審　議　事　項

1	
幹事会	１０６

提　　案

英国王立協会（The Royal Society）からの依頼に対する
回答「People and the planet study: call for evidence」の決定について

提 案 者　　人間及び地球研究対応委員会委員長

議　　案　　英国王立協会（The Royal Society）からの依頼に対する回答「People and the planet study: call for evidence」を決定すること。

提案理由　　英国王立協会（The Royal Society）からの「人間及び地球研究（People and the planet study）」という長期プロジェクトへの関連情報及び根拠データ収集の依頼について、別添のとおり回答内容を取りまとめたので、英国王立協会に対し回答したいため。

People and the Planet Study: Response to the Call for Evidence
The Science Council of Japan

30 September 2010

It is our pleasure as well as honour to be of some assistance to the ambitious and obviously important *Project on People and the Planet Study*, which the Royal Society has just embarked on. The evidence sought is rather wide, and we had to be selective in our response to your request. Among the seven questions you have listed, we decided to focus on the questions No. 1 to No. 6, leaving the remaining question No. 7 to better qualified experts in other parts of the planet earth.

Our response consists of 4 sections, which correspond to your questions as follows:

Section 1 Population Changes in Japan: Trends, Prospects, and Policy Implications
Prepared by **Noriko Tsuya** and corresponds to your question No. 1 and No. 6.

Section 2 Some Findings with Evidence on Population in Japan and Asia
Prepared by **Shinichiro Ohgaki** and **Takashi Onishi** and corresponds to your question No. 2.

Section 3 Demographic Models and Population Projections in Japan: Evaluating the Strength and Weaknesses of Different Population Modelling Methodologies
Prepared by **Ryuichi Kaneko** and corresponds to your question No. 3.

Section 4 Some Interconnections among Population Change, Environments, Economies, Societies and Culture
Prepared by **Mariko Hasegawa** and corresponds to your questions No. 4 and No. 5.

There are four attachments. The first attachment is the file of figures mentioned in Section 2, whereas the other three attachments are background papers for Section 3. We very much hope that our response will of some help in your future research. We also wish you bon voyage in your ambitious venture.

Yours sincerely,

Kotaro Suzumura, Chair
Vice President of the Science Council of Japan
Professor, School of Political Science and Economics
Waseda University

For any inquiries, please contact Noriko Nakamura
Secretariat
Science Council of Japan
Email: noriko.nakamura〔a〕c a o.g o.j p
(Please copy to: i253〔a〕s c j.g o.j p)
Tel: +81-3-3403-1949

Section 1

Population Changes in Japan: Trends, Prospects, and Policy Implications

Noriko Tsuya
Council Member of the Science Council of Japan
Professor, Department of Economics
Keio University

Japan's population started to decline in 2005, after peaking at around 128 million in 2004. According to the medium variant of the latest government projection, the population is estimated to continue to shrink by about 30 percent during the first half of the 21st century, sliding to approximately 90 million in 2055 (National Institute of Population and Social Security Research 2007, pp. 84–85). Further, the pace of the future population decline is expected to accelerate. Of the projected 30-percent decline of the population from 2005 to 2055, around 10 percent (one third of the decline) will take place during the first 25 years (2005–2029) while the remaining 20 percent (two thirds of the shrinkage) will occur in the next 25 years (2030–2055).

The ongoing and future decline of Japan's population is due primarily to declines of fertility to below-replacement levels. While almost all Western countries have also experienced or been experiencing below-replacement fertility, the decline in Japan is notable in its rapid pace and sheer magnitude. After cutting it by more than half in one decade from a TFR of 4.5 per woman 1947 to 2.1 in 1957, Japan's fertility started to decline to below-replacement levels in the mid-1970s, reaching the "lowest-low" level—a TFR of 1.3 per woman according to Kohler *et al.* (2002)—in the early 2000s (National Institute of Population and Social Security Research 2010, pp. 50–51).

With little childbearing outside marriage (the proportion of unmarried births has been around 1–2 percent since 1960), Japan's fertility decline to below-replacement levels has been caused mainly by increases in delayed marriage and non-marriage. The proportion of the never-married among women aged 25–29 tripled from 18 percent in 1975 to 59 percent in 2005 (National Institute of Population and Social Security Research 2010, p. 109). The corresponding increase for women aged 30–34 was even sharper, from 8 percent in 1975 to 32 percent in 2005—fourfold increase. The proportion never-married at age 50—the most commonly used measure of the prevalence of permanent non-marriage—also shows a sign of increase in recent years. While it was only less than 2 percent for Japanese women in early postwar years, it rose to 7 percent in 2005, implying a departure from the traditional Japanese/Asian pattern of universal marriage. In the 1990s marital fertility also began to decline due mainly to decreases in the rate of second births (Tsuya *et al.* 2009), thereby accelerating the pace of overall fertility decline.

Delayed marriage and less marriage are similarly evident and even more dramatic among Japanese men. The proportion of the never-married among men aged 30–34 more than tripled from 14 percent in 1975 to 47 percent in 2005 (National Institute of Population and Social Security Research 2010, p.109). The corresponding increase for men aged 35–39 was fivefold, from 6 percent in 1975 to 30 percent in 2005. Furthermore, the proportion of never-married men at age 50 rose phenomenally from mere 2 percent in 1975 to 16 percent in 2005—eightfold increase. This indicates that in 2005 approximately one out of every six men aged 50 was never-married. This in turn implies that, given the persistence of little childbearing outside marriage, the country will soon face dramatic increases in the number of elderly men who do not have a spouse and children to support and care for them. Since almost all social systems in Japan, including the social security schemes, have long been based on the assumption (and until recent years the fact) that a vast majority of Japanese men and women marry and have children, this future ballooning of the childless elderly will pose serious challenges not only to the government but also to the society as a whole.

Japan’s mortality has also been declining, and life expectancy is rising. Following dramatic increases from 50.1 years for males and 54.0 years for females in 1947 to 65.3 years for males and 70.2 years for females in 1960, life expectancy at birth has continued to increase steadily. Reaching 79.3 years for males and 86.1 years for females in 2008, the Japanese, especially Japanese women, are among the longest living populations in the world (National Institute of Population and Social Security Research 2010, p.79). Further, decline in mortality of the elderly has been even more rapid than in the total population in recent years. Lingering at around 11 to 12 years in the 1950s and 1960s, life expectancy at age 65 increased rapidly thereafter—from 12.5 years for men and 15.3 years for women in 1970 to 18.6 years and 23.6 years in 2008, respectively.

These remarkable declines in fertility and mortality have led to rapid population aging. The proportion of the elderly (persons age 65 and above) had remained at around 5–6 percent in Japan during the 1950s and 1960s until it started to increase in the early 1970s, surpassing 10 percent in 1985 and reaching 20 percent in 2005 (National Institute of Population and Social Security Research 2010, p.30). Compared to Western countries, the rapidity of Japan's aging is notable. For example, France took 115 years (from 1864 to 1979) to double its proportion of the elderly from 7 percent to 14 percent (United Nations 1956, 2008). It was 85 years (1887–1972) for Sweden, and 46 years (1929–1975) for the United Kingdom to experience the same doubling (from 7 percent to 14 percent) of the proportion of the elderly. In contrast, Japan took only 24 years from 1970 to 1994 to witness its proportion aged 65 and above to double (National Institute of Population and Social Security Research 2010, p. 39). With the proportion of the elderly being 22.1 percent in 2008, Japan is currently the most aged population in the world.

According to the latest population projection, Japan's mortality is estimated to decline even further in the first half of the 21st century, reaching a life expectancy at birth of 83.7 years for males and 90.3 years for females in 2055 (National Institute of Population and Social Security Research 2007, pp. 6–8). The medium variant of the same projection also estimates that Japan’s fertility will remain very low with a TFR of 1.2 to 1.3 per woman during 2006–2055.

With low levels of international migration, the further prolonging of life expectancy and the stabilization of fertility at very low levels will bring about not only further population decline at an accelerated pace as mentioned above, but also population aging to an unprecedented level. The proportion of population aged 65 and above is projected to reach 41 percent in 2055, around two-third of whom being aged 75 and above (National Institute of Population and Social Security Research 2007, pp. 6–8). The rapid shrinkage of population and extreme population aging will no doubt pose difficult policy challenges as they will have profound impacts on Japan's economy and social institutions including, among others, the public pension, national health insurance, and long-term care insurance schemes.

Being gravely concerned about the country's demographic and socioeconomic prospects, the Japanese government has formulated various policies and programs especially since the early 1990s. To halt the sliding of fertility to very low levels, the government launched a series of policies and programs—the Angel Plan of 1994, the New Angel Plan of 1999, the Plus-One Plan of 2002, and the Support Plan of 2004, to name a few—that were designed to help couples/parents accommodate their work and domestic responsibilities by providing more childcare services and encouraging the workplace to become more family friendly. The government also enacted the Maternity and Childcare Leave Law (*Ikuji Kyugyo Ho*) in 1992 and revised it in 1995 and 2005. Launched originally in 1972, the child allowance scheme (*jido te-ate seido*) has been expanded notably since 2000 (Tsuya 2005).

However, these policy actions and programs appear to have been so far largely ineffective in the sense that the strains and pressures on couples (especially on working mothers) do not seem to have been alleviated to any notable degree (Tsuya *et al.* 2005), and Japan's fertility has remained very low. Comparing 18 member countries, OECD (2001, chapter 4) ranked Japan as the second from the bottom in terms of the effectiveness of its policies for "work-family reconciliation" and family-friendly work arrangements. Japan ranked especially low in the effectiveness of policies for work and family-life balance as measured in terms of the extensiveness of maternity and parental leave schemes and provisions of childcare services, although the country was well below the average in the family-friendliness of its labor market. Given the serious, long-term demographic and socioeconomic consequences of the persistence of very low fertility as stated above, Japan has no choice but to strengthen its policy and society-wide efforts to help women and couples make work and family life more compatible.

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The replacement level is the level at which a generation of women have just enough number of next-generation females to replace themselves. In a population such as Japan in which mortality from birth to the end of reproductive years (age 49) is very low, the replacement level equals to a total fertility rate (TFR) of a little below 2.1 children per woman.

Similarly rapid and even more dramatic fertility declines occurred in other East Asian countries such as South Korea and China. Korea experienced one of the most spectacular declines ever recorded, with its fertility falling without hiatus from very high (a TFR of 6.0 per woman) to a below-replacement level (1.6 per woman) from the early 1960s to mid-1980s. In 2005 Korea's TFR dropped to 1.1 per woman, the lowest in the world. Though may not be as well publicized and recognized as in the cases of Japan and Korea, after a dramatic decline from very high to a little above the replacement level from the early 1970s to the 1980s, China's fertility has also entered the below-replacement phase in the early 1990s. By 2005, its fertility reached around 1.5 per woman (Tsuya *et al.* 2009).

Section 2

Some Findings with Evidence on Population in Japan and Asia

Shinichiro Ohgaki* and Takashi Onishi**
**Vice President of the Science Council of Japan*
President of the National Institute for Environmental Studies
*** Member of the Science Council of Japan*
Professor, Department of Urban Engineering, Graduate School of Engineering
The University of Tokyo

1. Long-Term Trends of Population Changes in Japan (see attached slide: p. 1)
The total population in Japan came to its peak and began decreasing gradually as increasing its speed. It may reach about a third of the present level in 2105, which is equivalent to that of 1900.

The old-age dependency ratio, calculated by dividing the elderly population (EMBED Equation.3 65 years old) by working-age population (15 EMBED Equation.3 65) has began increasing in the beginning of 1970 from its long-time stable level of about 9%, and will reach its highest level of about 85% in 2070.

This prediction shows that a working-age person must support 0.85 person at old age in the future, which obviously means the collapse of many social system, such as pension, health insurance, other social security and even communities.

2. Rapid Urbanization in Asia
Urban population in Asia is growing and will occupy 54% of that in the world in 2050, while the share of urban population in Europe and North America was and is decreasing. The main places of urban activities are gradually shifting from major cities in Europe and North America to in Asia (see attached slide: p. 2-p. 4).

Tokyo will be still the largest metropolitan area with the population of 34 millions in 2030, while Indian metropolitan regions will grow rapidly (see attached slide: p. 5 and p. 6).

3. Demographic Changes in Tokyo Metropolitan Region
People lived in the rather limited areas of Tokyo in its earlier stage and have been expanding after 1960 to the suburbs reducing its night-time population density in its center (see attached slide: p. 7 and p. 8).

People came back to the central part to live recently in Tokyo. Chuo Ward, one of the central wards of Tokyo, recorded the highest population growth rate in the country in 2000-2005.

Average number of people in a household is decreasing and single families, in which young or old people live alone, will occupy the largest share in family category near future (see attached slide: p. 9).

For attached slide, please see Attachment A.

Section 3

Demographic Models and Population Projections in Japan: Evaluating the Strengths and Weaknesses of Different Population Modelling Methodologies

Ryuichi Kaneko
Member of the Science Council of Japan
Research Director, Department of Population Dynamics
National Institute of Population and Social Security Research

1. Overview of Population Modelling and Its Methodologies

Like many other social and economic processes, population dynamics can be viewed as a relationship between instantaneous states (or stock) and flows. Population size and its structure at a particular point in time are the basic aspects of the state. The flow originates from vital and migratory events that alter the state of population in the passage of time. The current state of population is captured by a census. The annual vital and migration statistics monitor counts of the demographic events (the flows) that have taken place during a year. The future state of population is completely determined by the way in which the basic events occur. Birth, death and migration are the only events that directly alter population.

Therefore the two major research areas in population modelling are to describe resulting state of the population given the current state and the basic demographic events, and to describe the ways in which the demographic events occur. The former field includes structured population dynamics models such as the stable population model, while the latter includes age schedule models of life events such as model life tables.

Population projection is carried out by integrating both kinds of models and simulating the real process of population change under the assumptions of the future course of the vital and migratory events. The projected population, therefore, is simply a translation of the assumptions on birth, death and migration changes into future developments in the state.

We now provide more precise descriptions of the projection process: we describe structured population dynamics models, age schedule models of life events, and the resulting population projections.

Structured Population Dynamics Models

Structured population dynamics models (SPDMs) are mathematical models of the composition of a population, originating from the stable population model formulated and investigated by A. J. Lotka. Such a model is the mathematical formulations of age structure, intrinsic growth rate and other traits of closed population in equilibrium under constant fertility and mortality schedules. These formulations encode strong formal expressions of an ergodic relationship between population structure and demographic events. The weaknesses of the original stable population models include restrictive presuppositions on vital events to be constant, homogeneity of population, lack of a feedback mechanism, and difficulty in dealing with the two-sex setting.

The stable population model has subsequently been enhanced under conditions of variable fertility, mortality and even migration (McKendrick 1926, Preston and Coale 1982). Other work has built toward multistate population models which incorporate other dimensions than age and sex structure (Rogers 1975, Schoen 1988). Incorporation of the feedback process in which the vital events are affected by current population conditions has been one of the major challenges in this field (Gurtin and MacCamy 1974, Metz and Diekmann 1986).

The Leslie matrix model is a discrete version of the stable model expressing the population process by matrix algebra which is readily applicable to population projections. It also has been expanded to multidimensional models.

Age Schedule Models of Life Events

Age patterns of the mortality rate in human populations show certain regularities: the rate is high in infancy, lowest around age ten and gradually rises toward infinity as one ages. In fact, Gompertz found that the rise after about age 30 was exponential early in the 19th century (the Gompertz law of mortality). This regularity is utilized to predict mortality over the entire age range from measurements at one age or from an estimate for overall mortality level. (The regularity is believed to arise from the pattern of biological vitality for humans as a result of evolution as well as the general nature of durability in organization).

There are three types of models to describe the regularity in mortality: (1) mathematical formulations, (2) empirical standardizations, and (3) relational models.

(1) Mathematical Formulation

Many mathematical models have been developed to represent the age pattern of mortality since Gompertz. The Gompertz-Makeham model, Beard model, Perks model, and the logistic model have all been used for graduation, smoothing, and extension of mortality rate to old ages in the process of producing life tables. However, those models cover only a part of the lifecycle beyond a certain age around the onset of senescence. The Heligman-Pollard model is one of the most widely used mathematical descriptions that covers all age range. The weakness of this model is that it requires eight parameters to adequately describe mortality, whereas the dimension of variation of mortality is two or three in addition to age according to empirical observations (described below).

(2) Empirical Standardization: The Model Life Table

The model life tables provide standard age patterns of mortality at various levels in terms of numerical life tables. They are derived from the huge collection of empirical life tables, and sorted by sex, mortality level and (often) a factor most commonly associated to region. They offer practical accuracy without complication and are widely used in demographic estimations and projections. Nonetheless, model representation by means of massive numerical tables is poorly suited for systematic applications.

(3) Relational Model

The relational model can be viewed as a hybrid of mathematical and empirical models. It describes an arbitrary age schedule of mortality as the mathematical transformation of a standard schedule given by an empirically derived numerical sequence. The most widely used is the Brass Logit life table system which is represented as

$$\text{logit}\,[l(x)] = \alpha + \beta\,\text{logit}\,[l_s(x)],$$

where $l(x)$ and $l_s(x)$ are survival probabilities to age x for arbitrary and standard schedules, α and β are two parameters that relate the two schedules, and logit $[z]$ is the logit transformation, or ln $[(1 - z)/z]$. α bears mortality level, while β represents the relation between young and old mortality in the schedule. The Brass Logit life table system provides age schedule of mortality at any level with a standard schedule and two parameters. It offers parsimony with minimal parameters and flexibility with the empirical standard schedule. There have been proposed several extensions to gain additional accuracy.

The relational model is an effective tool for projecting and estimating whole mortality schedule or life table with few parameters. The Lee-Carter model is a widely-used standard model of mortality projection in population projection today; it is a relational model that enables us to project the whole mortality schedule in the past into future with only one parameter.

For fertility and migration, the other two essential events controlling population change, the framework of the age schedule models are the same as those used for mortality. The Coale-McNeil (CM) model (and its extensions) and the Hernes model are widely-used mathematical formulations of fertility schedule by birth order (Coale and McNeil 1972, Hernes 1972). The generalized log-gamma model is an effective extension of CM model (Kaneko 2003), which is flexible enough to apply in population projections. Though empirical standardization via model fertility tables and some relational models have been developed, in these cases they have little advantage over the mathematical models in practical use.

In particular, the degree of the regularity found in migration schedules is not so high as those in mortality and fertility. Describing it requires more flexibility at the cost of additional parameters. One of most flexible models for the age schedule of migration is that developed by Rogers and Little (1994), which consists of several exponential and double exponential terms.

Population Projection

Population projection is achieved via a numerical simulation to project various changes in the demographic structure (such as population size and age composition by sex) into the future based on assumptions on future course of fertility and mortality rates, as well as international migration levels (Kaneko 2008). The future population may be projected by fitting a specific mathematical function (e.g., an exponential or logistic curve) to the total population size as was commonly done in the past. However, this simple procedure does not take into account the dependence of population growth on age composition. The results also do not provide a classification of the composition of the projected population even by age and sex. Therefore current population projections employ age structured population models, so-called the cohort component method, and integrate structured population dynamics and the vital and migratory events such as those described above.

Population projection thus translates the assumption on birth, death and migration changes into "future" population. Hence population projections provide accurate population forecasts if and only if the assumptions are accurate forecasts. But at the present state of the art this is highly unlikely. The vital and migratory events are generally unpredictable especially in their quantitative form, which imposes uncertainty on population projection. In most official population projections today, uncertainty is handled by giving possible population ranges with multiple projections, called variants, on the basis of alternative sets of assumptions, called scenarios. The drawback of the scenario approach arises from the fact that the different variants produced by automatically combining component scenarios are not necessarily equally plausible.

Another way of dealing with the uncertainty of population projections is by means of probabilistic projections, where instead of preparing multiple scenarios the vital events are described with probability distributions. The probabilistic approach to uncertainties in demographic changes is a solution to the combination problem of the scenario approach and one of the most noteworthy developments of population projection in recent years. However, it should be noted that the probability distribution of a projected population and its indices is not tantamount to the probability of their realization because the parameter distribution of vital events does not represent the probabilities of their realization.

Since the recent unprecedented trends of below-replacement fertility and declining old age mortality in advanced countries make prediction so difficult, a new paradigm is sought for projections of population changes in the 21st century. In addition to population models with multidimensional extensions, the micro-simulation approach and agent-based simulation models in particular are one of the more promising strategies for dealing with the complexity of population movement accompanied by the advancement in computing technologies both in hardware and software.

2. Population Projection in Japan

Based on the results of the 2005 population census and the newly obtained vital statistics, the National Institute of Population and Social Security Research in Japan announced a latest population projection for Japan in December 2006 (Kaneko et al. 2008). The projection covers the total resident population of Japan, starts from the population at the time of the 2005 Census, and extends the period up to 2055, enumerating the population as of October 1 each year. It also includes calculations of the population up to 2105 in order to examine the long term demographic development assuming constant vital rates at the level of 2055 afterwards.

The population (segmented by sex and single year of age) is projected through the cohort component method with assumptions on vital events and international migration based on past trends. Because of the uncertainty in future movements of birth and death, three assumptions are made for each factor to produce a range of forecasts for the future population by means of the nine variants, i.e. 3 × 3. The assumed total fertility rate in 2055 is 1.26 for the medium fertility variant, 1.55 for the high variant, and 1.06 for the low variant. The life expectancy at birth in 2055 is 90.34 years, and 83.67 years respectively for female and male for the medium mortality variant, 89.17 years and 85.41 years for the high variant, and 91.51 years and 84.93 years for the low variant.

When the results of the medium fertility variant are combined with the medium mortality level the total population is projected to fall from 127.8 million in 2005 to 89.9 million in 2055. This is a loss of 37.8 million or 30% of the initial population. Initially, the decline takes place slowly, but after 2039 it accelerates to a pace of more than one million every year. The uneven changes in population by age group result in an age structure that is very different from the starting population. In 2055 the proportion of children under 15 is down to 8.4 per cent from 13.8 per cent in 2005. The working age group 15 to 64 is reduced to 51.1 per cent from 66.1 per cent in 2005. And the proportion of the elderly grows from 20.2 per cent in 2005 to 40.5 per cent 50 years later.

Assumptions about Fertility Rates

Fertility assumptions underlying the projection were made on the basis of the cohort-fertility method. That is, the whole fertility schedule of each female birth cohort including those whose birth process is not yet completed is statistically projected by means of an empirically adjusted mathematical model, the generalized log-gamma model (Kaneko 2003), extrapolating its parameters such as the level of completed fertility and indices of the birth timing by each birth order. The age-specific and total fertility rates of future years can be obtained by converting the cohort rate into annual data. For younger cohorts for which no or only scant actual data were available, the cohort born in 1990 served as a reference cohort whose figures were examined in depth. The index was projected based on actual statistics for first marriage, reproductive behaviour of couples, as well as divorce, bereavement and remarriage. The annual fertility rate for the total resident population is obtained by combining the fertility rates of Japanese and non-Japanese women.

Mortality Assumption for Future Life Table

The Lee-Carter model was adopted as a basis to construct future annual life tables. However, the procedure is modified by introducing new features called the shifting logistic model which describes improvements in the mortality rate as a shift of the aging process toward old age. This modification reflects actual mortality trends in Japan, that is, continuing life expectancy gains. Combining the Lee-Carter model with the shifting logistic model seems to be a better way of accounting for this trend. The high and low variants of mortality are derived from the boundaries of the 99 per cent confidence interval of the mortality level parameter of the Lee-Carter model (denoted k_t in the original literature).

Assumption of International Migration Rate and Numbers

Separate assumptions were made for the net international migration rate of Japanese citizens, on one hand, and the net immigration rate of non-Japanese citizens, on the other. For the former, a fixed migration rate was assumed for the future based on the average annual net international migration rate from 1995 to 2005. For the international migration of the non-Japanese population, the number of future net migrants by sex was calculated for the period from 2006 to 2025 by projecting the actual trend of net migrants from major sender countries. The figure was assumed to be unchanged after 2026.

Uniqueness: Life Course Approach

The population projections in Japan are unique not only in combining the world's lowest fertility assumptions with the highest life expectancy, but also in their sophisticated life course approach to constructing assumptions on vital rates. Through this framework, they provide measures for the projected life of women via the multistate life table techniques applied to the projected population.

For instance, life time probability of childlessness and having no grandchildren are estimated as 38.1% and 50.2%, respectively, in the female cohort born in 1990. The average life time spent in never married status increases to 42.5 years (or 47% of the life expectancy) in the cohort born in 1990 from 25.3 years (31%) in those born in 1950. These measures indicate that long, but less-reproductive and non-familial lives prevail among new generations, resulting in a drastic increase in elderly who have no offspring or family in the current sense (Kaneko et al. 2009).

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See the papers cited above for other references. Please see also Attachment B, C and D for the author's background papers.

