth of the world's total. The immense population acts as the leading factor controlling the socio-economic development. During the 58 years after the foundation of People's Republic of China, it has experienced a 21-year high-increment stage and a following 37-year low-increase stage (see Table 1and Figure 1). 1949 to 1970 was a stage of high birth and low mortality rate instead of high birth and great mortality rates prior to 1949 and thus a period of sharp drop of crude mortality compared to the high birth rate of >30‰ to 37‰, where the sharp fluctuation is an exception in 1959 to1961 for natural disaster-hit years. The yearly increment of Chinese population had reached the first population peak of 23.21 million, when the yearly growth rate was 28.77‰ till 1980. The period from 1971 to present is one dominated by birth rate, which had formed a second population peak of 17.93 million till 1987, with mortality reduced to < 7‰, showing that the fast increase in population is suppressed, leading to significant decrease in the birth rate and natural augmentation. Total fertility rate (TFR) of women has been reduced from 5.8 to 1.8 since 1970s, which makes China enter into the low level of birth country half a century ahead of other developing countries (PRC, 2006).

Till the end of the 1990s the reproduction of population reached a stage of low birth rate, low mortality rate and low augmentation rate, an eventful change of the problem that China took a bit more than 30 years to realize compared to the period of nearly 200 years taken by foreign countries. China has achieved the struggling goals successfully, which are demanded by the white book "*Population and development for the 21st century in China* " of PRC State Council and the Fifteen Planning, to control the total population in 1.33 billion and to control the annual natural growth rate in 9‰ at the end of 2005 (Research, 2007). China has added up to reduce 400 million population after carrying out the policy of family planning 30 plus years, which delayed the world population date of 6 billion 4 years, suppressed the fast increase in population effectively, promoted the development of economy and society, strengthened the comprehensive national power and improved the living standard of people. We also made solid foundation for modernization construction and implement the well-off society in all round way. Meanwhile, we have made outstanding contribution for the world population's development and control. However, the problem of population's increase is still terribly grimness, as china has oversize population. In the period of the eleventh five-years planning, China will receive the forth birth population peak. From 1990 to 1999, the average annual net increase population was 12.73 million, and from 2000 to 2006 it was about 8.09 million. Those people will consume about thirty or forty percent of new increasing GDP, which exerts great pressure on socio-economic development. China's modernization requires population's increase in harmony with economy, society, resources and environment on a sustainable basis. Thus, the current basic tasks of most importance and urgency for building the overall society in all round way are to make a stabilization of low birth rate, to improve their quality and structure, to redistribute the population and to ensure the security of population. Consequently, scientific prediction of the future population situation is of great significance to the strategic decision-making for socio-economic development in our country.

2. Establishment of two new grey-increment models

We usually adopt the model of self-regression or the processing calculation method of population's age on the basis of time sequence analysis for the prediction of population. The premise of the self-regression model must be a smooth sequence. If not, the prediction precision might not be great, even lack of the prediction function as the irrational choice of the expositive variables or unreasonable design (Zhao, 2003, Fan, 2003). The processing calculation method of population's age is hard to calculate precisely, because it involves the structure of population's age, the mode of women's bearing, the mode of population's death and so on. Theory on grey systems has as its research object "uncertain systems with information partially known and partially unknown" that are small-sampled and poor-information, and the research is undertaken largely by extracting useful information from the generation and exploitation of the part of known information to realize the correct understanding of the system's operation pattern and viable control(Liu, 2004). The population system is a typical grey system and is thus suitable for being studied by using a grey model to extract and gain insight into an inherent law contained in synthesized greyness factors of primitive time series. The literatures (Men,2004, Men,2005) first brought forward the grey increment model of population's prediction, which gave full play in the contribution of increment information to the population increase. Thus, we got higher prediction precision. This article is based on the grey increment model, and is trying to establish two new grey prediction models with higher precision and more stability for extended and long-range predictions.

