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China's Uncertain Demographic Present and Future

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Contents

Abstract

This paper will apply methods of probabilistic population forecasting to assess the range of uncertainty of China's future population trends. Unlike previous applications of probabilistic population projections that consider stochastic future fertility, mortality and migration, this paper will also account for the significant uncertainty of China's current fertility level (with estimates ranging from 1.2 to 2.3) and the related uncertainties about the sex ratio at birth (with estimates from 1.06 to above 1.2) and the size of the youngest cohorts in the 2000 census. The model applied in this paper will be based on expert based uncertainty ranges for current conditions, in addition to the probabilistic treatment of future trends. Given the sheer size of China's population, these significant uncertainties about current conditions are of high importance not only for the future population of China but also on a global scale.

Acknowledgments

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Introduction

Trends in China's population are directly relevant to what happens with the world's population. More than with any other country, the sheer size of China's population – which constitutes around 20 percent of the world's total – makes it a key determinant of global population trends. In this light it is surprising how much uncertainty exists about the current demographic conditions in the world's biggest country. Recently published estimates of China's total fertility rate around 2000 range from 1.22 (NSB 2002a, 2000b) to 2.0 (Zhang Weimin and Cui Hongyan 2003) – a remarkable difference, especially seen on a relative scale (a factor of 1.64). There are probably few countries in the world where estimates about current fertility rates differ by such a factor.

Because of China's weight in the world population, the estimates of the current global fertility rates are significantly affected by this uncertainty, as are projections for the world population. If fertility in China were currently below 1.5, as many authors estimate and the UN publishes in its 2004 fertility data sheet (UN 2005), instead of the 1.85 assumed by the UN in its recent long range projections (UN 2004), this would influence the assumed fertility level over the coming decades and result in markedly lower projected rates of population growth (shrinking later in the century) both in China and the world.

Fertility is not the only uncertain demographic condition in China today. Estimates for the sex ratio at birth range from 113 (Wang 2003) to 123 (Ma 2004). This is a remarkable difference that will significantly influence the future proportion of men to women in the adult population and hence population dynamics.

Important uncertainty also exists around the size of the youngest age group. The size of the age group 0-4 in 2000 is given as 71 million in the census, but is estimated to be 86 million (Zhang Weimin et al. 2004). The difference of 15 million in just one age group is not only daunting in absolute numbers but also represents a sizeable relative difference of 20 percent.

This paper will first discuss how demographers have traditionally dealt with the issue of uncertainty about current conditions – which was mostly by ignoring it – and about future trends and the options for systematically including quantitative information about this uncertainty in population estimates and projections. We then discuss the wide range of estimates about China's current fertility level, sex ratio, and the size of the younger population. Next, we consider the range of future fertility (including the sex ratio), mortality, and migration that should be reflected in our projections and carry out probabilistic projections which cover both the uncertainty of current conditions and future trends. The final sections will present and discuss the results and draw some conclusions.

How Demographers Deal with Uncertainty about Current Conditions and Future Trends

To be uncertain about the exact size and age structure of a population or the current level of fertility, mortality, and migration, is nothing new for demographers. Almost all empirical information, be it from censuses, vital registration or surveys, is imperfect, but the degree of imperfection varies significantly from one setting to another. The typical response to such imperfection on a minor scale has been to settle for one number (and publish it in an authoritative volume) and then quickly try to forget that this number is indeed associated with uncertainties. In the rare cases that these published numbers are publicly challenged or when the demographers themselves feel that the degree of imperfection of the given empirical information is intolerable as a basis for analysis and interpretation, demographers tend to have two alternative strategies: either go out to the field and collect new information or use various kinds of statistical techniques to improve the given data. Sometimes both methods are combined, but the goal is typically the same: to come up with one point estimate that should be as close as possible to the real world. In international comparisons, these point estimates typically enter tables where, e.g., the highly reliable estimate for life expectancy derived from the Finnish population register stands next to the estimate for Mozambique, where hardly anything is known about current mortality conditions, especially in the face of unknown HIV prevalence.

Typically the user of such internationally comparative tables is not given any indication about differential uncertainties surrounding these point estimates. But even if the researchers working with the data are painfully aware of the uncertainty of a given point estimate, they mostly see no other choice than to base their projections and other analyses on this uncertain point estimate of demographic conditions at a given time. It is considered better to have one imperfect number which roughly characterizes the actual situation than to have no number at all.

Unlike some other disciplines, there is no tradition in demography to process fuzzy information and yet be able to maintain the information about the uncertainty of a given indicator in the subsequent steps of the analysis. In this paper we propose to do so by expanding methods of probabilistic population projections to include uncertainty distributions of the starting conditions of the projections.

The field of probabilistic population projections has recently seen a dynamic development. In 2004 the *International Statistical Review* published a special issue on how to deal with uncertainty in population forecasting (Lutz and Goldstein 2004). It presents a state of the art summary of different dimensions of and different approaches to probabilistic population projections. It also shows how dynamically the field has been expanding since *Frontiers of Population Forecasting* (Lutz et al. 1999b) and the National Research Council (2000) report on population projections were written. There is no space here to review this field of studies. It should only be mentioned that originally there were three rather different approaches, which recently have seen some convergence. The first one is based on the analysis of errors in past population projections and the assumption that future errors will be similar to past errors (Alho 1997; Keilman 1999; Lee 1999). The second approach is largely based on time series analysis and produces stochastic projections on the assumption of structural continuity and constant variability (Lee 1993; Lee and Tuljapurkar 1994). The third approach largely rests on subjective probability distributions produced by experts in the process of an argument-based discussion process about the likely future range of uncertainty in fertility, mortality, and migration (Lutz et al. 1997, 1999a). While the first two approaches usually distinguish between assumptions on the trend (which is mostly based on expert opinion) and the variance (which is derived from past errors or time series), under the third approach, trend and variance are assumed jointly as being part of the same uncertain process.

There is considerable debate at the moment about which of the three approaches is the most appropriate under different conditions of data availability, stages in the process of demographic transition, and other contextual conditions. This discussion, which seems to move in the direction of combining elements of the different approaches and is summarized in Lutz and Goldstein (2004) has not yet resulted in a broad methodological consensus and is unlikely to do so in the near future because of the great variety of conditions under which such projections are being produced. In the context of this study on China, it is important to note that the full range of options is not applicable for all countries. The use of past projection errors is only applicable for populations for which both a series of past projections and reliable empirical data for verification exist. The time series approach can only be pursued if sufficiently long, high-quality time series are available. These preconditions significantly limit the number of countries to which all three methods are applicable. As discussed in detail below, China clearly does not meet these preconditions.

Methodologically, this paper goes an important step beyond previous probabilistic projections in applying the probabilistic approach not only to capture the future uncertainty but also to address the uncertainty about current conditions. For this task the approaches other than subjective probabilities based on expert knowledge are not applicable. The time series approach depends on reliable empirical data by its very nature and is meaningless without them, hence, by definition it cannot be applied to uncertain empirical information. The approach of learning from past errors could theoretically be expanded to refer to errors about point estimates that have later been revised as better empirical information has become available. But this would have to be based on the very strong assumption that there is a universal pattern of biases when producing point estimates under conditions of uncertainty about the real level of demographic indicators. There is no reason to assume that there is such a universal and predictable pattern of biases in estimating current fertility levels, sex ratios or age group sizes that would hold for all countries and times. Hence, the only alternative is to look carefully at what some of the best experts in the country under consideration and the entire scientific literature have to say in terms of different attempts to estimate current demographic conditions and then infer an uncertainty distribution from this informed judgment.

