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Population Projections for Japan: Methods, Assumptions and Results

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Abstract The National Institute of Population and Social Security Research officially announced a new round of population projections for Japan in January 1997. This article outlines the projection results and describes the methods used to obtain them. The projections, made following the release of 1995 census data, provide three variants based on three different scenarios of fertility prospects: medium, high, and low fertility variant projections. According to the medium projection, the population of Japan will increase from 125.6 million in 1995 to a peak of 127.8 million in 2007, followed by a constant decrease to 100.5 million in 2050. The proportion aged 65 and over will expand from 14.6% in 1995 to 32.3% in 2050. The projected loss of population and aging will be due mainly to the continuous below-replacement fertility rate during the past and coming decades. The projections incorporated some factors of low fertility such as later and fewer marriages. This article explains how the fertility and mortality prospects were provided for the projections as well as the results of analyses on which the prospects were based.

1. Introduction

According to the population projections prepared by the National Institute of Population and Social Security Research in 1997, the aging population in Japan will reach a much higher level much faster than predicted in 1992. The difference between the 1992 and 1997 projections is that the 1997 projection assumes a relatively lower fertility rate. In particular, the declining fertility rate, which in recent years has dipped below the population's replacement level, apparently will significantly increase the aging population and lead to a diminished population overall.

The results of the population projections are presented in section 2, together with a summary of our method and assumptions. Detailed information on the method and assumptions is provided in section 3.

This report includes population projections for Japan by age and sex for the years 1995 to 2050. These numbers are based on an estimated 1 October 1995,

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resident population consistent with the 1995 census as enumerated and are projected forward using the cohort-component method with alternative assumptions for future fertility, life expectancy, and net immigration levels. The main projection period is taken to be 55 years up to the year 2050. The projection for Japan has been carried forward for an additional 50 years up to the year 2100 as a reference projection.

This projection includes three variants concerning the future trend in fertility rates. The total fertility rate based on a medium variant assumption will decline from 1.42 at the beginning of 1995 to 1.38 in 2000. Thereafter, a gradual upward change is predicted, and by 2030 the rate will be 1.61. Thereafter, the rate will be constant. Population projections based on a high variant assumption indicate that the total fertility rate will turn upward beginning in 1997, and when it reaches 1.85 by 2030, it will maintain that level. The population projections based on a low variant assumption show that the downward trend in the total fertility rate will continue until 2005, when it will reach 1.28, and thereafter, a slight upward movement. It is predicted that even after the year 2030 it will cease at the 1.38 level.

For assumptions of survival rates, future life tables have been constructed. The average life expectancies of both sexes, which in 1995 were 76.36 years for men and 82.84 years for women, would continue growing constantly from then onward: 77.40 years for men and 84.12 years for women in 2000, 78.80 and 85.83 in 2025, and 79.43 and 86.47 in 2050.

The assumption of net international immigration rates assumed that the recent international net immigration rates would remain constant in the future as well. To divide the future number of newborns into male and female, we need to estimate the sex ratio of births. Based on the sex ratios of previous births, fluctuations on a yearly basis are negligible. For this reason, we assumed that the mean value (105.6) of the sex ratios of births from 1991 to 1995 would also remain constant from 1996 onward.

2. Projection Results

2.1. The Arrival of the Diminishing Population Era

According to the 1995 National Census, the starting point for our population projections, the gross population of Japan was 125,570,000. From the findings of the population projection based on the medium assumption, the population will gradually increase and reach 126,890,000 by the year 2000. It will then peak at 127,780,000 by 2007. Thereafter, it will continue to decline for a long period of time (Fig. 1; see also Table A-3 in App.). In 2017 the population will nearly return to the 1995 level, and by 2050 it will diminish to 100,500,000. Furthermore, by the year 2051, as a reference projection, and thereafter, the population will continue to decline, and at 2100 it will be sealed at 67,370,000.

Based on the population projection using the high variant assumption, the total population will peak at 129,560,000 by 2011, which is slightly behind the medium variant assumption. Thereafter, the trend will decline, and in 2050 the population will be reduced to 110,960,000. On the other hand, the low variant assumption indicates that the population will peak at 127,050,000 by 2004 and thereafter continually decline to 92,310,000 by 2050.

Thus, as soon as the 21st century begins, the population of Japan will enter an era of decline, ending the continuous increase in population. This historic change has already affected the fertility rate (population replacement level, total fertility rate—approx. 2.08 level) defined as maintaining the stationary population level since the middle of the 1970s.

2.2. A Society with Fewer Children

The number of births in Japan decreased from 2,090,000 in 1973 to 1,190,000 in 1995. Based on the low birth prediction for the next few years, the child

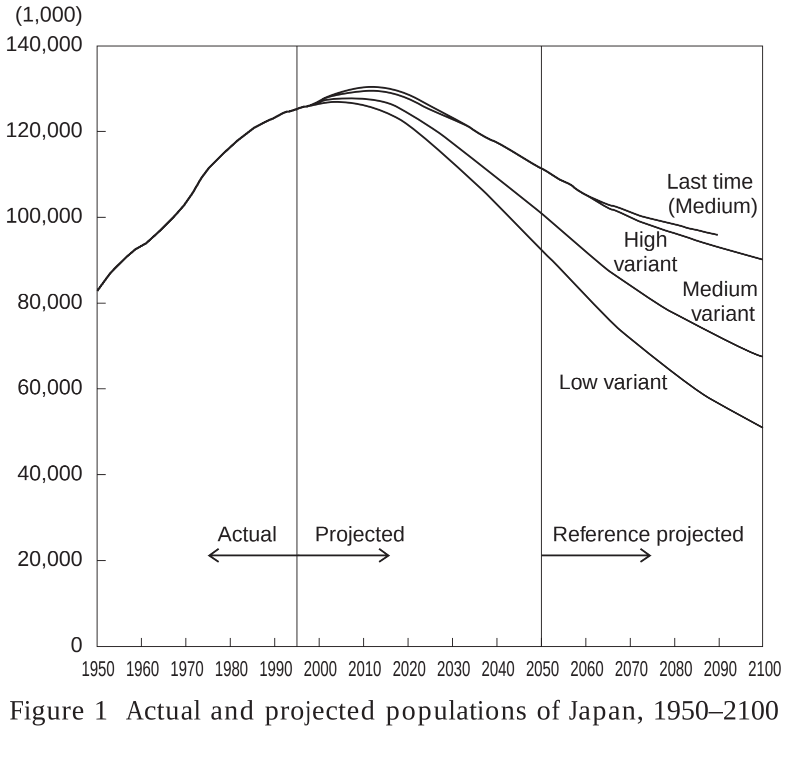

Figure 1 Actual and projected populations of Japan, 1950–2100

population aged 0–14 started to decrease from 27,000,000 beginning in 1980 (Fig. 2; see also Table A-3 in App.).

Whereas the 1995 National Census gave a child population of 20,030,000, the medium variant assumption shows that that population will decrease to 18,000,000 by 1999. Thereafter, until 2014, it will temporarily stabilize at around 18,300,000. However, after 2015 it will dip to the 18,000,000 level and gradually decline for a long time. By the end of 2050 it is predicted that the child population will be reduced to about 13,000,000. Based on the reference projection of 2051 and thereafter, the long-term downward trend will continue. The population will drop to 12,000,000 by 2059 and to below 10,000,000 by 2090. Indications are that it takes approximately one century to reduce the child population to half its size.

In making assumptions about population trends, when examining the future fertility rate according to high and low variants, the high variant assumption shows that due to the second baby boom the child population will temporarily decrease but will recover to 20,000,000 by the year 2010. Nevertheless, in the long term the population will continuously decrease due to the low fertility rate.

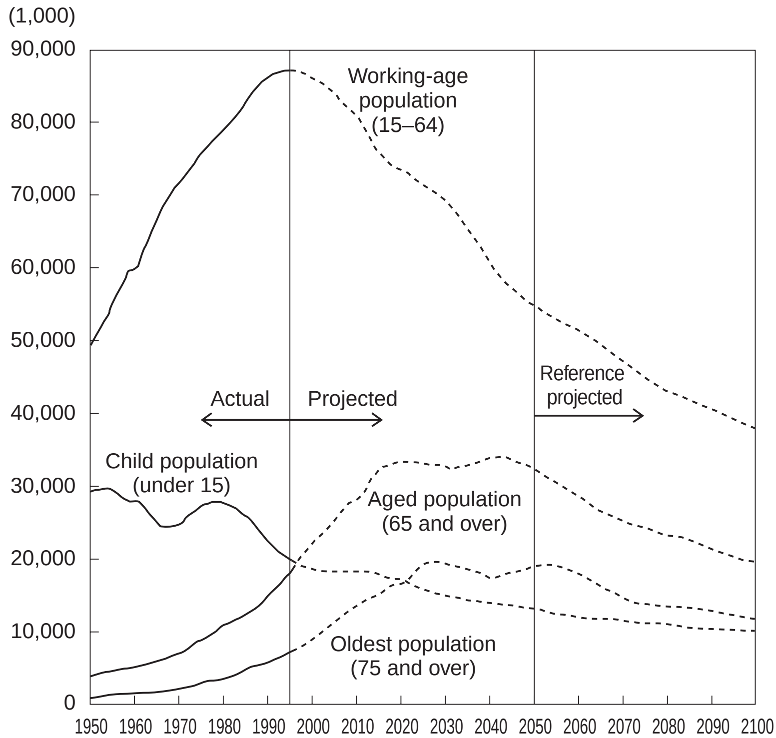

Figure 2 Trends in major age composition of the total population: Medium variant, 1950–2100

The high variant assumption shows that at 2050 the population will reach 17,060,000, and then by 2100 it will decline to 14,770,000.

The low variant assumption shows that due to the extremely low fertility rate it is projected that the population will rapidly decline. The 1995 population level of 20,000,000 will drop to the 15,000,000 level by 2020. By the middle of the 21st century the population will plummet to 10,000,000, which is one-half of the 1995 population. At the end of the 21st century it is projected to shrink to 6,600,000.

Thus, if the extremely low fertility rate continues to decline, the child population cannot grow, and it is inevitable that Japan will have a diminishing population.

In considering the proportion of the total population to the child population, however, the total population will not change significantly. The reason is that the total population decreases simultaneously while the ratio of the child population to the total population gradually decreases proportionally. The results of our projections based on the medium variant assumption show that the proportion of the child population will decline from 16.0% in 1995 to 14.3% in 2007, which will see the peak population of Japan. Thereafter, the population will gradually fall off. By the middle of the next century the child population will settle at the 13.11% level.

2.3. Aging of the Working Population

The working population, aged 15–64 years, has been consistently increasing since World War II and, according to the 1995 National Census, reached 87,260,000 in that year. Based on the results of the medium variant assumption, since that population reached its peak in 1995, it has experienced a downward trend. In 2030 it will drop below 70,000,000, and by 2050 it will fall to 50,000,000 (Fig. 2; see also Table A-3 in App.). In particular, the population of new graduates (aged 20–24) entering the workforce for the first time will rapidly decline—from 99,100,000 in 1995 to 61,800,000 by 2025. After 2050, the absolute number of the working-age population will continue to decrease as the low fertility rate and the child population decline. By 2100, the final year of the reference population projection, it will reach 38,090,000, which is less than half of the 1995 level.

In studying the differences in the fertility rate using the high and low variant assumptions, the high variant indicates that the decline of the working-age population is rather slow. It is projected to drop below the 70,000,000 level in 2035 and thereafter will decline to 61,450,000 in 2050 and to 52,240,000 in 2100. Based on the high variant assumption, over the long term the population will not decline more than 50%. Still, it is indicative of a downward trend. The low variant shows that the population will decrease below 70,000,000 in 2027 and

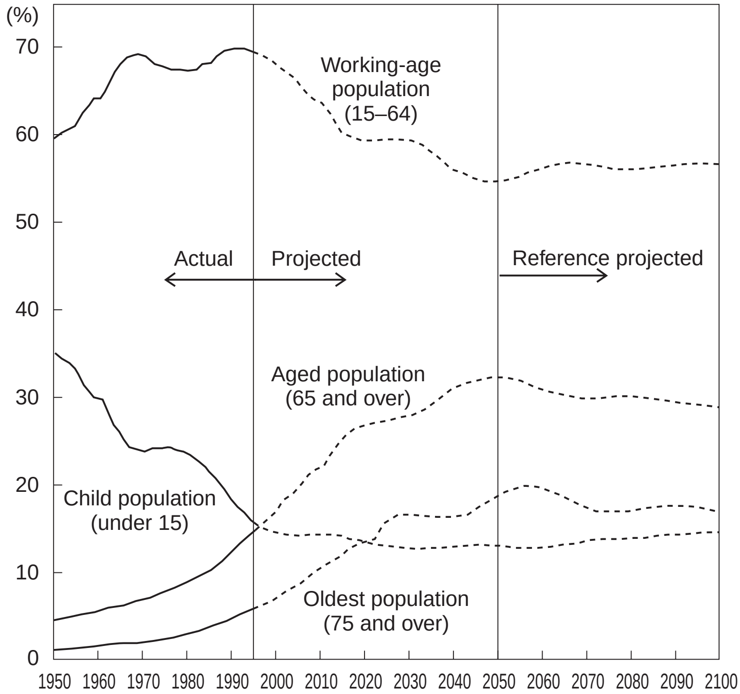

Figure 3 Trends in the composition of the total population, by percentage or major age group

below 50,000,000 in 2050. By the year 2100 it will be curtailed at 27,760,00.

Thus, depending on the future trend in the fertility rate, the degree and rate of decline of the working-age population will vary. However, assuming a continuous decline in the fertility rate, a reduction in that population is inevitable. Such a change may result in a diminished labor force among young people, an aging of the labor force, and a decline of the total labor force.