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

$$P^{(0)}=[p^{(0)}(1),p^{(0)}(2),\cdots,p^{(0)}(n)]$$

To make the economic increment information contribute as much as possible to economic growth and get still higher prediction precision, the authors do not construct a prognostic 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, in order to separate the increment part.

$$x^{(0)}(t)=\Delta\, p^{(0)}(t+1)=p^{(0)}(t+1)-p^{(0)}(t)$$

Followed by first-order accumulative addition of the increment time series $x^{(0)}$ through 1-AGO (accumulating generation operator) to get a newly-generated sequence $x^{(1)}$, namely,

$$x^{(1)}(k)=\sum_{i=1}^{k}x^{(0)}(i) \qquad (k=1,2,\cdots,n)$$

2. 1 Establishment of discrete gray increment prediction model (DGIM)

Make a discrete GM (1, 1) prediction model

$$x^{(1)}(k+1)=\beta_1 x^{(1)}(k)+\beta_2$$

where β_1 and β_2 are coefficients to be determined, obtained through the following expression via the least squares method $\hat{\beta}=\left(\beta_1,\beta_2\right)^T=\left(B^TB\right)^{-1}B^TY$,

in which
$$B=\begin{pmatrix} x^{(1)}(1), & 1 \\ x^{(1)}(2), & 1 \\ \cdots & \cdots \\ x^{(1)}(n-1), & 1 \end{pmatrix}$$

$Y_n=(x^{(0)}(2),x^{(0)}(3),\cdots,x^{(0)}(n))^T$

Where $x^{(1)}(1)=x^{(0)}(1)$, the solution is the time response function in the form

$$\begin{cases} \hat{x}^{(1)}(k+1)=\beta_1^k x^{(0)}(1)+\dfrac{1-\beta_1^k}{1-\beta_1}\beta_2 \\ \hat{x}^{(0)}(k+1)=\hat{x}^{(1)}(k+1)-\hat{x}^{(1)}(k) \end{cases}$$

And then the result is retrieved to the total by means of $p^{(0)}(t+1)=p^{(0)}(t)+x^{(0)}(t)$. The model presented here is called a discrete grey increment model(DGIM). When setting up a general GM(1, 1), the basic form $x^{(0)}(k)+az^{(1)}(k)=b$ is a discrete equation, while the whitenization equation $dx^{(1)}/dt+ax^{(1)}=b$ is a continuous one. The parameters got from the basic form are put into the whitenization equation, which makes prediction precision degradation from the discrete form to the continuous form. Therefore, a general GM(1, 1) can get a high prediction precision only when the model is used for short-range prediction or the development coefficient –a is small. The model of discrete grey not only conquers this problem, but also solves the problem of GM(1, 1) about stability on a certain extent(Xie,2005).

2. 2 Establishment of grey increment model with new initial value (NGIM)

Make $Z^{(1)}$ mean generation of consecutive neighbors sequence of $X^{(1)}$,

$$Z^{(1)}=(z^{(1)}(2),z^{(1)}(3),\cdots,z^{(1)}(n))$$

where $z^{(1)}(k)=\alpha x^{(1)}(k-1)+(1-\alpha)x^{(1)}(k)\ (k=2,3,\cdots,n)$. We usually get $\alpha=0.5$ and establish the grey model $x^{(0)}(k)+az^{(1)}(k)=b$. Where a and b are coefficients to be determined, obtained through the following expression via the least squares method

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

in which
$$B=\begin{pmatrix} -z(2), & 1 \\ -z(n), & 1 \\ \cdots & \cdots \\ -z(n), & 1 \end{pmatrix},$$

$$Y_n=(x^{(0)}(2),x^{(0)}(3),\cdots,x^{(0)}(n))^T.$$

The solution is the response function in the form

$$\begin{cases} \hat{x}^{(1)}(k+1)=(x^{(1)}(m)d-\dfrac{b}{a})e^{-a(k+1-m)}+\dfrac{b}{a} \\ \hat{x}^{(1)}(k+1)=(1-e^{a})(x^{(1)}(m)d-\dfrac{b}{a})e^{-a(k+1-m)} \end{cases}$$