Uncertainty Ranges of Current Demographic Conditions in China

Current fertility level

Table 1 gives a long list of more than 30 different estimates of China's total fertility rate (TFR) around 2000 that have recently been published. This sheer number of different values estimated for a situation in which only one number can be true gives an indication of the uncertainty as well as the controversy surrounding the current fertility level in China. In this study we will restrict our consideration to published estimates. The number of unpublished estimates produced by different institutions or individuals is probably much greater. These published estimates of the total fertility rate in China in 2000 span a range from 1.22 (NSB 2002a, 2000b) to 2.0 (Zhang Weimin et al. 2004). All the other estimates that are based on a transparent rationale lie between these values but are clearly not evenly distributed.

Table 1. Different estimates of the total fertility rate for China in 2000.

Source	TFR	Notes
Wang Jinying (2003)	1.718[1]; 1.703[2]; 1.723[3]	(1) Uncorrected fertility pattern: calculation directly by age-specific fertility rate of 2000 census without considering the underreporting of children; (2) Adjustment by reconstructing the underreporting of children: to keep age-parity-specific rate of 2000 census stable, re-estimate the fertility pattern after reconstructing those children who are underreported in the census; (3) Adjustment by fertility pattern of the second child: due to the serious underreporting of the second child, re-estimate the fertility pattern of the second child by reconstructing those children who are underreported in the census.
Liang Zhongtang (2003)	2.3	
Yuan Jianhua et al. (2003)	1.71[1]; 1.78[2]; 1.63[3]	(1) Calculation by National Statistical Yearbook; (2) Statistics of State Family Planning Committee; (3) Using the surviving method for children aged 0-10 years in 2000, the number of births has been estimated for each year assuming a life expectancy in 1990 of 67.767 for males and 71.15 for females, and in 2000 of 69.54 for males and 73.01 for females.
CPIC (2003)	1.80	
NSB (2002a, 2000b)	1.22	
Zhang Weimin et al. (2004)	1.63[1]; 2.0[2]	(1) Adjustment by the underreporting rate of 18.94% for 0-9 years old; (2) Assuming the number of population aged 10-19 years old is correct, the underreporting rate for children aged 0-9 years old is 13.68%, the adjusted TFR is 2.0 assuming the underreporting rate is the same between 1990 and 2000.
Zhai Zhenwu (2003)	1.8	
Guo Zhigang (2003, 2004)	1.58	Calculation by author eliminating tempo effects.
Zhang Guangyu (2003, 2004)	1.5~1.6	
Retherford et al. (2004)	1.36[1]; 1.38[2]; 1.58[3]	(1) Calculation by own-children method; (2) Calculation by birth history reconstruction; (3) Adjustment by a factor from the comparison between the 1990 and 2000 censuses.
Ding Junfeng (2003)	1.35	
Guo Zhigang (2004)	1.23[1]; 1.3[2]	(1) Calculation by the method of children-mother match with 2000 census, 1% microdata; (2) Author's opinion based on actual reflected TFR from national survey and census.
SFPC (2002)	1.45	
Cui Hongyan and Zhang Weimin (2002)	1.3	
Yu Xuejun (2002)	1.55[1] ; 1.32[2]; 1.6-1.8[3]	(1) Estimated by the number of population from 2000 census data; (2) Estimated by the number of children from 2000 census data; (3) Estimated by author.
ESCAP (2002)	1.8	

U.S. Bureau of the Census (2004)	1.7	
Zhang Weimin and Cui Hongyan (2003)	1.38[(1)]; 1.63[(2)], 2.0[(3)]; 1.8[(4)]	(1) Calculation using only the census long form; (2) Lower limit value; (3) Upper limit value; (4) Author's estimated round value.
SFPC (2001)	1.8	

To put things into a temporal perspective, Table 2 gives the times series for the TFR since the mid-1980s from five independent sources of data. These show considerable variation, but all give values of below 1.5 since the mid-1990s. There is, however, widespread agreement among experts that they all tend to be subject to underreporting of births, particularly in the years immediately preceding the census/survey. The critical question is what degree of underreporting is being assumed, and accordingly, what correction factors should be applied? This is where the alternative estimates for the TFR around 2000 differ.

Table 2. Total fertility rate for China since 1990. Sources: Cited from Guo Zhigang (2004).

Year	NSB[1]	1992 Survey[2]	1997 Survey[3]	2001 Survey[4]	2000 Census[5]
1986	2.42	2.46	2.59		
1987	2.59	2.57	2.66		
1988	2.31	2.28	2.41		
1989	2.25	2.24	2.40		
1990	2.17	2.04	2.29	2.29	2.37
1991	2.01	1.66	1.75	1.77	1.80
1992	1.86	1.47	1.57	1.59	1.68
1993	1.71		1.51	1.52	1.57
1994	1.56		1.32	1.41	1.47
1995	1.43		1.33	1.45	1.48
1996	1.55		1.35	1.36	1.36
1997	1.46			1.27	1.31
1998	1.11			1.34	1.31
1999	1.45			1.29	1.23
2000				1.45	1.23

[1] NSB (1988-2000)
[2] Yu Jingyuan and Yuan Jianhua (1996)
[3] Guo Zhigang (2000)
[4] Ding Junfeng (2003)
[5] Guo Zhigang (2004)

There is no space here for a detailed discussion of the rationales and methods of the individual estimates. These are well documented in the studies themselves. For defining an uncertainty distribution of fertility around the year 2000, we considered two alternative approaches: (1) Simply give every study equal weight and calculate the mean and variance of the distribution of different estimates, which then are used to define a normal distribution. (2) Try to exert some judgment about which studies are more authoritative than others and have the distribution informed by that choice. While the first rather mechanistic approach is intellectually unsatisfactory because it gives no room for quality judgments, the second is in danger of being too dependent on our personal (possibly biased) judgment about quality. After extensive considerations and discussions (including those at a high level forum on low fertility in East Asia held in Beijing in May 2005), we reached a compromise between the two alternative approaches. It was decided to use the Retherford et al. (2004) estimate for the TFR of around 1.5, based on a systematic application of the own-children method, as the median of a normal distribution which covers 95 percent in the range between 1.2 and 1.8. This uncertainty range with a symmetric distribution around 1.5 found the broadest consensus among the experts that were involved in the discussions. In the projections, the TFR value for 2000 (the starting year of the projections) was randomly chosen from this distribution for each of the 1,000 independent cohort component projection runs.

As to the future, the uncertainty interval for fertility was assumed to open up a bit for the coming decades. Since it is unclear whether the fertility level in China will continue to fall or whether it will recover as a consequence of government policies that aim at stabilizing fertility around 1.8-1.9, the assumed 95 percent uncertainty range will go to 1.0-2.0 by 2030 (with linear interpolation between 2000 and 2030). After 2030 the range was assumed to shift slightly upwards to 1.2-2.2 in accordance with the substantive considerations discussed in Lutz et al. (2004). The assumed uncertainty distribution for TFR is graphically depicted in Figure 1.