2.4. Arrival of an Advanced Aging Society

According to the medium variant, the child population will continue to decline. Whereas the working-age population has started to decline, the aged population (over 65 years) will continue to increase significantly—from 18,000,000 in 1995 to 33,000,000 by 2025. Thus, a proportion of the population will increase from 14.6% in 1995 (1997) to 25% in 2015 (Fig. 3; see also Table A-3 in App.). Although the aged population will keep approximately 33,000,000 people between 2015 and 2050, due to the low fertility rate the proportion will increase

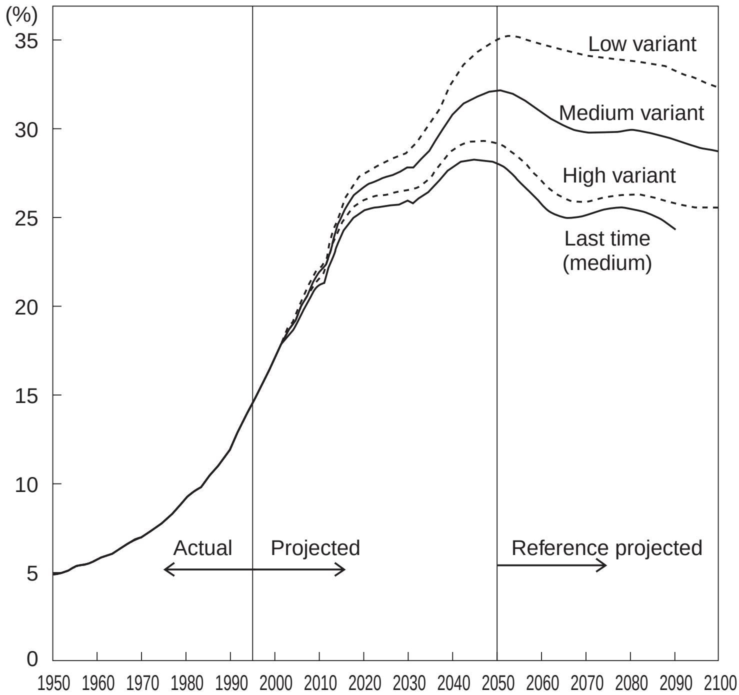

Figure 4 Trends in the percentage of the aged population: Medium, high, and low variants, 1950–2100

by 2015 and thereafter. By 2050 the population will reach the 32% level.

After 2050 the aged population will begin to decline. Because of the projected long-term decline in the fertility rate, there will be fewer elderly people than in the previous generation. Therefore, the population of the aged will also decline. It is predicted that the aged proportion of the population will be slightly lower than the 32% level of 2050, and that it will reach 28.8% in 2100.

In examining the differences in the aging trend based on assumptions of the future fertility rate, there is a discrepancy of 1.7 points between the low variant (28.2%) and the high variant (26.5%) in 2025 (Fig. 4; see also Table A-3 in App.). The differences indicate that the future fertility rate will have an impact on the aging population, and the gap between the three variants will further widen over the years. By 2050 there will be a gap of 6 points between the 29.2% high variant and the 35.2% low variant. Thus, if the society maintains a low fertility rate for a long period, the aged proportion of that society will continue to increase.

2.5. Changes in the Population Pyramid

The population pyramid of Japan indicates that the country's overall population will become aged because of the rapid increase and decrease of the past fertility rates (e.g., first a baby boom—rapid growth of the fertility rate between 1947 and 1949 and an echo effect—rapid decline of the fertility rate between 1950 and 1957). Furthermore, the high and low birthrates repeatedly fluctuated thereafter. Thus, the pyramid shows frequent ups and downs or rough contours (Fig. 5).

In the 1995 population pyramid, the first baby boom generation appeared in the group aged 45–50, and the second baby boom generation appeared in the group aged 20–25. In 2025 the first-generation will reach ages 70–75, and the second generation will reach ages 50–55. The aging population up to the year 2050 is centered around the first generation baby boomers. On the other hand, the elevated aging level around 2050 was caused by the aging of the second-generation baby boomers. It was also affected by the continuously low fertility rate. It indicates that the population will shrink in every generation. Thus, the population pyramid of Japan will transform from the prewar shape of Mt. Fuji to the shape of a temple bell in 1995 and to the shape of a vase in 2050.

2.6. Changes in the Population Dependency Ratio

The population dependency ratio is an index number to indicate the degree of the burden of support by the working-age population and compare the relative differences between the child and the aged populations. The old-aged dependency ratio based on the medium variant (value = aged population – working population) will rise from 21% (4.8 workers to support 1 old-age dependent) in 1995 to 45% (2.2 workers to support 1 old-age dependent) in 2020 (Fig. 6; see also Table A-1 in App.). By 2050 it is projected that the child dependency ratio (value = child population – working-age population) will shift from the 1995 level of 23% (1 child dependent supported by 4.3 workers) to a range of 21% to 24%.

In spite of the declining child population due to the low fertility rate, the reason for the increasing (rather than declining) level of the child dependency ratio is that the working population of the parents' generation has been declining.

The population dependency ratio is defined as the sum of the child and old-age dependency ratios; it indicates relationships between the working population and the degree of the total support. The overall population dependency ratio will increase along with the old-age dependency ratio. Because the working-age population is shrinking, it is projected that the population dependency ratio will increase from 44% in 1995 to 78% by 2025; thereafter, it will reach the 83% level in 2050.

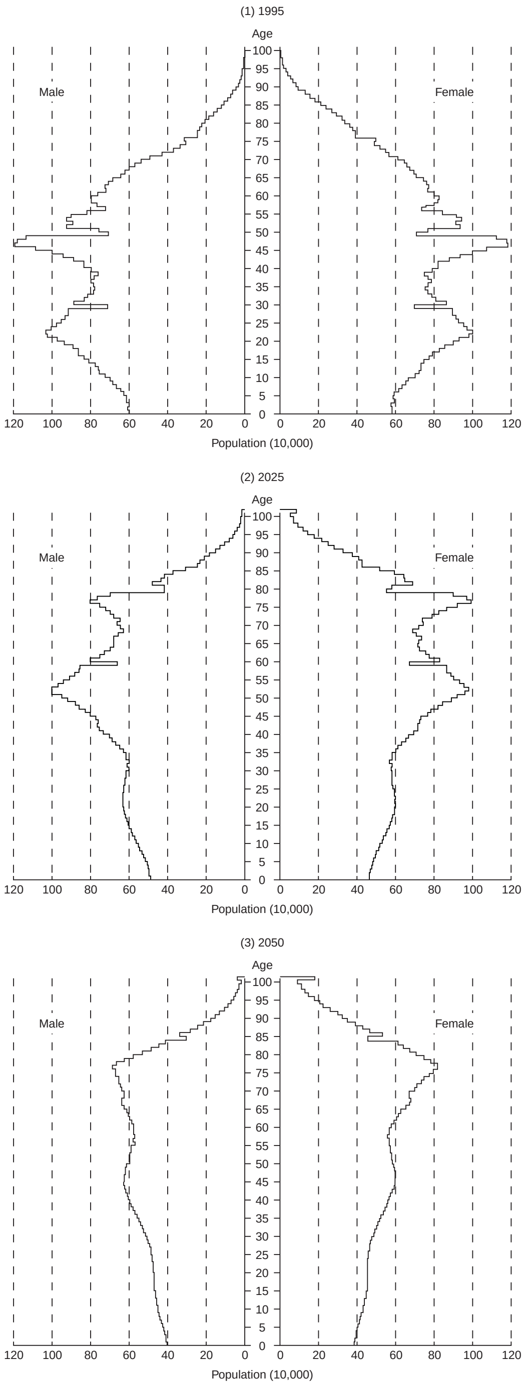

Figure 5 Changes in the population pyramid: Medium variant, 1995, 2025, 2050

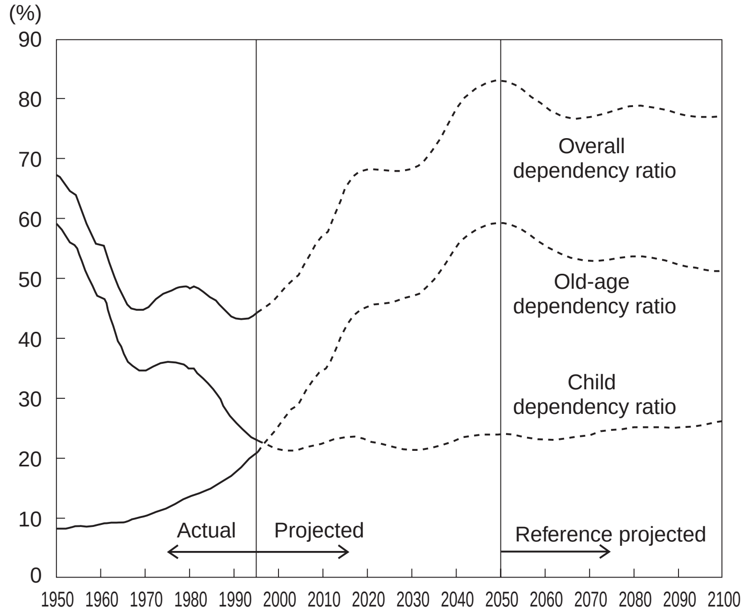

Figure 6 Trends in age dependency: Medium variant, 1950–2100

2.7. The Impact of an Aging Society

The rising proportion of the population aged 65 and over, referred to as population aging, is a central subject of research among social scientists. This is because, in every society, the socioeconomic effects of a growing aged population is a critical issue for social policy. It is important for demographers and other scientists to study the effects of population aging and to offer guidance to policymakers.

3. Projection Techniques and Assumptions

The future population size and its age-sex structure can be predicted if the future number of deaths by age and sex, births with sex ratios, and rate of immigration are all known. Therefore, the future population of Japan is projected by assuming its future mortality, fertility with sex ratios at birth, and rate of immigration from abroad.

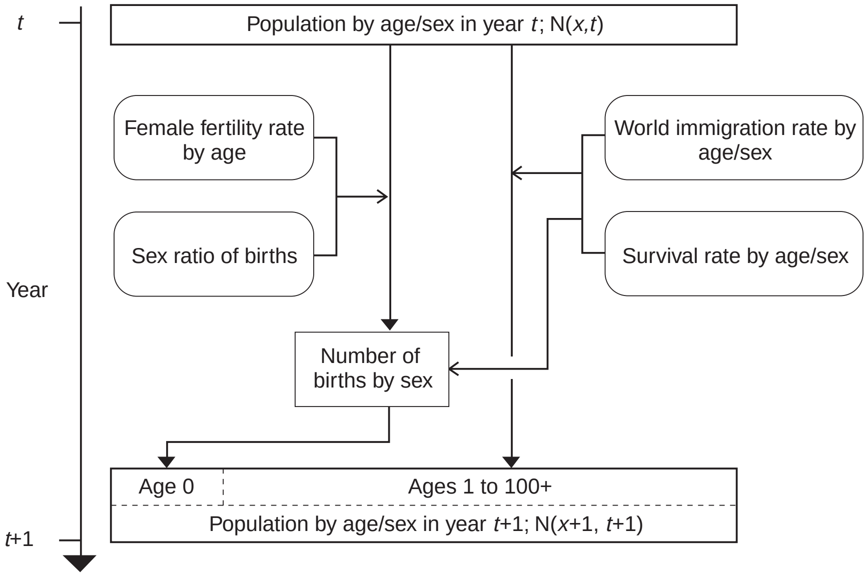

Figure 7 Procedures for projecting population

3.1. Projection Techniques

We adopted the usual cohort component projection method. This method starts off with the population by age/sex as of a base year, then applies the assumed survival rate by age/sex, international immigration rate by age/sex, and female fertility rate by age, in addition to the sex ratio at birth, to determine the future population. The basic calculation procedures for the cohort component method are illustrated in Figure 7.

Let us, for example, calculate the population for the following year (t+1) from the known population by age/sex in year t. The population aged one-year old and older in year t+1 can be found by applying the pertinent survival and international migration rates both by age/sex to the population in year t. The female population multiplied by its age-specific fertility rate and sex ratio at birth yields the number of births by sex. We then apply to these numbers the survival rate and the international immigration rate to find the population by sex under age one in year t+1. These values add up to the projected population in year t+1.

More specifically, as regards each population by age/sex from age 1 to 99 and “100 or over,” the population of age x is multiplied by the assumed survival rate for that age group, and is adjusted by the number of international immigrants from age x to age x+1, to find the population of age x+1 on the following 1 October. For the population under age one, we find the average population of females in the reproductive age period (15–49) during the base year. Then, we multiply this value by the assumed rate of female age-specific fertility to find the number of births for one year. Next, we divide that number by using the sex ratio at birth to get the sex breakdown. Finally, we multiply the figures by the survival rate (the probability that the newborns will live to the next year), and adjust for the number of international immigrations to determine the population under age one on the following 1 October.

After repeating these procedures, we project the future annual population by age/sex. Therefore, the data needed for the cohort component method used in this projection are (1) base population by age/sex, (2) the assumed female age-specific fertility rate, (3) the assumed survival rate by age/sex, (4) the assumed rate of international immigration by age/sex, and (5) the sex ratio at birth.

3.2. Base Population

The base population, which is what we start with when making a population projection, consists of the male and female population figures, classified by age group (including non-Japanese residents) as of 1 October 1995. This population is based on the 1995 national census with adjustments for the unknown age population. Therefore, for each age group, there is a slight difference between the values of the national census and the base population used in this projection.

3.3. Assumptions of Fertility Rates

When projecting a future population by means of the cohort component method, the populations of coming generations start off with the number of live births for each future year. The number of live births in each year is taken to be the total number of babies to which females in the reproductive period (ages 15–49) give birth in the year concerned. The number of live births by females in each age bracket is calculated by multiplying the female population of each age group by the age-specific fertility rate for the applicable age. The female population for each age group in the future is calculated by applying its survival rate and international immigration rate to the base population (described in detail in the next section). In this section we will discuss how to estimate female fertility rates by age. However, the fertility rate estimates are based on several assumptions about future marriages and births. For these assumptions to be accurate, we must understand the recent fertility trends in Japan.

3.3.1. Overview of Recent Fertility Trends and Future Prospects

The total fertility rate (TFR) in Japan has been declining since 1973.[1] It showed a temporary increase between 1982 and 1984 but then continued to decrease. In 1989 it was 1.57, below the lowest recorded level in Japanese history in 1966, the year of "Hinoeuma" (fiery horse). After that, it continued falling, with some fluctuations, to 1.42 in 1995 (Fig. 8).