Where $x^{(1)}(m)d$ mean select m from 1 to n in turn. After comparing we can choose m, which makes the response function the least average error, and establish the best prediction model. When $m=1$, it is just the general GM(1,1). In the common condition, we can get satisfactory prediction precision, when $m=n$. Then the result is retrieved to the total by means of $p^{(0)}(t+1)=p^{(0)}(t)+x^{(0)}(t)$.We call it the grey increment model with new initial value (NGIM) as we adopt $x^{(1)}(n)$ to be the new initial value. The initial value $x^{(0)}(1)$ of the general grey model is not related to its prediction of it, which does not make good use of the original sequence's information, so it doesn't fit for the least information principle of the gray system theory. Thus, it also produces some errors in the prediction. According to the theory of new information first, we can improve the prediction precision of grey model by putting large weight on new information. Meanwhile, we can make full use of the "least information", optimize and improve the model by means of the initial value $x^{(1)}(n)$ replace the original value $x^{(0)}(1)$. Thus, we can improve the prediction precision effectively. We adopt the above two new gray increment models in the following passage, to make demonstration research on the short-term, medium-term and long-term prediction of China's population (Zhang, 2002, Dang, 2005).

3. Pediction and analysis of the future population of China

3. 1 Testing Prediction of the Population of China from 2005 to 2007

To select a suitable model, we single out 5~9 dimensions short series to construct general-type GM (1, 1) model, DGIM model and NGIM model for experimental prediction of the total population of China from 2005 to 2007. Test shows that the 6-dimension model gives the closest result, which is thus taken for use, with the values from all the gray prediction models summarized in Table 2, 3 and 4.

Comparison of tests of table 2 to 4 indicates that models of DGIM and NGIM have higher prediction accuracy and better effect than other models. In 2007, the accuracy of two models reached 99.997% and 99.990% separately.

To sum up, it is superior to other models in some respects: a) High precision accuracy and stability are maintained in extended and long-range predictions (far exceeding other ordinary models); b) No large quantities of data are demanded in collection [Five to eight samples can be chosen for model establishing, which is especially fit for the occasion that data are difficult to get]; c) It is flexibility and handy in model operation [with small calculation]. Consequently, models of DGIM and NGIM are ideal and economic new tools for population prediction.

3. 2 Population prediction and demonstration analysis of China in the future

From the above comparison, we select a DGIM model and a NGIM model on a 6-dimension basis by data from 2002 to 2007 separately,

$$\hat{x}^{(1)}(k+1) = -23234.25 \times 0.96614^{k} + 24060.25 \tag{1}$$

$$\hat{x}^{(1)}(k+1) = -19541.92 e^{-0.0357143(k-5)} + 24246.92 \tag{2}$$

Tests show that the mean fitting precision of Model (1) is 98.45% and Model (2) is 98.21%. The two new models satisfy first-grade accuracy requirement for the use of the extended and long-range prediction of the total population of the country, with the predictions shown in Table 5.

Compared with table 5, the results of two new model-based predictions are much close. It indicates the feasibility of two new models used. To reduce the relative error, we can utilize the combination of the two new grey models to indicate the total population in the relevant years by putting the values of NGIM as the upper limit, that of DGIM as the lower limit and the mean of them as the prediction.

It needs to state that the natural growth rate in PRC National Statistics Bureau equals the annual net-increase individuals divided by yearly averaged total population (the births minus deaths in the involved year), and the increase rates in Tables 6 are acquired approximately by the prediction of net growth in a year divided by the total number of the preceding year.

4. Conclusions and discussions

From the above, we see that utilization of DGIM and NGIM model is able to make the effect on increment information prominent and weaken effect of disturbing factors, thus revealing the operational law of the system used for higher precision of the prediction. At the same time, the two new models are new ideal tools in population predictions for their absoluteness, facility and easy control. Not all raw data are used for establishing a grey model and different dimensions (or lengths) produce different values of a and b, leading to different predictions that constitute a prognostic grey interval. According to grey modeling theory, the established grey model is significative when $a \in (-2, 1)$. One-step forecast precision is above 98% and two to five step forecast precisions are above 97% as $|a| \le 0.3$, while one to two step forecast precisions are above 90% and ten-step forecast precision is above 80% as $0.3 < -a \le 0.5$ (Liu, 2004). In a word, the established GM (1,1) can be used in the extended and long-range prediction while $a \in (-2, 1)$ and $a \ge -0.3$. Thus, choosing the grey model with appropriate dimensions is the key to improve experimental prediction and actual effect. At the end of 2007, the actual population of China is 1.32129 billion, and the first step prediction precision is as high as 99.997% in this paper by testing. Therefore, the effect of prediction is quite satisfactory.