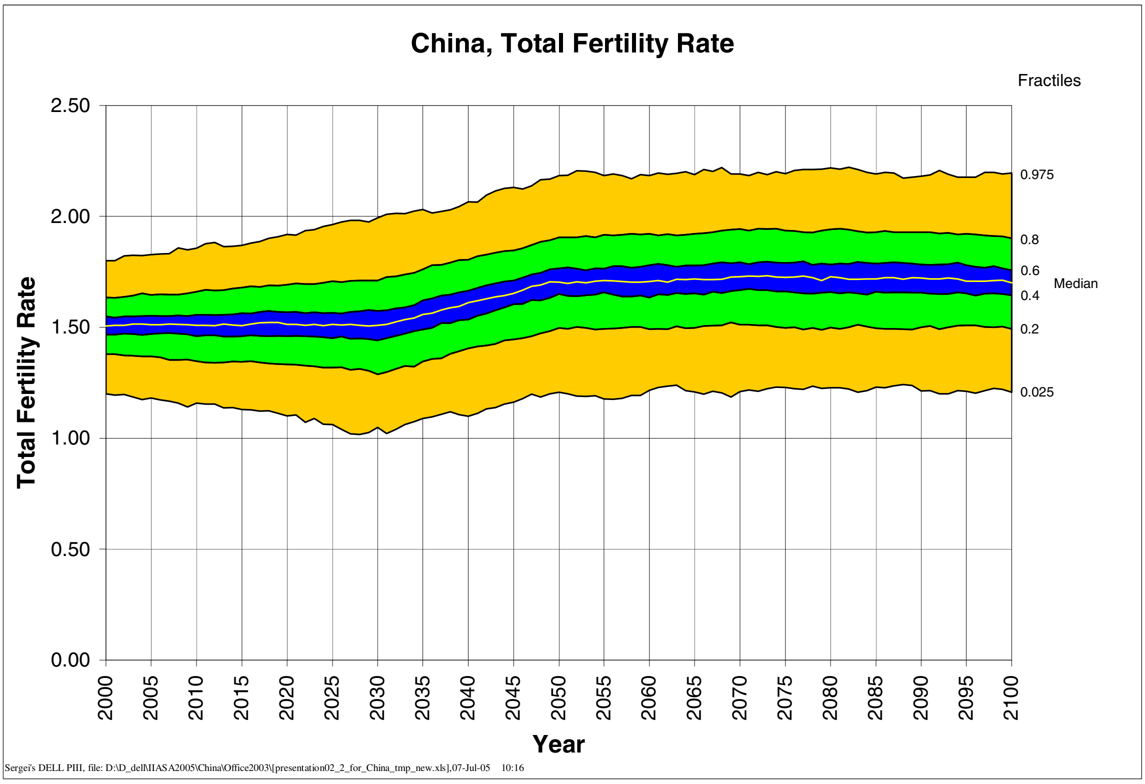

Figure 1. Assumed uncertainty distribution for the total fertility rate of China.

Sex ratio at birth

Tables 3 to 5 provide different estimates of the sex ratio at birth in 2000, another uncertain and highly controversial demographic variable. Table 3 indicates that the problem of biased sex ratios is particularly strong for higher parities. Table 4 reflects that the trend of biased sex ratios has become more serious since the mid-1980s. Since we only need the total sex ratio for the projections, we focus on the data given in Table 5. It gives seven different estimates of the sex ratio at birth in 2000 that range from 1.13 to 1.23. We decided to operationalize this uncertainty range by assuming a normal distribution with 95 percent between 1.13 and 1.23. Over time we assume that by 2030 a normal sex ratio at birth of 1.05 will be reached with linear interpolation between 2000 and 2030.

Table 3. Sex ratio at birth by parity, 1989, 1994, 2000. Data for 1989 and 2000 are taken from NSB (1993, 2002b); data for 1994 are taken from NSB (1997).

Year	Total	First Child	Second Child	Third Child and Above
1989	111.3	105.2	121.0	127.0
1994	115.6	106.4	141.1	154.3
2000	116.9	107.1	151.9	159.4

Table 4. Historical trends in the sex ratio at birth in China, 1953-2000. Sources: Gu Baochang and Xu Yi (1994) for 1960-1992; Lu Hongping (2003) for 1993-2000.

Year	Sex Ratio at birth	Year	Sex Ratio at birth	Year	Sex Ratio at birth
1953	104.9	1973	107.3	1987	111.0
1960	110.3	1974	106.6	1988	108.1
1961	108.8	1975	106.4	1989	111.3
1962	106.6	1976	107.4	1990	114.7
1963	107.1	1977	106.7	1991	116.1
1964	106.6	1978	105.9	1992	114.2
1965	106.2	1979	105.8	1993	114.1
1966	112.2	1980	107.4	1994	116.3
1967	106.6	1981	107.1	1995	117.4
1968	102.5	1982	107.2	1996	118.5
1969	104.5	1983	107.9	1997	120.4
1970	105.9	1984	108.5	1998	122.1
1971	105.2	1985	111.4	1999	122.7
1972	107.0	1986	112.3	2000	119.9

Table 5. Different estimates for the sex ratio at birth in 2000.

Source	**Sex Ratio at Birth**
Wang Jinying (2003)	113.40
SPFPC and CPDC (2003)	116.86
NSB (2002b)	117.79
Ma Yingtong (2004)	122.65
Lu Hongping (2003)	119.9
Judith Banister (2002)	120
Zhang Weimin and Cui Hongyan (2003)	>=115

The distorted sex ratio at birth is very clearly visible from the asymmetry of the age pyramid in Figure 2. The projection results (see Figure 3) show this asymmetry, particularly for the cohorts born in 1985 and (following our assumptions) in 2030. Since fertility rates are only applied to women, this distorted sex ratio has a dampening effect on population growth.

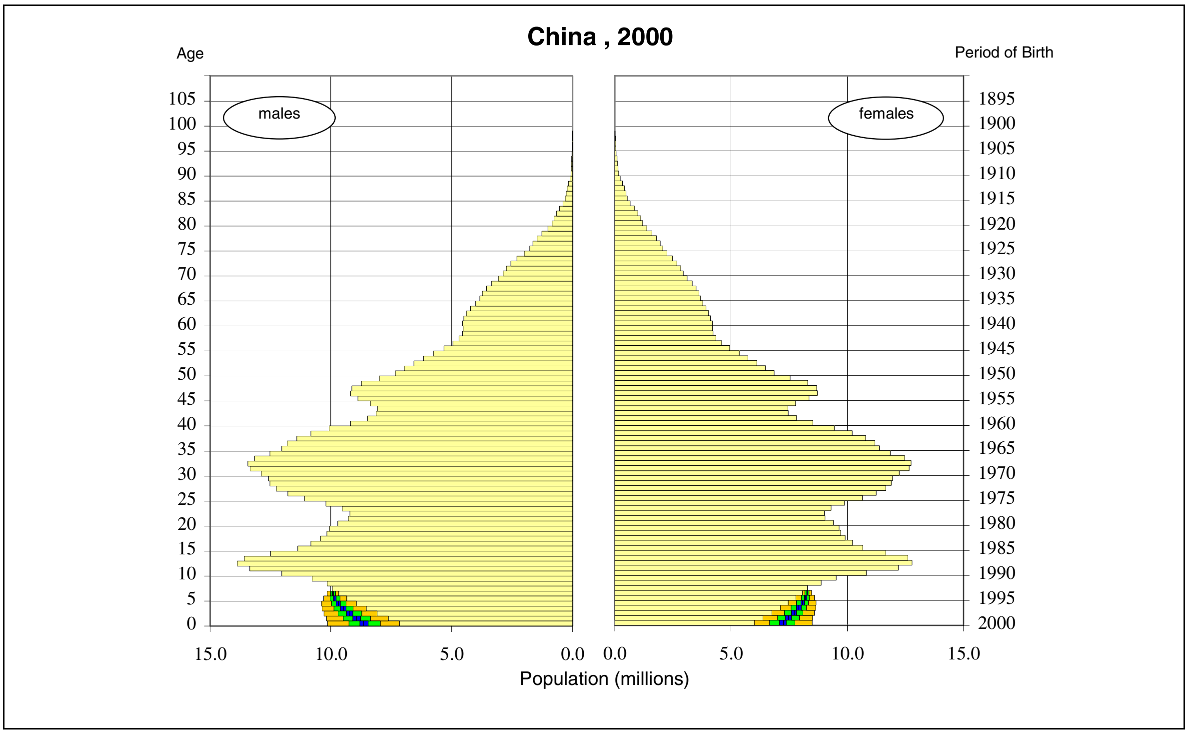

Figure 2. Probabilistic age pyramid, 2000.

Size of youngest age groups

The third kind of uncertainty of starting conditions which was considered explicitly here concerns the age structure, and in particular, the relative size of the youngest age groups. Table 6 provides the age distribution as given by the official census data. Again there is reason to assume that it includes significant underreporting of children that corresponds to the underreporting of births in the measurement of recent fertility. This underreporting becomes evident when producing projections of the Chinese population based on the starting year 1990 and when applying alternative fertility rates considered plausible.