Section 4

Interconnections among Population Change, Environments, Economies, Societies and Culture

Mariko Hasegawa
Member of the Science Council of Japan
Professor, Department of Evolutionary Studies of Biosystems
The Graduate University for the Advanced Studies

Compared to other countries, Japan's uniqueness lies in the rapid economic recovery and miraculous development after the Second World War with the least possible inequality among people. The GDP of Japan linearly increased every year while the Gini idex linearly decreased from 0.31 for 1950s to 0.21 for 1980s. This was the period of high economic growth in Japan along with the rapid increase of university enrollment among young people (less than 10 % of the 18-years-old population n 1950s to nearly 40 % in 1980s). All the while unemployment rate remained quite low. In addition to those factors, the uniquely Japanese systems of lifetime employment and seniority-based wages by major companies were widespread. The combination of those factors provided young people with an unusually secure, stable prospect for future. If one would make an effort to enter a university, one's possibility of getting a good job would become high, and then the job would be secured until one was about 60 years old, with a steady increase of income every year. This social setting brought in, quite unexpectedly, a drastic linear decrease in homicide rates in Japan (Hiraiwa-Hasegawa, 2005). The atmosphere of the society at that time may be well grasped in one of the national poll conducted in 1970 in which 25% of Japanese people, on average across various occupations, answered that the most important source of Japan's economic development was the workers' willingness to work, more than any other parameters like managers' initiatives or government policies (内閣総理大臣官房広報室「社会意識に関する世論調査」1971 年８月).

All through the period of economic development during 1960s to 1980s, a nuclear family of husband and wife with 2 children had been the standard social model of Japan. This model probably set quite a strong stereotyped ideal of Japanese people's plan of their life, because the design of the public housing, tax systems and insurance systems were all built on this idea of standard nuclear family. Population transition in Japan had already started before the Second World War, but the TRF rapidly decreased from about 4 right after the war to about 2 during 1950s up until 1970s. However, as the society put an emphasis on higher education more and more, the cost of education gradually increased, and the TRF decreased and remained below 2.0 but above 1.5 until early 1990.

On investigating the causes of fertility deline, the life history theory of evolu-tionary biology may be useful. The life history theory tells us that an organism's efforts to live can be divided into 2 different components; somatic efforts and reproductive efforts. Somatic efforts are all the energy devoted to the maintenance and development of self for future reproduction, and reproductive efforts are all the energy devoted to mating and rearing. There is a certain amount of trade-offs between somatic and reproductive efforts as observed in any of the life history traits, for example, size and quantity of offspring. If the size of an individual offspring is big, the number of offspring produced at a time must be small. Likewise, if an organism put a lot of energy to somatic efforts, it cannot afford to put an equal amount of energy to reproductive efforts at the same time.

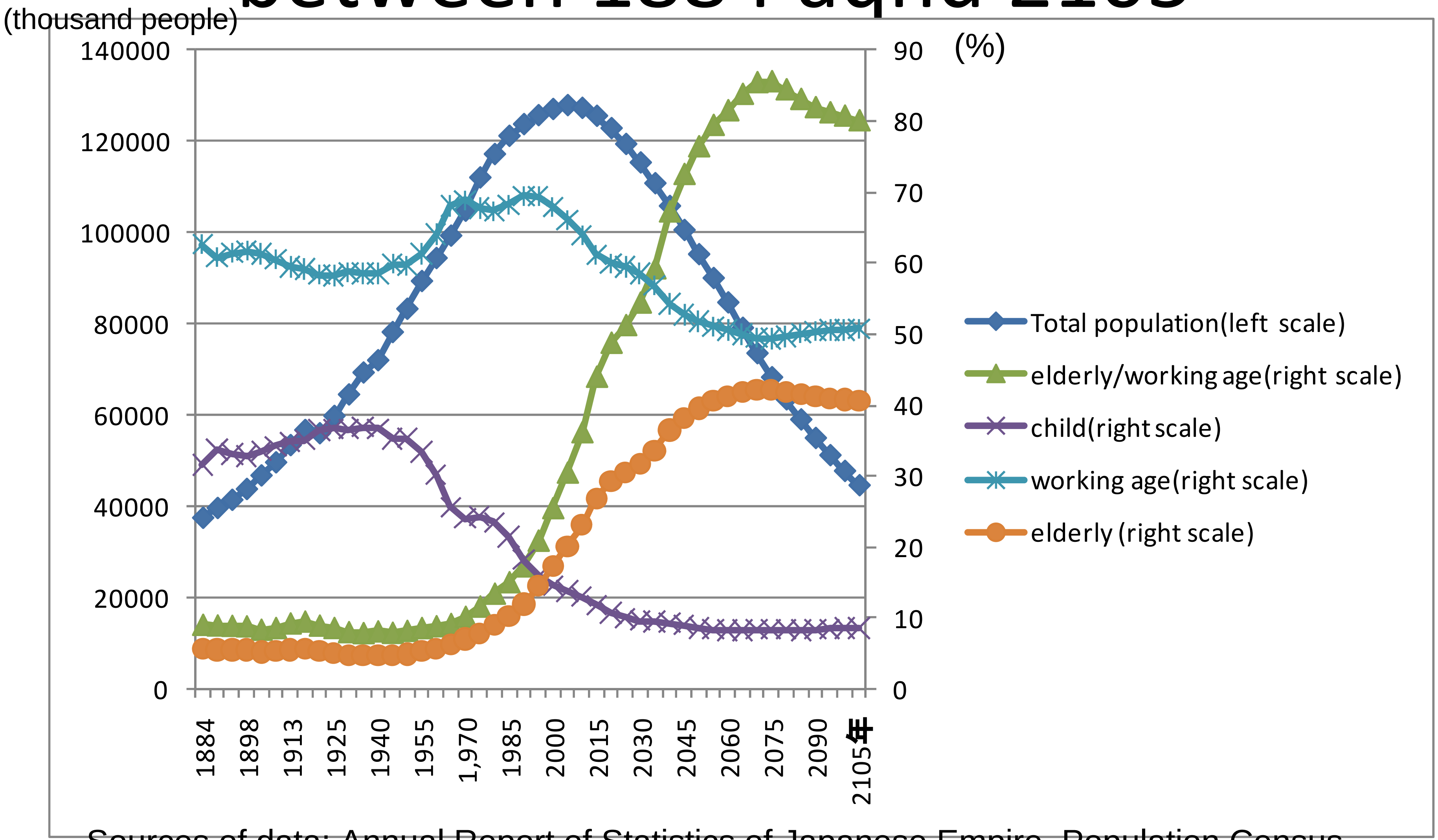
This can be generalized to apply to human cognitive efforts. If one has much motivation for the sustenance and improvement for the self, i.e. somatic efforts, motivation for reproduction may be reduced. In Japan, the path for women's social and economic equality was opened after the Second World War and gradually extended since then. This means that it became actually possible for women to pursue their own career, accumulate their own money, and spend money for themselves. These are somatic efforts of women, which were impossible before the war. Before the war, the only possible option for adult women was to concentrate on reproductive efforts.

At the same time, as the society's inclination toward higher education augmented, people's perception of the cost of education increased, and the reproductive efforts became more and more unattractive. These interconnections can be suggested from the life history perspective of evolutionary biology.

As for the relationships between population change, technology and consumption, one of the very important candidate factor is the personalization of technology. Recent technologies since 1980s have all been for personal convenience and satisfaction of personal desire at any time. Starting from Sony's Walkman to iPod, plastic bottles for any kind of drinks, personal computers, mobile phones, microwave ovens, ready-made foods, and 24-hour open convenience stores, those technologies all helped people to act as they like, live as they like, work as they like, in some extent, without strong conformity with others. At least in Japan, this personalization of technology greatly weakened the interpersonal relationships, even family ties, and may contribute to the recent tendency for young people to stay alone (non-marriage). Personal technologies are satisfactory and they make them feel real face-to-face human relations cumbersome.

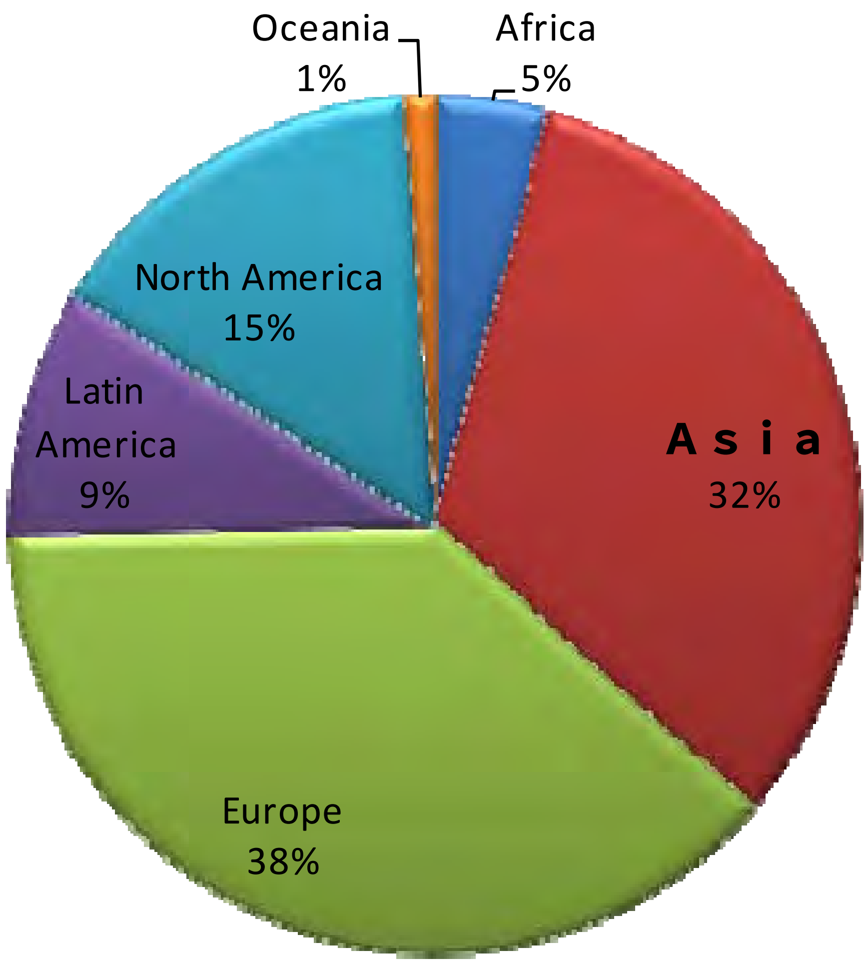
Hiraiwa-Hasegawa (2005): "Homicide by Men in Japan, and Its Relationship to Age, Resources and Risk-Taking," *Evolution and Human Behavior*, Vol. 26, pp. 332-343.

Population changes in Japan between 1884 aqnd 2105



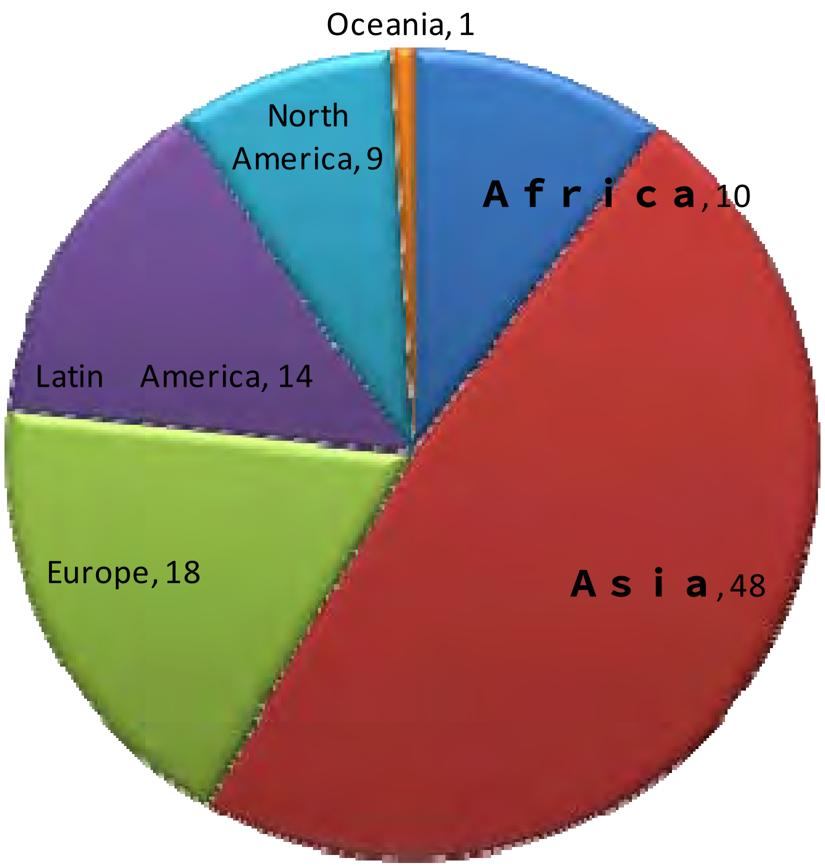
Sources of data: Annual Report of Statistics of Japanese Empire, Population Census, Population projection by National Institute of Population and Social Security Research

Share of Urban Population in 1950, United Nations



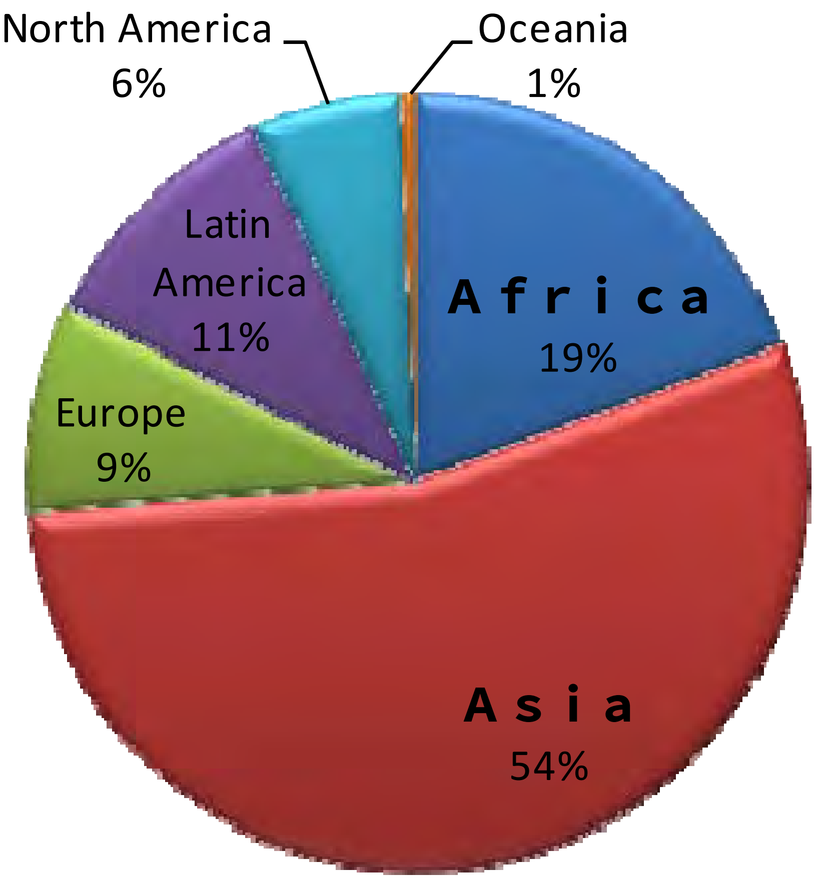
Sources: World Urbanization Prospects by United Nations

Share of Urban Population in 2000, United Nations



Sources: World Urbanization Prospects by United Nations

Share of Urban Population in 2050, United Nations



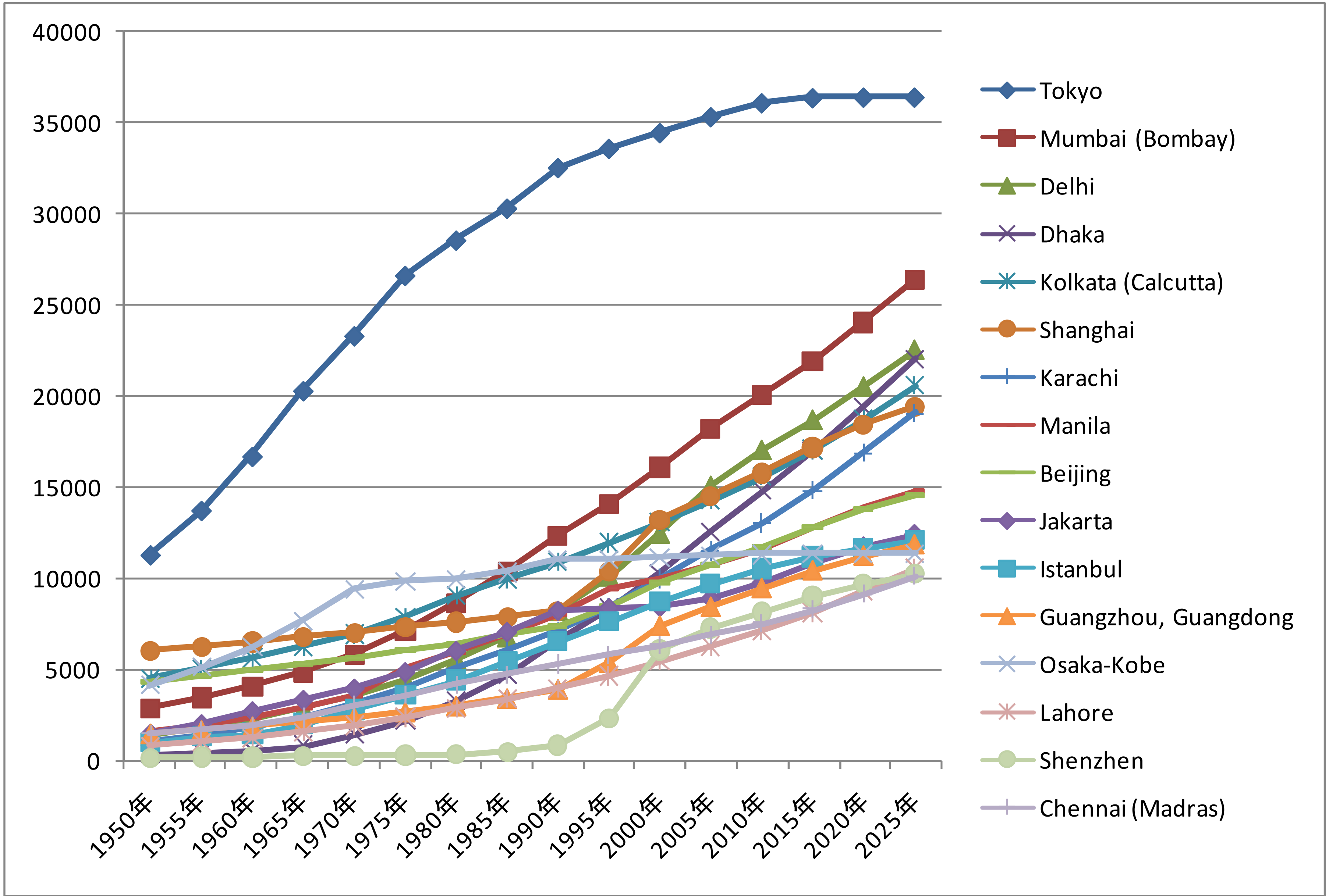
Sources: World Urbanization Prospects by United Nations

Number of large-scale metropolitan regions

	1950年	1975年	2000年	2025年
Africa	0	0	1	3
Asia	1	1	8	16
Europe	0	0	1	2
S&C America	0	1	4	4
N America	1	1	2	2
Oceania	0	0	0	0
World	2	3	16	27

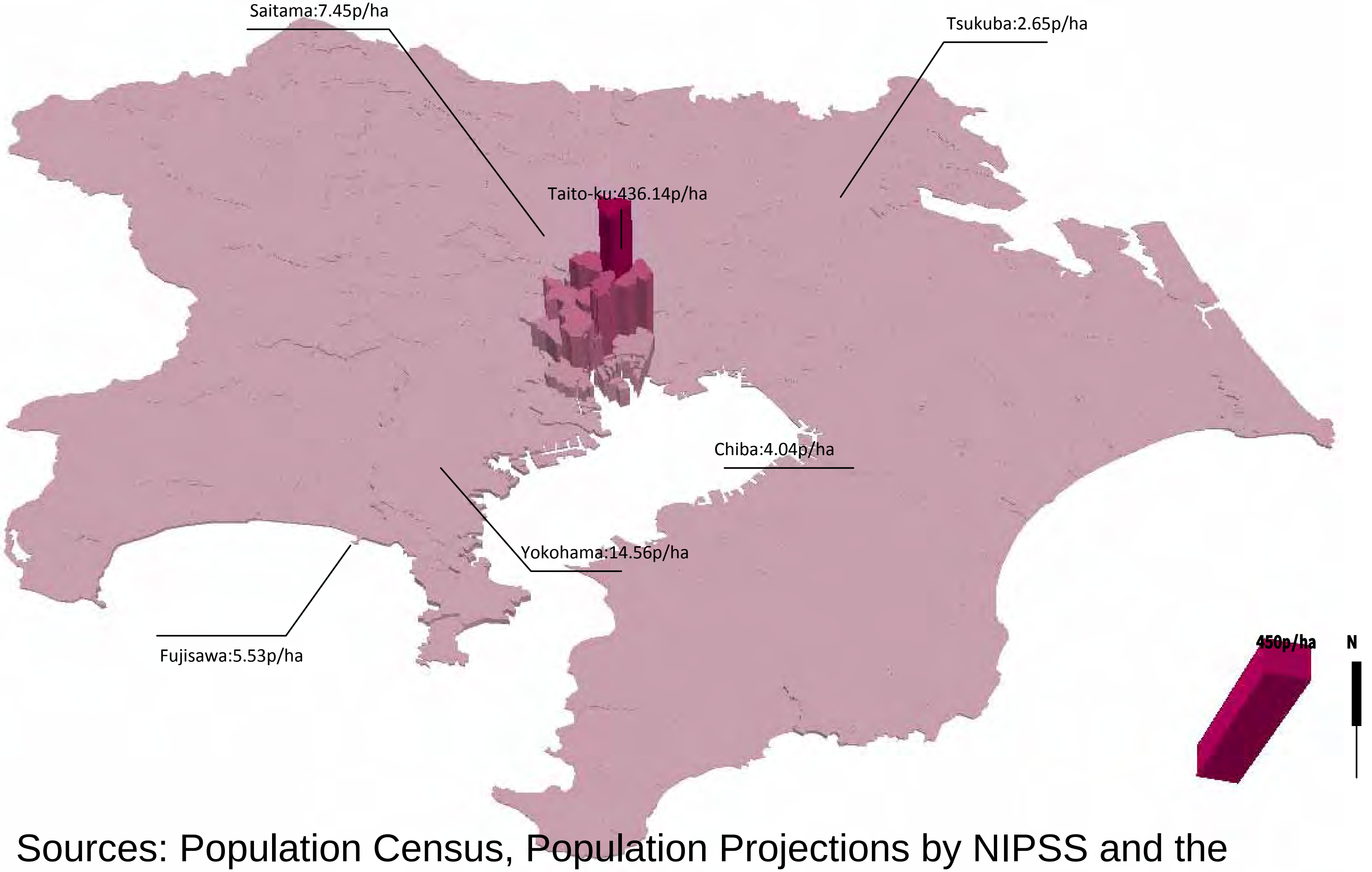
Sources: World Urbanization Prospects by United Nations