In keeping the normal operation of the present population system, the following conclusions are available:

(1) The natural growth rate of the population on a yearly basis is expected to reduce to 4.97‰ in 2006-2010 compared to 11.60‰ in 1990-1995, 9.12‰ in 1996-2000 and 6.25‰ in 2000-2005, respectively. And the rate would be lowered to about 4.6‰ in 2010 and 2.5‰ in 2025 that is equivalent to the figure reached in developed countries.

(2) The annual net increase in population in China is expected to decline from 6.60 to 6.16 million in 2008-2010, about 3.10 million persons in 2030, no more than 1.60 million persons in 2050.

(3) The population is about 1.32789 billion at the end of 2008 and no more than1.3405 billion at the end of 2010. So we can completely accomplish the restrictive target of the total to be kept inside 1.36 billion at the end of 2010 and annual natural growth rate of 8‰ during 2006-2010. At the end of 2020, the total would be 1.3917 billion, while it would exceed 1.4 billion at the end of 2023. India will become the largest population country instead of China as reported. At

the end of 2030, 2040 and 2050 the total would be 1.428, 1.454 and 1.473 billion, respectively. It can be expected that the total would not exceed 1.48 billion persons with the persistent and efficient implementation the policy family planning, on the basis of markedly prosperous socio-economic situation, pronouncedly raised spiritual civilization and significantly improved qualification of national citizenship in the future.

As shown by the thematic slogan for World's 6 Billion Population Day in 1999, the selection of mankind's birth policies affects the choice of their future in the end. And the essence of the population problem is the development. But the drop in birth rate and stability depend eventually on socio-economic development. We come to the conclusion that the present stage for the population development is in the third interval of the second period (1970 to present). The characteristic of the period is slowly declining at lower birth rate into a stabilized low-rate stage. With fast advance in economy, improved living standard and health care, the crude death rate in China would be slowly declining to the bottom limit of 6.2‰ and maintained at 6.2~6.3‰ in a long time. A chief factor that determines the growth in the future 40~50 years is birth rate. Consequently, the only strategic decision-making is to strictly control the birth rate for keeping lower rate as our serious target on a long-term basis. Although the mission is prolonged and arduous, we should not be lax.

Currently, the structure of the population is becoming increasingly prominent in the process of solving the issue, as follows:

(1) Baby sex pro rata is serious lopsided and goes beyond the range 103~107, high to 119:100. Now male is 18 million more than female in the nubile period and we can forecast that in 2020, the male will be 20 million more than the female at the age of 20~45. China goes through a longest duration with the highest baby sex pro rata. It will induce adverse effect to social stability and harmony (Xin,2007) .

(2) There are 0.8~1.2 million invalids every year, 30% dead, 40% lifelong defective, and only 30% can be cured or corrected, so we loss about 1 billion every year. Proportion of invalids is higher and the total population of invalids has exceeded 60 million as reported, amount to the population of France.

(3) Data provided by National Elder Committee indicates that the population of people older than 60 is 143 million, about 11% of total population. As the Ministry of Affairs reported, the population of the people over the 65 years old is 104.19 million at the end of 2006. It is 7.9% of the total population and raises 0.2% compared with last year. The population of the old people will be 240 million at 2020. It indicates the society of aging is coming ahead, but the whole society has not prepared completely (Xin, 2007).

Besides that, we are facing such problems as qualities of the population out of phase with development, social consequences from population fluidness and ex- and immigration for development, employment, spreading of diseases as AIDS endangering the population's security, etc. Although the increasing quantities of the population have effect on the economic increase, the population's structure and qualities are also the keys. We shall continue to put into strict control the population augmentation and stabilization of birth rate at lower level and place the focus on bettering the population's structure, establishing systems of sound child rearing and social security in an attempt to overall raise the qualities of population, mobilize all departments and the whole society for integrative management of the problem to stepwise realize a long-term harmonic development of population, resources and society. As noted by Mr. Zhao Baige at Oct 9th, 2006, Assistant Director of the National Committee of Population and Planned Birth, China will meet the three population peaks (Xin, 2006): laboring age, aging and total of the population one after another next half century to follow and we should be ready for the challenge.