The decreasing fertility rate in Japan is a direct result of the sharp decline in the marriage rate of individuals in the childbearing years. This, in turn, results from the younger generation's tendency to marry later in life and therefore its tendency to remain unmarried during the reproductive ages. Of women in their late twenties, 80.3% were married in 1970, but only 49.6% in 1995. The proportion of the divorced and widowed in a population may contribute to the decrease in the proportion married in general. However, because the proportion never married in this 35-year period soared from 18.1% in 1970 to 48.0% in 1995, we can say that the sharp increase in the proportion never married has mostly contributed to the decrease in the proportion married. (Yearly statistics of the proportion never married by age group are shown in Fig. 9.) There are also changes in age at marriage behind the increase in the proportion never married. In other words, since the mean age at first marriage for females increased

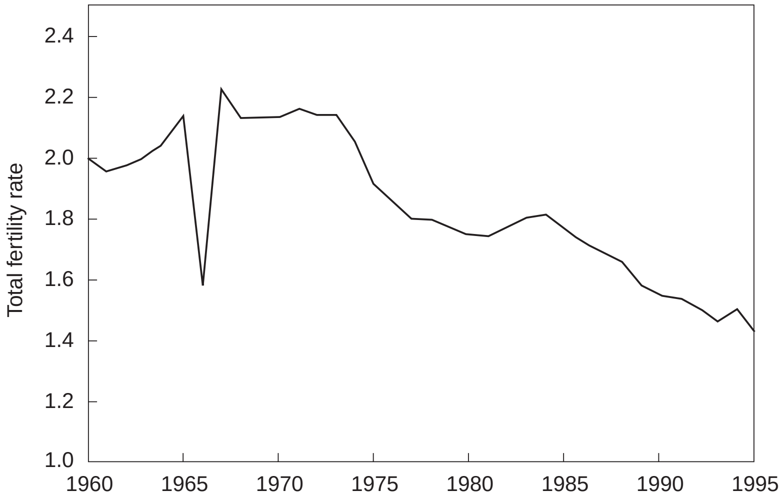

Figure 8 Annual fertility rate, 1960–1995

[1] The TFR is the sum of female age-specific fertility rates in all reproductive ages (usually between 15–49) observed in a given calendar year. These fertility rates are equivalent to the average number of live births that are expected if the females remain fertile according to the given age-specific fertility rates for that year.

substantially from 24.2 years in 1970 to 26.3 years in 1995, it is likely that the increase in the proportion of women who remained single in their twenties can be attributed to their tendency to marry later in life.

We can determine the actual magnitude of the effect of the decrease in the proportion of married women on the fertility rate during these periods. Table 1 provides a decomposition analysis of the changes in TFRs between 1970 and 1995. The changes in TFRs are decomposed into changes caused by the differences in the proportion of married females and those caused by changes in the fertility rate during marriage. Results of the decomposition according to age group are also presented in the table.

According to these findings, the TFR from 1970 onward decreased in each period, and notably the decomposition analysis reveals that effects from the changes (decreases) in the proportion of married women were always greater than the effects from the changes in the marital fertility rate. In particular, the marital fertility rates from 1980 acted to increase the TFR. In other words, a tendency toward fewer childbirths in this period resulted mainly from the increasing proportion of unmarried people (especially in their twenties), but not from a declining fertility rate of married couples.

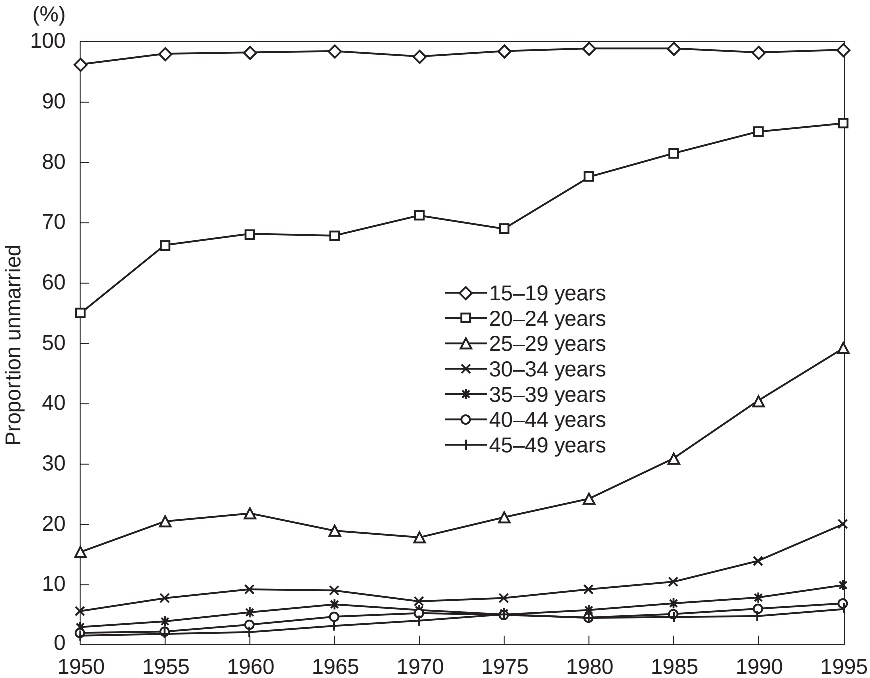

Figure 9 Annual rate of unmarried women by age group, 1950–1995

When forecasting future fertility rates in Japan, therefore, the key points are to see how long and until when the tendency to marry late in life or not at all will last, how far it will reach, and how much it will increase the proportion of people who will never marry. It also seems likely that we will be required to determine to what extent the total number of children for married couples (average number of live births produced by married couples in their lifetime), which so far has been stable at about 2.2, will decrease due to the trend toward later marriage. When we projected the population in this study, we also conducted a detailed analysis of population statistics regarding these matters and, based on our findings, adopted a method by which assumptions can be made about the future behavior of marriage and fertility rates. An overview of this is provided in section 3.3.3. First, however, let us explain how we obtained future age-specific fertility rates for each year if such assumptions are made.

3.3.2. Projection Method for Age-Specific Fertility Rates

Future age-specific fertility rates in each calendar year can be found by rearranging fertility rates for relevant female cohorts. Since the female fertility rate at age *x* in a certain year is the fertility rate at age *x* of the female birth cohort born *x* years ago, age-specific fertility rates at ages ranging from 15 to 49 in that year can be found as a set of fertility rates at the proper age of 35 cohorts born

Table 1 Decomposition of the changes in total fertility rates: 1970–1995

Year	1970	~	1980	~	1990	~	1995
Total fertility rates	2.13	→	1.75	→	1.54	→	1.42
Change		–0.39		–0.20		–0.12	
				Effects from changes in proportion married			
Total (all ages)		–0.24		–0.36		–0.15	
15~19		–0.01		–0.01		0.00	
20~24		–0.14		–0.13		–0.02	
25~29		–0.09		–0.20		–0.09	
30~34		–0.01		–0.03		–0.04	
35 and over		0.00		0.00		0.00	
				Effects from changes in marital fertility			
Total (all ages)		–0.14		0.16		0.03	
15~19		0.01		0.00		0.00	
20~24		0.01		–0.02		–0.02	
25~29		–0.05		–0.01		–0.03	
30~34		–0.07		0.14		0.04	
35 and over		–0.04		0.05		0.03	

Note: Calculations are based on five-year groups.

15 to 49 years ago. In this projection, we estimate age-specific fertility rates for each cohort and rearrange them into age-specific fertility rates for each calendar year (cohort fertility rate method). The reason we first estimate cohort fertility rates, instead of directly finding them for each calendar year, is that the age pattern of fertility is generally more stable in a cohort context.

Fertility rates for a cohort are estimated by employing a suitable mathematical model with several parameters that represent some features of marriage and birth behavior. Specifically, the fertility rates are projected using a generalized log-gamma distribution model, with parameters such as the female cohort's mean age at first marriage and those at birth by birth order, the proportion never married by age 50, and the proportion having birth by birth order.[2] This model enables our projection system to express basic change patterns of cohort fertility, such as a tendency to marry and bear children later in life (matching recent trends in Japan), or future effects expected to result from an increase in the proportion of never-married females.

A comparison of the predicted by this model with the actual values for age-specific fertility rates for three female birth cohorts appears in Figures 10–12. The fertility rates are simulated according to birth orders (from 1st child to 5th child and later). As a sum, the age-specific fertility rates are obtained. When using data available by 1995, actual fertility rates for up to age 45, age 35, and age 25, respectively, can be obtained from (1) a cohort born in 1950; (2) a cohort born in 1960, and (3) a cohort born in 1970. In the case of (1), it is likely that fertility process will have almost ended, so that the period to be projected by the model is quite short. The groups in (2) and (3), however, are still in the process. As for

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[2] In this model, the fertility rate f_n for each birth order n is first given as a function of age x to form this expression:

$$f_n(x)=C_n\frac{|\lambda_n|}{b_n\Gamma\left(1/\lambda_n^2\right)}\left(\frac{1}{\lambda_n^2}\right)^{\lambda_n^{-2}}\exp\left[\frac{1}{\lambda_n}\left(\frac{x-u_n}{b_n}\right)-\frac{1}{\lambda_n^2}\exp\left\{\lambda_n\left(\frac{x-u_n}{b_n}\right)\right\}\right]$$

Where f_i and exp are a gamma function and an exponential function, respectively. C_n cu_n cb_n, and λ_n are parameters of each birth order (n). This formation is an extended version of the expression known as the Coale-McNeill Model, which is one of the generalized logarithm gamma distribution formulas. The birth orders consist of five groups, the 1st through the 4th child, and the 5th child and later. However, this method alone places a limit on the reproducible ability of actual fertility rates by age. Therefore, through error analysis using the actual results of fertility rates in Japan, we have modified it by extracting a standard error pattern ($\varepsilon_n(x)$).

As a result, $f(x)$, the fertility rate function by age of cohort, can be calculated using this expression:

$$f(x)=\sum_{n=1}^{5}\left\{f_n\left(x;C_n,u_n,b_n,\lambda_n\right)+\varepsilon_n(x)\right\}$$

For more details, see Ryuichi Kaneko, "A Projection System for Future Age-Specific Fertility Rates" (in Japanese with English summary), *Jinko Mondai Kenkyu* (*Journal of Population Problems*), 49(1) (April 1993): 17–38.

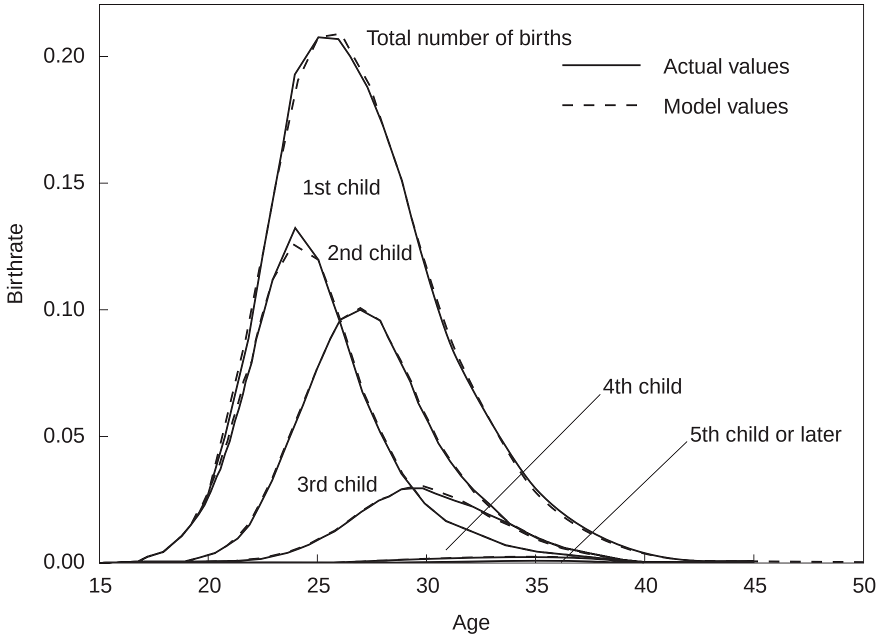

Figure 10 Cohort birthrate by age and birthrate by age/birth order (actual values and estimates): Women born in 1950

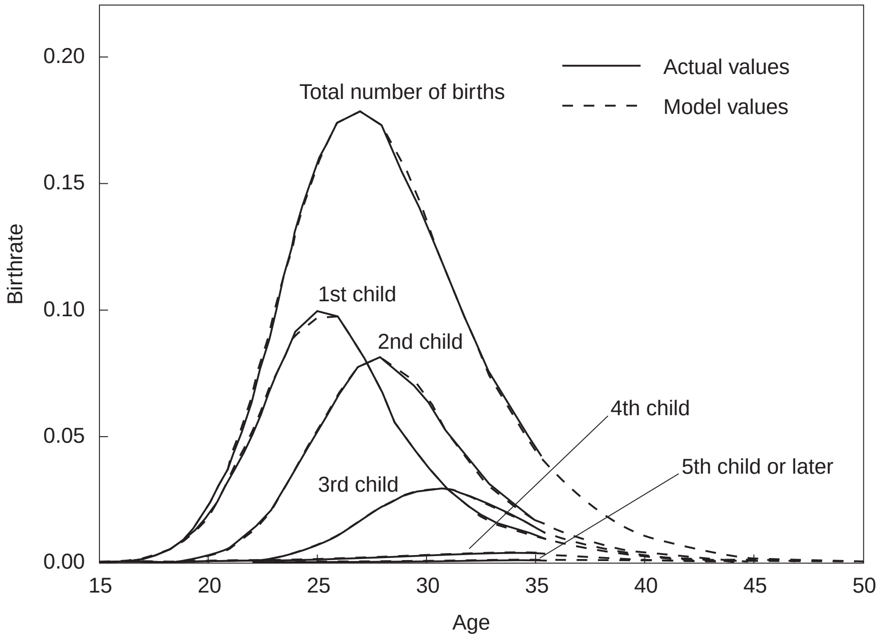

Figure 11 Cohort birthrate by age and birthrate by age/birth order (actual values and estimates): Women born in 1960

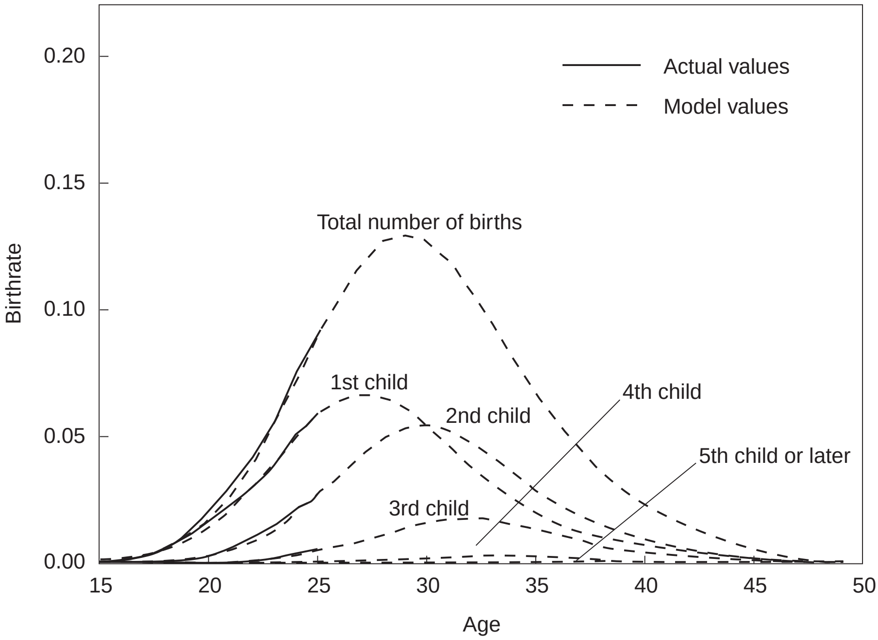

Figure 12 Cohort birthrate by age and birthrate by age/birth order (actual values and estimates): Women born in 1970

the group in (2), since the overall fitness of the simulated to the actual values is regarded as good, it is likely that future fertility rates (for subjects aged 36 and older) will not divert much from the predicted values of the model, taking into account the acknowledged stability of age patterns of fertility.