Large-scale metropolitan region in Asia



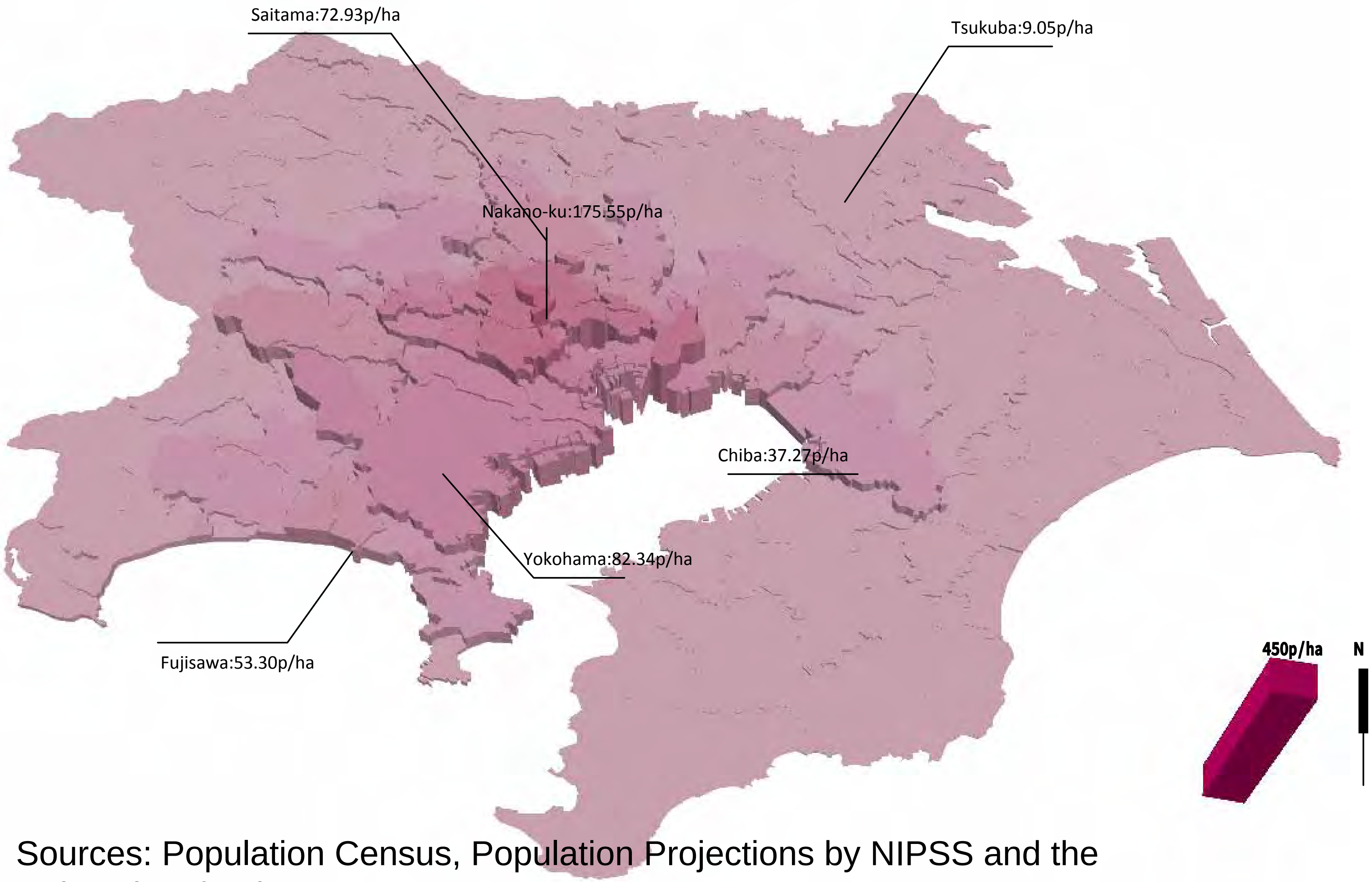
Sources: World Urbanization Prospects by United Nations

Population distribution in Tokyo Regions in 1920



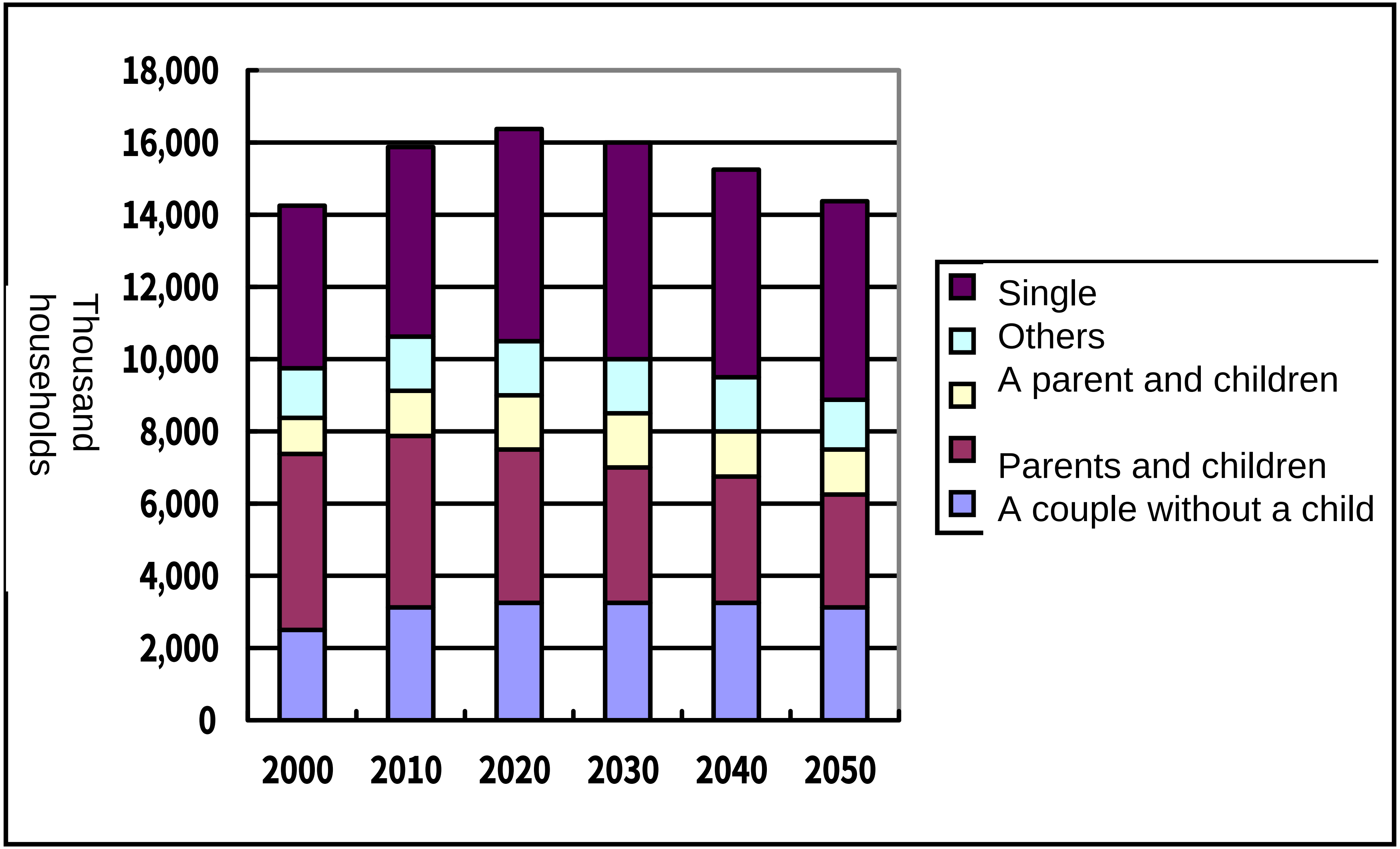
Sources: Population Census, Population Projections by NIPSS and the University of Tokyo

Population distribution in Tokyo Regions in 2050



Sources: Population Census, Population Projections by NIPSS and the University of Tokyo

Structure of family types in Tokyo



Sources: Population Census, Population Projections by NIPSSR and the University of Tokyo

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Commentary to Population Projections for Japan —A Supplement to Report of the 2006 Revision—

Ryuichi Kaneko, Akira Ishikawa, Futoshi Ishii, Tsukasa Sasai, Miho Iwasawa, Fusami Mita, and Rie Moriizumi

Introduction

The National Institute of Population and Social Security Research in Japan announced the "Population Projections for Japan" in December 2006, based on the results of the 2005 Population Census. The Population Projections for Japan attempt to project various key changes in the demographic structure, such as the population size and age-sex structure of Japan into the future, based on assumptions on future Japanese fertility and mortality rates, as well as international migration levels. The results of these projections, as well as the method of projections, basic data and so on, are explained in published report (NIPSSR 2007, Kaneko et al. 2008). To supplement the report, the present article contains various commentaries and explications believed to be useful when utilizing the population projections. The objective of this supplement is to contribute to providing the accountability that is required of official population projections for the public and policy makers so that it will result in the projections being used more widely, and being utilized to a greater extent as basic information resources for working toward a better society in the future.

1. Basic Nature of Population Projections and Their Interpretations

(1) Outline of "Population Projections for Japan"

The National Institute of Population and Social Security Research (formerly Institute of Population Problems) has been projecting future population developments in Japan in response to requests from various parties since before the Second World War. After the war, it has been making projections regularly since 1955. Recently, in particular, it has been making projections of the total population living in Japan, population distribution by prefecture, the number of households and other indexes every 5 years, in synch with the public announcement of the Population Census. In December 2006, it announced its newest contribution, "Population Projections for Japan (December 2006)," the 13th Population Projections study of the total population development published since the Second World War.[1]

The report "Population Projections for Japan" has so far served as a baseline for various socio-economic plans, most notably in the design of the government's social security systems. The projections are also used as fundamental figures in a wide range of applications, including projections of regional population distributions such as the aforementioned prefectural population projections, projections of labor force as well as population continuing their education and enrolling in schools, projections of the number of households, projections of population groups eligible for certain welfare measures and more.

The framework of the projections can be summarized as follows. First of all, the projections cover the total population living in Japan, including non-Japanese residents. This definition is the same as the one used by the Population Census of Japan. The period of projection is 50 years, from 2006 to 2055, with the 2005 Population Census as the starting point (jump off population), projecting the population as of October 1 for each year. Note that the projections also calculate and report longer-term projections up to 2105 (as of October 1 for each year), setting vital rates and other assumed values after 2056 constant, to be used as references for analyses of long-term population development.

The method of projection is as follows: assumptions are made by age for population process components such as birth, death, and international migration, and population by sex and age in the future is projected through the cohort component method. Assumptions are made based on actual statistics for each component through the demographic-projective method. For further details, refer to NIPSSR 2007, and Kaneko et al. 2008, as well as Section 3 of this article, "Commentary on Assumptions."

(2) Basic Nature of Population Projections

1) Requirements for Official Projections

One of the first questions to be considered is, what are population projections[2] actually? As explained above, the "Population Projections for Japan" attempts to project various changes in the demographic structure, such as population size and age composition by sex, into the future based on assumptions on future Japanese fertility and mortality rates, as well as international migration levels. These projections are used in a wide range of applications, most typically as a baseline for planning various systems and measures by the national and regional governments. For this reason, they can be expected to be used for a variety of purposes, and it is not desirable if the projections have been created with particular intentions or perspectives in mind. That is, the greatest possible degree of objectivity and neutrality is required for official projections in order to eliminate arbitrariness and bias as much as possible.

How can objective and neutral projections be achieved, then? To put it in simple terms, it is necessary to use accurate actual statistics and make projections using a scientific methodology in order to achieve such projections. Clearly, the most objective projections at any given point in time can be achieved if the best data is used in combination with the best methodologies currently available. In order to make such projections, it is necessary to apply expert knowledge firmly rooted in the global perspective; yet, at the same time, it is equally necessary to be able to execute accountability to accurately convey the projection results and the basis on which they are grounded to the people who will be making use of them. Making sure to satisfy both these requirements is considered to be a major criterion when making official projections.

2) Population Projections as Prediction

Some might argue that the most important quality of population projections is that they "turn out to be true." If the population projections that serve as a baseline for planning the future social economy turn out to be wrong, it may result in wrong choices being made by the decision makers. For this reason, one might say that population projections should always be aimed at making the most correct guess of the future possible at any given time. This is a natural way of thinking, but it requires further consideration before it can be taken as a guiding principle for making projections in general. In order to discuss this point, it is first necessary to touch upon the subject of prediction in the context of social science.

Making "predictions" of population changes and other phenomena covered by social science is different from trying to foretell the future, which is known as forecasting. Unlike the orbit of a celestial body or the weather, a socio-economy changes continually due to the actions of humans within it, and thus such a thing as a pre-determined future at the present time simply does not exist. As a consequence, no scientific method that would allow one to correctly predict the future exists, either. That is to say, there are an infinite number of possibilities for future socio-economic developments depending on our future actions, and projecting such future developments is inherently different from the statistical estimation of the mean of some variables based on data samples. Namely, it is wrong to say that the true values to be projected are unknown; these values simply do not exist (yet). In particular, we humans often act consciously in such a way as to prevent undesirable projections from coming true.

Therefore, in general, the role of scientific prediction in the context of social science is not to foretell the future as such. Instead, the aim is to show what can happen in the future, based on scientifically reasonable premises. The exact same thing can be said for the population projections considered here as well. In this case, the current situations and trends of the events affecting population movement (birth, death and migration) are analyzed and used as premises for the projections.

3) Population Projections as Projection

Incidentally, countries worldwide use the term "projection" to formally refer to their population projections. Literally, this word means to clarify details of a small object at hand under scrutiny, illuminating it and projecting it onto a screen in front to obtain an enlarged view. Figuratively speaking, population projections can thus be understood as actions undertaken to closely study signs hidden in the most recent population movement in detail by projecting and enlarging them onto the screen called the future. As a matter of fact, in the "Population Projections for Japan" as well, assumed values are obtained by understanding the details of the current conditions and trends of population movement through analysis of actual statistics and projecting them toward the future. The figures in the "Population Projections for Japan" have been calculated based on such assumed values. Thus, it is safe to say that the "Population Projections for Japan" indicates the image of the population that may come to exist if our country continues to progress in the direction we are currently heading, which in turn may be used as a basis of reference when considering our actions toward the various future possibilities. Moreover, if the actual population developments are measured and start to show a course deviating from the population projections, the situation must clearly have changed in some way compared to when the projection was made, for instance due to new effects that have not been included in the premises or acceleration or deceleration of already observed trends. Actually, detecting such changes as they occur is another important role of population projections.[3]

4) Interpretation of Official Projections

So far, this report has discussed the difference between straightforward prediction of the future (forecast) and projections based on certain assumptions. Considering these differences, is it even possible to use population projections as prediction, then? Actually, it all depends on how the premises (assumptions) on which the projections are based are interpreted. That is, if the premises can be acknowledged as prediction, then the consequent population projections are also prediction. Conversely, if the premises are nothing more than hypotheses, then the resulting population projections must be considered as hypothetical as well. Thus, the true issue is what premises should be made when estimating the future population of Japan.

It is safe to say that premises other than those based on accurate actual statistics must necessarily contain arbitrariness in one form or the other, and this arbitrariness will carry over to the final analysis. It can also be said that among the different methods of setting assumptions based on actual statistics, the method of projecting the trends of demographic fluctuation factors into the future is the most natural, and thus a very objective way of setting assumptions. The "Population Projections for Japan" are also conducted based on this philosophy. The current social science does not have any desirable standards whose degree of objectivity exceeds the objectivity of the method used in "prediction" of population described above either. Therefore, the "Population Projections for Japan" are 2-faceted; on one hand they provide a "frozen image" of the population with fixed prior conditions, i.e., the population develops in the direction indicated by current actual statistics as is, yet on the other hand they illustrate the most objective image of the future population that can be obtained at the current moment.

5) Relationships with Dynamic States of Social Economy

In population projections, so-called demographic variables such as fertility rates, mortality rates and migration rates only are used as assumptions. The question is, is it all right to ignore economic fluctuations, changes in people's awareness and so on in doing so? In other words, what are the relationships between socio-economic dynamics and population projections? In this regard, it is wrong to say that the "Population Projections for Japan" does not reflect socio-economic dynamics. The assumed future developments of the vital events (deaths, births and migration), based on which the population projections are made, are themselves projections based on their actual developments, and these actual developments are data that already reflect changes in socio-economic environments. Therefore, results obtained by projecting such data can still be said to reflect some changes in socio-economic environments.

However, is it possible to incorporate economic fluctuations and changes of public awareness more explicitly, rather than through such indirect ways of reflection? The answer is that this is not practiced in existing official projections for three main reasons. Firstly, since it is not possible to incorporate all the numerous socio-economic factors that might have an impact on the future demographics, it becomes necessary to pick out certain factors and discard others. Clearly, such a selection of factors is necessarily subjective, and the arbitrariness caused by this conflicts with the principles of objectivity and neutrality, which are required of official population projections. Secondly, no sufficiently universal quantitative model linking the vital events and any socio-economic variables has been established so far. Thus, using a model that is known to be insufficient will increase the uncertainty of the projections. Thirdly, in order to reflect socio-economic changes in the projected population changes, it is necessary to project the socio-economic changes into the future as well. Under normal circumstances, doing so with sufficient precision is far more difficult than projecting individual population variables independently. For example, projecting such variables as economic trends and public awareness several decades into the future is considered far more difficult than projecting the total fertility rates and life expectancy. In fact, perspectives of labor force distributions, consumption trends and other major socio-economic factors are made based on population projections.

Unless the issues above are somehow solved, incorporating socio-economic changes explicitly in population projections is unlikely to contribute to the realization of the purposes of the projections.[4] To highlight this fact, it is noted that there are currently no official population projections that explicitly attempt to incorporate socio-economic changes into the population projections anywhere in the world, whether made by other countries' government institutions or by interna-tional organizations.

(3) Interpretation of Population Projections

1) Basic Interpretation of Population Projections

Having discussed the basic nature of population projections so far, this section summarizes how to interpret them. In general, population projections are used in order to obtain baselines or guidelines that can, in turn, be used to conceptualize future society. With this point in mind, the "Population Projections for Japan" can be interpreted as the population distribution that may be achieved if society continues to develop in the direction it is currently headed. Moreover, if the premises are acknowledged as predictions, the population projections can be interpreted as an prediction of the population distribution that will be achieved in the future. On the other hand, if the premises cannot be considered to be predictions, then the population projections are merely the result of a simulation. However, since the premises of projections project the trend of actual statistics, they can be said to represent the most objective future image of the population distribution at this particular moment in time, in the sense that they are the least arbitrary calculations that can be made.

Therefore, it is considered that the most appropriate usage of population projections is to use them as common standards or basic data when considering the most likely development in the future with various alternative scenarios. In the process of preparing plans for a long list of measures, marketing schemes, etc., in society, it is considered to be very beneficial to use the population projections as the standard in order to maintain consistency among such plans and ensure comparability among them.

2) Uncertainty of Projections and Interpretation of Projections based on Multiple Assumptions

Uncertainty is inherent to all population projections, but its causes are diverse. They can largely be divided into two types: uncertainty originating from the actual statistics used as basis and statistical methods and uncertainty related to the probability of the projected population development taking place. The former type is explained first. Assumed values used for the "Population Projections for Japan" are obtained by projecting trends of actual statistics into the future, but these projections do not necessarily result in a single accurate result, and the results should rather be understood as probable ranges depending on the specific interpretation of the trends and so forth. This is the reason why three fertility variant assumptions and three mortality variant assumptions are made.

For the fertility assumptions, the trends of four indexes related to reproductive behaviors (mean age of first marriage, lifetime proportion of never married, completed number of births from married couples and coefficient of divorce, bereavement and remarriage on fertility rates) are measured and projected into the future for each female generation. A probable range is determined for each of these indexes, and the combination of values that produces the highest fertility rate determines the assumption for the high-variant fertility and, conversely, the combination that produces the lowest fertility rate determines the assumption for the low-variant fertility (Table 1-1).

The mortality assumption, on the other hand, has been considered to be relatively stable in the past and hence only one assumption was made until this time. However, based on recent analyses of the development of mortality rate, it was decided to take uncertainty in the mortality assumption into account as well in the projections made in December 2006. A 99% confidence interval is calculated according to the distribution of statistical errors inherent in the actual evolution of the time-series indexes indicating mortality level,[5] and the upper mortality rate boundary is set as the assumption for the high-variant mortality while the lower mortality rate boundary is set as the assumption for the low-variant mortality.

By combining the aforementioned three fertility variant assumptions with the three mortality variant assumptions, a total of nine projection results are provided in the projections made in December 2006. Through the use of these assumptions, it is possible to address the uncertainty in the projection results to some extent. That is to say, by estimating the upper and lower boundaries projected from the current trends of the variables used in the assumptions while using the main projections based on the medium-variant fertility and medium-variant mortality as references, it is possible to provide certain safety margins that may be applied in a given application.

In the following, the projection results obtained by different combinations of assumptions are compared. For instance, looking at the population size, the combination of the high variant of fertility and low variant of mortality projections results in the largest population, while the combination of the low variant of fertility and high variant of mortality projections results in the smallest population. Using these values as the basis for projections, the span between the upper and lower bounds on the population size in 2055 becomes 17.15 million, which is equivalent to 19.1% of the population size, obtained by assuming the medium variants of both fertility and mortality.

Table 1-1 Assumptions of Four Indexes of Factors Influencing Fertility Rate in Population Projections for Japan (Made in December 2006)

Index of factors influencing fertility rate of women	Actual values 1955 cohort	Fertility rate assumption used in population projections 1990 cohort		
		Medium-variant fertility assumption	High-variant fertility assumption	Low-variant fertility assumption
(1) Mean age of first marriage (years old)	24.9	28.2	27.8	28.7
(2) Lifetime proportion of never married (%)	5.8	23.5	17.9	27.0
(3) Completed number of births from married couples	2.16	1.70	1.91	1.52
(4) Coefficient of divorce, bereavement and remarriage on fertility rates	0.952	0.925	0.938	0.918
Cohort total fertility rate (fertility rate limited to childbirth of Japanese women)	1.94	1.26 (1.20)	1.55 (1.47)	1.06 (1.02)

Note: The index factors influencing the fertility rate are all related to marriage and childbirth of Japanese women (not including marriage between non-Japanese women and Japanese men, as well as non-Japanese women giving birth to children with Japanese men as fathers). Note that the total fertility rates are the values defined by the "Vital Statistics" and the values limited to Japanese women are shown in parentheses. The coefficients of divorce, bereavement and remarriage on fertility rates indicate changes in the number of births due to these factors, and become equal to 1.0 if there is neither divorce, bereavement nor re-marriage.

Source: "Population Projections for Japan (December 2006)," National Institute of Population and Social Security Research

The proportion elderly, which indicates the degree of population aging (specifically, the proportion of the population of 65 years of age and over), on the other hand, obtains the largest value in case of projections obtained when assuming the low variants of both fertility and mortality. Conversely, the combination of high variants of both fertility and mortality yields the lowest degree of aging in the population. The proportion elderly in 2055 is 44.4% in the former case and 36.3% in the latter, resulting in a span of 8.1 percentage points.[6] In other words, the combinations of assumptions that yield the upper and lower boundaries on the projected values for the size of population are different from those for the proportion elderly. Thus, since the projections that yield the upper and lower boundaries are different from one population index to the next, it is always necessary to check the combination of assumptions that applies to a specific scenario when determining safety margins in projections.

Furthermore, when using multiple projections, there are other issues that must be considered in addition to the ones mentioned above; for example, the usage of the projections may be restricted because there is no quantitative information on the probability distributions among different projections. One of the methods to deal with these issues when using multiple projections is a method of presentation called probabilistic projections, which is introduced in Section 2 (4).

Note that, when using multiple projections, it is possible to evaluate the impacts of specific assumed values on the future population via mutual comparison. In particular, by comparing the constant assumption projections and the closed population projections (projections setting international migration to zero) shown in Chapter II of this report with the nine previously published projections, it is possible to analyze the significance of each assumption on the projected populations and measure their impact.

3) Other Projections Associated with the Population Projection for Japan (December 2006)

As mentioned above, the future projections made based on the "Population Projection for Japan" (December 2006) include "Population Projections by Prefecture" (projections in May 2007). The Japanese population changes in the future vary significantly among different regions and the trends have a strong relationship with various socio-economic dynamics as well. This particular projection attempts to predict the development of the population by prefecture until 2035. The

"Household Projections for Japan," which was published in March 2008, is a collection of future projections of the number of households in the nation. It predicts the development of various types of households, which are the basic units of livelihood and daily lives of the citizens as well as targets of numerous policy measures, until 2030. Moreover, the Household Projections for Japan by Prefecture will be published in the future. All these projection results are intended to be utilized as a baseline in planning various systems and measures under consideration by government authorities and autonomous bodies, and aim at providing the best possible scientific foundation for formation of future policies.

2. Commentary on Projection Results

(1) Mechanism of Population Decline – Prospecting the Century of Depopulation

Ever since the Meiji period, except for the war period, the total population of Japan has been increasing steadily at an average growth rate of 1% per year until 2004. However, between 2004 and 2008 the growth rate has been zero, and the Japanese population seems to have peaked in this period. In fact, from now on, the population will start showing negative growth, and this downward trend will undoubtedly continue for a long term. According to the projections corresponding to the medium variants of both fertility and mortality of the "Population Projection for Japan" (December 2006), the population size of 127.77 million as of 2005 will decrease to less than 100 million in 2046 and fall even further to below 90 million in 2055 (89.93 million). This corresponds to a decrease of approximately 38 million (29.6%) compared to the population in 2005, i.e., Japan will lose some 30% of its population in the coming 50 years. Continuing these extrapolations according to the reference values, the population will have dwindled down to 44.59 million in 2105, 100 years in the future, a mere 35% of the population in 2005. The population has never before in Japanese history shown such a constant decreasing trend for such a long period of time, literally making the 21st century a century of depopulation for Japan.

Of course, it is difficult to project as far as 50 or 100 years into the future, and it must be pointed out that there is no guarantee that the population will undergo such a radical change as described above. However, even with projections based on the high-variant fertility and low-variant mortality assumptions, corresponding to the upper boundary on the population development, the population is still projected to decrease by 22.1% by 2055 and 51% by 2105, indicating that a significant population decrease cannot be avoided. Actually, it can be said with a significantly high degree of certainty that the Japanese population will continue to decrease for a large part of the 21st century. In order to understand the reasons for this, it is necessary to understand two concepts related to the mechanism of population decrease: the population replacement level of fertility rate and the population momentum.