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Table 1. Statistics of China's population from 1949 to 2007

year	total pop(10^4)	birth rate (‰)	mortality (‰)	natural growth (‰)	net increase(10^4)	increase rate (‰)
1949	54,167	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
2005	130,756	12.40	6.51	5.89	768	5.91
2006	131,448	12.09	6.81	5.28	692	5.29
2007	132,129	12.10	6.93	5.17	681	5.18

Note: The data are taken from the "China Statistical Yearbook"(2000-2007). The right-hand-side net increase of population and increase rate are based on integrative treatment by the writers.

Table 2. Comparison of various grey models-based predictions for China's total population for 2005(Units: 10^4 persons)

model	statistics	prediction	residual difference	relative error (‰)
GM (1, 1)	130756	130851.70	95.70	0.73
DGIM	130756	130685.99	-70.01	0.53
NGIM	130756	130704.28	-51.72	0.39

Table 3. Comparison of various grey models-based predictions for China's total population for 2006 (Units: 10^4 persons)

model	statistics	prediction	residual difference	relative error (‰)
GM (1, 1)	131448	131563.92	115.92	0.88
DGIM	131448	131471.21	23.21	0.18
NGIM	131448	131495.53	47.53	0.36

Table 4. Comparison of various grey models-based predictions for China's total population for 2007 (Units: 10^4 persons)

model	statistics	prediction	residual difference	relative error (‰)
GM (1, 1)	132129	132244.7	115.7	0.876
DGIM	132129	132133.4	4.38	0.033
NGIM	132129	132115.7	-13.28	0.101

Table 5. Two new grey models-based predictions of China population for 2008-2050 (Units: 10^4 persons)

year	total			net increase			growth rate (‰)		
	DGIM	NGIM	AVE	DGIM	NGIM	AVE	DGIM	NGIM	AVE
2008	132791	132787	132789.0	662	658	660.0	4.97	4.96	4.965
2009	133431	133423	133427.0	639	636	637.5	4.79	4.77	4.780
2010	134049	134037	134043.0	618	614	616.0	4.61	4.58	4.595
2011	134646	134631	134638.5	597	594	595.5	4.43	4.41	4.420
2015	136840	136812	136826.0	520	518	519.0	3.80	3.79	3.795
2020	139189	139150	139169.5	438	436	437.0	3.15	3.13	3.140
2025	141167	141119	141143.0	369	367	368.0	2.61	2.60	2.605
2030	142831	142778	142804.5	310	309	309.5	2.17	2.16	2.165
2035	144232	144177	144204.5	261	260	260.5	1.81	1.80	1.800
2040	145412	145354	145383.0	220	220	220.0	1.51	1.51	1.510
2045	146405	146345	146375.0	185	185	185.0	1.26	1.26	1.260
2050	147241	147181	147211.0	159	156	157.5	1.08	1.06	1.070

Note: DGIM denotes the discrete grey increment model and NGIM denotes the grey increment with new initial value model.

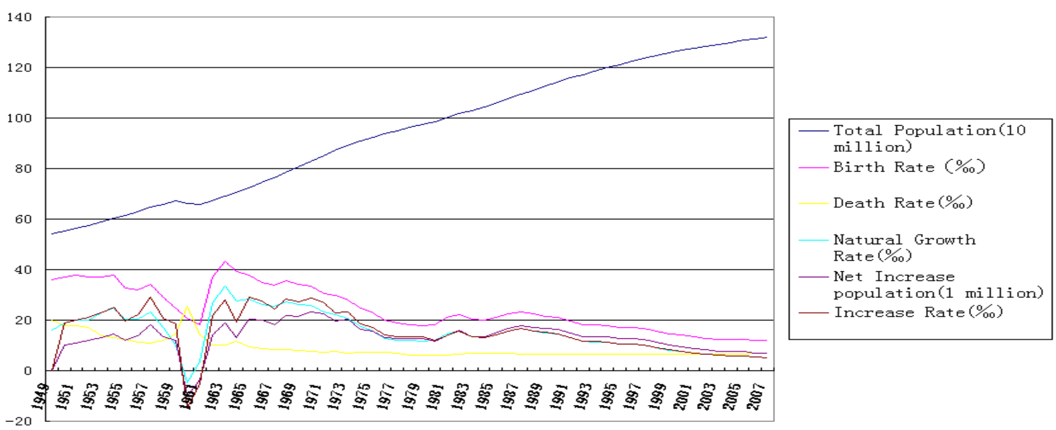

Figure 1. Natural change of China's population from 1949 to 2007