There also have been several attempts to correct the age structure of the 2000 census although the number of such efforts has been much smaller than the number of different fertility estimates. We decided not to systematically study these correction attempts of the age structure because we would have no direct use of them in our probabilistic population projections. This is due to the necessary consistency between our assumptions on the level of fertility in 2000 and the size of the youngest age group in that year. If we choose a rather high fertility level from our uncertainty distribution of the 2000 TFRs, we also need to choose a size of the youngest age group that is comparatively larger because it was produced by these higher fertility rates over the past few years.

Table 6. Age distribution of the 2000 census, adjustment by Jiang and Ren. The number of the population (20.72 million) was distributed into different age groups in order to make the total number of the population equal to 1.26583 billion. Source: Jiang Leiwen and Ren Qiang (2005).

	Male	Female	Total
0-4	39080442	32330340	71410782
5-9	50803287	44105742	94909029
10-14	68852541	63165421	132017961
15-19	51910244	48709494	100619739
20-24	44167951	44101447	88269398
25-29	57358164	56362758	113720922
30-34	63871217	62751382	126622599
35-39	56371339	54871791	111243130
40-44	43225101	40999383	84224484
45-49	45995722	44185113	90180835
50-54	34357617	32420433	66778051
55-59	25405390	23864012	49269402
60-64	22783865	21047268	43831133
65-69	18515844	18251975	36767820
70-74	13059340	13791954	26851294
75-79	7541698	9210723	16752421
80-84	3409902	4890141	8300043
85-89	1090862	1992949	3083811
90+	274580	702567	977147
Total	648075107	617754893	1265830000

In order to deal with this consistency issue between the chosen level of TFR and the size of the youngest age groups, we designed a specific routine that calculates a separate age distribution for the year 2000 for each of the 1,000 separate simulation runs. This routine is based on the assumption that underreporting primarily affects children below school age. It assumes that the number of seven year old girls and boys reported in the census is more or less correct (of course, the method can also be applied assuming a higher age at which underreporting of children stops). Based on this assumption, we were able to calculate which level of TFR in 1993 produces the given number of children of that age group. Next, for each simulation run, a TFR value for 2000 was randomly chosen. Then for each simulation, the following calculations were performed: A linear interpolation was applied between the TFR estimated for 1993 and the one assumed for 2000. The resulting TFRs were then applied to a projection that reproduced the number of births between 1993 and 2000. Applying plausible child mortality rates produced a new age structure for the year 2000. As a result, for each simulation run we have a separate age structure for children, which is exactly consistent with the fertility level chosen for the specific run.

Figure 2 (above) shows the resulting uncertainty distribution of the age pyramid of China in 2000. The green area shows the age-specific uncertainties due to the alternatively estimated age distributions.

Projections

For the projection methodology itself, we chose the same approach as extensively discussed in Lutz et al. (2004). It is a stochastic simulation with annual fluctuations of vital rates within a variance as defined by expert opinion. The trends and the assumed ranges follow the same logic as in Lutz et al. (2004); we do not have room to discuss them here. In short, for fertility a normal distribution was assumed with a mean of 1.5 and 95 percent of all cases in the range between 1.0 and 2.0 before 2030, and after that with a mean of 1.7 and 95 percent of all future cases in the range between 1.2 and 2.2. This assumption implies that there is a chance that five percent will fall outside this range on either side. For morality the starting life expectancy for 2000 was assumed to be 69.7 years for men and 74.5 years for women. We took this as a point estimate without explicit consideration of uncertainty. For the future, however, we assumed that life expectancy would on average increase by two years per decade with 95 percent of the uncertainty distribution falling between an increase of only one year and three years per decade. This implies that for 2050 the ranges for life expectancy at birth go from 74.7 to 84.7 for men and from 79.5 to 89.5 for women. We also assumed a closed population, i.e., no net migration gains or losses.

Results

Figures 3 to 7 show the results of 1,000 simulations, each a separate cohort-component projection with the starting conditions as well as fertility, sex ratio at birth, and mortality drawn from the uncertainty distributions as described above. The figures present the results in terms of fractiles of the resulting distributions. The orange area gives the range into which 95 percent of the simulated cases fall, the green area the 60 percent range, the blue area the inner 20 percent, and the white line in the center gives the median.

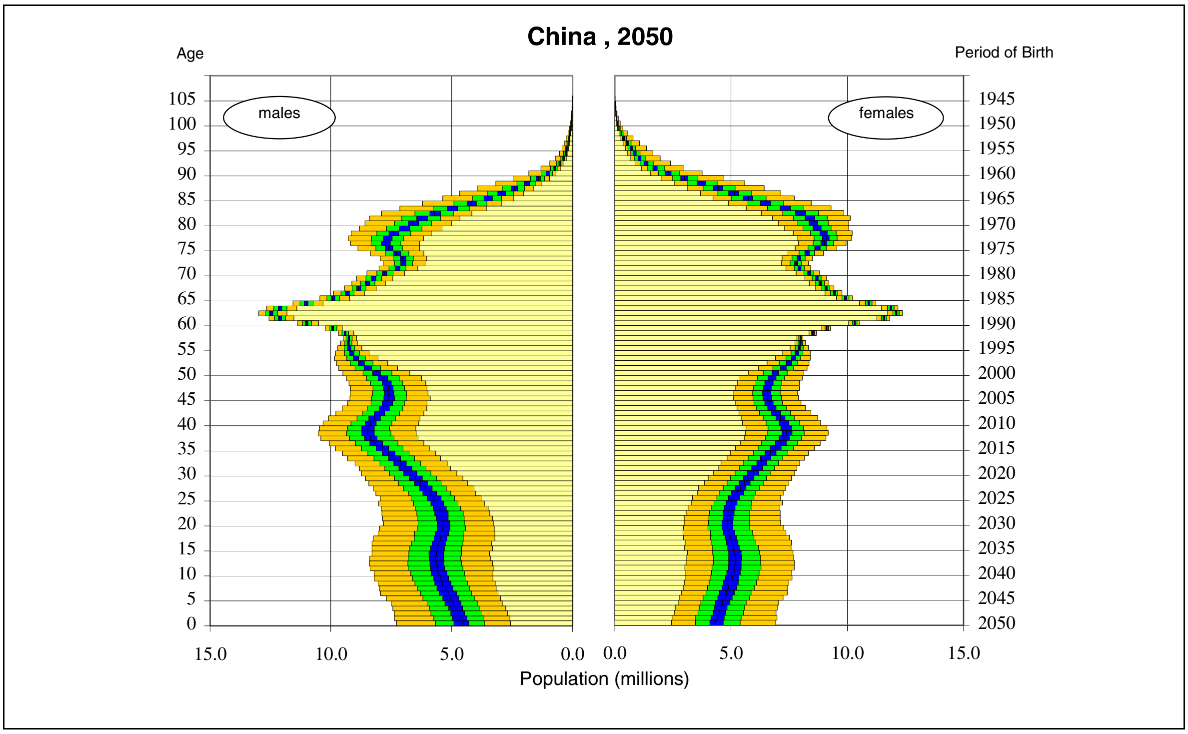

Figure 3. Probabilistic age pyramid, 2050.

Figure 3 shows the probabilistic age pyramid for China in 2050. To the left it lists the single years of age and to the right the corresponding years of birth of the cohort. For all cohorts below age 50, i.e., those born after 2000, the broad band of uncertainty reflects the combination of uncertain fertility in 2000 and uncertain future fertility trends. For the youngest cohorts, this uncertainty range is quite significant with the 95 percent interval going from around 2.5 million girls to 7.5 million girls; the difference is a factor of three. For those aged 50-70 in 2050, the uncertainty range is the smallest. This is because these cohorts are already born and the cohort size is roughly known (subject only to the uncertainty about the current age distribution as discussed above) and they have not yet entered the high mortality ages when the uncertainty about future old-age mortality comes to bear. It is also remarkable that as a consequence of the Chinese demographic history, these very large age groups born between 1985 and 1990 are not only the biggest cohorts today, but will also be by far the biggest cohorts in 2050. And as the figure illustrates, there is very little uncertainty about this.