1) Population Replacement Level

Whether the population increases or decreases is determined by the number of births and deaths as well as quantity of migration (entries and exists). If it is assumed that there are no entries and exits,[7] the long-term increase/decrease of the population is determined by the levels of fertility and mortality. The level of fertility where the population neither increases nor decreases over an extended period of time under some fixed level of mortality is called the "population replacement level." For example, assuming the current level of mortality in Japan,[8] the population replacement level of the total fertility rate is just about 2.07.

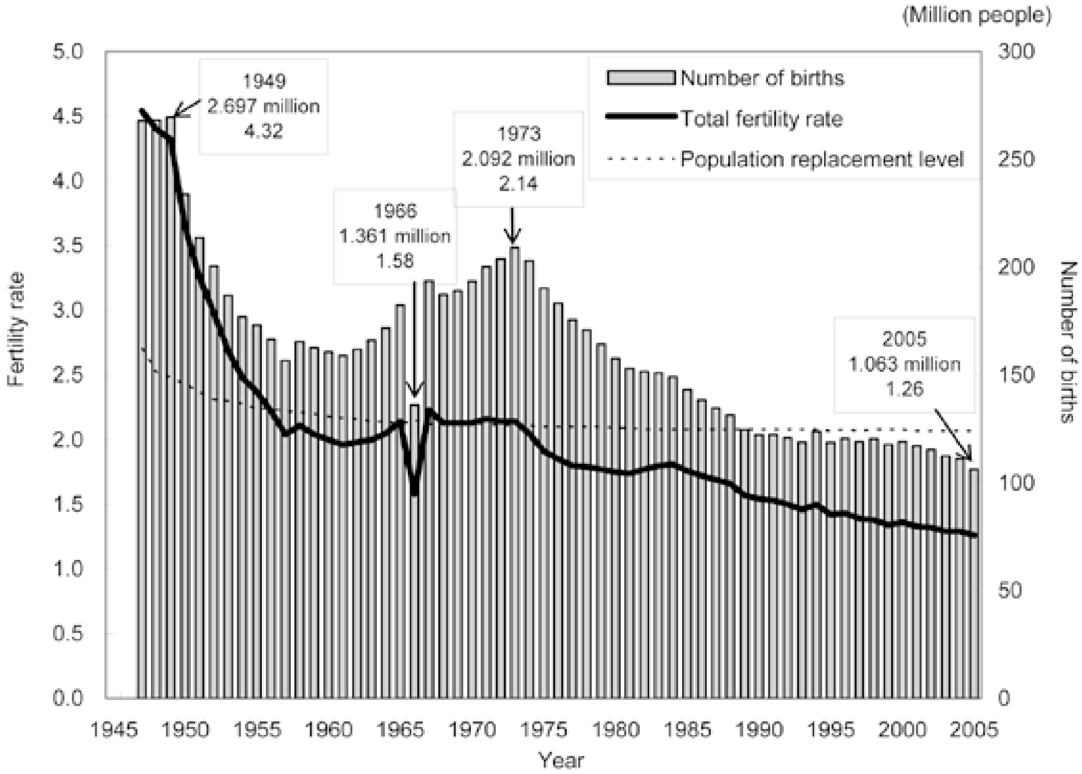
Figure 2-1 shows the past development of the number of births, the total fertility rate and the population replacement level of the total fertility rate in Japan. As can be seen from this figure, the fertility rate in Japan has been dropping ever since 1974 for more than 30 years, constantly remaining below the population replacement level. It is the very consequence hereof that Japan is entering a period of depopulation.

However, if the population decreases because the fertility rate drops below the population replacement level, another question naturally arises from this figure. If the fertility rate in Japan has been below the population replacement level consistently for more than 30 years in the past, why didn't the population start to decrease much earlier? Actually, the reason behind this observation is the key to obtaining a deeper understanding of the future population decrease. This mechanism, coinciding with the population structure, is known as population momentum.

2) Population Momentum

We first consider the case where the fertility rate is higher than the population replacement level and the population continues to increase. The Japanese population had followed such trends in the past and the majority of developing countries are still experiencing such conditions even now. Under these demographic conditions, even if the fertility rate suddenly drops to the population replacement level at some point in time, the size

Figure 2-1 Trends of Number of Births, Total Fertility Rate and Population



Sources: "Vital Statistics" by the Ministry of Health, Labour and Welfare and "Latest Demographic Statistics" by the National Institute of Population and Social Security Research

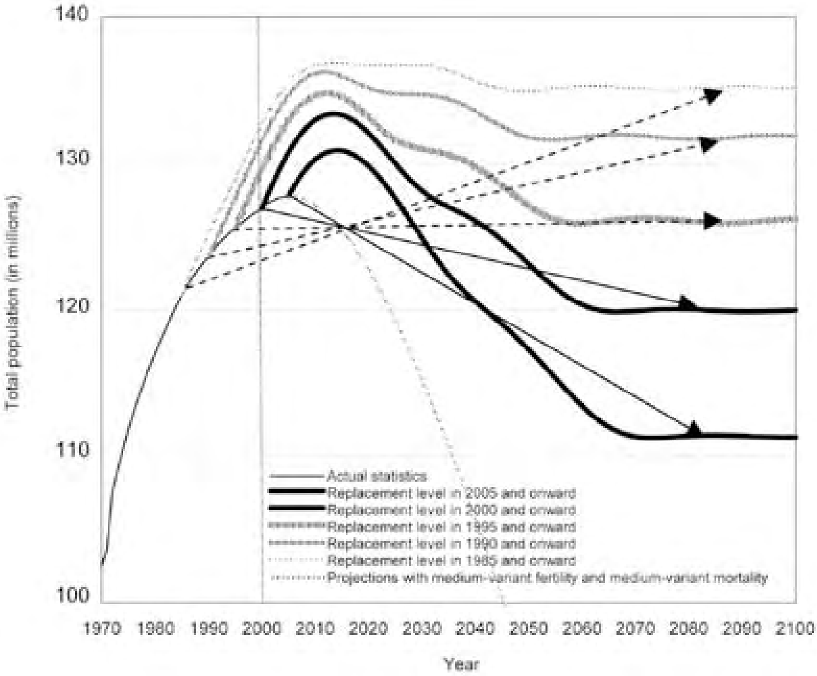
of the population will not level off and become constant immediately at that point. The population will continue to increase for a while and will not become constant until it reaches a significantly higher level. This phenomenon is a special characteristic that can be understood as a form of inertia in a growing population, and is referred to by the term "population momentum."

The true identity of population momentum is to be found in the structure of the population, i.e., the age structure of the population. More specifically, if the fertility rate exceeds the population replacement level for a prolonged period of time, the size of the population of the younger generations and those in the generations who become parents and give birth (female population in the reproductive age) will keep growing for a while. That is, even if the average number of children delivered per person decreases, the total number of newborn children may not decrease. In other words, even if the fertility rate of each generation (the rate at which women give live birth to children) drops below the level where each generation can no longer replace its own generation with their children, the structure of the population compensates for the lower fertility rate and prevents the population from decreasing immediately.

As a matter of fact, this population momentum has been working in Japan as well, which is demonstrated here through a counterfactual simulation. Figure 2-2 illustrates simulations of the population development in Japan in the cases where the fertility rate is abruptly set to the population replacement level at various points in time in the past (the mortality rate is assumed constant and the international migration rate is set to zero). The top graph in the figure shows the development of population in the case where the fertility rate is abruptly set to the population replacement level in 1985. As seen from the graph, the population does not stabilize at the level in 1985, but continues increasing to attain a level considerably higher than the population size in 1985, and then eventually converges to a constant level.

The development of the population with this inertia is observed in other cases where the replacement level is reached at other points in time as well. In other words, the Japanese population continued to increase due to the inertia in the upward direction built in the age structure during these periods even if the fertility rate were to drop below the population replacement level. In Japan, the fertility rate has been below the population replacement level for more than 30 years now, but the population kept on increasing until recently due to this mechanism.

Figure 2-2 Population Prospect if the Fertility Rate were Equal to the Population Replacement Level



Looking at Figure 2-2, it can furthermore be seen that the later the replacement level is reached, the lower the peak level reached afterwards and the lower the final convergence level of the population development becomes. This indicates that the population growth inertia, i.e., the population momentum, grew weaker with time. If the replacement level were reached in 1995 or later, the final convergence level would be even lower than the level at the starting point, although the fertility level was set to the population replacement level. This can be understood as the Japanese population beginning to have a negative inertia from that point in time and onward.[9]

3) Era of Negative Momentum

Table 2-1 shows the development of the population, stationary population obtained with the fertility rate at the replacement level, and population momentum (see footnote 11) since 1955. As can be seen, the population momentum kept decreasing throughout this period and dropped below 1 in the second half of the 1990s, where the downward trend picked up speed. This indicates that the size of the younger generation population shrunk as a result of a continuous low fertility rate for a prolonged period of time, and the number of births as a whole will no longer increase even if the number of births per person may recover. As shown here, an inertia opposite to that of the past, driving in the downward direction, has taken root in the age structure of the current Japanese population. We call this inertia a negative momentum.

Populations exhibiting such negative momentum are destined to shrink eventually, even if the fertility rate recovers to the replacement level. As we have already seen, the Japanese population entered the era of negative momentum already during the latter half of the 1990s, and we are now in a situation where, even if the fertility rate may recover somewhat, we cannot avoid a population decrease. This is the main reason why it was stated earlier that it is highly likely that the population will continue to decrease throughout the most part of the 21st century. As a matter of fact, even in the extremely unlikely case where the fertility rate recovers to the population replacement level in 2005 and onward and maintains that level afterward as well, the population will continue decreasing until the 2070s (Figure 2-2), at which point it will have shrunk to approximately 87% of the original population before stabilizing (Table 2-1). Thus, the conclusion is clear: Japan is facing an inevitable long-term population decrease.

(2) Evolution of Population Pyramid – Perspective of Aging Population

At the end of the day, the development of the population pyramid illustrates the structural change of future population more vividly than anything else (Figure 2-3). The figure shows that the middle-aged and elderly brackets represent the largest portion of the population as of 2005, but reflecting the ongoing low fertility in the future,

Table 2-1 Total Population, Size of Stationary Population and Ratio of Stationary Population (Population Momentum) by Year

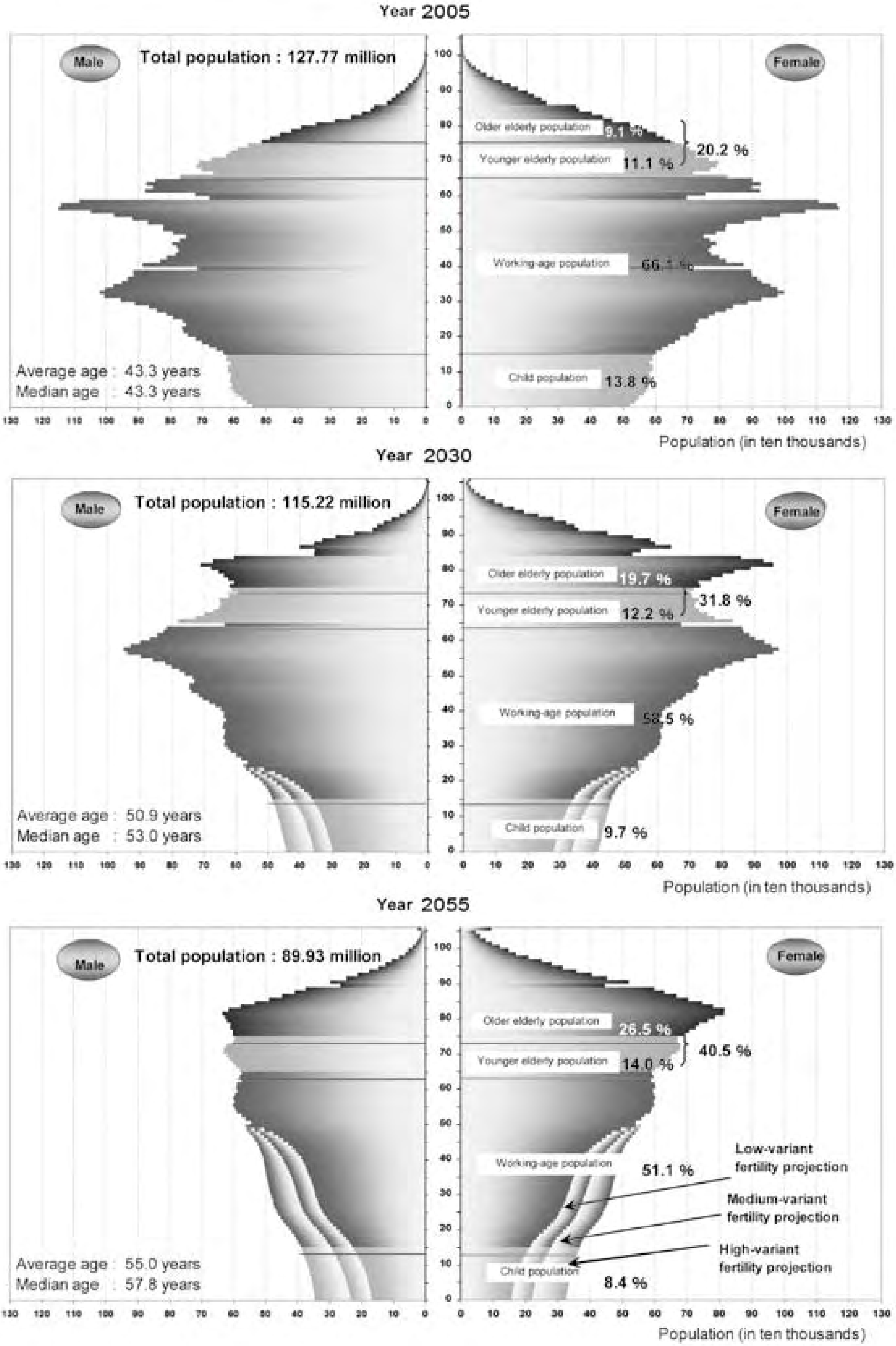
Year	Total population (in millions)	Size of stationary population (in millions)	Ratio of stationary population (population momentum)
1955	89.28	128.79	1.44
1960	93.42	129.42	1.39
1965	98.27	130.79	1.33
1970	103.72	133.19	1.28
1975	111.94	137.60	1.23
1980	117.06	136.49	1.17
1985	121.05	135.13	1.12
1990	123.61	131.79	1.07
1991	124.04	131.03	1.06
1992	124.45	130.01	1.04
1993	124.76	128.72	1.03
1994	125.03	127.85	1.02
1995	125.57	126.08	1.00
1996	125.86	125.75	1.00
1997	126.17	124.26	0.98
1998	126.49	122.94	0.97
1999	126.69	121.13	0.96
2000	126.93	119.97	0.95
2001	127.29	118.55	0.93
2002	127.44	117.35	0.92
2003	127.62	115.59	0.91
2004	127.69	113.93	0.89
2005	127.77	111.36	0.87

Note: This table expresses the population momentum of the Japanese population during each period as the ratio of stationary population (the ratio of the stationary population size achieved by setting the fertility ratio to the population replacement level and dividing by the total population size—simply called population momentum as well). The ratio is less than one (negative momentum) from 1996 and onward.

the shape gradually changes to have an increasingly narrow bottom. 50 years from now, the shape will be transformed into an inverted triangle with a very high center of mass, completely lacking stability – much like a pyramid balancing on its tip. The protrusion which can be seen for the second baby-boomer generation born in between 1971 and 1974, who are in the early 30s age group in 2005, will be in their late 50s in 2030 and in their early 80s in 2055, clearly illustrating how the entire population distribution is moving upward year by year.

The graphs in the figure show the results of three projections, combining the medium-variant mortality assumption with each of the three fertility variant assumptions, i.e., high, medium and low. Since the same mortality rate is assumed for each projection, the populations of 25 years of age or more in 2030 and 50 years of age or more in 2055 are common for the three projections.[10] For this reason, it can be seen that it is the future development of the fertility rate that changes the balance between young and elderly people in the population pyramid; in other words, it determines the degree of the overall aging of the population. In these two graphs, the bottom part of the pyramid exhibits a significantly different shape for each of the three fertility variant assumptions (arranged in the order of high-variant fertility, medium-variant fertility, and low-variant fertility projections from outside). According to these projections, the proportion of population elderly (65 years of age and over) in 2055 will be 40.5% in the medium-variant fertility projection, while the corresponding values are 37.3% and 43.4% in the high- and low-variant fertility projections, respectively, generating

Figure 2-3 Evolution of Population Pyramid: 2005, 2030 and 2055



Source: Same as for Table 1-1. The different profiles in the young generations are caused by differences in fertility assumptions (the medium-variant assumption is used for the mortality rate in all cases). Note that all the figures shown in the graphs are obtained by the medium-variant fertility (with medium-variant mortality) projection.

a span of approximately 6 percentage points between the upper and lower bounds (numerical values are indicated for the medium-variant fertility projection only in the graphs). To look at it differently, the proportion elderly (20.2% in 2005) can be expected to approximately double from 2005 to 2055 in all three scenarios. Even if we were to assume that the fertility rate will increase to a much higher level than today, given the current situation, Japan will be unable to avoid having the highest proportion elderly in the world; and the trend will continue.

As can be seen from the evolution of the population pyramid, the aging of Japanese population exhibits the following characteristics: although the total population will decline in the coming 50 years, the population size in the bracket of 65 years of age and older will in fact increase, while the population in the age brackets younger than that will decrease dramatically. As a matter of fact, according to the medium-variant fertility (with medium-variant mortality) projection, while the total population decreases by approximately 38 million, which corresponds to approximately 30% of the original population, the population of children under 15 years of age decreases by approximately 10 million and the working-age population from 15 to 64 years of age decreases by approximately 38 million, resulting in the population decline of 48.5 million people in total among the population below 65 years of age (48% of the original population of that age bracket). In other words, except for the elderly, the population will decrease by almost half in the coming 50 years. In contrast, the elderly population (65 years of age and over) shows an increase of 10.7 million people, which means that the elderly portion of the population grows by 41.5% compared to the same age bracket in the original population. The aging population explained above occurs as a result.

There are several other indexes that show the aging population, and one of them is the median age. This is the age at which the population is divided into two equal-sized groups. This takes a smaller value if the population is concentrated in the younger brackets and a higher value if the population concentrates in the elder brackets. As a matter of fact, in 1955, when the Japanese population pyramid used to exhibit a mountain shape, the median age of the Japanese population was 23.7 years (while the average age was 27.6 years). This means that half of the population was 23.7 years old or less, i.e., young people. On the contrary, the median age 50 years later, in 2005, is 43.3 years of age (the average age is also 43.3 years), corresponding to an increase of approximately 20 years, suggesting that the distribution of population in the younger brackets has become sparse. In the future, the median age will be 53.0 years (the average age will be 50.9 years) in 2030 and 57.8 years (the average age will be 55.0 years) in 2055, indicating that half of the population will be as old as the current retirement age or older 50 years into the future.

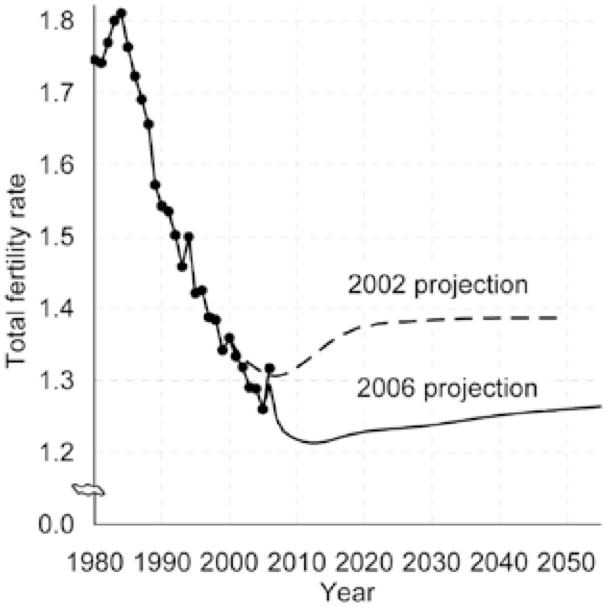
Coincidentally, the population size of 89.28 million in 1955—50 years ago—is approximately the same as the total population of 89.93 million in 2055 obtained by the medium-variant fertility (with medium-variant mortality) projection. That is, in the coming 50 years, the Japanese population will revert to the size it had approximately 50 years ago. However, the median age was 23.7 years in 1955 but will be 57.8 years in 2055, showing that the age structure will be completely different and that the population composition will definitely not go back to how it was. In addition, it must be considered that such turnovers in age structure necessarily must occur in any sub-aspect of the population as well. For example, in case of the labor market and consumer market, attention must be paid not only to the reduction of size, but also to the rapid aging that occurs within these markets.

(3) Effects of New Assumptions in the Population Projections

As explained above, population projections are calculated by making various assumptions on the future population development, i.e., births, deaths and international migrations. Moreover, when making new projections, the actual statistics announced after the previous projections were made are compared with various indexes assumed in previous projections, and the causes of deviations are analyzed in order to reflect the results when setting new assumptions. Therefore, differences between new assumed values and old assumed values reflect new developments in actual statistics observed in the period in between the projections.

On the other hand, differences between assumed values manifest themselves as differences in future population projected based on them. For this reason, analyzing the differences between the results of previous projections and new projections helps us understand the impact of recent changes in such factors on the future population. For example, if the fertility rate assumption is adjusted downward in accordance with the recent records, the future child population will be smaller than in the previous projections, both the pace of the population aging and the level achieved will increase, and the speed of population decrease

Figure 2-4 Comparison of Assumed Total Fertility Rates



Note: The vertical axis is enlarged to emphasize the differences.

will accelerate as well. Consequently, it is possible to measure the effects of recent new development in the fertility rate on the population changes by obtaining such population changes through comparison between the two projections. The same thing applies to other factors as well.

In this report, we compare the projections made in January 2002 (NIPSSR 2002)(abbreviated to “2002 projections”) and the projections made in December 2006 (NIPSSR 2007) (abbreviated to “2006 projections”) in order to analyze the effects of the recent development of vital rates, etc., that occurred between the points in time where these projections were made, on future population changes.

1) Comparison of Assumed Values between 2002 and 2006 Projections

First of all, the differences between the 2002 and 2006 projections are examined based on the medium-variant assumptions of the total fertility rate (hereinafter “fertility rate”) (Figure 2-4). In the 2002 projections, the fertility rate drops from the rate of the base year (2000), 1.36, down to 1.31 in 2007, but later shifts to an upward trend and reaches 1.32 in 2010 and 1.39 in 2050. The actual statistics until 2005, however, are lower than these assumed values: the difference was 0.05 in 2005. Note that the actual statistical value in 2006 jumped to 1.32, which was higher than the assumption. In contrast, the assumed values in the 2006 projections were based on the actual statistics for the previous five years and future fertility rates were projected to remain at levels lower than the previous projections. Compared to the 2002 projections, the fertility rate was set 0.10 lower for 2010, 0.15 for 2025, and 0.13 for 2050. This is because a steady reduction of the fertility was observed among the new generations in these 5 years, and various indexes were adjusted accordingly (explained in detail later).