On the contrary, for cohort (3), it is hard to tell if its suitability to the entire age range is good or not, judging from the comparison between the actual values and the model to date. In fact, in the cases of (1) and (2), we can identify model values (parameter values) using a formal statistical technique (maximum likelihood estimation method), and the result is relatively stable. But in the case of (3), the result from such a method is unstable, and it is more difficult to specify a unique result. Obviously, this tendency is more remarkable in a younger cohort with a shorter fertility experience. To estimate future fertility rates for such a cohort, we should provide some external assumptions to make up for its instability. In addition, for the younger cohort whose members are not yet 15 years old, it is impossible to determine the future values through statistical techniques, because actual values for fertility rates cannot be obtained at all. Consequently, we end up providing such younger cohorts (and unborn cohorts) with assumptions about their overall fertility. How to provide these assumptions is discussed later (section 3.3.3).

If age-specific fertility rates for a series of cohorts are estimated by the aforementioned methods, age-specific fertility rates for each calendar year can be obtained by rearranging them according to age. For example, fertility rates from ages 15 to 49 in the year 2000 can be obtained by combining the fertility rates for a cohort of 15-year-olds born in 1985, a cohort of 16-year-olds born in 1984, and a cohort of 49-year-olds born in 1951. With this combination, fertility rates in all years of a projection period can be found.[3] In Figure 13, actual values are compared with the model values of fertility rates obtained from this combination.[4]

The cohort model birthrates at this stage do not account for any short-term effect (period effect) that temporary socioeconomic fluctuations may have on marriage rates and birthrates. Of course, it is extremely difficult to know what temporary fluctuations might take place in the future. But it seems that current fluctuations have affected the birthrate statistics for the next year, as well as for the last few years. This period effect appears as differences between the model

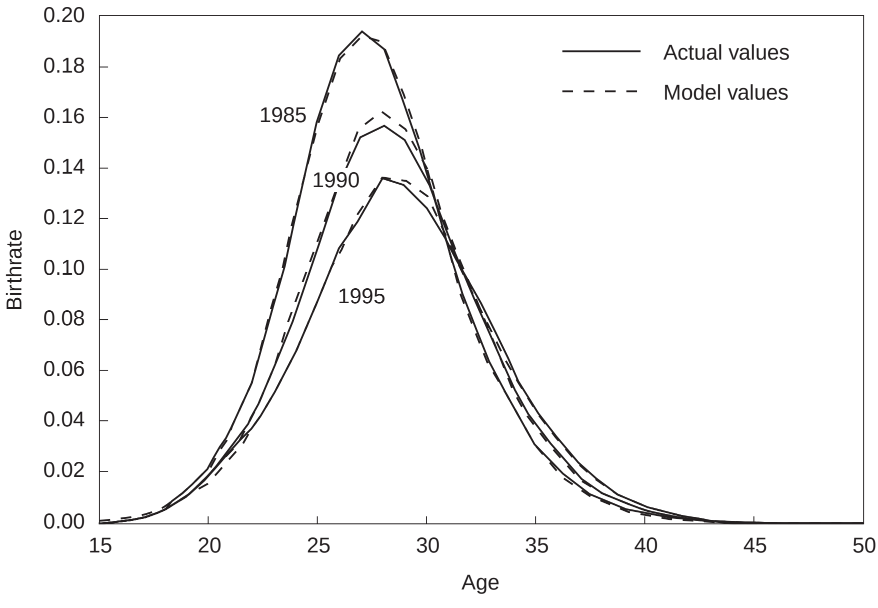

Figure 13 Comparison of actual values of birthrates with age and model values for 1985, 1990, 1995

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3 Technically speaking, fertility rates by age of the population at age x of year t involve two cohorts, such as those who are born in year $(t-x)$ and those born in year $(t-x-1)$.

4 Since actual values of fertility rates are calculated using the mid-year population, they are slightly different from officially announced values which are calculated from population data as of 1 October 1995.

values and the actual values in Figure 13. To handle this period effect for the previous and next few years, a time series projection is made based on monthly data of birthrates by birth order, and according to the results, the estimates from the cohort model are graduated. The estimates obtained by the projection method are made significant on the premise that future values (assumed values) of parameters incorporated into a cohort are appropriate. The next section explains how we set up these parameters.

3.3.3. Assumption of Fertility for Cohorts over an Extended Period

3.3.3.1. Method by Which Assumptions Are Made

The fertility level for a cohort is basically determined by the married females' reproductive behavior, which in turn is affected by the first-marriage-rate distribution by age for each live birth cohort. To estimate the fertility level that is eventually achieved, or TFRs for cohorts over an extended time, we must assume the age-specific first-marriage rate for a target cohort. Then, from the age at first marriage and experience model for the total number of newborns that is obtained from the assumed first-marriage rate and basic survey data on birth trends in the past, we can determine the average number of live births for married females of the birth cohort. However, since fertility is somewhat affected by separation resulting from divorce and death after marriage, as well as children born out of wedlock, we need to take into account the effect of the separation-by-divorce-and-death index as a coefficient. In consideration of the above, the TFR for a long-term cohort can be calculated from the equation given in Table 2.

To use this equation, estimate (1) the proportion never married and the mean age at first marriage for the target female birth cohort and (2) the average number of births for a married woman by age at first marriage based on the estimated mean age at first marriage for the female cohort. Then (3) estimate the coefficient for the divorce/death effect separately.

Table 2 Total fertility rate equation for a cohort

Total Fertility Rate of Cohort	=	(1− Proportion Never Married)	×	Completed Number of Newborns of Married Couples	×	Effect Coefficient for Divorce/Death

Note: The proportion never married is the proportion of singles at age 50 of the general population, and is calculated by subtracting the accumulated age value (accumulated first-marriage rates) of the first-marriage rate by age from 1. The completed number of newborns for married couples is the average number of births by married females by the age of 50. Also, the effect coefficient for divorce/death represents the degree by which divorced and widowed persons effect the birthrates, which can be estimated from the number of births from married couples obtained from the total fertility rate for the cohort, and basic survey data on birth trends in the past.

3.3.3.2. The Target Cohort

The cohort used for this research is comprised of subjects aged 15 as of 1995 (those born in 1980). This cohort was used because the marriage and birth effects for this age group end when the subjects become 50 years old in the year 2030, allowing us to estimate future birthrates at least until that date. In addition, the female subjects who were 15 years old in 1995 should behave according to the recent changes in marriage and birth behavior. If a cohort of age 25 were the target cohort, the marriage and birth behavior from 2020 onward would be fixed. On the other hand, if a cohort of age 5 were selected, it would be difficult to estimate the changes in marriage and birth behavior because the cohort would exhibit such behavior in the remote future. Therefore, in this projection, the target cohort consists of subjects who were born in 1980.

3.3.3.3. Changes in a Cohort's Mean Age at First Marriage and the Proportion Never Married

Before estimating the first-marriage rate for our target cohort born in 1980, we calculated the age-specific first-marriage rate for each female cohort from 1935 onward. In calculating this rate, we took into account the delay in registration of the number of first marriages obtained from vital statistics (Fig. 14).

Based on these first-marriage rates, we estimated the mean age at first marriage and the proportion never married for each cohort. When making these estimates, we had to consider the cohorts whose marriage behavior has not

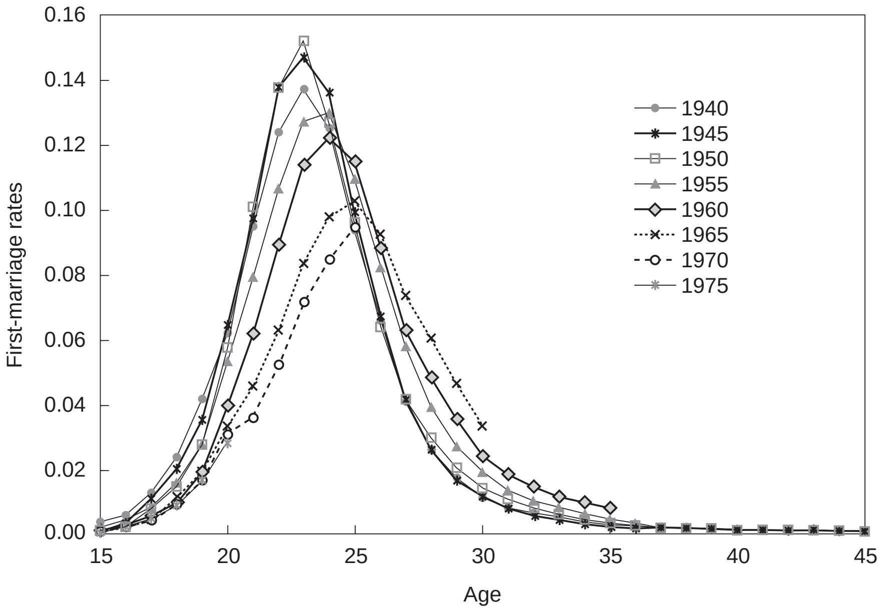

Figure 14 First-marriage rates by age of female cohorts born in 1935 or later

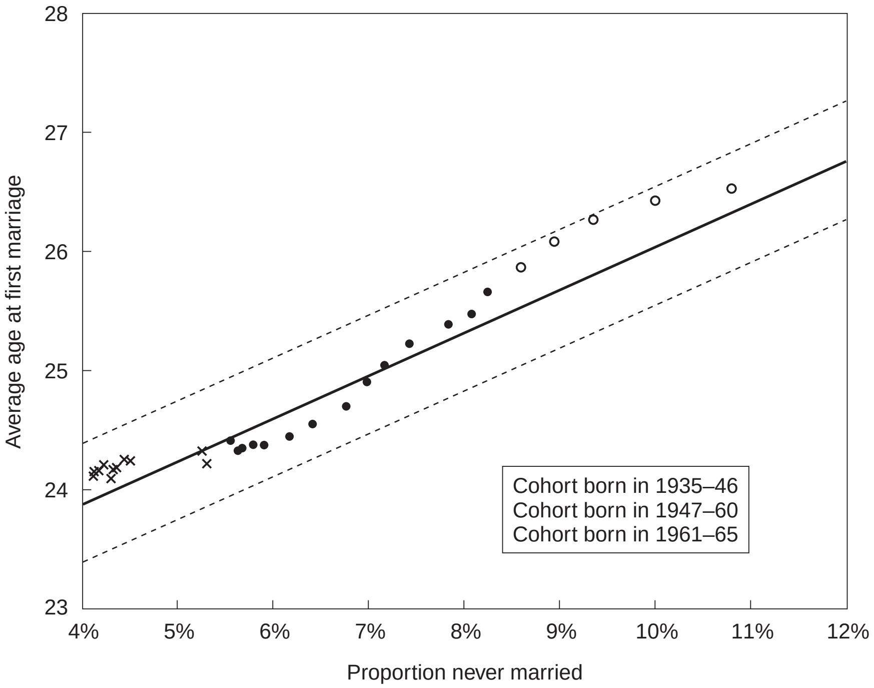

Figure 15 Relationship between average age at first marriage and proportion never married for cohorts born in 1935 or later

ended. For example, the subjects born in 1960 were only 35 years old in 1995 and could undoubtedly marry after that. For the first-marriage rate distribution for those aged 35 or older for this kind of birth cohort, we estimated the age distribution for first marriages using a logarithm gamma model. The resultant relationship between the average age at first marriage and the proportion never married for each cohort born from 1935 to 1965 is shown in Figure 15.

Incidentally, the proportion never married is the remainder of the proportion ever married figured as the accumulated age-specific first-marriage rates up to age 50. The points marked by *x* in the figure are the mean age at first marriage and the proportion never married for those who were born in 1935 to 1946. Except for the two cohorts born in 1945 and 1946, these cohorts are stable in that they uniformly married at an early age. For example, their mean age at first marriage is about 24, and their proportion never married is over 4%. The bulleted points in Figure 15 are the cohorts born from 1947 to 1960. Although these groups started exhibiting changes in marriage behavior from the late 1960s, gradual increases in the mean age at first marriage and the proportion never married are seen. Similar trends are also presumed for cohorts born from 1961 to

1965. Thus, we find that for females born in 1935 or later, the age at first marriage and the proportion never married tended to increase, while we see a certain change in the pattern from the baby boom generation onward.

Based on these trends, we conclude that the mean age at first marriage and the proportion never married for the cohort born in 1980 will be an extension of the trends in changes that have been shown by the previous birth cohorts.

3.3.3.4. Forecast of Marriage and Birth Parameters for Cohort Born in 1980

Although first-marriage rates by age for the cohort born in 1980 is an extension of changes in the past, it is difficult to predict to what extent the average age at first marriage and proportion never married will reach. In this forecast, we estimated theoretically possible values at a variety of levels through separate simulation of average age at first marriage and proportion never married for the cohort born in 1980.