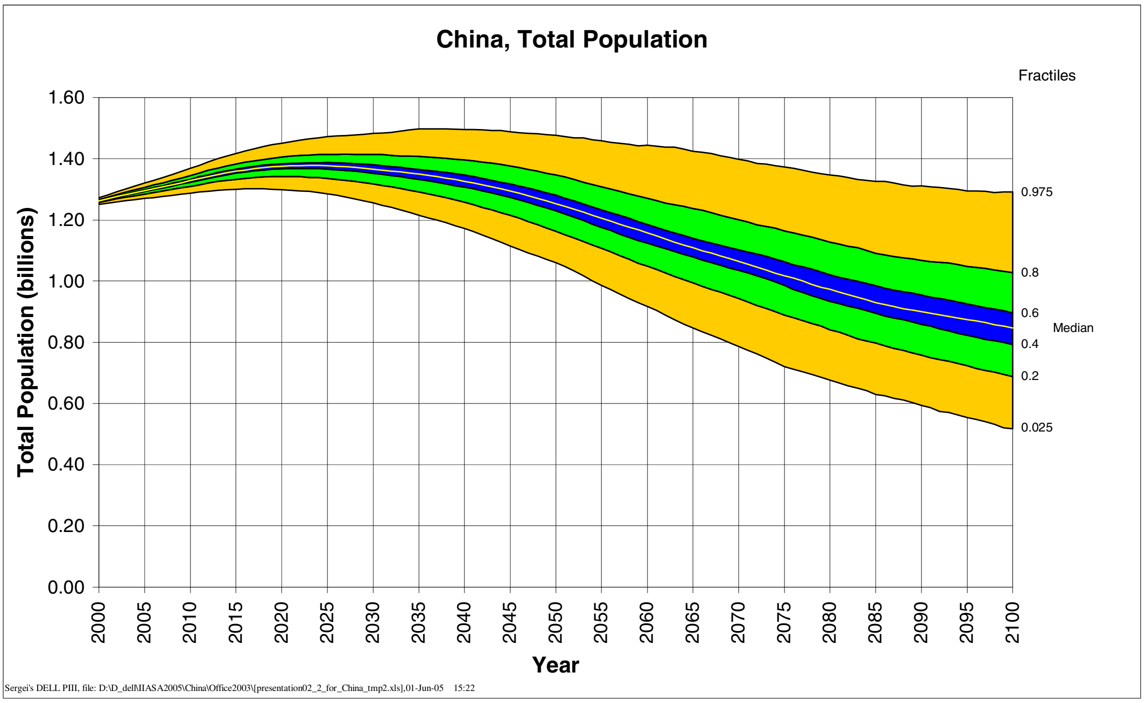

Figure 4. Fractiles of distribution for total population, 2000-2100.

Figure 4 shows the resulting uncertainty distribution for total population size. The median of the distribution shows further growth until reaching a peak of 1.38 billion in 2020-2030 and then starts to slowly decline. In 2050 the median is already down to 1.25 billion. But as can be expected the uncertainty range opens with the passage of time. The upper 0.975 fractile keeps growing until around 2035, reaching almost 1.5 billion; the lower 0.025 fractile starts to go down in 2015 after having reached a peak of 1.30 billion. The 95 percent range in 2050 goes from 1.10 billion to 1.54 billion.

Figure 5 shows the proportion of people below age 15. Here it is clearly visible that the uncertainty about the size of the youngest age groups today, together with the uncertainty of the current level of fertility, cause a quite unusual distribution up to 2025 after which point the pattern becomes more regular and essentially reflects the uncertainty of future fertility levels. Comparing this figure to the age pyramid (Figure 3), it is evident that the proportion of children in the population is less uncertain than the absolute number of children. This is because in the case of a high fertility trajectory, both the number of children and the total population will be higher.

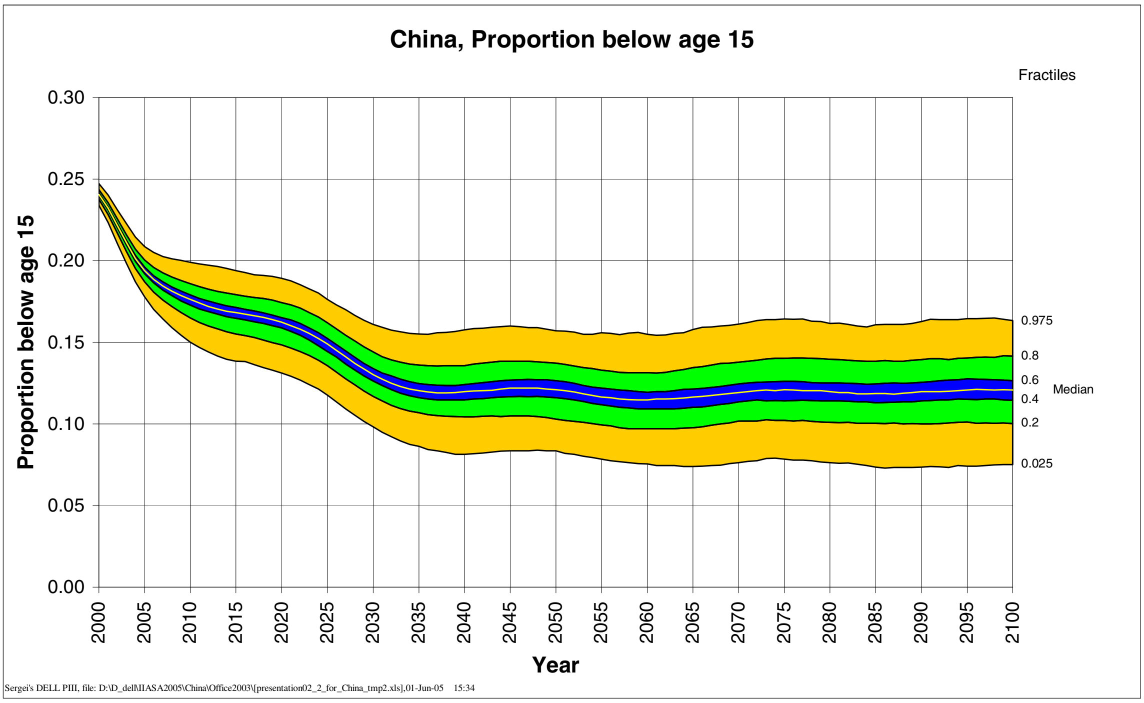

Figure 5. Fractiles of distribution for proportion below age 15, 2000-2100.