Next, the life expectancies projected by the medium-variant mortality assumptions for the two projections are compared (Figure 2-5). The life expectancy has been showing consistent growth for both male and female populations in recent years, reaching 75.9 years for males and 81.9 years for females in 1990, and 77.7 years for males and 84.6 years for females in 2000. In the latter 1990s, however, the growing life expectancy began to show signs of slowing down (especially for the male cohort). For this reason, the changes were reflected in the 2002 projections and the life expectancy was assumed to be 80.95 years for males and 89.22 years for females in 2050. Subsequently, however, the actual statistics resumed the steady growth and developed at a pace that clearly exceeded the assumed values. Consequently, when these actual observations were incorporated in the 2006 projections, the life expectancy was projected to increase steadily to reach 83.37 years for males and 90.07 years for females in 2050. Various factors, such as a re-evaluation of basic theories related to improvement of mortality and extension of lifespan, influenced these assumptions (explained later). Note that, with this revision, the

Figure 2-5 Comparison of Assumed Life Expectancies

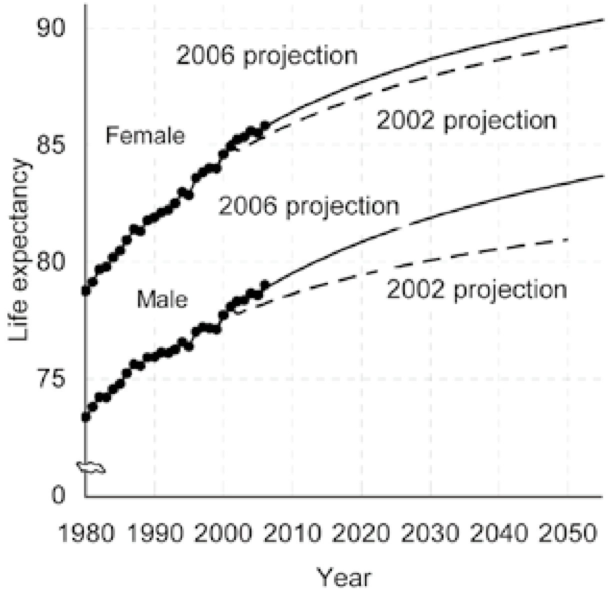
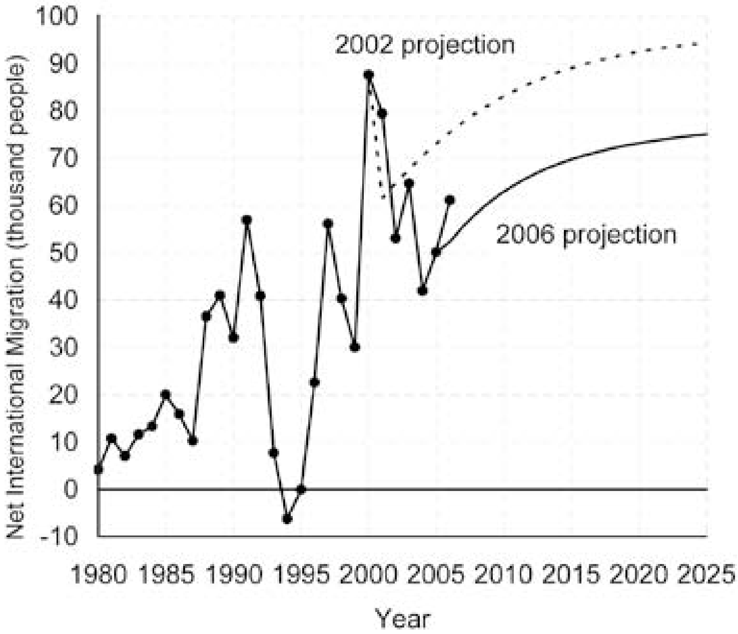


Figure 2-6 Comparison of Assumed Number of Net Migrants of Non-Japanese Origin



difference in life expectancies between males and females was revised from the broadening trend observed in the 2002 projections to the assumption that they will change in parallel with each other.

Looking at international migration, separate assumed values are set for both Japanese and non-Japanese; the net international migration rate is set by age group for the Japanese and the number of net international migration of all age brackets is set for the non-Japanese as a whole. In case of native Japanese, the international migration (obtained by computing the difference between the number of entries and exits) is extremely small, and its impact on population change is also small. For this reason, this report compares only the number of net migrants of non-Japanese origin (Figure 2-6). International migration has generally been on an upward trend since the 1980s, but started to show short-term fluctuations in the 1990s. The 2002 projections, drawing on the upward trend in latter 1990s, assumed that international migration would further increase in the long run to eventually exceed 90,000 people per year by 2025. However, the actual statistical development afterward peaked in 2000 and was since then on a downward trend until 2005. Note, however, that many factors causing short-term fluctuations have occurred in these 5 years, such as the 9/11 terrorist attacks (2001), the large-scale outburst of SARS (Severe Acute Respiratory Syndrome, became evident in 2003) and other temporary circumstances. Moreover, the influx of foreign nationals decreased further due to changes in laws and regulations; for example, the rules regarding acquisition of student visas by Chinese citizens were made stricter from the end of 2003.[11] For this reason, it was assumed in the 2006 projections that although the long-term upward trend will continue in the future, the number of international migration will decrease by approximately 20,000 people per year compared to the previous projections.

2) Impact of Assumed Values on Population Projections

The impact that the differences among the values assumed for each factor have on the size of the Japanese population is measured as follows. For each of the assumptions made in the 2002 projections, the future population is projected with the year 2005 as the base point rather than the original 2000, and the difference compared to the original population projection is obtained. Then, this difference is interpreted in terms of differences in the starting population, which in turn are caused by differences between the assumed values and actual statistics from 2000 to 2005.[12] Next, the population is projected using the assumptions of the 2006 projections for the fertility rate only and compared with the 2002 projections from the year 2005 and onward. The differences in this case are considered to have been caused solely by the difference in the fertility assumptions of the 2002 and 2006 projections. Moreover, by conducting similar comparisons for the mortality rate and international migration, the impact of the differences in assumptions on each factor can be measured. Note that this assumes that the methods used for the two projections are exactly the same. In reality, adjustments were made in the projection method and thus the impact of differences between such projection systems is included as a factor causing differences between the two projection results.[13] However, such impact is negligible, as shown below.

Table 2-2 Difference between New and Previous (January 2002) Projection Results and Factors Influencing Them: Year 2050

	Total population		0 to 14 years of age		15 to 64 years of age		65 years of age and over	
		Contribution (%)		Contribution (%)		Contribution (%)		Contribution (%)
	Population (in thousands)							
New projections[1)]	95,152		8,214		49,297		37,641	
Previous projection[2)]	100,593		10,842		53,889		35,863	
Difference from the previous projections[3)]	-5,442	-100.0	-2,627	-100.0	-4,592	-100.0	1,778	100.0
Difference caused by the starting population[4)]	-810	-14.9	-120	-4.6	-346	-7.5	-344	-19.4
Difference caused by assumed values[5)]	-4,743	-87.2	-2,436	-92.7	-4,412	-96.1	2,105	118.4
Fertility	-5,759	-105.8	-2,242	-85.3	-3,517	-76.6	0	0.0
Mortality	2,524	46.4	-4	-0.1	99	2.1	2,429	136.6
International migration	-1,509	-27.7	-191	-7.3	-994	-21.7	-324	-18.2
Population projection system[6)]	112	2.0	-71	-2.7	166	3.6	17	0.9
	Population ratio (%)							
New projections[1)]			8.6		51.8		39.6	
Previous projection[2)]			10.8		53.6		35.7	
Difference from the previous projections[3)]			-2.1	-100.0	-1.8	-100.0	3.9	100.0
Difference caused by the starting population[4)]			-0.0	-1.5	0.1	5.0	-0.1	-1.4
Difference caused by assumed values[5)]			-2.0	-94.4	-1.9	-106.0	3.9	99.6
Fertility			-1.7	-80.5	-0.5	-25.8	2.2	55.8
Mortality			-0.3	-12.5	-1.2	-69.6	1.5	38.3
International migration			-0.0	-1.4	-0.2	-10.7	0.2	5.6
Population projection system[6)]			-0.1	-4.1	0.0	1.0	0.1	1.8

1) December 2006 Projections [Medium-variant fertility (with medium-variant mortality)]
2) January 2002 Projections (Medium-variant)
3) New projections – previous projections
4) Difference caused by differences in the starting populations (previous projection: 2000 Population Census, new projections: 2005 Population Census)
5) Difference caused by differences in assumed values of the new and previous projections.
6) Difference caused by changes made to the population projection system

Finally, the differences between the populations estimated in the 2002 and 2006 projections are examined. First of all, looking at the population as of 2050, the 2002 projections estimated a total population of 100.593 million, whereas the corresponding result in the 2006 projections is 95.152 million, which is 5.442 million (5.4%) less. In other words, although both projections are based on medium-variant assumptions, the population is projected to be around 5% smaller in 2050 according to the new projections.

Looking at the breakdown of the factors causing this difference, the difference in the starting populations causes a deviation of -810,000 people (-14.9% of the total difference), differences in each assumed value causes a deviation of -4,743,000 people (-87.2% of the total), and the changes to the population projection system causes a deviation of 112,000 people (2.0% of the total, but in the direction of population growth) (Table 2-2). That is, the impact of adjusting the assumption settings brings about the most part of the difference between the two population projections (the aforementioned 5.4%).

Furthermore, looking at which assumption setting has the greatest impact on the difference between the population projections, it can be seen that the fertility assumption contributed -105.8%, the mortality assumption 46.4%, and the international migration assumption -27.7%. It can be determined that the impact of adjusting the fertility assumption contributed with a difference that is almost equivalent to the entire reduction of the projected population. On the contrary, the revision of the mortality assumption had the effect of increasing the projected size of the population. This is because a greater population is projected to live to more advanced ages due to a longer lifespan.

Next, the differences in age structure of the population are examined. First, the size of the child population (0 to 14 years of age) in 2050 was revised from 10.842 million to 8.480 million, and the proportion of children among the total population was changed from 10.8% to 8.6%. In this change, the impact of adjusting the fertility assumption is significant for both the actual number of children and for the proportion, contributing with 85.3% and 80.5% of the differences, respectively. In addition, the adjustment of the mortality assumption also had an impact on the decrease of the proportion of the child population (12.5%). This indicates that the elderly population increases due to improvement of mortality, and the proportion of the child population thus decreases in comparison.

The working-age population (15 to 64 years of age) was revised from 53.889 million to 49.297 million, corresponding to a decrease from 53.6% to 51.8% of the total population. Examining the difference in terms of the actual size of the working-age population first, the impact of adjusting the fertility assumption yields a contribution of 76.6%, while the impact of revising the international migration is 21.7%. However, of the 1.8 percentage-point difference in terms of the proportion of the working-age population to the total population, 69.6% can be accounted for by the unexpectedly large effect of the adjustment made to the mortality assumption, followed by the impact of the fertility assumption at 25.8% and international migration assumption at 10.7%.

Next, the elderly population (65 years of age and over) increased by 1,778,000 people, from 35.863 million to 37.641 million. The proportion of the elderly population also increased by 3.9 percentage points, from 35.7% to 39.6%. First, the factors contributing to the increase of the actual number of the elderly are examined. The change was mostly caused by the updated mortality assumption. The revision of the international migration assumption contributed only slightly in the direction to decrease the population. Note that the fertility assumptions have no impact on the population of 65 years of age and over (because the projected generations born according to the fertility assumptions would not have reached 65 years of age in 2050). The situation is different in case of the difference in the proportion of the elderly population (3.9 percentage points); here, the impact of adjusting the fertility assumption is the largest, showing a contribution of 55.8%, followed by the difference in mortality assumptions with a contribution of 38.3%. In general, there is a strong view that the aging of the population is caused by extension of lifespan, but this result shows that the level of aging varies significantly according to the assumption of future fertility rates.

(4) *Uncertainty of Population Projection and Provisional Probabilistic Projections*

Since the future development of birth, death, migration and other factors determining the future population is uncertain, the “Population Projections for Japan” has attempted to understand the future population development as likely ranges by setting three variants, “medium, high and low,” for the fertility assumptions, which are particularly uncertain. In the projections made in December 2006, it was judged that it became necessary to evaluate the uncertainty in the development of mortality rates (or life expectancy) as well, given the backdrop of recent changes in the pattern of mortality improvement. Three variant assumptions of the same kind as the fertility assumptions (high, medium and low) are set for the mortality assumptions, thus providing nine different population projections in combination with the fertility assumptions. Using these in comparison allows taking a broader look at the uncertainty of the future population caused by fluctuations in birth and death rates.

In population projections, such methods of setting multiple assumptions are considered to express the uncertainty of projection results explicitly. On the other hand, however, it is also pointed out that the probability of any given projection coming true and the confidence interval of the projection results are not clear. For example, projections based on combinations of extreme assumptions are considered to have a lower chance of coming true compared to projections using median assumptions, but to what degree this is so is not evident. If information regarding the degree of certainty of each projection result is available, such results may be used more effectively.

In relation to such issues, research into how to express the uncertainty of population projections using a methodology called "probabilistic projection" has recently been conducted. In this section, cases where one application of this methodology, the so-called expert opinion method, is used in population projections for Japan are introduced.

1) Method of Probabilistic Projections

The following probabilistic projection method is applied here. First, assumptions are set by probability for fertility and mortality (survivorship ratio), and projection simulations are then performed many times based on such assumptions, thereby allowing investigation of confidence intervals and other probabilistic characteristics related to future population. In the following, each process is explained in further detail.

First, for the projection period of 2005 to 2055, random numbers are used to generate life expectancy and total fertility rate (TFR) values for both men and women, such that they follow certain probability distributions. The probability distributions of life expectancy and total fertility rate used here determine the type of probabilistic projection. The probabilistic projection methods can be largely classified into expert argument-based method, methods using changes in actual index values, methods using errors of past projections and so on. In this section, the distribution of replies obtained from an expert survey (Takahashi 2005) conducted by a study group of the Ministry of Health, Labour and Welfare is used. Specifically, the distributions of estimated fertility, mortality, etc., obtained in the expert survey are used to adjust the assumed medium-variant fertility and medium-variant mortality, which are then used as new assumptions for the projection values.

Replies to surveys are typically subjective. On the other hand, comprehensive predictions may be obtained through such surveys, which incorporate the fluctuations that cannot be captured in objective statistical analyses as well as factors that could not be measured. Although there are limitations due to the subjective nature of the indexes, they can be assumed to reflect the collective opinions of the expert groups who have the insight into population development under the present set of circumstances.

Figure 2-7 shows the distribution of life expectancy predictions in 2050, to which the distribution of the experts' predictions is applied. Figure 2-8 shows the distribution for the total fertility rate predictions. (In both cases, some adjustment processing such as smoothing has been applied.)

Based on the life expectancy and TFR assumption distributions as of 2050 thus obtained, an assumption distribution over the entire projection period is plotted. Specifically, the average value of the assumption distribution of each year is matched with the assumption development of the projections in December 2006 (medium-variant

Figure 2-7 Distribution of Average Life Expectancy Predictions

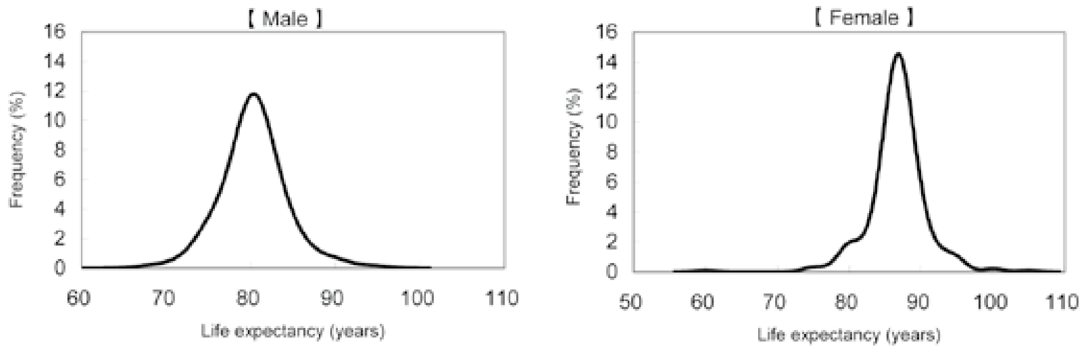


Figure 2-8 Distribution of Total Fertility Rate (TFR) Predictions

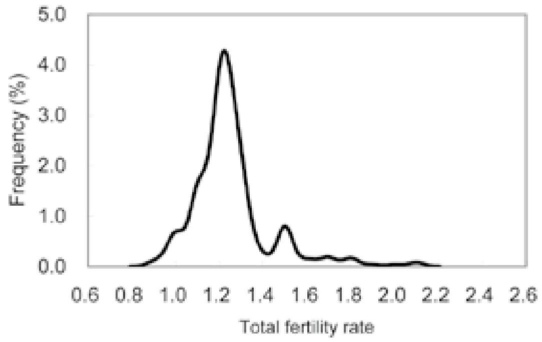
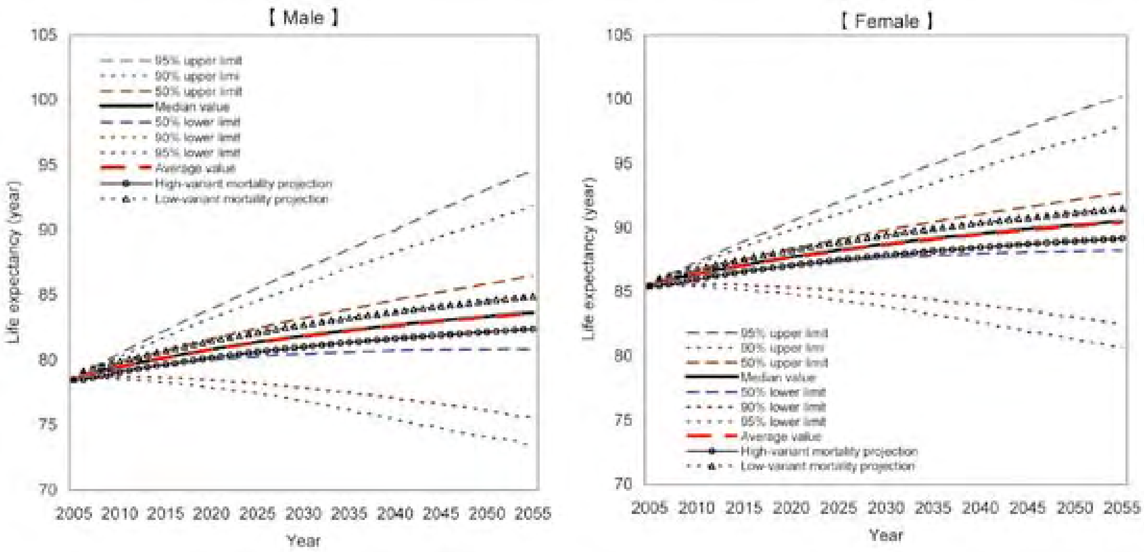


Figure 2-9 Yearly Development of Confidence Intervals of Life Expectancy



fertility and mortality rates). The coefficient of variance is set to zero for 2005 and to the value obtained from the expert survey for 2050, and the coefficients for the years in between are plotted by linear interpolation between these values. Note that for the assumed values in these years, auto-correlation coefficients obtained from the past actual statistics are used; thus, the values are allowed to develop while maintaining their own correlations. Finally, the original projection is used as is for international migration.

The generated life expectancy and TFR assumptions are paired and converted to the age-specific survivorship ratios and fertility rates year by year, and the future population is then projected by using the cohort component method as in the original projections. By making such projections many times (10,000 iterations here), the probabilistic distributions of assumption pairs and population projections can be obtained.

Figure 2-9 shows annual developments of the 50%, 90% and 95% confidence intervals for life expectancy *e*0, as well as the average and median values of the distributions. For comparison, the figure also shows the development of life expectancy with the high-mortality and low-mortality variant assumptions in the projections made in December 2006. The 50% confidence interval of the life expectancy in 2055 is 5.7 years (80.9 to 86.5) for males and 4.5 years (88.2 to 92.7) for females. The same values for the 95% confidence interval are 21.3 years (73.4 to 94.7) for males and 19.6 years (80.7 to 100.2) for females. Note that, for females, the life expectancy of 100 years is also within this 95% confidence interval. Furthermore, the difference of life expectancy between high-mortality and low-mortality variant assumptions in 2055 in the projections made in December 2006 is 2.52 years (82.41 to 84.93) for males and 2.34 years (89.17 to 91.51) for females, which are much narrower than the 50% confidence intervals above.[14]

Figure 2-10 shows the yearly development of the 50%, 90% and 95% confidence intervals for the total fertility rate (TFR), as well as the average and median values of the distributions. In the same way as above, the development of the high-fertility and low-fertility variant assumptions used in the projections made in December 2006 is shown together with the confidence intervals for easy comparison.

The confidence intervals of the total fertility rates in 2055 are as follows: the 50% confidence interval is 0.16 (1.15 to 1.31) and the 95% confidence interval is 0.89 (0.95 to 1.84). The difference of TFR between the high-fertility and low-fertility variant assumptions in 2055 in the projections made in December 2006 is 0.49 (1.06 to 1.55), which is wider than the 50% confident interval above, but narrower than the 95% confidence interval.[15]

Figure 2-10 Yearly Development of Confidence Intervals of TFR, etc.

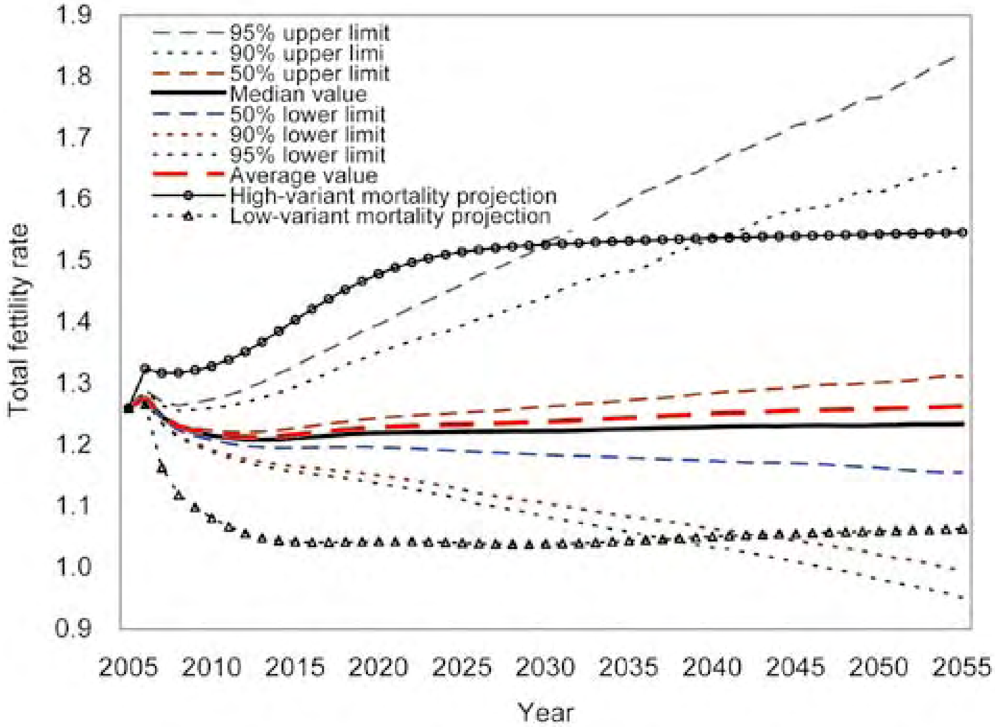


Figure 2-11 Confidence Intervals of the Total Population Projection Results

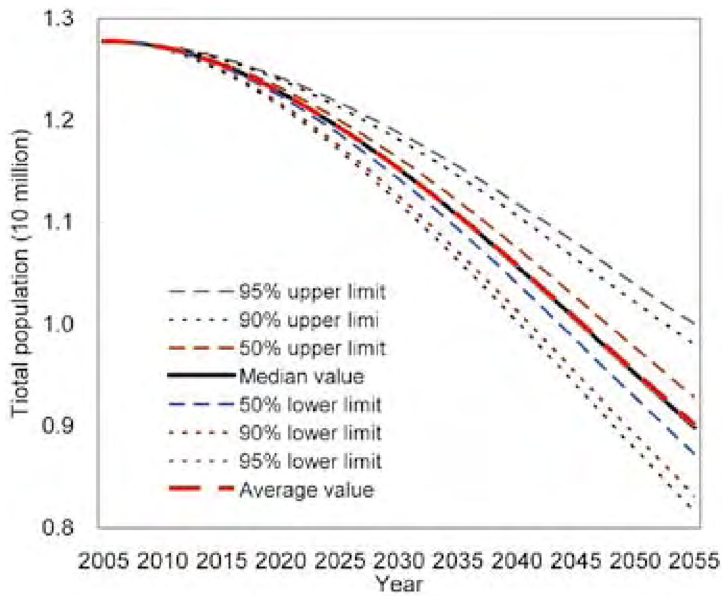
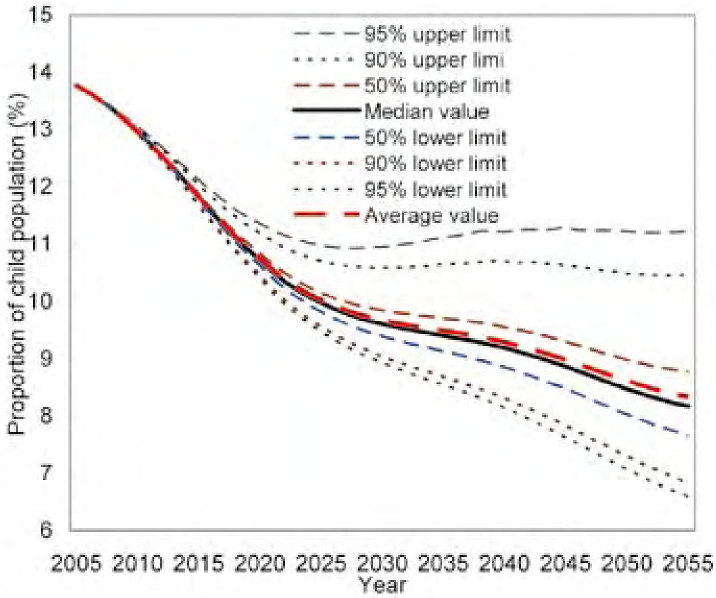


Figure 2-12 Confidence Intervals of Projection Results of Proportion of Child Population



2) Probabilistic Projections of Total Population and Proportion by Age Group

Figure 2-11 shows the results of total population projection. The further into the future the population is projected, the wider the confidence intervals of the projections become, illustrating the increasing uncertainty.[16] The 50% confidence interval of the total population in 2055 is 5.56 million (87.24 million to 92.8 million) and the 95% confidence interval is 18.43 million (81.60 million to 100.02 million). Since the basic philosophy behind the assumption settings of these projections is different from that of the projections made in December 2006, it is not possible to make an easy comparison. Nevertheless, the 2006 projections of the population as of 2055 yield estimates ranging from 99.52 million according to the high-fertility/low-mortality variant assumptions (largest population size), down to 82.38 million according to the low-fertility/high-mortality variant assumptions (smallest population size). Its span of 17.15 million is only slightly smaller than the 95% confidence interval of the probabilistic projections, and covers virtually the entire distribution of collective opinions of experts.[17]

On the other hand, looking at the projections of proportion of population by age group, the projections look different for each age group. First, the proportion of the child population is examined (Figure 2-12). The 50% confidence interval in 2055 is 1.1 percentage points (7.7% to 8.8%) and the 95% confidence interval is 4.6 percentage points (6.6% to 11.2%). In the projections made in December 2006, the proportion of the child population in 2055 is the highest (11.0%) with the high-fertility/high-mortality variant assumptions, which falls within the 95% confidence interval. In contrast, the same projection yields a proportion of 6.4% with the low-fertility/low-mortality variant assumptions, which is equal to or slightly lower than the lower limit of the 95% confidence interval. Its span of 4.6 percentage points, however, is equal to the 95% confidence interval and it can be said to cover virtually the same range.