When we observed age-specific first-marriage rates according to each cohort and calculated their growth rates, we paid attention to the fact that the rate of increase in first-marriages shows a strongly positive growth tendency at later ages if negative growth rate is shown in the rate of increase in first marriages by age for younger age groups. For this reason, when we look at a cohort born in 1970, we find that the age-specific first-marriage rate up to age 25 has already been obtained (Fig. 16). From the growth rate of age-specific first marriages in the past, we assumed the age distribution when this first-marriage rate would recover to grow in the future at various levels (Fig. 17). Then, we assumed that the growth rate of age-specific first marriages would converge toward zero for the cohort born in 1980. Based on this assumption, when we estimate age-specific first-marriage rates from 1995 onward using the growth rate of those rates, we can estimate age-specific first-marriage rates for the cohort born in 1980, which are classified according to recovery levels of the growth rate for the cohort born in 1970.

In accordance with the aforementioned method, we can estimate the mean age at first marriage and the proportion never married for the cohort born in 1980. This estimate is illustrated in Figure 18. As shown in this figure, there are more cases of growth in age-specific first-marriage rates. That is to say, if the proportion never married is low, the mean age at first marriage will increase because first-marriage rates increase for older age groups. It is also likely that the proportion never married tends to increase, since a large increase in the mean age at first marriage is not produced on the grounds that a lot of first marriages will not take place for older age groups if there are fewer cases of growth in first-marriage rates.

We can obtain one point of intersection when plotting the theoretically

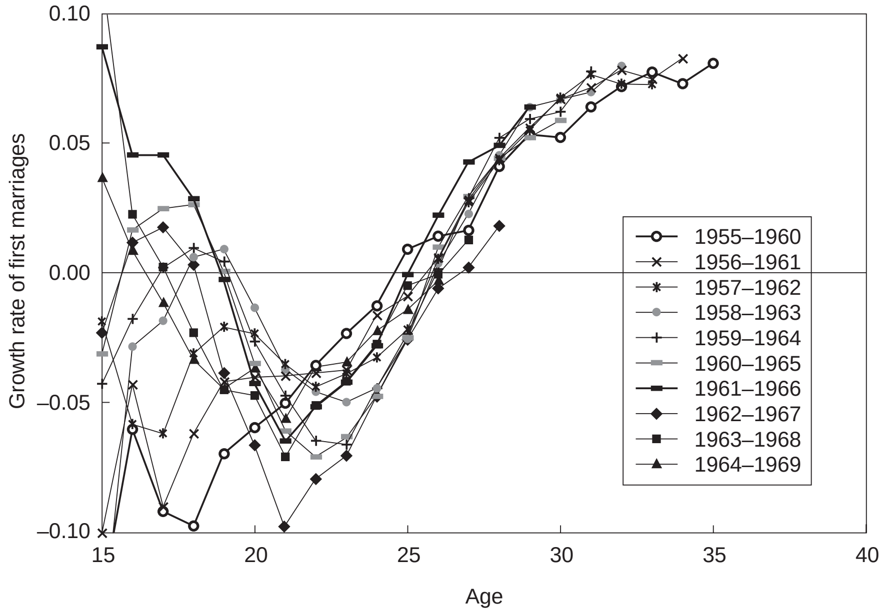

Figure 16 Growth rate of first marriages between cohorts, 1955–60 to 1964–69

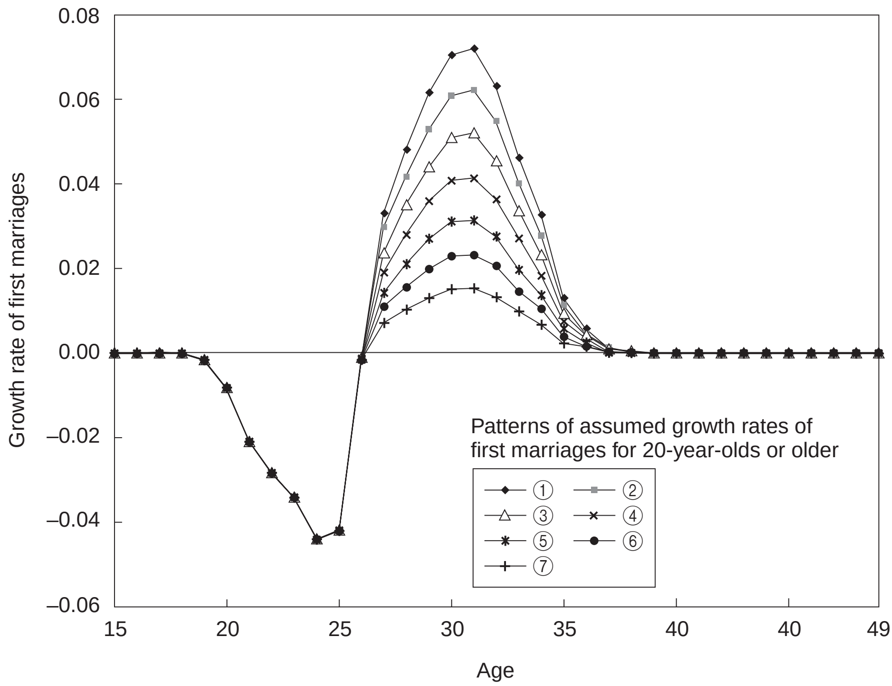

Figure 17 Growth rate of first marriages assumed for the cohort born in 1970: Levels from 1 to 7 of growth rates of first marriages

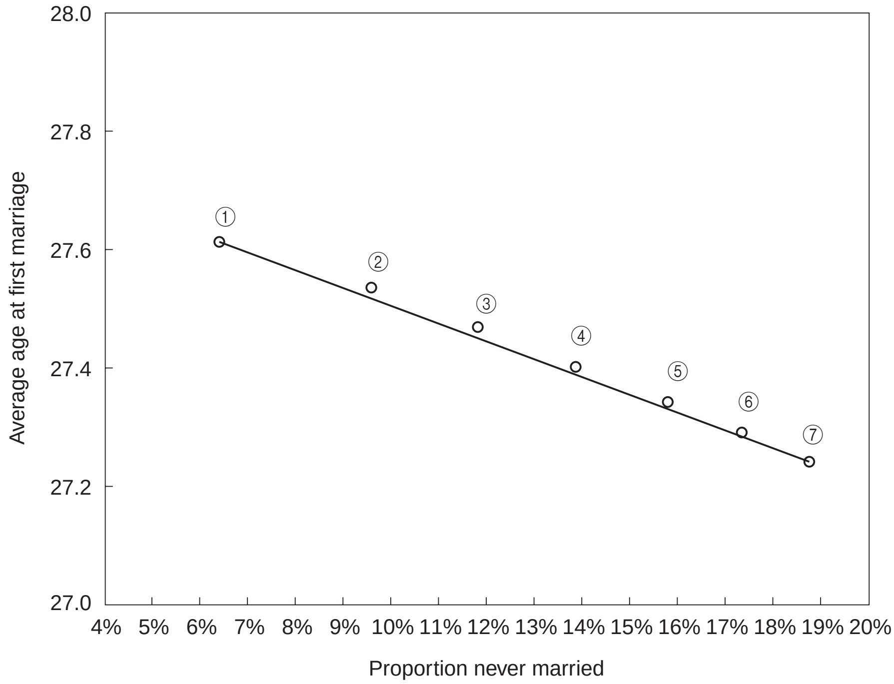

Figure 18 Estimated values of average age at first marriage and proportion never married for the cohort born in 1980, which are assumed from the growth rate of first marriages at levels from 1 to 7

possible relationship between the mean age at first marriage and the proportion never married for the cohort born in 1980 and the relationship between the observed mean age at first marriage and the proportion never married for the cohorts born in 1953 and later on the same graph (Fig. 19). This point of intersection is a combination of the expected mean age at first marriage and the proportion never married for the cohort born in 1980, which is determined by the trends in mean age at first marriage in the past.

In this projection, we assumed from this point of intersection that the mean age at first marriage of the target cohort born in 1980 was 27.4 years and the proportion never married was 13.8%. This assumption serves as the basic value when making an assumption for birthrates at the medium level. In addition, because there are considerable uncertain elements in the trends of mean age at first marriage and proportion never married, we make three kinds of assumptions: for medium, high, and low levels.

To estimate the low level of fertility rates for the cohort born in 1980, we made an assumption about marriage based on experience in a region where the

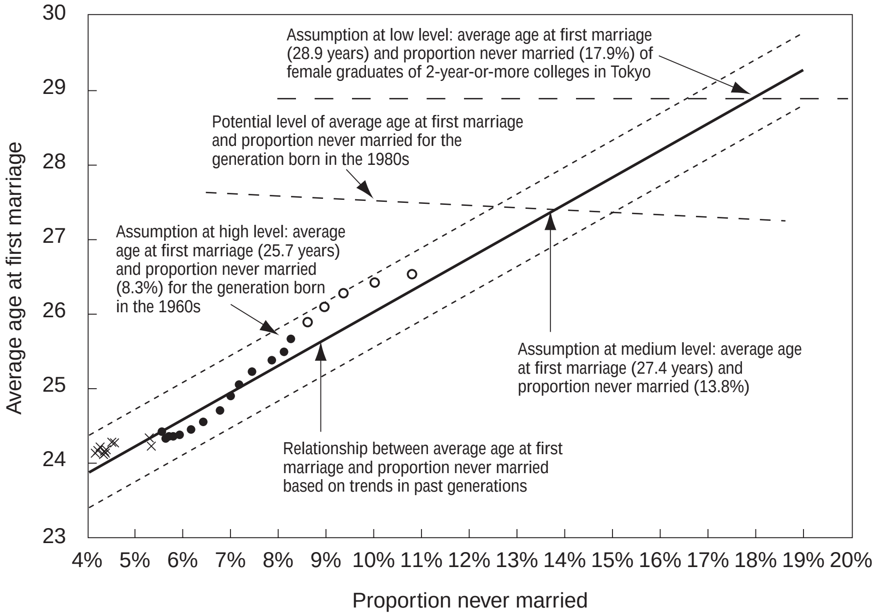

Figure 19 Relationship between average age at first marriage and proportion never married for a cohort born in 1980

tendency to marry later in life will become pronounced and the proportion never married will increase to the largest possible level. As the female population of Tokyo that graduated from college or other higher educational facility (graduates of 2-year colleges and 4-year-or-more universities) has the highest mean age at first marriage among various conceivable socioeconomic groups in Japan, we assumed that the cohort born in 1980 throughout the country would display similar marriage behavior to that of college graduates in Tokyo. From this assumption, we derive their mean age at first marriage as 28.9 years and the proportion never married as 17.9%.

At the high level it is assumed that there will be fewer changes in marriage behavior, which is contrary to the assumption at the low level. Here, we supposed that no change would occur for the cohorts born in 1961 or later, on the assumption that the estimated mean age at first marriage was 25.7 years of age and proportion never married was 8.3% for the cohort born in 1960.

After estimating the mean age at first marriage for medium, high, and low levels of fertility, we considered the number of children born according to distribution of age at first marriage for the cohort born in 1980. The total number of children born on the average in terms of age at first marriages can be modeled

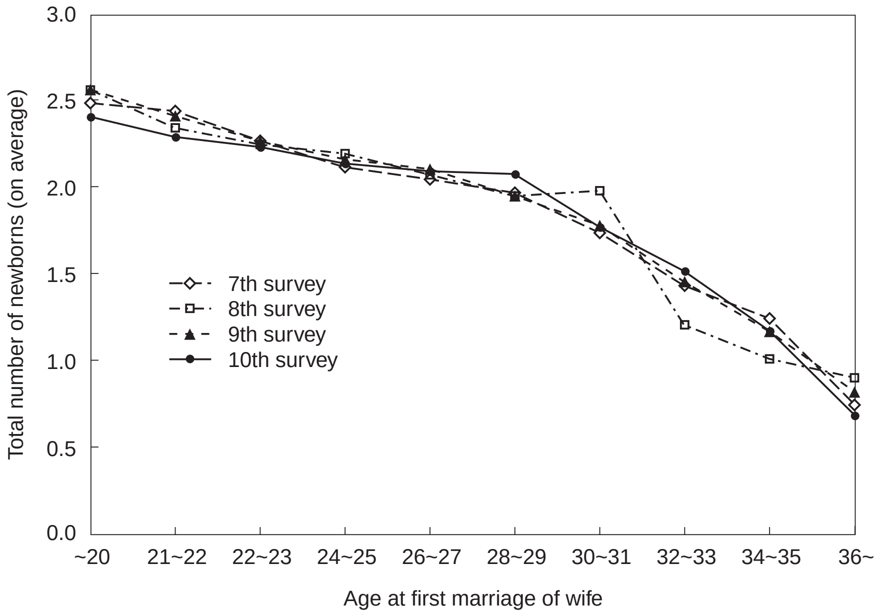

Figure 20 Total number of newborns on average according to age at first marriage from individual studies: Basic surveys (7th to 10th) on birth trends

as a stable relationship from the basic survey data for birth trends in the past (Fig. 20). This model assumes that the number of births produced by married women for the cohort born in 1980 were 1.96 children at the medium level, 2.12 at the high level, and 1.76 at the low level.

Calculation of the TFR for the entire cohort born in 1980 took into account the proportion of those who remained single for life, as well as the effect of birth behavior after the first marriage, which was influenced by separation resulting from divorce or death of either husband or self. The influence exerted by separation resulting from divorce or death indicated a stable trend, extrapolating from basic survey data on birth trends and vital statistics from the past. Therefore, we assumed 0.945 as the coefficient for the divorce/death effect in this estimate.