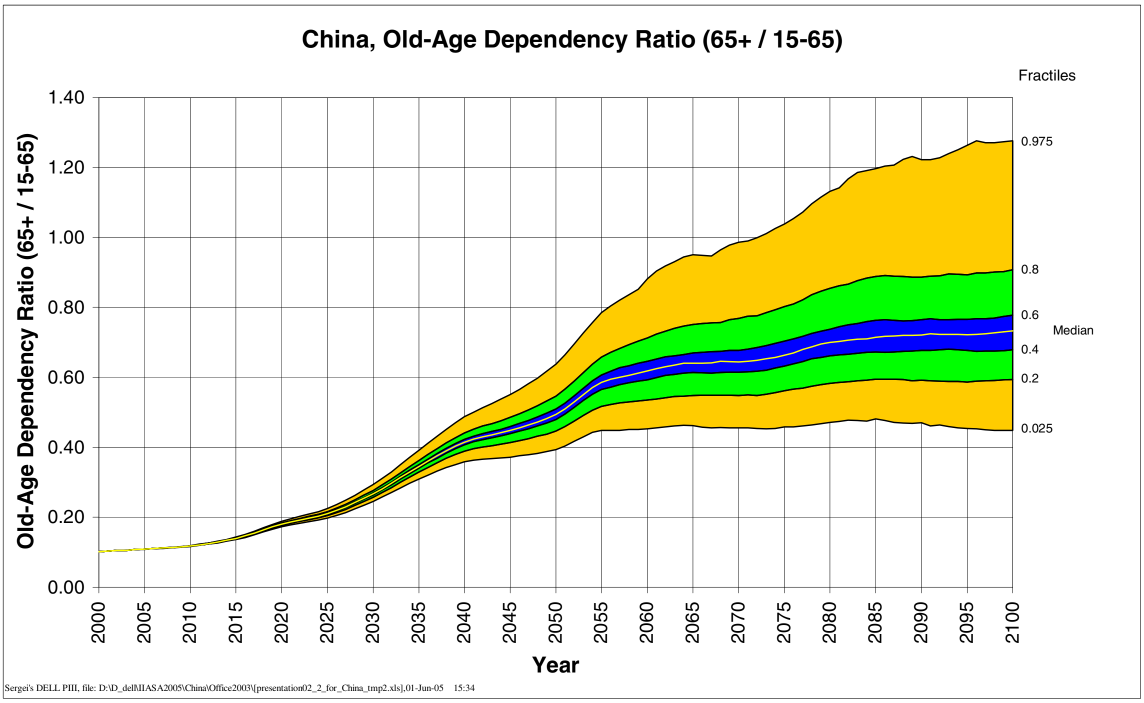

Figure 6. Fractiles of distribution for old-age dependency ratio, 2000-2100.

Figure 6 shows the old-age dependency ratio (65+/15-65). This graph shows a most dramatic increase with very little uncertainty until around 2035. The old-age dependency ratio is almost certain to triple in only over three decades. This can be said with high confidence as the 95 percent uncertainty range is very narrow, a consequence of the fact that much of this increase is already preprogrammed in today's age structure. And even considering the uncertainty about this age structure does not change this pattern significantly. By around 2050 the old-age dependency ratio is expected to increase by almost a factor of five.

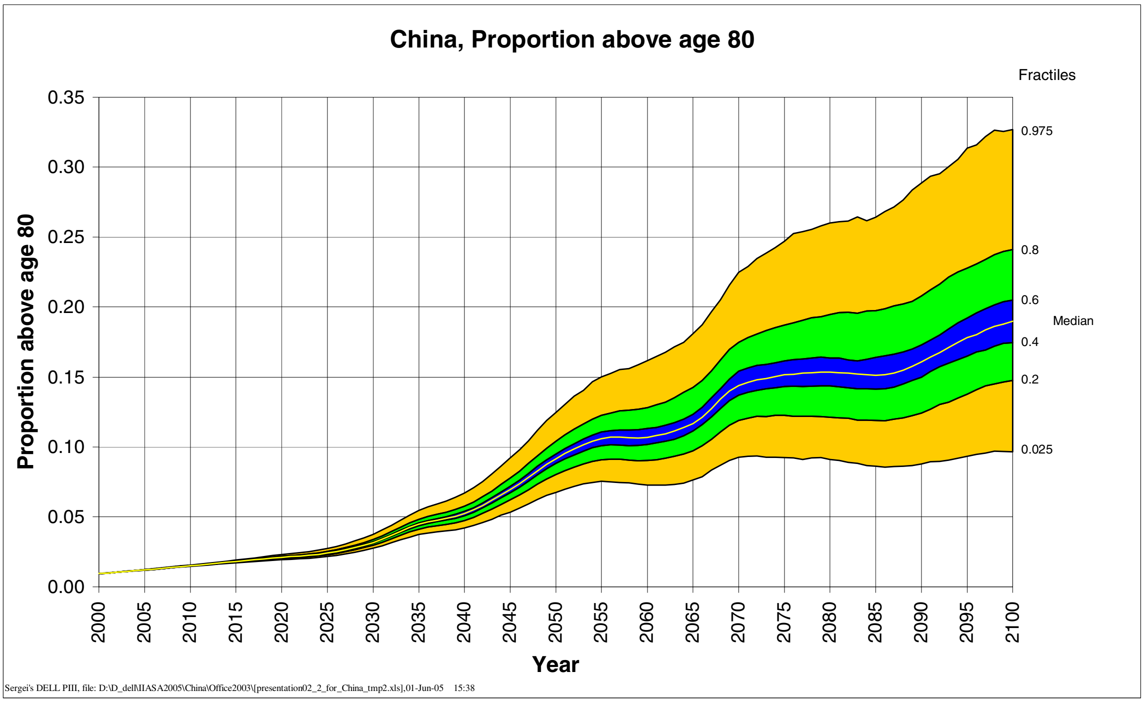

Figure 7. Fractiles of distribution for proportion above age 80, 2000-2100.

Figure 7 gives a long term view on the possible size of the very old population in China, namely, those above age 80. Currently only around one percent of the total population of China belongs to this age group. This group is expected to gradually increase over the coming few decades to around three percent in 2030 with very little uncertainty. But over the decades 2030-2050, it is likely to see a marked increase reaching around 10 percent by the middle of the century, i.e., 10 times its current size. Much of this increase is already embedded in the current age structure of the population due to the strong cohorts born around 1970. Another significant push in the proportion above age 80 is expected before 2070 when it is likely to jump to close to 15 percent of the total population because the very big cohorts born in the mid-1980s will reach this high age. Of course, the uncertainty range around this median projection significantly broadens during the second half of the century. Like in most other low fertility countries in the world, the future course of old-age mortality is highly uncertain. If the proponents of an unabated increase in life expectancy are correct, then China may well have a quarter of its total population above the age of 80 by the end of the century. If the "pessimists" are correct, this proportion would still increase to between 10 and 15 percent of the population.

Conclusions

This paper has demonstrated that over the coming decades, the world's biggest national population will experience some of the most rapid and most massive processes of population aging in world history. Neither the current uncertainty about the level of fertility, the sex ratio, the number of children already born, nor the uncertainty about future vital rates significantly weakens this very robust forecast.

When it comes to population size, however, the uncertainties considered do have quite some impact. The projections show that there is about an 80 percent chance that by the end of the century, China's population size will again fall below one billion, even though over the coming decades we will see further increase due to the momentum caused by a young age structure. Almost certainly (with more than 97.5 percent probability) China's population will surpass 1.3 billion over the next decades or so. The point at which it will begin to fall greatly depends on the assumptions made about current and future fertility trends as discussed. Our projections show that almost certainly (more than 97.5 percent) the population will not reach 1.5 billion. The median shows a peak of 1.377 around 2025. After that, the population starts to decline with the median in 2100 showing 850 million people, almost 40 percent below its peak level.

China is currently benefiting from a very low total dependency ratio. There are few children and not yet many elderly. This demographic window of opportunity, which is also one factor behind the currently very high economic growth rates, will close in the foreseeable future. Our projections show that there is no uncertainty that the old-age dependency burden will dramatically increase over the coming decades. This will pose serious challenges for China's social and economic structure and needs to be addressed soon because such institutional adjustments take time.

This expected population aging and shrinking will also have significant impacts on the projected global trends. Contrary to earlier world population projections, fertility is now being assumed to lie in the 1.4-1.5 range around the year 2000 rather than in the 1.8-1.9 range as previously assumed, which will result in lower projected global population sizes. In its recent long range projections (still based on a 2000 TFR of 1.8) the UN Population Division projects a population for China of 1.395 billion in 2050 and 1.181 billion in 2100 (UN 2004). In its 2004 fertility data sheet, the UN gives a TFR estimate of 1.4 for 2001 (UN 2005). This has not yet been implemented into their published projections. Based on these newer assumptions, our projections presented here show that the population of China would likely be 334 million less in 2100 than the number given in the UN long range projections. This implies that the world population size would have to be corrected downwards by 0.33 billion in 2100.