Looking at the proportion of working-age population (Figure 2-13) in 2055, the 50% confidence interval is 2.1 percentage points (49.9% to 52.0%) and the 95% confidence interval is 7.2 percentage points (47.1% to 54.3%). The former interval is considerably narrow. In the projections made in December 2006, however, the proportion of the working-age population in 2055 is the highest (52.7%) with the high-fertility/high-mortality variant assumptions and the lowest (49.2%) with the low-fertility/low-mortality variant assumptions, and the difference of 3.5 percentage points is slightly wider than the 50% confidence interval.[18]

Looking at the proportion of the elderly population in 2055, which most clearly shows the progress of the aging population (Figure 2-14), the 50% confidence interval is 2.7 percentage points (39.3% to 42.1%) and the 95% confidence interval is 9.4 percentage points (36.2% to 45.5%). In the projections made in December 2006, the proportion of elderly population in 2055 is the highest (44.4%) with the low-fertility/low-mortality variant assumptions and the lowest (36.3%) with the high-fertility/high-mortality va-riant assumptions,

Figure 2-13 Confidence Intervals of Projection Results of Proportion of Working-age Population

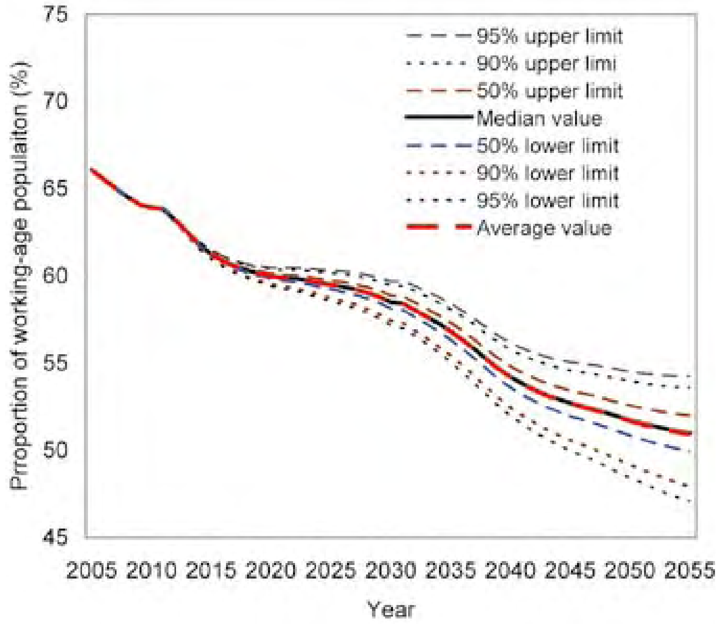
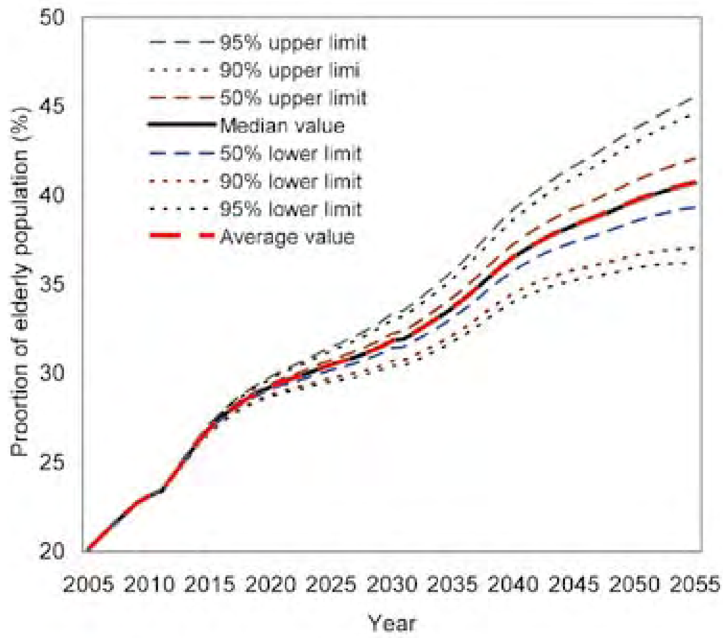


Figure 2-14 Confidence Intervals of Projection Results of Proportion of Elderly Population (Growth Rate of Aging Population)



and the difference of 8.1 percentage points is wider than the 50% confidence interval and close to the 95% confidence interval.

As already mentioned in Section 1, the future population will change reflecting the influence of future socio-economic developments, and it is thus intrinsically impossible to eliminate uncertainty entirely, whatever projection techniques one might employ. The report “Population Projections for Japan” has been expressing this uncertainty by providing projections as certain ranges based on investigation of changes of actual statistics of various indexes and theories and models considered predominant. It is hoped that users will take this point in account when using these multiple projection results and address the uncertainty in the course of utilization.

Additionally, if the probabilistic characteristics of the projected future population are available and, for example, statistical confidence intervals and similar information is presented, the scope of applicability of the "Population Projections for Japan" will broaden significantly.

From this point of view, researchers around the world are actively studying methodologies that allow probabilistic expression of population projections. The expert argument-based method introduced here is one such methodology. By applying this method to the Population Projections for Japan, we were able to obtain a glimpse of the potential applicability of probabilistic projections and, furthermore, were able to examine such issues as whether the range of existing projections is reasonable by comparing it to the distribution of current consensus of expert opinions. However, what we must keep in mind is that the future population, including its probabilistic characteristics, is not something we can predict at the present time, and the probabilities that are pre-sented with the projections do not express the probabilities of occurrence, as in the case of a weather forecast. We used the results of the expert survey as a substitute for the probabilistic characteristics of the future population, and any other method would be nothing more than a substitute as well. For this reason, probabilistic projections must be used only after thoroughly understanding the premises on which such probabilities stand. If such requirements are satisfied, however, the results of probabilistic projections may potentially be applied more widely and would no doubt be useful in various discussions.

3. Commentary on the Assumptions

(1) Meaning of the Total Fertility Rate 1.26

According to the medium-variant fertility projections of the "Population Projections for Japan" (December 2006), it is assumed that the total fertility rate, which was 1.26 in 2005, will gradually decrease to 1.21 in 2013, and then shift to a slight upward trend, reaching 1.26 again by 2055. Such development of the fertility rate seems to indicate that in the future, the downward trend of fertility will hit its lowest point and then remain stable. Is this actually true?

Looking back on the past statistics, the Japanese total fertility rate had fallen below the population replacement level (2.11 at that time) in 1974 and since then has shown a dramatic drop to the recent level of under 1.3. Compared to such rapid changes, the changes in the total fertility rate predicted for the future may seem insignificant. In fact, some people might even be under the impression that the falling birthrate is already a phenomenon of the past. However, contrary to the impression people may get from the movement of such indexes, it is from now on that the changes in behaviors concerning childbearing would truly manifest themselves in a fundamental way. A total fertility rate of 1.26 in 2055 has significance completely different from the fact of the same rate being 1.26 in 2005. The following examines the mechanisms of changes in births in order to uncover the differences in reproductive behaviors that are concealed behind the same total fertility rate at different points in time.

1) Period Total Fertility Rate and Cohort Total Fertility Rate

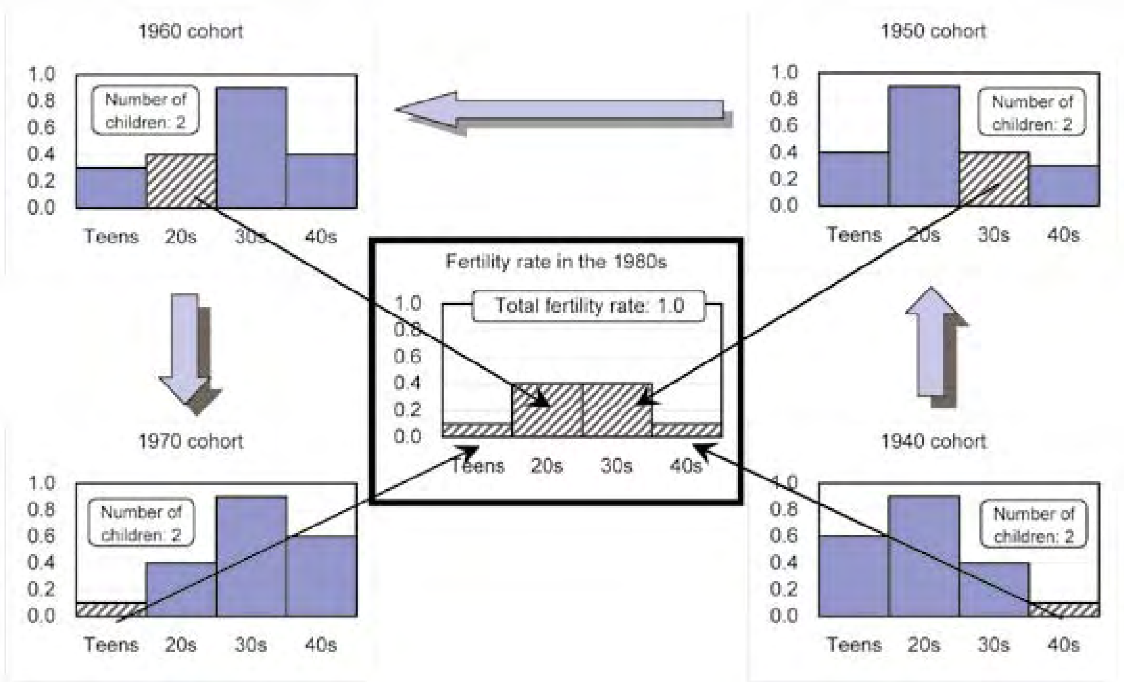
The total fertility rate is the sum of age-specific fertility rates of women from 15 to 49 years of age. Under normal circumstances, the sum of age-specific fertility rates observed in a certain year is calculated. To be precise, this value is called a period total fertility rate. Aside from this, there is another index that sums age-specific fertility rates experienced by women in a certain generation (i.e., belonging to the same birth cohort) from 15 to 49 years of age: the cohort total fertility rate. As a matter of fact, this value matches the average number of children women in the generation give birth to in their entire lives (completed number of births).[19]

Let us consider the period total fertility rate again. The entire population of 15 to 49-year-old women in a certain year (2005, for example) is comprised of generations in all childbearing phases, i.e., the young generation of women who are just starting to bear children, the generation of women entering the so-called childbirth rush, as well as the generations that are finishing childbearing. Summing these age-specific fertility rates is equivalent to connecting the childbirths of many generations living in that year and may be regarded as a snapshot observation of a "virtual life". In other words, if a hypothetical generation of women goes through their lives subject to the childbearing behavior of women in a single given year, the period total fertility rate would be the average number of children borne by such generation. This is a simple interpretation of the period total fertility rates. Here, however, it should be noted that the notion of such a generation is an absolutely imaginary concept.

2) Drop of Period Total Fertility Rate due to Postponed Childbirth

The period total fertility rate in Japan has been

Figure 3-1 Structure of the Total Fertility Rate in the 1980s: Development of Delayed Childbearing



Note: The fertility rate in a certain year (1980 in this example) is composed from the age-specific fertility rates of multiple generations.

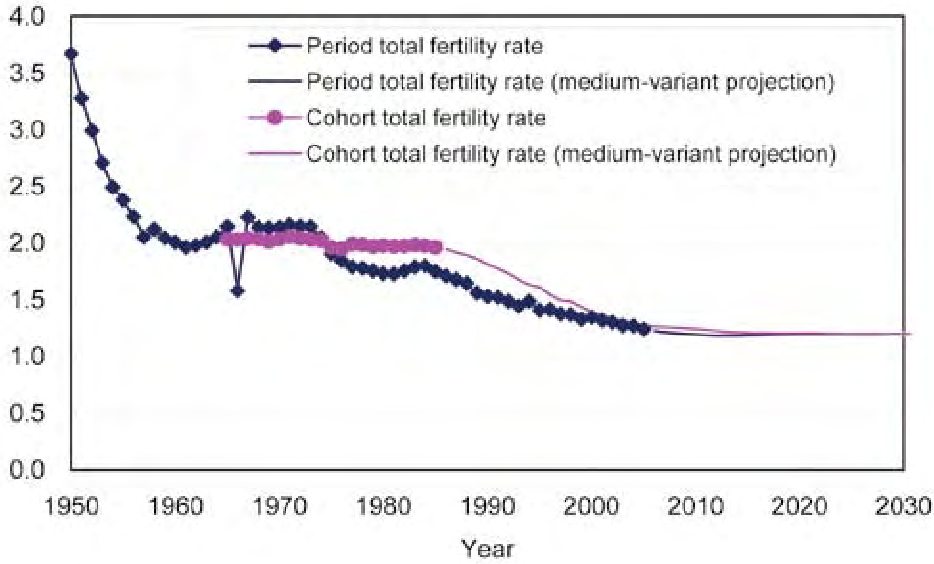
dropping since the middle of 1970s. The drop since that time is worthy of note because it fell consistently below the population replacement level. What happened to the age-specific fertility rates during the same period, then? This can be examined by pattern diagrams. The central graph of Figure 3-1 shows the age-specific fertility rates in the 1980s. The four graphs surrounding the graph in the center illustrate the age-specific fertility rates in the entire lives of the four generations who were in reproductive ages at the time. The situations are slightly exaggerated in the figures to facilitate understanding.

What is interesting here is that for all the generations, the sum of each of the age-specific fertility rates, i.e., the cohort total fertility rate, is 2.0. Looking at the age-specific fertility rates of each generation in detail, however, it is found that women born in the 1940s and 1950s entered their peak reproduction period while they were in their teens and 20s, whereas the peak reproduction period of women born in the 1960s and 1970s shifted to the 30s and 40s. That is, it can be seen that while the number of children borne by women in their entire lives are the same from the 1940 cohort to 1970 cohort, the later generations tend to bear children at significantly later ages (delayed childbearing).

Now, the period total fertility rate in the 1980s is obtained by combining and summing the age-specific fertility rates of these generations. In the graph in the center, only the lower age-specific fertility rates of the 1940 and 1950 cohorts who have already passed their reproductive peak as well as the 1960 and 1970 cohorts, who have not yet entered their peak reproductive period, are selected, yielding a total value of 1.0. Although all the women belonging to these reproductive cohorts give birth to two children on average in their entire lives, the period total fertility rate in the 1980s is significantly below that number. Hence, as mentioned above, the age-specific fertility rates in 1980s shown in the graph in the center indicate how women give birth to children in that year, but a generation of women who actually spent their whole lives following such child-bearing behavior do not exist.

As this example illustrates, the period total fertility rate has a tendency of causing large fluctuations in the time series even when there are no actual changes in the total number of children delivered by each generation, as in cases where the patterns in the childbearing ages are different from generation to generation. As a matter of fact, the sharp drop in the period total fertility rate from the latter half of the 1970s to the latter half of the 1980s could basically be explained away with this mechanism. Due to the increase in the proportion

Figure 3-2 Period Total Fertility Rate and Cohort Total Fertility Rate



Note: The figure shows the yearly development of the period total fertility rate and the cohort total fertility rate of the group of women who were 30 years of age in the corresponding year. The fertility rates are calculated for Japanese females only.

of women pursuing higher education and other factors, the events of first marriage and birth of the first child, which used to occur while the women were in their early 20s, have gradually become postponed to their later 20s. As a consequence, the period total fertility rate had fallen below the cohort total fertility rate.

Figure 3-2 shows the yearly development of the period total fertility rate, super-imposed with the cohort total fertility rate of the generation who was 30 years of age in the corresponding year (from a certain point, the cohort total fertility rates shown are projections based on medium-variant assumptions). From this graph, it can be seen that although the cohort total fertility rate shows little change until latter 1980s, the period total fertility rate drops significantly below 2.0. Although the cohort total fertility rate later shows a drop as well, its level is consistently above the period total fertility rate. Such differences used to be caused by younger generations bearing children at later ages, and the trend was such that the gap would have closed (the period fertility rate would recover to the cohort fertility rate) if the delayed childbearing trend were stopped. From around 2000, however, the gap started to close due to the drop in the cohort fertility rate. The reason for this is explained later.

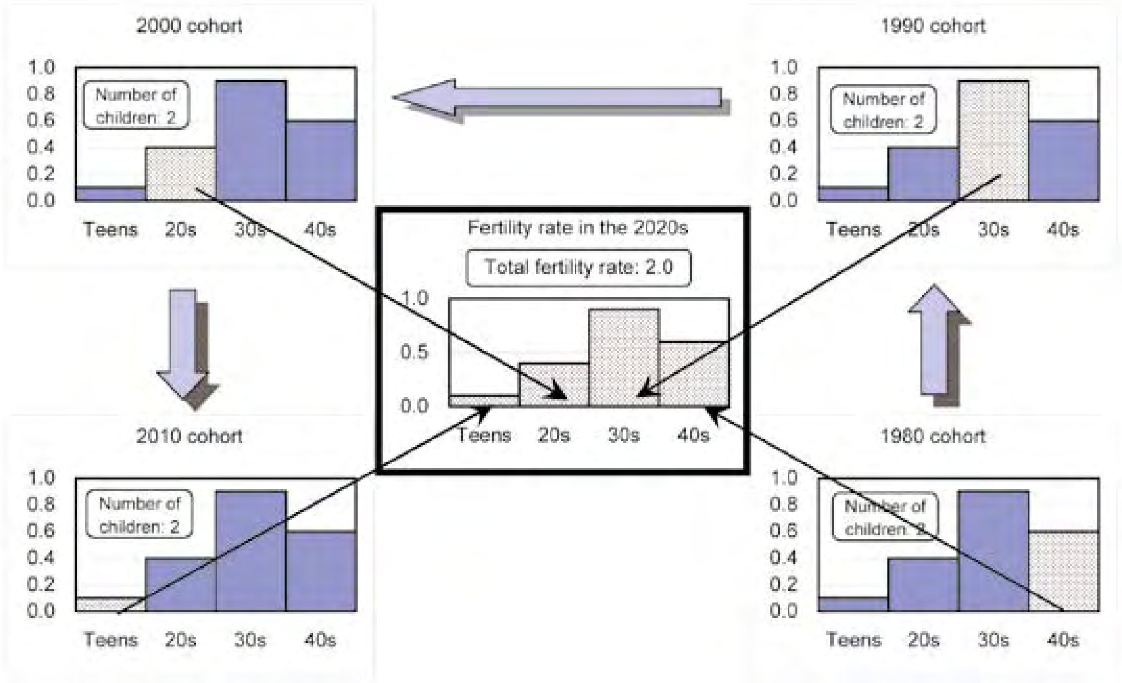
3) Rebound and Increase of the Period Total Fertility Rate due to Recuperation

The fall of the period total fertility rate caused by postponing of childbirth seen among young generations in their early 20s was observed in almost all developed countries since the 1960s, mainly in Europe. In most countries, however, the generations who postponed birth in their young ages started to have children after entering the latter half of the childbearing ages and the total fertility rate increased again. This mechanism is further illustrated by pattern diagrams.

Figure 3-3 shows the same picture as Figure 3-1, but this time it is assumed that the trend of delayed childbearing has already taken root. In the generations appearing during this period, it is assumed that women bear children at a later age than in the past generations, but the number of children they deliver throughout their entire lives does not change. Then, all the generations show similar delayed childbearing patterns and thus the age-specific fertility rates of the period become equal to the cohort age-specific fertility rates. It can thus be seen that the period total fertility rate, which is the sum of all the rates, has recovered to the same level as the cohort total fertility rate.

In the countries that experienced a drop in the period total fertility rate in the 1980s, such as France, Denmark, Netherlands and other countries, the rate rebounded and increased during the 1990s, and little change was observed in their cohort total fertility rates. Most of the changes can be explained by the mechanism of changes of childbearing timing, i.e., postponing of childbirth and recuperation.

Figure 3-3 Structure of the Total Fertility Rate in the 2020s: Established Delayed Childbearing (France, Denmark, Netherlands etc.)



Note: This is a virtual scenario simulating the fertility rate structure in 2020. It is composed from age-specific fertility rates of multiple generations.

4) Period Total Fertility Rate not Rebounding

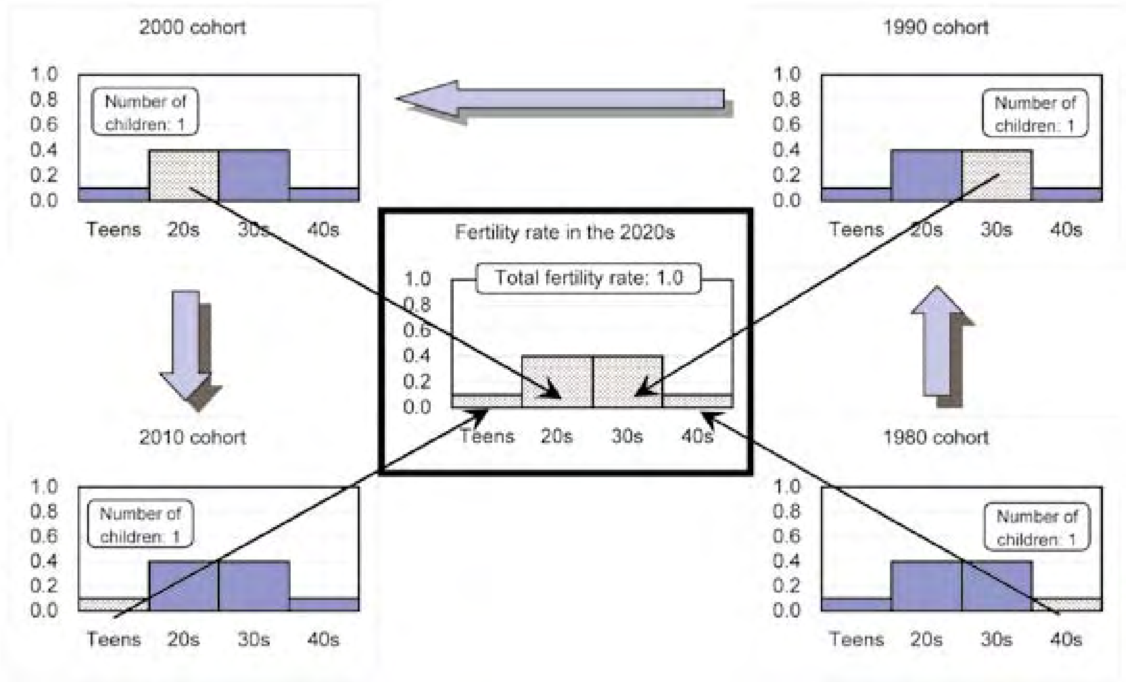
Unlike the aforementioned countries, however, the total fertility rate of Japan is projected (based on medium-variant fertility assumptions) to remain at the current level, with little increase in the future. What situation does this represent? In Figure 3-2 above, it was confirmed that the cohort total fertility rate is dropping to a level close to the period total fertility rate in recent years. This means that the situation in Japan is fundamentally different from the aforementioned countries where the fertility rate recovered. That is, in Japan, not only is the age of childbearing women higher, but the number of children delivered throughout their entire lives is also decreasing.

The period total fertility rate shown in the graph in the center of Figure 3-4 is at the same level (approximately 1.0) as in the graph displaying the situation in the 1980s shown in Figure 3-1. Looking at the generations composing the total fertility rate, however, the cohort total fertility rate is 1.0 in all the generations. In this situation, the mechanism observed in the aforementioned European countries, where the trend of delayed childbearing ends and the fertility rate recovers, does not work. Unless the cohort total fertility rate itself recovers, the period total fertility rate will remain low for an indeterminate time to come.