3.3.3.5. Assumed Values of Cohort's Birthrate

TFRs for the cohort born in 1980 at each of three levels, which are found from the equation in Table 2 based on the proportion never married, mean age at first marriage, the total number of children of married couples and the adjustment factor for the effect of divorce/death established by the aforementioned procedures are 1.61 for the assumption at the medium level, 1.85 for the assumption at the high level, and 1.38 for the assumption at the low level. The assumed values and TFRs for this cohort are summarized in Tables 3 and 4.[5]

3.3.4. Projected Fertility Rate

The annual statistics of future TFRs that have been estimated by the three assumptions used in this study are illustrated in Fig. 21 (see also Table A-1 in App.). According to the estimate based on the assumption at the medium level, the TFR would decrease to 1.38 in 2000 from 1.42 in 1995, then slowly increase to 1.61 in 2030 and finally settle at a constant level from then on. In the case of the estimate based on the assumption at the high level, the TFR would start increasing from 1997 to 1.85 in 2030, then remain constant at this level. In the case of the estimate based on the assumption at the low level, the decreasing trend in recent years would continue until 2005, when the TFR would decrease to 1.28, then slowly increase, but remain at 1.38 from 2030 on.

Table 3 Assumed variables for marriage and birth as well as total fertility rates for female cohort born in 1980

Level of Assumption	Proportion Never Married (%)	Average Age at First Marriage	Completed Number of Newborns of Married Couples	Effect Coefficient for Divorce/Death	Cohort's Total Fertility Rate
Medium	13.8	27.4	1.96	0.954	1.61
High	8.3	25.7	2.12	0.954	1.85
Low	17.9	28.9	1.76	0.954	1.38

Table 4 Assumed total fertility rates and distribution of quantity of live births for female cohort born in 1980

Level of Assumption	Cohort's Total Fertility Rates	Distribution of Quantity of Live Births (%)					
		None	1 Birth	2 Births	3 Births	4 Births	5 Births or more
Medium	1.61	23.0	15.9	42.2	15.5	2.8	0.6
High	1.85	14.0	15.4	47.0	19.4	3.4	0.8
Low	1.38	32.4	15.8	36.2	12.7	2.3	0.5

[5] However, as described in section 3.3.2, the fertility rates for the cohort are also slightly different from these values because the period effect is added to the finally estimated fertility rates for the future.

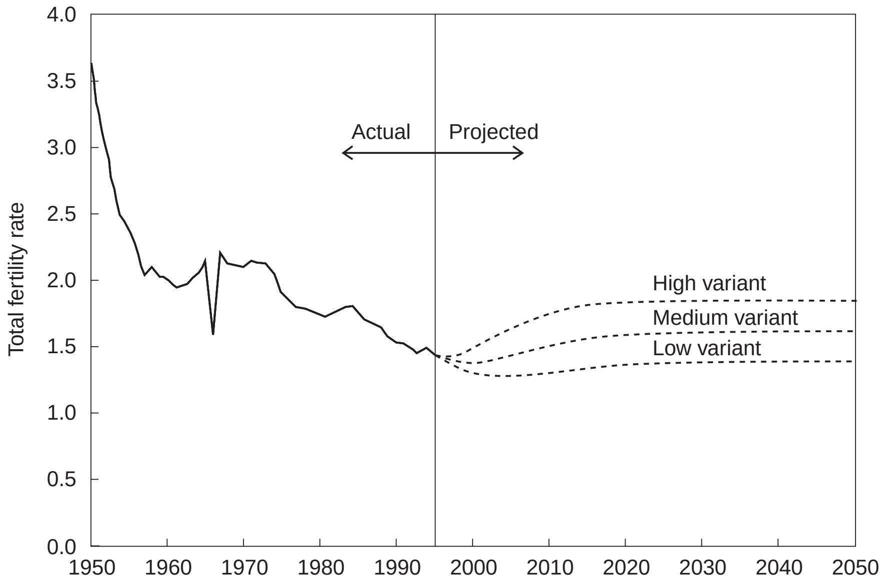

Figure 21 Annual statistics for total fertility rates at medium, high, and low levels, 1950–2060

3.4. Assumptions for Survival Rates (Future Life Table)

3.4.1. Estimation Methods

To estimate the population of the following year based on the existing population of a given year, we must know the survival rate by age and sex. For this purpose, we need to prepare a future life table. The demographic methods currently used to develop such a table include (1) constructing a model life table, (2) constructing a best life table, (3) extrapolating age-specific death rates, (4) extrapolating cause-specific mortality by age, (5) extrapolating standardized cause-specific mortality, or (6) employing the relational model method.[6]

The *model life table*, the first method, is used to predict the average life expectancy for countries where life expectancy is relatively short and mortality data are inadequate. This method would be limited in terms of accuracy if used to prepare a future life table for Japan. The *best life table*, the second method,

[6] For future life tables, see Jyumyougaku Kenkyukai, "Life Span," *Seimeihyou no Shorai Suikei Shiryo* (Estimated Data of the Future Life Table) 13, (September 1988); W. Brass, "On the Scale of Mortality," in W. Brass, ed., *Biological Aspects of Demography* (London: Taylor and Francis, 1971); A. J. Coale and P. Demeny, with B. Vaughan, *Regional Model Life Tables and Stable Populations*, 2nd edition (New York and London: Academic Press, 1983); and L. Heligman and J. H. Pollard, "The Age Pattern of Mortality," *Journal of the Institute of Actuaries* 107(434), Part 1 (1980): 49–80.

was previously used by the National Institute of Population and Social Security Research to make population projections; it is based on the lowest actual age-specific death rates collected from life tables classified by country and region (prefecture). A best life table prepared in this way can provide practical target values inasmuch as such tables are also used for other populations. This method has been used in international population estimates developed by the United Nations to obtain target life tables for countries where the average life expectancy is longer than usual. However, even though the best life table can be a highly practical life table, it is impossible to determine the point in time when it can be put into practice. Therefore, predictions about changes in life span must be made separately. And for the estimates prepared by the United Nations, future levels of average life expectancy are also estimated separately. For these reasons, the best life table has been used only to determine death patterns by age. Because the average life expectancy in Japan has already reached one of the top levels in the world, a best life table based on a life table by country cannot be used. For reference purposes, the best life table prepared using the life table classified by administrative divisions of Japan (1990) shows average life expectancies of 78.57 years (males) and 85.13 years (females), which represent increases of 2.21 years (males) and 2.29 years (females) compared with the corresponding levels for 1995.

The third method—extrapolating age-specific death rates—involves finding a constant time-wise law by applying trend lines to changes in age-specific death rates, then using predictions of age-specific death rates in the future after the elapse of a certain period, which are made by extrapolating the law to the future cases. In this method, a life table for any given time can be prepared. We used this method in our population projections for the 1981 revision.

The fourth and fifth methods-extrapolating cause-specific mortality by age and extrapolating standardized cause-specific mortality-are basically extended versions of the third method, by which future death rates by cause of death are estimated. When observing the death rates according to cause of death, these methods have the advantage of being able to more easily obtain a curve extending time series data (as opposed to when the curve is extended using only age-specific death rates) and to reflect various features of each cause of death. But the fourth method, in which the death rate is extrapolated and extended based on cause of death and age, requires estimating about 468 curves for both sexes (two classifications), ages (18 age classifications in increments of 5 years), and causes of death (13 classifications). Therefore, this method tends to become complicated, and it cannot always obtain stability and regularity because some causes of death consist of only a few cases. The fifth method is a simplified version of the fourth, by which future parameters of standardized age mortality are found for each cause of death, and then future age-specific death rates are estimated by applying the parameters uniformly to cause-specific mortality for each age. This method was used for our population projection made in 1986 and the previous estimate in 1992.

Whereas the third to fifth methods are designed to prepare a future life table based on the extension of time series data, the sixth method-the relational model method-expresses age patterns of standard death rates using several parameters, and a life table of death standards at any given level is prepared through conversion of the parameters. However, this method requires estimating future values for each parameter separately. Currently, there are also problems ensuring accuracy.

For this study, we improved the “extrapolating standardized cause-specific mortality” method that was used for the previous estimate and then prepared a future life table, taking into account the evaluation of each method.

3.4.2. Factors Influencing Average Life Expectancy Growth in Recent Years

The average life expectancy for both sexes in Japan increased all at once by about 15 years-from 50.1 to 65.3 years for males and from 54.0 to 70.2 years for females-between 1947 and 1960, then leaped to the levels of other advanced countries. This mainly resulted from the fact that the number of infant deaths due to infectious diseases such as pneumonia, bronchitis, and gastroenteritis had decreased rapidly and young deaths caused by tuberculosis had been virtually wiped out.

The average life expectancy then increased slowly but steadily, reaching 76.36 years for males and 82.84 years for females in 1995. In considering how much the decreasing death rate of different age groups contributed to an increasing life span during 1955 to 1995, it was found that the decrease in the death rate of younger age groups, especially infants and young children, had been declining year after year, whereas the death rates of middle-age-or-older population had been on the increase. In terms of the growth of average life expectancy from 1990 to 1995, it is recognized that 49.8% of males and 89.3% of females making up the growth rates resulted from decreases in the death rate of those aged 65 and older.

In recent years, the major causes of death have included the three top adult diseases: malignant neoplasm, cerebrovascular disease, and cardiac disease. Among these, however, deaths resulting from cerebrovascular disease have decreased rapidly—both in men and women. And in examining trends over the past 20 years (1975–1995), from the viewpoint of standardized death rates (per 100,000) for those aged 65 and older, we see that the rates decreased by about 30%—from 2,322 to 675 for males and from 1,985 to 641 for females. Cardiac disease has also declined since the 1970s. On the other hand, malignant neoplasm has decreased in women but increased in men.

3.4.3. Assumptions of Death Rate (Future Life Table and Survival Rates)

The extrapolating standardized cause-specific mortality method, which was adopted for our previous estimate, consists of extrapolating standardized death rates for all age groups to each cause of death and then preparing a life table using that extrapolated data. But in this estimate, we adopted the method by which the standardized cause-specific mortality is classified according to age, its future values are estimated, and a future life table is prepared by converting the future values to death rates by age. Specifically, we employed the following procedures.

First, to observe fluctuating trends in cause-specific mortality by age up to 1995, we determined cause-specific median mortality by sex/age, classified in increments of 5-year age groups (death rates where the mid-year population is the denominator) for the 20 years from 1975 to 1995. The causes of death were divided into 13 categories: (1) tuberculosis, (2) malignant neoplasm, (3) diabetes, (4) cardiac disease, (5) hypertensive disease, (6) cerebrovascular disease, (7) pneumonia and bronchitis, (8) gastric ulcer and duodenal injury, (9) chronic liver disease and hepatic cirrhosis, (10) nephritis, nephrotic syndrome, and nephrosis, (11) accidents, (12) suicide, and (13) others.

Second, based on the 5-year age groups, we calculated standardized cause-specific mortality for four age categories where the Japanese population by sex/age group in 1990 (median population) served as the standard. In considering levels of death rates, differences in fluctuations, and so on, we decided on 4 age categories: 0 to 14 years, 15 to 39 years, 40 to 64 years, and 65 years and older.

Suppose the standardized mortality for age category (A) and cause of death (i) in year t is $d^s(i,A,t)$. Then, we apply a standard curve, based on the standardized cause-specific mortality by sex/4 age categories for 1975 to 1995 ($d^s(i,A,t)$), which has already been obtained for applicable cases, and extrapolate it to future years up to 2050. The applied curve could be an exponential curve, corrected exponential curve, logistics curve, and so forth. Furthermore, to determine the exponent based on the standardized mortality in 1995 for 1996 to 2050, the determined exponent of age category (A) and cause of death (i) in year t should be $\theta(i,A,t)$ ($= d^s(i,A,t)/d^s(i,A,t_0)$). Here, $t_0=1995$.

Meanwhile, we determine the total cause-specific death rates for each age for 1992 to 1994 from the number of deaths for each age/cause of death for both sexes. Suppose that the number of deaths for age x is $D(x)$ and the number of deaths resulting from cause of death (i) is $D(i,x)$. We then determine the cause-specific death proportion $M(i,x)$ from $D(i,x)/D(x)$.

Based on the aforementioned values, we determine the survival probability for each age $p'_x(t)$ in future year t from the following expression:

$$P'_x(t)=\Pi P_x(t_0)^{M(i,x)\cdot\theta(i,A,t)}$$

Incidentally, we determine $px(t0)$ from l_{x+1}/l_x through the use of the number of survivors (l_x) based on the simplified life table for 1995. However, because people aged 95 and older are generalized as a single set of data in the simplified life table, we determined several functions by extrapolating death rates (q_x) of older age groups to the group of 95-year-olds and older by means of a corrected exponential curve. Then we prepared a life table for up to age 100 and made it a reference life table. In addition, because the calculated $p'_x(t)$ is the result on which tendencies for each age category are reflected, unnatural trend lines are created at the beginning and ending ages in the age category. For this reason, we determine death rates by age $q_x(t)$ by graduating $q'x(t)$ $(=1–p'_x(t))$.

Then, depending on how you want to prepare the life table functions, use the following expressions:

$$l_{x+1}(t)=l_x(t)\times(1-q_x(t))$$

$$L_x(t)=\frac{l_x(t)+l_{x+1}(t)}{2}$$

However, we estimated $L_0(t)$ and $e_{100}(t)$ separately, as follows.

To $L0(t)$, we applied the corrected exponential curve of the average survival years of those who died at age 0, $f_0=(L_0\text{-}l_1)/d_0$ for 1975 to 1995 and determined $f_0(t)$ for 1996 to 2050. Then, to find $L_0(t)$, we calculated:

$$L_0(t)=l_1(t)+f_0(t)\times d_0(t)$$

To $e_{100}(t)$, we applied the corrected exponential curve based on actual values for 1960 to 1995, then calculated:

$$\Sigma L_{100}(t)=l_{100}(t)\times \overset{0}{e}_{100}(t)$$

$$T_x(t)=\Sigma L_x(t)$$

$$\overset{0}{e}_0(t)=T_x(t)\,/l_x(t)$$

3.4.4. Estimated Results of the Future Life Table

The average life expectancy by sex based on the estimated future life table is illustrated in Figure 22 (see also Table A-2 in App.). Based on this figure, the average life expectancy of both sexes, which was 76.36 years (males) and 82.84 years (females) in 1995, would continue growing constantly from then onward to 77.40 (males) and 84.12 (females) in 2000, 78.80 (males) and 85.83 (females) in 2025, and 79.43 (males) and 86.47 (females) in 2050. The difference between males and females—6.48 years in 1995—would increase gradually to 6.71 in 2000, 7.03 in 2025, and finally settle at 7.04 from then on. The reason for the continuing difference between the sexes is that women initially live longer and men show a somewhat slower growth in life span.