This paper has also shown that existing methods of expert-based probabilistic forecasting can readily be expanded to include uncertainty about the current demographic conditions. They provide a comprehensive tool to jointly consider all sources of uncertainty that can influence the evolution of population age and structure over time. To the user they can provide an easy to understand summary of all expert knowledge and expert judgment on what can be said about likely future population patterns and the degree of confidence with which such information should be seen.

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Appendix Tables

China, proportion below age 15

Ind	Interval	Sex	2004	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
prop 0-15	0.025	tot	0.187	0.178	0.150	0.138	0.131	0.118	0.098	0.086	0.081	0.083	0.084	0.078	0.075	0.074	0.076	0.078	0.076	0.074	0.074	0.074	0.075
prop 0-15	0.2	tot	0.195	0.187	0.165	0.155	0.148	0.136	0.117	0.107	0.104	0.105	0.103	0.099	0.097	0.098	0.102	0.102	0.101	0.100	0.100	0.101	0.100
prop 0-15	0.4	tot	0.200	0.192	0.173	0.165	0.159	0.144	0.126	0.116	0.115	0.117	0.116	0.112	0.109	0.110	0.113	0.114	0.114	0.113	0.114	0.115	0.114
prop 0-15	0.6	tot	0.203	0.196	0.179	0.171	0.165	0.152	0.134	0.125	0.124	0.127	0.126	0.122	0.119	0.121	0.124	0.126	0.125	0.125	0.125	0.128	0.126
prop 0-15	0.8	tot	0.207	0.200	0.186	0.179	0.174	0.162	0.144	0.136	0.136	0.138	0.137	0.133	0.131	0.135	0.138	0.140	0.140	0.138	0.139	0.140	0.142
prop 0-15	0.975	tot	0.215	0.209	0.199	0.194	0.189	0.176	0.161	0.155	0.158	0.160	0.157	0.156	0.155	0.158	0.161	0.164	0.162	0.161	0.163	0.164	0.163
prop 0-15		mean	0.201	0.194	0.175	0.167	0.161	0.148	0.130	0.121	0.120	0.122	0.121	0.117	0.114	0.116	0.119	0.121	0.120	0.119	0.119	0.121	0.121
prop 0-15		Median	0.201	0.194	0.176	0.168	0.162	0.149	0.130	0.120	0.120	0.122	0.121	0.117	0.115	0.116	0.119	0.121	0.120	0.118	0.120	0.121	0.121
prop 0-15		std	0.007	0.008	0.012	0.015	0.015	0.016	0.016	0.018	0.019	0.020	0.020	0.020	0.020	0.021	0.022	0.022	0.022	0.022	0.023	0.023	0.023

China, life expectancy

Ind	Interval	Sex	2004	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
e0	0.025	tot	72.269	72.353	72.810	73.175	73.717	74.104	74.543	74.753	75.250	75.747	75.868	76.014	76.683	76.996	77.982	78.211	78.245	79.052	79.670	80.719	79.956
e0	0.2	tot	72.524	72.674	73.448	74.169	74.891	75.686	76.364	76.951	77.641	78.446	79.188	79.958	80.818	81.562	82.264	83.114	83.789	84.638	85.744	86.603	87.041
e0	0.4	tot	72.657	72.837	73.799	74.725	75.619	76.554	77.445	78.387	79.259	80.040	81.104	81.809	82.939	83.834	84.739	85.466	86.610	87.624	88.792	89.776	90.572
e0	0.6	tot	72.779	73.003	74.084	75.141	76.262	77.318	78.417	79.520	80.488	81.469	82.438	83.527	84.637	85.729	86.873	87.923	88.887	90.347	91.163	92.426	93.473
e0	0.8	tot	72.934	73.188	74.436	75.672	76.956	78.223	79.472	80.663	81.982	83.078	84.302	85.498	86.843	87.827	89.306	90.500	92.110	93.251	94.735	95.920	97.272
e0	0.975	tot	73.183	73.523	75.079	76.816	78.385	79.939	81.413	83.306	84.980	86.033	87.800	89.350	90.821	92.467	94.082	95.366	97.129	98.745	101.077	101.758	103.471
e0		mean	72.721	72.926	73.939	74.942	75.962	76.979	77.946	78.915	79.883	80.796	81.760	82.741	83.782	84.743	85.791	86.774	87.842	89.001	90.144	91.190	92.075
e0		Median	72.716	72.916	73.944	74.934	75.956	76.916	77.907	78.965	79.847	80.853	81.766	82.657	83.777	84.836	85.857	86.860	87.670	89.042	90.144	90.969	92.018
e0		std	0.238	0.301	0.587	0.910	1.207	1.517	1.834	2.207	2.513	2.743	3.032	3.375	3.622	3.834	4.137	4.379	4.814	5.117	5.459	5.601	6.032

China, proportion 15-65

Ind	Interval	Sex	2004	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
prop 15-65	0.025	tot	0.709	0.713	0.716	0.708	0.689	0.682	0.666	0.633	0.599	0.577	0.551	0.507	0.485	0.468	0.459	0.445	0.427	0.417	0.411	0.405	0.403
prop 15-65	0.2	tot	0.716	0.721	0.728	0.721	0.701	0.694	0.678	0.644	0.611	0.593	0.572	0.536	0.523	0.511	0.504	0.492	0.482	0.475	0.471	0.470	0.468
prop 15-65	0.4	tot	0.719	0.725	0.735	0.727	0.707	0.700	0.683	0.650	0.618	0.602	0.583	0.551	0.539	0.530	0.526	0.519	0.507	0.501	0.499	0.500	0.496
prop 15-65	0.6	tot	0.723	0.729	0.740	0.733	0.713	0.706	0.689	0.656	0.625	0.609	0.593	0.563	0.554	0.545	0.542	0.536	0.527	0.523	0.522	0.521	0.521
prop 15-65	0.8	tot	0.727	0.733	0.747	0.741	0.721	0.713	0.695	0.662	0.632	0.618	0.602	0.576	0.569	0.564	0.562	0.556	0.549	0.544	0.545	0.545	0.543
prop 15-65	0.975	tot	0.734	0.741	0.760	0.756	0.733	0.726	0.707	0.675	0.646	0.634	0.621	0.598	0.595	0.590	0.591	0.589	0.585	0.582	0.586	0.588	0.585
prop 15-65		mean	0.721	0.727	0.738	0.731	0.711	0.703	0.686	0.653	0.622	0.605	0.587	0.556	0.545	0.536	0.532	0.524	0.514	0.509	0.507	0.507	0.505
prop 15-65		Median	0.721	0.727	0.737	0.730	0.710	0.703	0.686	0.652	0.621	0.605	0.588	0.557	0.546	0.538	0.534	0.526	0.516	0.513	0.512	0.510	0.508
prop 15-65		std	0.006	0.007	0.011	0.012	0.012	0.011	0.011	0.011	0.012	0.015	0.018	0.023	0.028	0.032	0.034	0.037	0.040	0.043	0.045	0.046	0.047