The situation projected in 2055, using the medium-variant fertility assumptions in the projections made in December 2006, signifies that the levels of cohort total fertility rates of all the generations involved are extremely low. From the point of view of population reproduction, the total fertility rate remaining at 1.26 for a prolonged period of time means that the replacement capability is only 61% of the required population replacement level of 2.07. In other words, with each generation (approximately 30 years), the population will shrink to 61% of the size it had at the start of that generation. If this situation continues for several generations, the population will clearly shrink very rapidly. This trend may be easier to understand if it is presented in terms of how the daily lives of Japanese citizens change, rather than in terms of macro-effects.

In the past, Japanese society has maintained a structure where the ratio of women without children was only around 10% and the average completed number of births from married couples was 2 children or more. In the future demographics projected by the medium-variant fertility assumptions, the ratio of women without children is a little less than 40% (37.4%) and the average completed number of births from married couples drops below 1.7 children. As can be understood from these figures, the period total fertility rate remaining at the current low level for a prolonged

Figure 3-4 Structure of the Total Fertility Rate in the 2020s: Fixed Low Birth Rate (Japan)



Note: This is a virtual scenario simulating the fertility rate structure in 2020. It is composed from age-specific fertility rates of multiple generations.

period of time does not signify that the situations surrounding childbearing and family patterns stabilize. Rather, it suggests a society with the highest ratio of childless women in the history of the world. This point is examined in more detail in (5) in this section.

(2) Why the Life Expectancy Keeps on Growing

According to the medium-variant mortality assumptions of the "Population Projections for Japan (December 2006)," the life expectancy in Japan is projected to keep on growing and reach 83.67 years for males and 90.34 years for females in 2055, which is approximately 5 years higher than that of 2005 for both cohorts.[20] There are various views on the future developments of life expectancy in Japan, where the longevity is increasing and life expectancy remains among the highest in the world. Some people believe that further extension cannot be expected, while others claim that the life expectancy will continue to grow at an accelerating rate due to future advancement of medical technology and other factors. This section explains the nature of mortality projections of the "Population Projections for Japan" and the reason why the projections anticipate that life expectancy keeps on growing in the future as well.

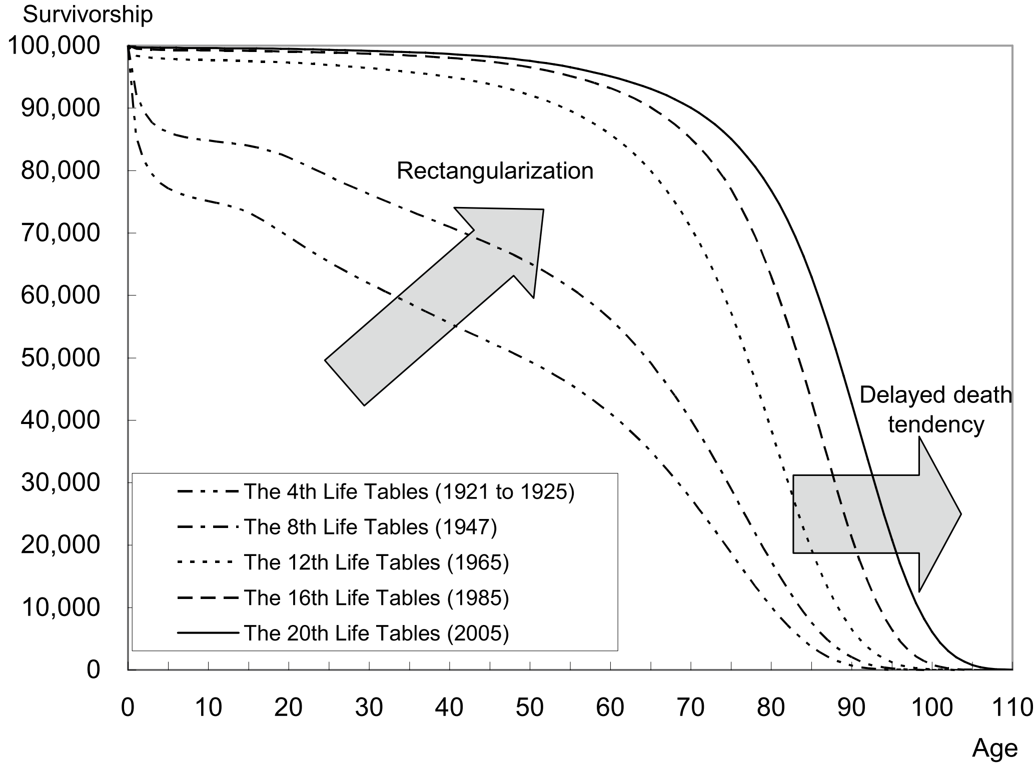
1) Population Projection and Life Expectancy

Official population projections serve as a baseline for a variety of purposes. One of the most notable applications is planning of various legal and socio-economic measures, and thus the greatest possible degree of objectivity and neutrality is required. For this reason, various indexes are projected using a methodology where the actual development of demographic data is projected into the future, which means that the projections of life expectancy are also obtained by projecting the development of mortality rate data of the past into the future. That is to say, they do not reflect arbitrary views on the future life expectancy, such as irregularity in expectations. On the other hand, however, when calculating the projections, it is necessary to accurately assess changes in mortality trends from the past to the present and construct models according to certain specific theories. In order to do so, a clear viewpoint on how the life expectancy should be interpreted in a demographic context is required.

2) Argument of Limited Lifespan and Mortality Rate Models

In the past, the predominant view among experts was that lifespan is biologically determined and therefore a ceiling exists for each species; thus, even if the living conditions continue to improve, the growth of human life expectancy will eventually slow down as it approaches its limit. If lifespan is indeed limited in this way, the logical

Figure 3-5 Development of Survivorship Curve (Women)



Source: "Life Tables" by the Ministry of Health, Labour and Welfare

consequence will be that eventually no people in the young demographic groups would die; instead, most of the people would die in their old ages near this natural limit. The survivorship curves in the life table would gradually become rectangular, a tendency known as "rectangularization." Figure 3-5 shows the development of the female survivorship curve in Japan. It clearly shows signs of rectangularization and also illustrates the extension of life expectancy. It is safe to say that such demographic developments used to support the argument that there is a biological limitation to the human lifespan.

However, observing the recent movement of the survivorship curves, it is seen that the age at which the survivorship rate drops is in fact shifting higher up in the elderly demographic group. This phenomenon, which can be called a "delayed death tendency," naturally gave rise to questions regarding the theory of limited lifespan. More and more, theories maintaining that there are no biological limitations on a lifespan or even if a limit does exist, that it will come much later than conventionally assumed, have begun to be seen as increasingly viable. Specifically, such theories seem to be supported by the facts that the mortality rates of the elderly, which were not expected to drop significantly, are dropping dramatically, and in Japan, Sweden and other countries with low mortality rates, the recorded maximum age at death has been replaced over time.

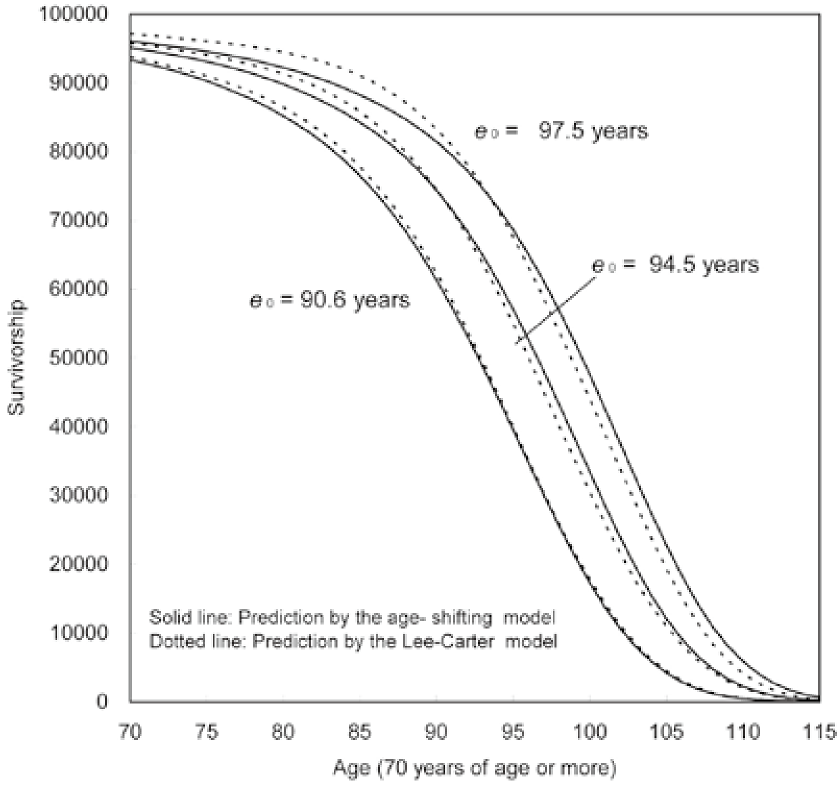
Such facts and theories provide important suggestions on models to be used in demographic projections of life expectancy in the population projections. The observation above indicates that a plausible model must be able to properly take the delayed death tendency into account at projection. In the projections made in December 2006, a new model was developed with that specific aim in mind. In the following, the points that were improved significantly in the mortality rate projection model used this time will be explained.

3) Development of Age-shifting Model

Taking the starting point in the Lee-Carter model, which is an international standard and used in the projections made in January in 2002 as well, we developed a new model that incorporated a new "age shift" interpretation of the mortality rate curves. The mortality rate model used for the projection of this study is thus able to express the phenomenon of delayed death tendency explicitly. In order to see the differences between the Lee-Carter model and the new model, the results of projections obtained using the two different models are compared.

Figure 3-6 compares the survivorship curves projected by the Lee-Carter model and

Figure 3-6 Comparison of Survivorship Curves by Two Types of Mortality Rate Models



the survivorship curves projected by the model improved by incorporating the age shift concept, assuming the same level of life expectancy. With the former model, it is clearly evident that the improvement of the mortality rates manifests itself strongly as the "rectangularization" trend in the survivorship curves, even with the same level of life expectancy. On the other hand, the age-shifting model expresses the improvement of mortality rates as a gradual shifting of the survivorship curves toward the right, better reproducing the improvement pattern of the actually observed mortality rates in recent years.

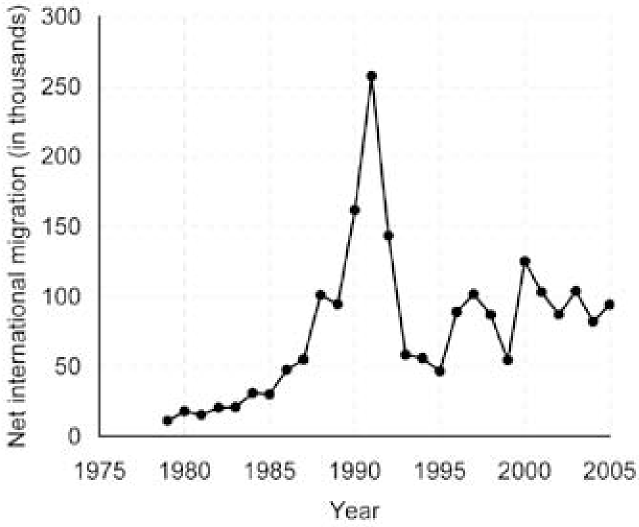
In case of Japan, which boasts one of the highest life expectancies in the world, it is necessary to develop new technologies to accurately capture such new trends, in addition to the technologies employed by other countries and international organizations. In the projections made in December 2006, the life expectancy was projected based on newly obtained statistical data and the significantly improved new model. As a result, projection results indicating that the life expectancy of Japan will continue to grow in the future were obtained. Thus, the hypothesis that Japan had already reached the limit of longevity is firmly rejected based on current statistical data. On the other hand, such new development of mortality rate improvement give rise to greater quantitative uncertainty, in particular regarding how much the life expectancy will have grown by a given year in the future. In fact, this is the main reason why high-variant and low-variant assumptions, in addition to the medium-variant assumptions, were set for the mortality rate as well in this projection.

(3) Assumptions of International Migration and their Effects

There are no universal models for setting assumptions regarding international migration. Internal migration fluctuates significantly with the advancement of globalization and economical fluctuations and is also affected by policies and conditions of both the country of origin and the destination country. For this reason, in case of assumption settings for population projections for Japan, the population is first divided into Japanese and non-Japanese, migration trends including countries of origin/destination, areas and differences according to sex are observed closely for each group, and finally mid- to long-term trends are captured and projected into the future. The outline of the trends of migration used for the assumption settings is given here.

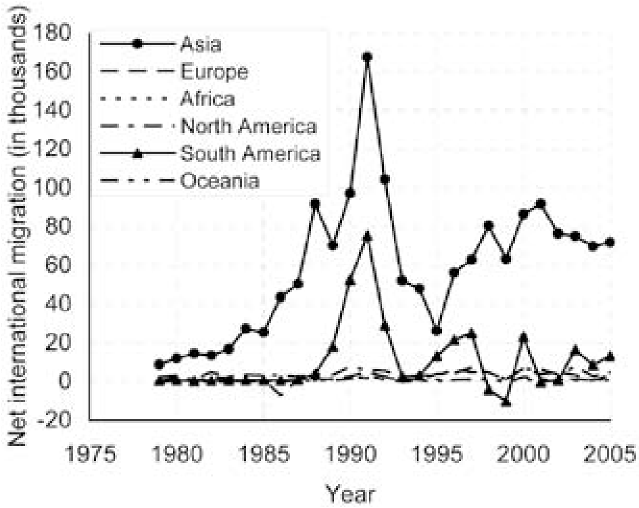
Moreover, in the projections made in December 2006, new assumptions regarding nationality

Figure 3-7 Net Migrants of Non Japanese Origin



Source: "Immigration Control Statistics" by the Ministry of Justice

Figure 3-8 Net Migrants of Non-Japanese Origin by Continent



Source: "Immigration Control Statistics" by the Ministry of Justice

change (naturalization and expatriation) between the Japanese and the foreign nationals living in Japan were set as well, based on actual statistics, and reflected in the projections for the sake of precision. These trends are also explained here.

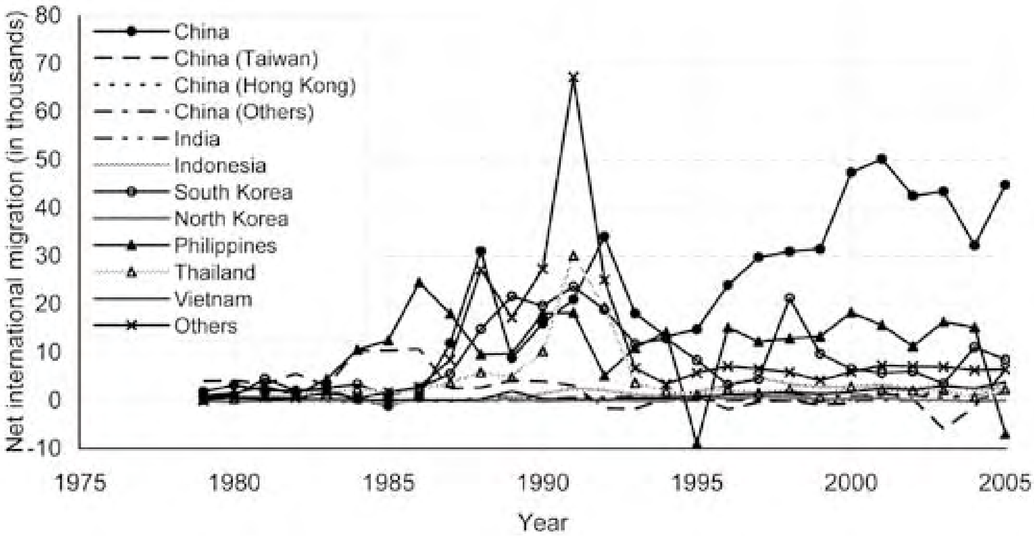
1) Conditions of Non-Japanese Entries and Exits

The net international migration of foreign nationals (Ministry of Justice) increased rapidly in the latter 1980s and reached a level exceeding 250,000 persons per year by the beginning of the 1990s. However, it then dropped rapidly until mid-1990s and finally recovered somewhat toward 2000, undergoing some fluctuations (Figure 3-7). In the 5 years since then, the number remains around 100,000 persons, and may be on a slight downward trend.

According to the breakdown of country of origin/destination by continent, the Asian region stands for the majority of net international migration (Figure 3-8). Furthermore, the trend of net international migration from South America shows significant changes since the latter part of the 1980s.

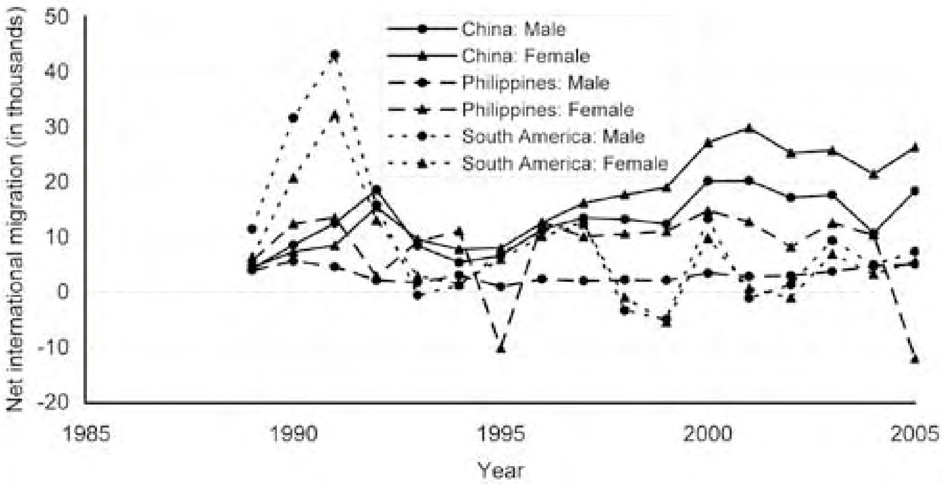
Further breakdown of the Asian region displaying large net international migration shows that four countries in particular, China, South Korea, Philippines and Thailand, greatly contribute to the number (Figure 3-9).

Figure 3-9 Net Migrants of Asian Origin (Non-Japanese)



Source: "Immigration Control Statistics" by the Ministry of Justice

Figure 3-10 Net Migrants of Non-Japanese Origin: Breakdown by Major Contributing Country and Sex



Source: "Immigration Control Statistics" by the Ministry of Justice

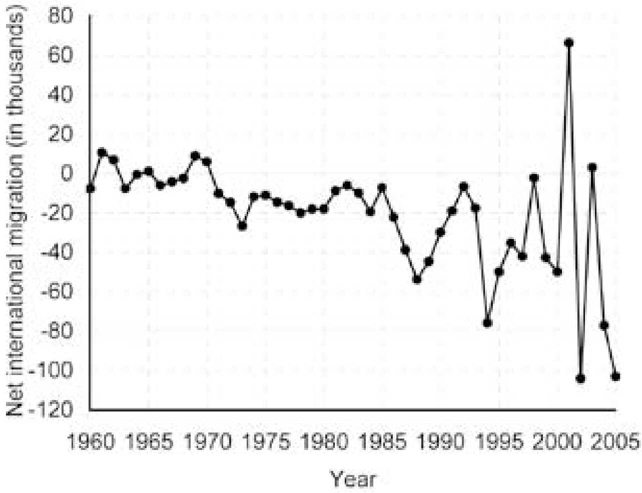
Next, the trends of the major contributing countries are examined by sex (Figure 3-10). South America (mostly Brazil) stands out in 1991, with 10,000 more male than female migrants. Moreover, looking at the development of net international migration from the Philippines, the graph depicts a peculiar negative migration (exits exceeding entries) of females twice, in 1995 and 2005; nonetheless, such trends are not seen for males from the same country.

2) Conditions of Japanese Net International Migration

The number of exits of Japanese citizens has been exceeding the number of entries since the 1970s. In recent years, the trend of exits exceeding entries has shown significant fluctuations, but for the most part, the outgoing trend in the order of a several hundred thousand people has continued[21] (Figure 3-11). Since the exits have been exceeding the entries for approximately 30 years since the 1970s, the number of Japanese living overseas, permanently or on long-term stays, are also increasing.

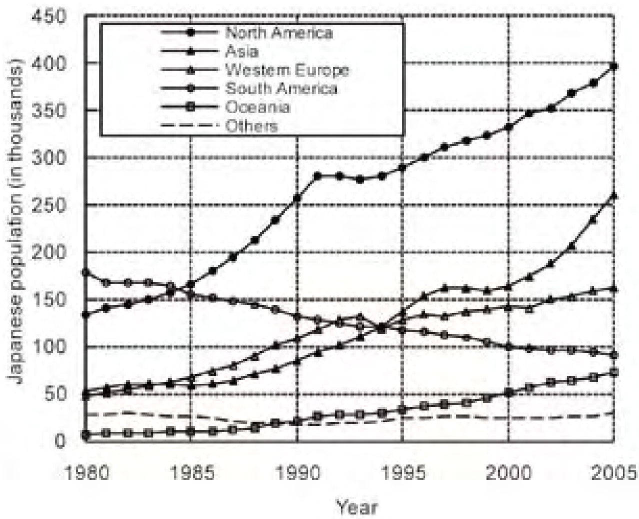
The international migration rate of the Japanese tends to be strongly influenced by global socioeconomic conditions, and its future development cannot be readily projected. Two of the significant events observed lately are the 9/11 terrorist attacks that occurred in the US in 2001 and the outburst of SARS (severe acute respiratory syndrome) that became evident in 2003, which then spread into

Figure 3-11 Net International Migration of Japanese



Source: Annual Report on Current Population Estimates" by the Statistics Bureau of the Ministry of Internal Affairs and Communications.

Figure 3-12 Number of Japanese Nationals Living Overseas by Region



Source: Annual Report of Statistics on Japanese Nationals Overseas" (Consular and Migration Policy Division of the Consular Affairs Bureau, Ministry of Foreign Affairs, Japan)

China and other Asian countries. These events triggered a rush of returning Japanese people from abroad and then an even larger exodus afterward in quick succession. However, as explained above, the overall number of exits has been exceeding the entries since the 1970s, showing that the average period in which Japanese people are living overseas is becoming longer given the backdrop of increased flow of people crossing boundaries in step with the socio-economic globalization. As a matter of fact, according to the "Annual Report of Statistics on Japanese Nationals Overseas" (Ministry of Foreign Affairs, Japan, Consular Affairs Bureau),[22] the number of Japanese staying overseas for more than three months has been increasing steadily since the 1970s and rose to more than 1 million in 2005 (Table 3-1).

Looking at the Japanese population living overseas by region,[23] the numbers are relatively large in Asia, North America, South America and Western Europe, and relatively small in other regions (Figure 3-12). Depending on the country of residence, different trends are observed in the development of Japanese population as well as

Table 3-1 Number of Japanese Living Overseas

Year	Japanese living overseas			Year	Japanese living overseas		
	Total	Long-term stay	Permanent residency		Total	Long-term stay	Permanent residency
1971	326,225	83,939	242,286	1990	620,174	374,044	246,130
1972	339,064	92,387	246,677	1991	663,049	412,207	250,842
1973	363,038	108,488	254,550	1992	679,379	425,131	254,248
1974	378,137	124,750	253,387	1993	687,579	432,703	254,876
1975	396,617	137,506	259,111	1994	689,895	428,342	261,553
1976	409,398	150,068	259,330	1995	728,268	460,522	267,746
1977	420,310	160,511	259,799	1996	763,977	492,942	271,035
1978	430,567	178,605	251,962	1997	782,568	507,749	274,819
1979	435,473	181,008	254,465	1998	789,534	510,915	278,619
1980	445,372	193,820	251,552	1999	795,852	515,295	280,557
1981	450,873	204,731	246,142	2000	811,712	526,685	285,027
1982	463,680	215,799	247,881	2001	837,744	544,434	293,310
1983	471,873	223,601	248,272	2002	871,751	586,836	284,915
1984	478,168	228,914	249,254	2003	911,062	619,269	291,793
1985	480,739	237,488	243,251	2004	961,307	659,003	302,304
1986	497,981	251,545	246,436	2005	1,012,547	701,969	310,578
1987	518,318	270,391	247,927				
1988	548,404	302,510	245,894				
1989	586,972	340,929	246,043				

Source: "Annual Report of Statistics on Japanese Nationals Overseas" (Consular and Migration Policy Division of the Consular Affairs Bureau, Ministry of Foreign Affairs, Japan)

in the regional distribution of Japanese residents. For example, the proportion of Japanese living in South America, which used to accommodate the greatest number of Japanese residents, is decreasing, while the proportion living in Asia and Oceania is increasing. The increase/decrease of the Japanese population in each region is influenced by economic relations between regions and political conditions of related government institutions, and is believed to depend largely on the particular situation of each region.

3) Trends of Change of Nationality

The proportions of Japanese and non-Japanese population relative to the total population living in Japan also fluctuate due to the influence of change of nationality. Changes of nationality are classified into three different types: change from a foreign nationality to Japanese nationality (naturalization), expatriation and denationalization of the Japanese nationality. The total number of people of Japanese nationality under-going expatriation and denationalization amounts to approximately 7,000 persons per year (in the past 5 years), whereas the number of people changing from a foreign nationality to Japanese nationality is more than twice this number.