The survival rate ranging from birth to 20 years old was 98.9% (males) and 99.2% (females) in 1995 and would increase to 99.2% (males) and 99.5% (females) in 2050. The survival rate up to age 65 was 83.2% (males) and 91.6% (females) in 1995 and would reach 86.9% (males) and 94.8% (females) in 2050.

Considering the contribution of the decrease in the death rate by age to the growth of average life expectancy, it is recognized that the contribution made by the 0 to 14 age group is low and will continue to decline, whereas the contribution of the middle-age-or-older age group, especially those who are in the prime of life (aged 40 to 64 years), is high and will have a greater effect on growth.

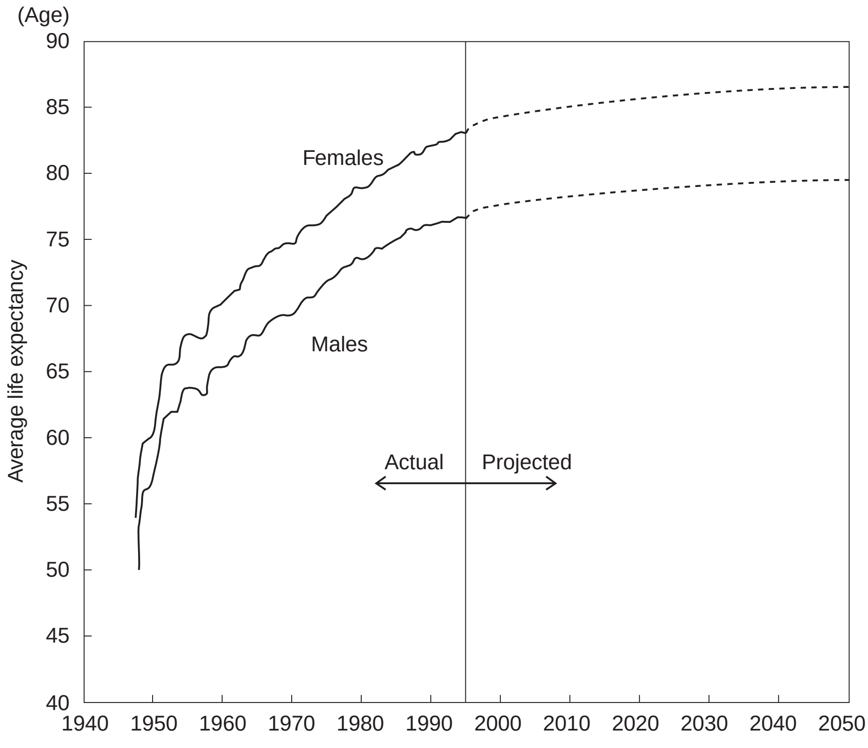

Figure 22 Annual statistics of average life expectancy: Actual and estimated values, 1940–2050

For the three top adult diseases (malignant neoplasm, cerebrovascular disease, and cardiac disease), according to the standardized death rates (per 100,000) of those aged 65 and older, it was likely that malignant neoplasm cases would continue increasing to 1,511 (males) and 734 (females) in 2050 from 1,456 (males) and 707 (females) in 1995. In the meantime, the instances of cerebrovascular disease and cardiac disease would decrease; in particular, cerebrovascular disease would show a noticeable improvement and decline by almost half or more in 2050.

3.5. Assumptions about the International Immigration Rate

For the future international immigration rate, we determined a mean value for excess immigration rates by sex/each age (=[number of immigrants – number of emigrants]/population) from 1990–1995 and assumed that this mean value would remain invariant from 1996 onward.

In recent years, the immigration rate for Japan has been undergoing considerable changes as the Japanese society has been internationalized and economic activity has fluctuated. According to the number of excess immigrants shown in the emigration and immigration control statistics of the Ministry of Justice, emigrants exceed immigrants in the Japanese population, whereas immigrants exceed emigrants in the foreign population. Over time the tendency of emigration and immigration of the Japanese population has been unstable and has not shown a particular trend. On the other hand, excess immigrants for the foreign population have declined annually since 1991, when they were at their peak (57,000 people were recorded as excess immigrants), and there were only a few of them in 1995. As a result, most of the excess emigrants in recent years have come from the Japanese population and there has been no particular trend.

In terms of recent differences in the number of immigrants and emigrants classified by age, it is difficult to predict the future because their levels have varied from year to year and their trends have remained irregular. In addition, the international immigration rate depends on changes in government policy (such as amendments to the immigration law). Because it is also affected by fluctuations in economic activity (business activity) and international circumstances, it is difficult to predict only from past trends.

Consequently, in this estimate we assumed that the recent international immigration rates would remain constant in the future as well. Specifically, we determined a mean value of excess immigration rates by age/sex for a recent 5-year period (1 October 1990–30 September 1995) that were listed in the “Currently Estimated Population” from the Statistics Bureau of the Management and Coordination Agency and assumed that it would remain constant from 1996 onward (Fig. 23).

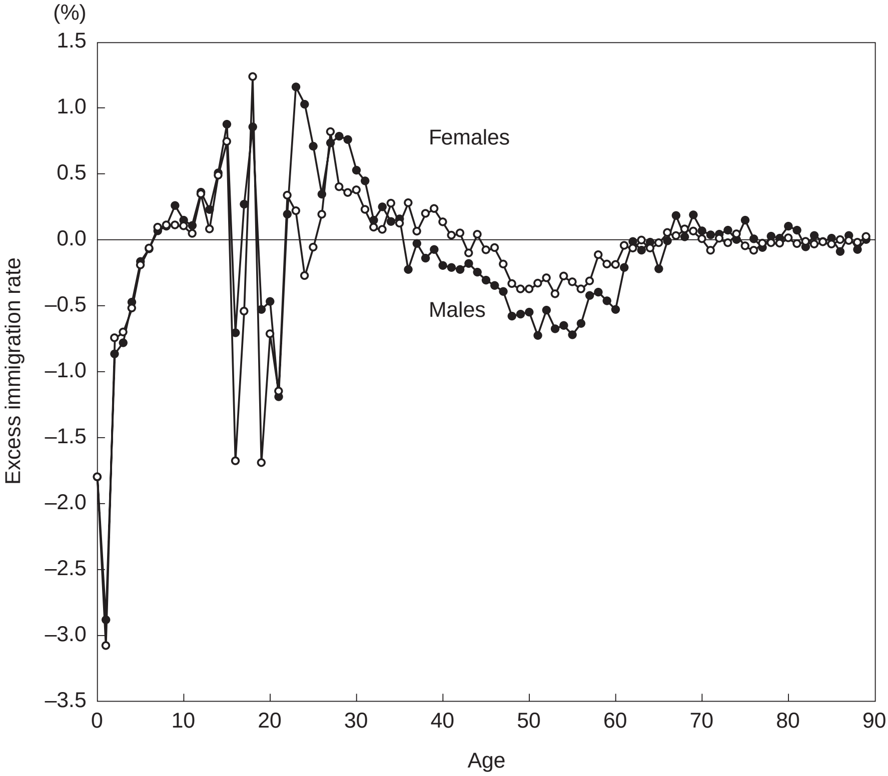

Figure 23 Excess immigration rates by age/sex: Average rates, 1991–1995

3.6. Sex Ratio of Births

To divide the future number of newborns into male and female, we need to estimate the sex ratio of births (=number of male births/number of female births × 100). According to past sex ratios of births, fluctuations on a yearly basis are negligible. For this reason, in this estimate we assumed that the mean value (105.6) of the sex ratios of births from 1991 to 1995 would also remain constant from 1996 onward (Fig. 24).

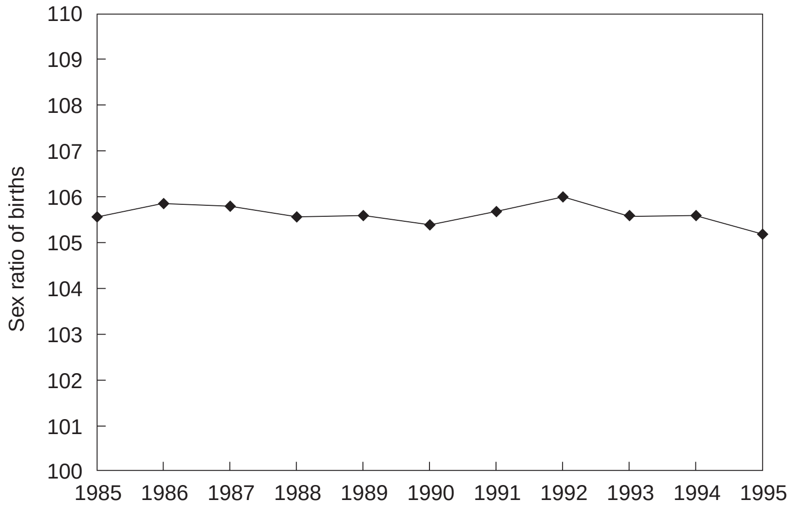

Figure 24 Annual statistics for sex ratio of births, 1985–1995

3.7. Assumed Values for the Long-range Population Projection

For the long range projection for 2051 to 2100 (the results are presented in Figures 1 through 4 and 6, we made the following assumption:

In accordance with practices for the long-range population projection of the United Nations, we assumed that the fertility rate would gradually increase from the level in 2050 to 2.07 (population replacement level based on mortality level of 2050) in 2150 for each of the medium, high, and low variants. We determined that the survival rate would settle at a constant level from 2050 onward, and sex ratios of births and international immigration rates would remain unchanged from the assumed values for 1996.

Appendix

Table A-1 Actual and assumed total period fertility rate under the three variants

Variant

Year	Medium	High	Low
1995*	1.42170	1.42170	1.42170
1996	1.42151	1.42151	1.42151
1997	1.39656	1.42620	1.37903
1998	1.38530	1.44524	1.35025
1999	1.38001	1.47012	1.32764
2000	1.37987	1.49919	1.31050
2001	1.38393	1.53074	1.29801
2002	1.39131	1.56327	1.28936
2003	1.40124	1.59545	1.28387
2004	1.41306	1.62632	1.28105
2005	1.42630	1.65537	1.28053
2006	1.44045	1.68212	1.28203
2007	1.45516	1.70628	1.28531
2008	1.47005	1.72782	1.29010
2009	1.48475	1.74684	1.29612
2010	1.49890	1.76345	1.30309
2011	1.51221	1.77781	1.31064
2012	1.52449	1.79017	1.31842
2013	1.53563	1.80071	1.32612
2014	1.54634	1.81015	1.33394
2015	1.55662	1.81862	1.34169
2016	1.56624	1.82606	1.34907
2017	1.57494	1.83243	1.35575
2018	1.58245	1.83765	1.36144
2019	1.58851	1.84170	1.36602
2020	1.59335	1.84480	1.36964
2021	1.59722	1.84717	1.37249
2022	1.60028	1.84897	1.37471
2023	1.60271	1.85032	1.37641
2024	1.60460	1.85133	1.37770
2025	1.60607	1.85208	1.37866
2026	1.60720	1.85263	1.37936
2027	1.60807	1.85303	1.37986
2028	1.60873	1.85331	1.38022
2029	1.60922	1.85352	1.38048
2030	1.60960	1.85367	1.38066
2031	1.60960	1.85367	1.38066
2032	1.60960	1.85367	1.38066
2033	1.60960	1.85367	1.38066
2034	1.60960	1.85367	1.38066
2035	1.60960	1.85367	1.38066
2036	1.60960	1.85367	1.38066
2037	1.60960	1.85367	1.38066
2038	1.60960	1.85367	1.38066
2039	1.60960	1.85367	1.38066
2040	1.60960	1.85367	1.38066
2041	1.60960	1.85367	1.38066
2042	1.60960	1.85367	1.38066
2043	1.60960	1.85367	1.38066
2044	1.60960	1.85367	1.38066
2045	1.60960	1.85367	1.38066
2046	1.60960	1.85367	1.38066
2047	1.60960	1.85367	1.38066
2048	1.60960	1.85367	1.38066
2049	1.60960	1.85367	1.38066
2050	1.60960	1.85367	1.38066

* Actual

Table A-2 Actual and assumed life expectancy at birth

(Years)

Year	Male	Female	Difference
1995*	76.36	82.84	6.48
1996	77.02	83.59	6.57
1997	77.12	83.73	6.61
1998	77.22	83.87	6.65
1999	77.31	83.99	6.68
2000	77.40	84.12	6.71
2001	77.49	84.23	6.74
2002	77.57	84.34	6.77
2003	77.65	84.45	6.80
2004	77.73	84.54	6.82
2005	77.80	84.64	6.84
2006	77.87	84.73	6.86
2007	77.93	84.81	6.88
2008	78.00	84.90	6.90
2009	78.06	84.97	6.91
2010	78.12	85.05	6.93
2011	78.18	85.12	6.94
2012	78.23	85.18	6.95
2013	78.29	85.25	6.96
2014	78.34	85.31	6.97
2015	78.39	85.37	6.98
2016	78.43	85.42	6.99
2017	78.48	85.48	7.00
2018	78.52	85.53	7.00
2019	78.57	85.58	7.01
2020	78.61	85.62	7.01
2021	78.65	85.67	7.02
2022	78.69	85.71	7.02
2023	78.73	85.75	7.03
2024	78.76	85.79	7.03
2025	78.80	85.83	7.03
2026	78.83	85.87	7.03
2027	78.87	85.90	7.04
2028	78.90	85.94	7.04
2029	78.93	85.97	7.04
2030	78.96	86.00	7.04
2031	78.99	86.03	7.04
2032	79.02	86.06	7.04
2033	79.05	86.09	7.04
2034	79.08	86.24	7.04
2035	79.10	86.15	7.04
2036	79.13	86.17	7.04
2037	79.15	86.20	7.04
2038	79.18	86.22	7.04
2039	79.20	86.24	7.04
2040	79.23	86.27	7.04
2041	79.25	86.29	7.04
2042	79.27	86.31	7.04
2043	79.29	86.33	7.04
2044	79.31	86.35	7.04
2045	79.33	86.37	7.04
2046	79.35	86.39	7.04
2047	79.37	86.41	7.04
2048	79.39	86.43	7.04
2049	79.41	86.45	7.04
2050	79.43	86.47	7.04

* Actual

Table A-3 Projected future population and proportion by age group, 1995–2050: Medium variant