China, proportion above age 80

Ind	Interval	Sex	2004	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
prop 80+	0.025	tot	0.011	0.012	0.015	0.017	0.019	0.022	0.028	0.037	0.042	0.053	0.067	0.076	0.073	0.076	0.093	0.092	0.091	0.086	0.088	0.093	0.097
prop 80+	0.2	tot	0.012	0.012	0.015	0.018	0.020	0.023	0.030	0.041	0.047	0.062	0.080	0.091	0.090	0.097	0.119	0.123	0.121	0.119	0.124	0.138	0.147
prop 80+	0.4	tot	0.012	0.012	0.015	0.018	0.021	0.024	0.031	0.044	0.051	0.067	0.088	0.101	0.102	0.111	0.137	0.143	0.144	0.141	0.150	0.165	0.175
prop 80+	0.6	tot	0.012	0.012	0.015	0.018	0.021	0.024	0.032	0.046	0.054	0.072	0.095	0.111	0.113	0.123	0.154	0.161	0.163	0.164	0.173	0.192	0.205
prop 80+	0.8	tot	0.012	0.012	0.015	0.019	0.022	0.025	0.034	0.048	0.058	0.078	0.104	0.123	0.128	0.143	0.175	0.187	0.195	0.197	0.208	0.228	0.241
prop 80+	0.975	tot	0.012	0.012	0.016	0.019	0.023	0.027	0.038	0.055	0.067	0.092	0.125	0.150	0.162	0.181	0.225	0.247	0.260	0.264	0.289	0.314	0.327
prop 80+		mean	0.012	0.012	0.015	0.018	0.021	0.024	0.032	0.045	0.053	0.070	0.093	0.107	0.110	0.120	0.148	0.156	0.159	0.159	0.168	0.185	0.195
prop 80+		Median	0.012	0.012	0.015	0.018	0.021	0.024	0.032	0.045	0.052	0.070	0.092	0.106	0.107	0.117	0.144	0.152	0.154	0.151	0.161	0.178	0.190
prop 80+		std	0.000	0.000	0.000	0.001	0.001	0.001	0.003	0.004	0.006	0.010	0.014	0.019	0.023	0.027	0.034	0.039	0.044	0.047	0.051	0.055	0.058

China, proportion above age 65

Ind	Interval	Sex	2004	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
prop 65+	0.025	tot	0.076	0.078	0.084	0.098	0.121	0.137	0.166	0.202	0.224	0.229	0.240	0.262	0.264	0.268	0.265	0.266	0.272	0.277	0.271	0.263	0.261
prop 65+	0.2	tot	0.077	0.079	0.086	0.100	0.125	0.143	0.176	0.215	0.244	0.254	0.269	0.297	0.305	0.309	0.307	0.311	0.319	0.323	0.320	0.320	0.322
prop 65+	0.4	tot	0.077	0.079	0.087	0.101	0.127	0.147	0.181	0.223	0.254	0.266	0.284	0.317	0.329	0.334	0.334	0.339	0.348	0.352	0.355	0.353	0.354
prop 65+	0.6	tot	0.078	0.079	0.087	0.103	0.129	0.150	0.185	0.229	0.262	0.277	0.297	0.334	0.349	0.355	0.358	0.365	0.377	0.383	0.384	0.383	0.386
prop 65+	0.8	tot	0.078	0.080	0.088	0.104	0.132	0.153	0.191	0.237	0.273	0.291	0.315	0.356	0.374	0.385	0.387	0.397	0.412	0.421	0.419	0.422	0.425
prop 65+	0.975	tot	0.079	0.081	0.090	0.107	0.136	0.161	0.203	0.255	0.298	0.324	0.354	0.401	0.430	0.444	0.450	0.465	0.482	0.498	0.507	0.515	0.513
prop 65+		mean	0.078	0.079	0.087	0.102	0.128	0.148	0.184	0.226	0.259	0.273	0.292	0.328	0.341	0.348	0.349	0.355	0.366	0.372	0.373	0.372	0.374
prop 65+		Median	0.078	0.079	0.087	0.102	0.128	0.148	0.183	0.226	0.258	0.272	0.291	0.327	0.338	0.345	0.345	0.352	0.361	0.367	0.368	0.369	0.372
prop 65+		std	0.001	0.001	0.001	0.002	0.004	0.006	0.009	0.013	0.018	0.022	0.028	0.035	0.041	0.045	0.048	0.051	0.055	0.058	0.060	0.061	0.063

China, old-age dependency ratio, (65+ / 15-65)

Ind	Interval	Sex	2004	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
O_PRPA	0.025	tot	0.107	0.109	0.117	0.137	0.173	0.198	0.245	0.309	0.359	0.372	0.393	0.448	0.453	0.462	0.455	0.459	0.471	0.482	0.470	0.454	0.449
O_PRPA	0.2	tot	0.107	0.109	0.118	0.138	0.177	0.205	0.257	0.329	0.389	0.414	0.447	0.518	0.536	0.549	0.549	0.561	0.583	0.595	0.592	0.587	0.594
O_PRPA	0.4	tot	0.107	0.109	0.118	0.139	0.179	0.209	0.264	0.341	0.408	0.439	0.480	0.565	0.594	0.613	0.615	0.632	0.662	0.672	0.677	0.677	0.679
O_PRPA	0.6	tot	0.108	0.109	0.118	0.140	0.181	0.212	0.270	0.351	0.423	0.459	0.510	0.606	0.646	0.669	0.677	0.704	0.738	0.763	0.764	0.766	0.778
O_PRPA	0.8	tot	0.108	0.109	0.119	0.141	0.184	0.217	0.277	0.362	0.441	0.486	0.547	0.658	0.713	0.752	0.769	0.802	0.854	0.888	0.887	0.893	0.908
O_PRPA	0.975	tot	0.108	0.109	0.119	0.143	0.188	0.225	0.293	0.391	0.487	0.550	0.638	0.785	0.882	0.951	0.986	1.038	1.133	1.197	1.223	1.263	1.277
O_PRPA		mean	0.108	0.109	0.118	0.140	0.180	0.211	0.267	0.347	0.416	0.451	0.498	0.592	0.630	0.656	0.664	0.687	0.726	0.747	0.752	0.751	0.760
O_PRPA		Median	0.108	0.109	0.118	0.140	0.180	0.211	0.267	0.346	0.414	0.449	0.495	0.586	0.619	0.641	0.644	0.663	0.700	0.715	0.721	0.722	0.732
O_PRPA		std	0.000	0.000	0.001	0.002	0.004	0.007	0.012	0.021	0.032	0.044	0.059	0.086	0.108	0.124	0.135	0.150	0.170	0.186	0.196	0.200	0.206

China, total population

Ind	Interval	Sex	2004	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
ptotr	0.025	tot	1.266	1.270	1.287	1.300	1.299	1.285	1.255	1.216	1.172	1.116	1.060	0.986	0.917	0.847	0.787	0.721	0.676	0.630	0.594	0.554	0.517
ptotr	0.2	tot	1.279	1.284	1.309	1.333	1.342	1.336	1.317	1.291	1.258	1.215	1.163	1.107	1.049	0.995	0.943	0.889	0.841	0.798	0.758	0.723	0.688
ptotr	0.4	tot	1.286	1.292	1.323	1.352	1.366	1.365	1.352	1.333	1.307	1.273	1.230	1.175	1.123	1.079	1.035	0.986	0.934	0.895	0.859	0.823	0.793
ptotr	0.6	tot	1.292	1.299	1.333	1.366	1.383	1.387	1.380	1.365	1.347	1.317	1.280	1.233	1.185	1.140	1.102	1.064	1.021	0.984	0.955	0.925	0.896
ptotr	0.8	tot	1.299	1.306	1.345	1.383	1.405	1.413	1.414	1.407	1.396	1.377	1.347	1.308	1.271	1.237	1.201	1.163	1.127	1.090	1.067	1.048	1.028
ptotr	0.975	tot	1.311	1.320	1.368	1.418	1.451	1.473	1.482	1.497	1.495	1.488	1.476	1.458	1.444	1.425	1.398	1.373	1.347	1.326	1.311	1.295	1.292
ptotr		mean	1.289	1.295	1.328	1.358	1.374	1.376	1.366	1.350	1.329	1.298	1.257	1.209	1.161	1.116	1.073	1.030	0.987	0.949	0.917	0.890	0.864
ptotr		Median	1.289	1.296	1.328	1.359	1.375	1.377	1.366	1.350	1.326	1.294	1.252	1.206	1.157	1.109	1.064	1.017	0.973	0.930	0.900	0.874	0.847
ptotr		std	0.011	0.013	0.021	0.029	0.038	0.047	0.058	0.070	0.082	0.095	0.107	0.118	0.130	0.141	0.152	0.162	0.171	0.179	0.187	0.193	0.199