Year	Population (1,000)				Proportion (%)		
	Total	0–14	15–64	65+	0–14	15–64	65+
1995	125,570	20,033	87,260	18,277	16.0	69.5	14.6
1996	125,869	19,707	87,158	19,004	15.7	69.2	15.1
1997	126,156	19,400	87,014	19,743	15.4	69.0	15.6
1998	126,420	19,099	86,848	20,473	15.1	68.7	16.2
1999	126,665	18,821	86,688	21,156	14.9	68.4	16.7
2000	126,892	18,602	86,419	21,870	14.7	68.1	17.2
2001	127,100	18,452	86,039	22,609	14.5	67.7	17.8
2002	127,286	18,335	85,652	23,299	14.4	67.3	18.3
2003	127,447	18,262	85,281	23,905	14.3	66.9	18.8
2004	127,581	18,230	84,977	24,373	14.3	66.6	19.1
2005	127,684	18,235	84,443	25,006	14.3	66.1	19.6
2006	127,752	18,257	83,747	25,748	14.3	65.6	20.2
2007	127,782	18,273	83,017	26,492	14.3	65.0	20.7
2008	127,772	18,303	82,323	27,145	14.3	64.4	21.2
2009	127,719	18,306	81,603	27,810	14.3	63.9	21.8
2010	127,623	18,310	81,187	28,126	14.3	63.6	22.0
2011	127,481	18,277	80,893	28,311	14.3	63.5	22.2
2012	127,292	18,227	79,834	29,232	14.3	62.7	23.0
2013	127,056	18,156	78,691	30,209	14.3	61.9	23.8
2014	126,773	18,060	77,547	31,166	14.2	61.2	24.6
2015	126,444	17,939	76,622	31,883	14.2	60.6	25.2
2016	126,068	17,791	75,856	32,421	14.1	60.2	25.7
2017	125,648	17,620	75,211	32,817	14.0	59.9	26.1
2018	125,184	17,427	74,670	33,087	13.9	59.6	26.4
2019	124,679	17,217	74,236	33,226	13.8	59.5	26.6
2020	124,133	16,993	73,805	33,335	13.7	59.5	26.9
2021	123,551	16,760	73,426	33,365	13.6	59.4	27.0
2022	122,934	16,522	73,115	33,297	13.4	59.5	27.1
2023	122,287	16,284	72,762	33,242	13.3	59.5	27.2
2024	121,612	16,049	72,362	33,202	13.2	59.5	27.3
2025	120,913	15,821	71,976	33,116	13.1	59.5	27.4
2026	120,193	15,604	71,590	32,999	13.0	59.6	27.5
2027	119,454	15,400	71,169	32,886	12.9	59.6	27.5
2028	118,699	15,210	70,686	32,803	12.8	59.6	27.6
2029	117,930	15,038	70,152	32,740	12.8	59.5	27.8
2030	117,149	14,882	69,500	32,768	12.7	59.3	28.0
2031	116,357	14,743	69,134	32,480	12.7	59.4	27.9
2032	115,557	14,622	68,393	32,542	12.7	59.2	28.2
2033	114,748	14,516	67,635	32,597	12.7	58.9	28.4
2034	113,934	14,425	66,829	32,680	12.7	58.7	28.7
2035	113,114	14,347	65,981	32,787	12.7	58.3	29.0
2036	112,290	14,280	65,068	32,942	12.7	57.9	29.3
2037	111,462	14,221	64,102	33,139	12.8	57.5	29.7
2038	110,632	14,166	63,086	33,379	12.8	57.0	30.2
2039	109,800	14,115	62,090	33,595	12.9	56.5	30.6
2040	108,964	14,062	61,176	33,726	12.9	56.1	31.0
2041	108,125	14,006	60,323	33,796	13.0	55.8	31.3
2042	107,285	13,945	59,557	33,782	13.0	55.5	31.5
2043	106,443	13,876	58,834	33,733	13.0	55.3	31.7
2044	105,601	13,799	58,171	33,631	13.1	55.1	31.8
2045	104,758	13,712	57,549	33,497	13.1	54.9	32.0
2046	103,915	13,616	56,990	33,310	13.1	54.8	32.1
2047	103,065	13,510	56,447	33,109	13.1	54.8	32.1
2048	102,211	13,394	55,908	32,909	13.1	54.7	32.2
2049	101,354	13,270	55,383	32,701	13.1	54.6	32.3
2050	100,496	13,139	54,904	32,454	13.1	54.6	32.3

Table A-4 Selected age-structure index of future population, 1995–2050: Medium variant

Year	Mean Age (yr.)	Median Age (yr.)	Defining Productive Age as 15–64 Years Old: Age Dependency Ratio (%) Total	Children	Old-age	Elderly-Children Ratio (%)	Defining Productive Age as 20–69 Years Old: Age Dependency Ratio (%) Total	Children	Old-age	Elderly-Children Ratio (%)
1995	39.6	39.7	43.9	23.0	20.9	91.2	47.6	33.6	14.0	41.5
1996	39.9	40.0	44.4	22.6	21.8	96.4	47.3	32.7	14.6	44.5
1997	40.3	40.4	45.0	22.3	22.7	101.8	47.1	32.0	15.2	47.5
1998	40.7	40.7	45.6	22.0	23.6	107.2	47.1	31.3	15.8	50.6
1999	41.0	41.0	46.1	21.7	24.4	112.4	47.3	30.8	16.5	53.6
2000	41.3	41.3	46.8	21.5	25.3	117.6	47.5	30.3	17.2	56.7
2001	41.6	41.6	47.7	21.4	26.3	122.5	47.9	30.0	17.9	59.7
2002	42.0	41.9	48.6	21.4	27.2	127.1	48.4	29.7	18.6	62.7
2003	42.3	42.1	49.4	21.4	28.0	130.9	48.8	29.5	19.4	65.7
2004	42.5	42.4	50.1	21.5	28.7	133.7	49.3	29.2	20.0	68.6
2005	42.8	42.6	51.2	21.6	29.6	137.1	49.9	29.1	20.8	71.4
2006	43.1	42.9	52.5	21.8	30.7	141.0	50.6	29.0	21.6	74.3
2007	43.4	43.2	53.9	22.0	31.9	145.0	51.3	29.0	22.3	76.9
2008	43.6	43.5	55.2	22.2	33.0	148.3	52.0	29.0	23.0	79.1
2009	43.9	43.7	56.5	22.4	34.1	151.9	52.5	29.1	23.4	80.6
2010	44.1	43.9	57.2	22.6	34.6	153.6	53.3	29.2	24.2	82.8
2011	44.4	44.2	57.6	22.6	35.0	154.9	54.5	29.4	25.1	85.3
2012	44.6	44.5	59.4	22.8	36.6	160.4	55.6	29.6	26.0	87.9
2013	44.8	44.9	61.5	23.1	38.4	166.4	56.6	29.8	26.8	90.1
2014	45.0	45.2	63.5	23.3	40.2	172.6	57.6	29.9	27.7	92.5
2015	45.3	45.5	65.0	23.4	41.6	177.7	58.1	30.0	28.1	93.6
2016	45.5	45.8	66.2	23.5	42.7	182.2	58.2	30.0	28.2	94.3
2017	45.7	46.2	67.1	23.4	43.6	186.2	59.7	30.2	29.6	98.0
2018	45.9	46.6	67.6	23.3	44.3	189.9	61.4	30.4	31.0	102.1
2019	46.1	46.9	67.9	23.2	44.8	193.0	63.1	30.6	32.5	106.3
2020	46.3	47.3	68.2	23.0	45.2	196.2	64.3	30.7	33.6	109.7
2021	46.4	47.7	68.3	22.8	45.4	199.1	65.2	30.7	34.5	112.5
2022	46.6	48.0	68.1	22.6	45.5	201.5	65.7	30.6	35.1	114.9
2023	46.8	48.3	68.1	22.4	45.7	204.1	66.1	30.5	35.6	116.9
2024	47.0	48.7	68.1	22.2	45.9	206.9	66.1	30.3	35.8	118.4
2025	47.1	49.0	68.0	22.0	46.0	209.3	66.1	30.1	36.1	120.0
2026	47.3	49.2	67.9	21.8	46.1	211.5	66.0	29.8	36.2	121.2
2027	47.4	49.4	67.8	21.6	46.2	213.5	65.7	29.6	36.1	122.0
2028	47.5	49.6	67.9	21.5	46.4	215.7	65.5	29.4	36.1	122.9
2029	47.6	49.8	68.1	21.4	46.7	217.7	65.3	29.2	36.1	123.9
2030	47.7	50.0	68.6	21.4	47.1	220.2	65.1	29.0	36.1	124.6
2031	47.8	50.1	68.3	21.3	47.0	220.3	64.9	28.8	36.1	125.2
2032	47.9	50.2	69.0	21.4	47.6	222.6	64.7	28.7	36.1	125.7
2033	48.0	50.3	69.7	21.5	48.2	224.6	64.7	28.6	36.1	126.3
2034	48.1	50.4	70.5	21.6	48.9	226.6	64.8	28.6	36.2	126.9
2035	48.1	50.5	71.4	21.7	49.7	228.5	65.2	28.6	36.6	127.9
2036	48.2	50.6	72.6	21.9	50.6	230.7	64.9	28.5	36.3	127.4
2037	48.2	50.6	73.9	22.2	51.7	233.0	65.4	28.6	36.8	128.5
2038	48.3	50.6	75.4	22.5	52.9	235.6	66.0	28.8	37.3	129.5
2039	48.3	50.5	76.8	22.7	54.1	238.0	66.8	28.9	37.8	130.7
2040	48.3	50.5	78.1	23.0	55.1	239.8	67.6	29.2	38.5	132.0
2041	48.4	50.4	79.2	23.2	56.0	241.3	68.7	29.4	39.3	133.5
2042	48.4	50.3	80.1	23.4	56.7	242.3	69.8	29.7	40.2	135.2
2043	48.4	50.2	80.9	23.6	57.3	243.1	71.2	30.0	41.2	137.2
2044	48.5	50.1	81.5	23.7	57.8	243.7	72.5	30.3	42.2	139.2
2045	48.5	50.0	82.0	23.8	58.2	244.3	73.7	30.6	43.1	140.7
2046	48.5	50.0	82.3	23.9	58.4	244.6	74.7	30.8	43.8	142.1
2047	48.5	49.9	82.6	23.9	58.7	245.1	75.4	31.0	44.4	143.0
2048	48.6	49.9	82.8	24.0	58.9	245.7	76.1	31.2	44.9	143.9
2049	48.6	49.9	83.0	24.0	59.0	246.4	76.6	31.3	45.3	144.5
2050	48.6	49.9	83.0	23.9	59.1	247.0	77.0	31.4	45.6	145.0

Table A-5 Trends and prospects of number of births, deaths, and natural increase: Medium variant

Year	Crude number (1,000)			Crude rates (%)		
	Birth	Deaths	Natural increase	Birth	Deaths	Natural increase
1996	1,220	911	309	9.7	7.2	2.4
1997	1,221	927	294	9.7	7.3	2.3
1998	1,225	952	273	9.7	7.5	2.2
1999	1,231	978	253	9.7	7.7	2.0
2000	1,239	1,004	235	9.7	7.9	1.8
2001	1,246	1,031	215	9.8	8.1	1.7
2002	1,251	1,059	193	9.8	8.3	1.5
2003	1,254	1,087	168	9.8	8.5	1.3
2004	1,254	1,115	139	9.8	8.7	1.1
2005	1,251	1,144	107	9.8	9.0	0.8
2006	1,245	1,173	71	9.7	9.2	0.6
2007	1,236	1,203	33	9.7	9.4	0.3
2008	1,225	1,233	–8	9.6	9.7	–0.1
2009	1,212	1,263	–51	9.5	9.9	–0.4
2010	1,198	1,293	–95	9.4	10.1	–0.7
2011	1,182	1,323	–141	9.3	10.4	–1.1
2012	1,164	1,353	–188	9.2	10.6	–1.5
2013	1,146	1,382	–235	9.0	10.9	–1.9
2014	1,128	1,410	–282	8.9	11.2	–2.2
2015	1,109	1,438	–329	8.8	11.4	–2.6
2016	1,090	1,465	–374	8.7	11.7	–3.0
2017	1,072	1,491	–418	8.6	11.9	–3.3
2018	1,054	1,516	–461	8.5	12.2	–3.7
2019	1,038	1,540	–502	8.4	12.4	–4.0
2020	1,022	1,563	–542	8.3	12.7	–4.4
2021	1,008	1,585	–578	8.2	12.9	–4.7
2022	995	1,606	–611	8.1	13.1	–5.0
2023	985	1,626	–641	8.1	13.4	–5.3
2024	977	1,644	–667	8.1	13.6	–5.5
2025	970	1,661	–691	8.1	13.8	–5.7
2026	965	1,677	–712	8.1	14.0	–6.0
2027	961	1,691	–730	8.1	14.2	–6.1
2028	959	1,704	–745	8.1	14.5	–6.3
2029	957	1,716	–759	8.2	14.7	–6.5
2030	956	1,727	–771	8.2	14.8	–6.6
2031	954	1,736	–782	8.3	15.0	–6.8
2032	953	1,743	–791	8.3	15.2	–6.9
2033	951	1,749	–798	8.3	15.4	–7.0
2034	949	1,753	–804	8.4	15.5	–7.1
2035	946	1,755	–810	8.4	15.6	–7.2
2036	942	1,756	–814	8.4	15.8	–7.3
2037	937	1,754	–818	8.5	15.9	–7.4
2038	931	1,751	–820	8.5	15.9	–7.5
2039	924	1,747	–823	8.5	16.0	–7.6
2040	916	1,742	–826	8.5	16.1	–7.6
2041	907	1,737	–829	8.5	16.2	–7.7
2042	898	1,729	–831	8.4	16.2	–7.8
2043	887	1,720	–832	8.4	16.3	–7.9
2044	877	1,710	–833	8.4	16.3	–8.0
2045	866	1,699	–833	8.3	16.3	–8.0
2046	854	1,690	–835	8.3	16.4	–8.1
2047	843	1,685	–842	8.3	16.5	–8.2
2048	832	1,678	–846	8.2	16.6	–8.3
2049	822	1,670	–848	8.2	16.6	–8.4
2050	812	1,661	–849	8.1	16.7	–8.5