Looking at the annual changes of the number of naturalized immigrants, the number was between 6,000 and 8,000 persons per year until the end of the 1980s; following that, it increased sharply in early 1990s to reach approximately 15,000 persons per year (Figure 3-13). Looking at naturalized immigrants by country of origin, the South and North Korean nationality represented 80% of the total in 1965, but this share gradually decreased and is now currently around 60%. In contrast, the number of nationalized immigrants formerly of Chinese nationality comprised only 10% in 1965, but this percentage increased to 30% in 2006. The total percentage of South/North Korean and Chinese nationalities still represent 90% of all naturalized immigrants.

In the assumptions set in the projections, the proportion of immigrants who changed their nationality to Japanese relative to the non-Japanese population was given by sex and age. Figure 3-14 shows the statistical data used as the baseline, i.e., the proportions of naturalized immigrants (immigrants who acquired Japanese nationality) relative to the non-Japanese population by sex and age (Statistics Bureau, the Ministry of Internal Affairs and Communications). These proportions show the same bimodal age pattern for both men and women, where the ratio achieves its maximum around 18 years of age, then decreases rapidly in the early 20s and then increases again in the 40s.

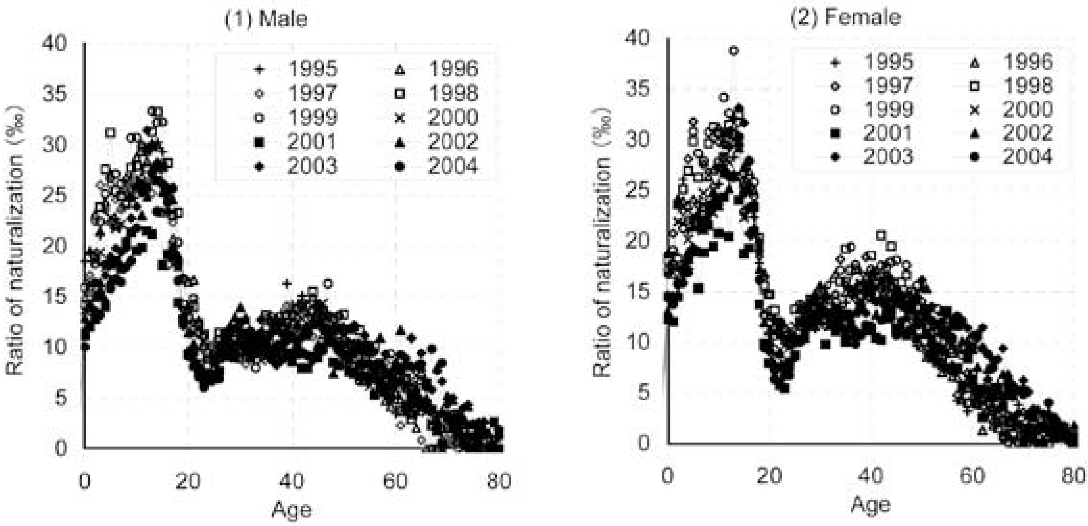
4) Impact of International Migration Assumptions on Future Population Changes

In the assumptions regarding the international population, the projections made in December

Figure 3-13 Number of Naturalized Immigrants (Immigrants who Acquired Japanese Nationality)

Source: Date of the Civil Affairs, Bureau of the Ministry of Justice

Figure 3-14 Proportion of Naturalized Immigrants (Immigrant who Acquired Japanese Nationality) by Sex and Age (relative to the Non-Japanese Population)



Source: "Annual Report on Current Population Estimates" by the Statistics Bureau , the Ministry of Internal Affairs and Communications

2006 envision that the international migration will become larger in the future. The international migration rate of Japanese will cause the population to decrease because the exits exceed entries. In contrast, the international migration rate of foreign nationals will cause the population to increase because the entries exceed exits. Moreover, the frequencies of migration differ significantly by age and are concentrated around certain ages, and thus influence the age structure of the projected population.

Therefore, in order to measure the impact of the trend of assumed international migration on the future population, the December 2006 projections are compared with a newly projected future population assuming that no international migration occurs—in other words, a situation where the Japanese population is closed. The impact of the international migration assumption on the future population changes in the projections in December 2006 is understood as the difference between these two projections. Note that the details of the projection results are provided in Chapter II of this report.

First of all, the projection with the medium-fertility/medium-mortality variant is compared

Figure 3-15 Comparison of Total Population: Medium-Variant Fertility (with Medium-Variant Mortality) Projection Result and Closed Population

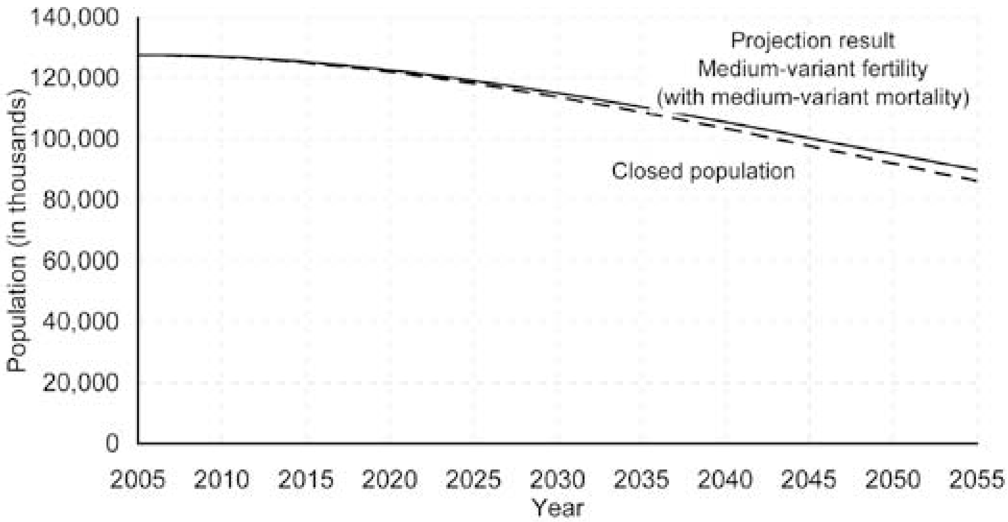
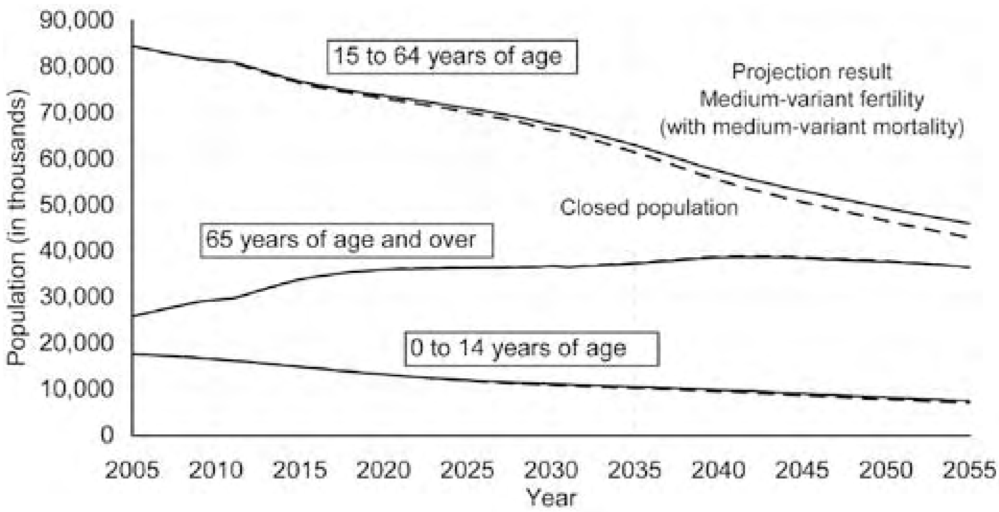


Figure 3-16 Comparison of Projected Total Population among the Three Age Groups: Medium-Variant Fertility (with Medium-Variant Mortality) Projection Result and Closed Population



with the closed population with respect to the future development of the total population. The closed population remains slightly smaller and the difference increases slightly year by year (Figure 3-15). In 2055, the projected population with the medium-fertility/medium-mortality variant assumptions is 89.93 million while the closed population is 86.36 million, only 3.57 million smaller. This means that the assumption of international migration in the medium-fertility/medium-mortality variant projection had the effect of increasing the population by this number.

In order to measure the impact on the age structure of the population, the projection result of population for the three age demographic groups are compared (Figure 3-16). There is little difference between the projected child populations (0 to 14 years of age) and elderly populations (65 years of age and over), but a comparatively clear difference can be seen in the working-age populations (15 to 64 years of age). The international migration rate assumptions have the effect of increasing the population of this age group by approximately 3 million. This is caused by the fact that the international migration of foreign nationals (net international migration) is concentrated around 20 years of age.

Similarly, the population proportions of the three age groups are compared (Figure 3-17). While the difference between the projections is

Figure 3-17 Comparison of Projected Proportions among the Three Age Groups: Medium-Variant Fertility (with Medium-Variant Mortality) Projection Result and Closed Population

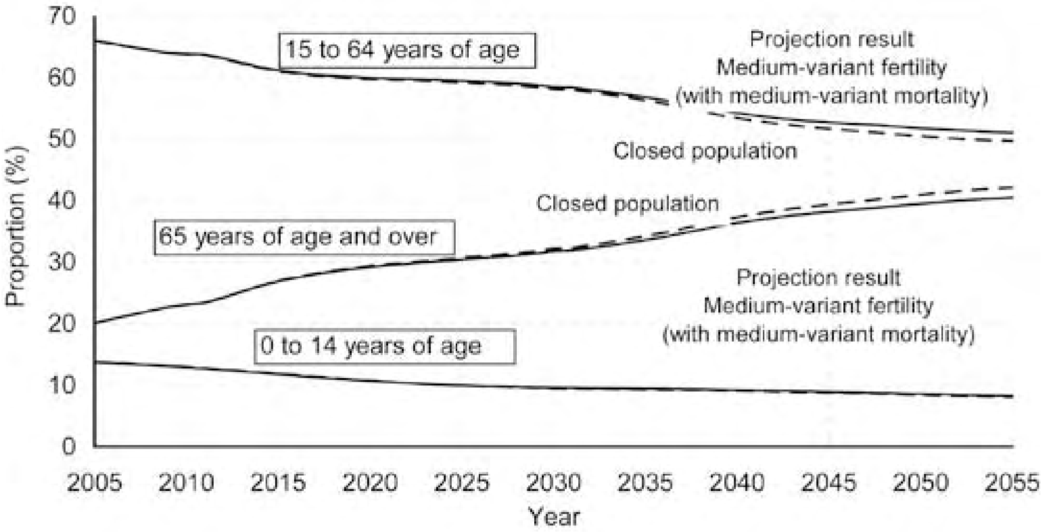
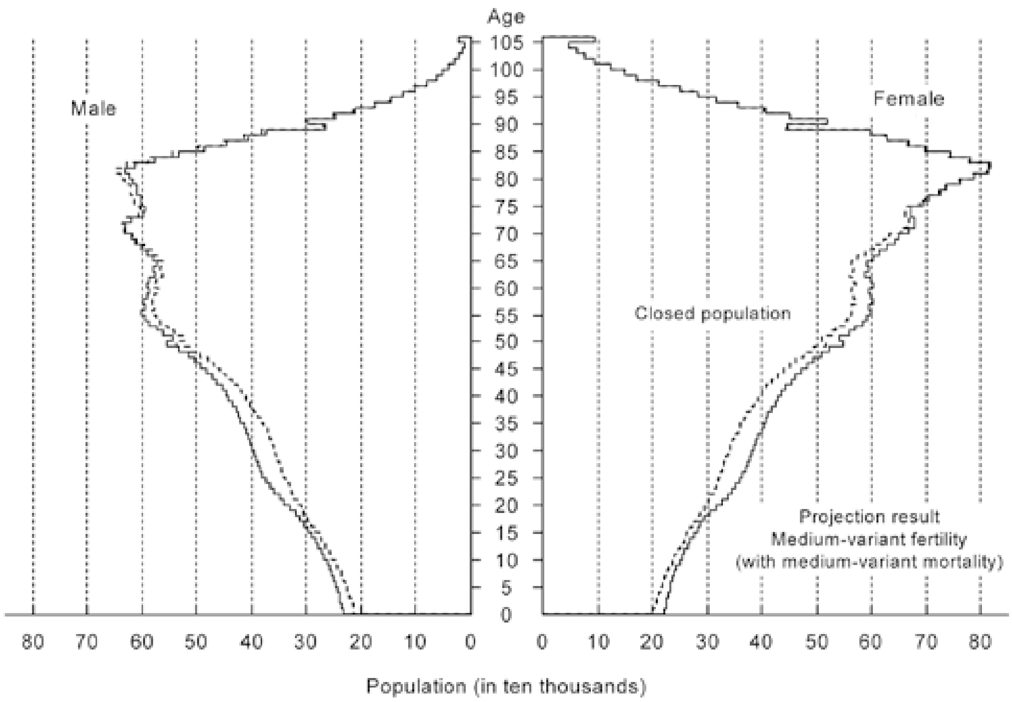


Figure 3-18 Comparison of Population Pyramid in 2055: Medium-Variant Fertility (with Medium-Variant Mortality) Projection Result and Closed Population



very small for the child populations, substantial differences are recognized in the proportions of the working-age populations and elderly populations. In case of the elderly populations, no difference was seen in the size of population, but the international migration rate assumption has the effect of lowering the proportion by 1.6 percentage points, i.e., it caused a weakening of the aging population effect.

By comparing the differences in the structure of the populations in 2055 using a population pyramid, it is possible to understand the overall picture of the effect of the international migration rate assumptions on the age structure (Figure 3-18). First of all, it is noted that the projected population is larger than the closed population in each of the age groups of 75 years of age and under. Particularly large differences occurred in the ages from 20 to 60 years of age. Moreover, for females, the differences are particularly large in the 20s to 30s and the population increases due to the international migration. As a whole, the pyramid clearly shows that the assumptions regarding the international migration rates tend to relax the aging population effect somewhat.

(4) International Comparison of Population Projections

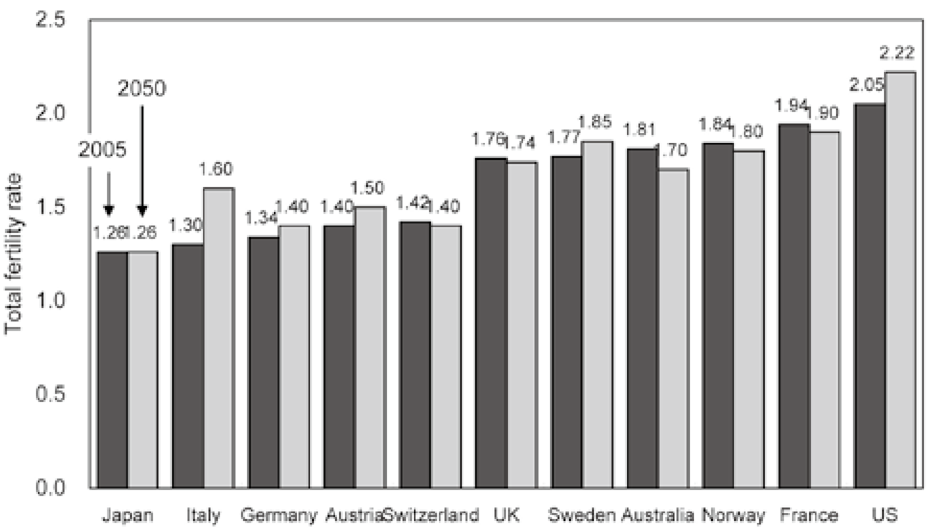
Since population projections serve as an important baseline for delineating a future picture of a country's demographic development, most countries have appointed a government organization in charge of making such projections. The most typical situation is that a country updates its population projections at intervals of 1 to 5 years using new demographic statistical data, and the most common projection period is around 50 years. The most common projection method in use today is the cohort component method. In this section, we turn our attention to population projections conducted overseas and compare them with the "Population Projections for Japan" in order to investigate the characteristics of future population development of Japan from an international viewpoint.[24]

First of all, Figure 3-19 compares values used in the projections in Japan with those of other major industrialized countries in terms of assumptions

Table 3-2 Comparison of Projected Population and Proportions among the Three Age Groups: Medium-Variant Fertility (with Medium-Variant Mortality) Projection Result and Closed Population

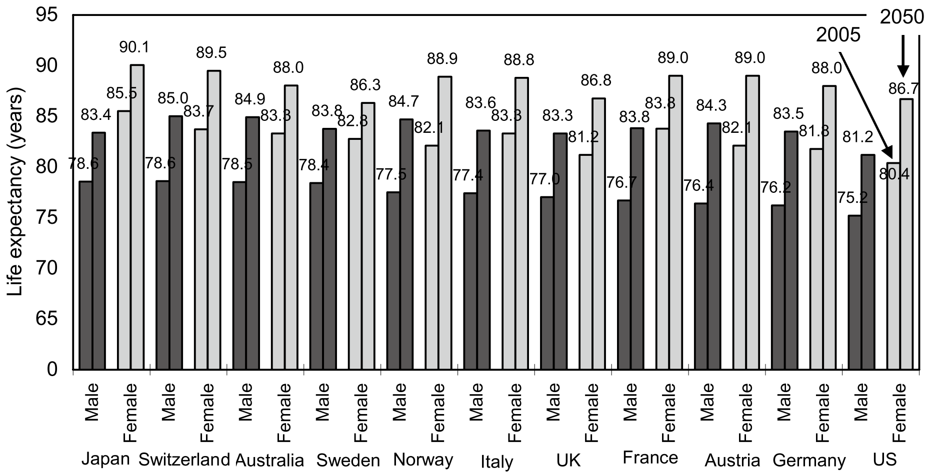
Year	Medium-variant fertility (with medium-variant mortality)				Closed population				Difference (closed population – medium-variant assumption)			
	Total	0- 14	15-64	65+	Total	0- 14	15-64	65+	Total	0- 14	15-64	65+
	Population (in thousands)											
2005	127,768	17,585	84,422	25,761	127,768	17,585	84,422	25,761	0	0	0	0
2010	127,176	16,479	81,285	29,412	127,069	16,530	81,133	29,406	-108	50	-152	-6
2015	125,430	14,841	76,807	33,781	125,118	14,908	76,430	33,780	-312	66	-378	-1
2020	122,735	13,201	73,635	35,899	122,145	13,218	73,010	35,917	-590	17	-625	18
2025	119,270	11,956	70,960	36,354	118,344	11,849	70,091	36,403	-926	-106	-869	49
2030	115,224	11,150	67,404	36,670	113,924	10,933	66,232	36,759	-1,300	-217	-1,172	89
2035	110,679	10,512	62,919	37,249	108,982	10,221	61,379	37,382	-1,697	-291	-1,539	133
2040	105,695	9,833	57,335	38,527	103,577	9,503	55,365	38,710	-2,118	-330	-1,970	183
2045	100,443	9,036	53,000	38,407	97,873	8,671	50,594	38,608	-2,569	-364	-2,406	201
2050	95,152	8,214	49,297	37,641	92,097	7,799	46,520	37,778	-3,055	-415	-2,777	137
2055	89,930	7,516	45,951	36,463	86,361	7,033	42,923	36,406	-3,569	-483	-3,028	-57
	Proportion (%)											
2005	100.0	13.8	66.1	20.2	100.0	13.8	66.1	20.2	—	0.0	0.0	0.0
2015	100.0	11.8	61.2	26.9	100.0	11.9	61.1	27.0	—	0.1	-0.1	0.1
2025	100.0	10.0	59.5	30.5	100.0	10.0	59.2	30.8	—	0.0	-0.3	0.3
2035	100.0	9.5	56.8	33.7	100.0	9.4	56.3	34.3	—	-0.1	-0.5	0.6
2045	100.0	9.0	52.8	38.2	100.0	8.9	51.7	39.4	—	-0.1	-1.1	1.2
2055	100.0	8.4	51.1	40.5	100.0	8.1	49.7	42.2	—	-0.2	-1.4	1.6

Figure 3-19 Fertility Rate Comparison: Actual Statistics in 2005 and Medium-Variant Assumption in 2050



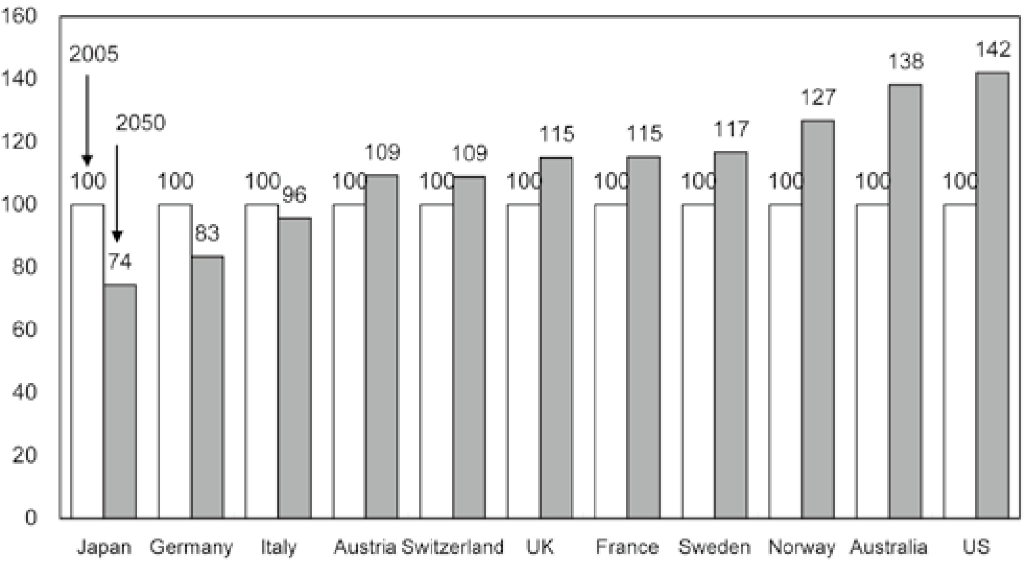
Note: The values for Switzerland and Norway are actual statistics in 2004.

Figure 3-20 Life Expectancy by Sex: Actual Statistics in 2005 and Medium-Variant Assumption in 2050



Note: The values for Switzerland and Norway are actual statistics in 2004.

Figure 3-21 Comparison of Population Sizes: Total Population in 2005 = 100



regarding the fertility rate. The majority of countries use three variant assumptions, but in this section, we shall focus only on the medium-variant assumptions typically used as base assumptions in the comparisons. Currently, the industrialized countries may largely be divided into three groups according to the level of the total fertility rate (TFR): a group of countries with super-low fertility rate of 1.5 or less, a group of countries with lenient low fertility rates of 1.5 to 2.0, and a small group of countries with fertility rates close to the population replacement level of 2.0 or higher.

Figure 3-19 shows the actual fertility rate values as of 2005 and the future assumptions in 2050 side-by-side, in the order of lowest to highest TFR as of 2005. It can clearly be seen that the prospect of the future fertility rate level is significantly different between the countries with super-low fertility rates (Japan to Switzerland) and the countries with lenient fertility rates and fertility rates exceeding 2.0 (UK to US). Except for Italy, the future fertility rate in all of the countries whose TFR is currently below 1.5 is projected to remain at 1.5 or less in 2050. Among these countries, Japan has the lowest fertility rate and no recovery is anticipated in the future either. On the other hand, the fertility rate in each country where the actual TFR in 2005 is 1.7 or higher is projected to maintain basically the same level in the future as well.

Figure 3-20 shows similar international comparisons regarding assumptions related to the mortality rate (life expectancy). Unlike the fertility rate, the future life expectancy is projected to grow in all the countries considered, and it is seen that the growth rate in many of the other countries is higher than in Japan. Nonetheless, Japan's life expectancy is currently one of the highest in the world and the mortality rate is anticipated to continue improving mainly among the elderly in the future as well, leading to the highest expected life expectancy in the world for both males and females as of 2050.

From these results, it is safe to say that Japan is a peculiar country in terms of applicable assumptions; 50 years from now, Japan will simultaneously have the lowest total fertility rate and the highest life expectancy in the world.

Next, the projection of the total population is examined. Figure 3-21 shows the size of the total population in 2050 as index values, setting the total population in 2005 as 100. Among the countries considered here, only three countries, Japan, Germany and Italy, present projection results showing negative population growth. Again, the rate of decline of the Japanese total population is found to be particularly high. Many of the other countries project that their total populations will increase by 10% to 30% by 2050, and Australia and the US anticipate a substantial increase of as much as 40%. Unlike Japan, however, the trend of immigration plays an important role in the population changes in these countries.

Next, the age structure of the future populations is also compared. Figure 3-22 shows population pyramids in 2010 and 2050 of the major countries whose future demographic data by age and sex have been published (all projections are based on medium-variant assumption).

In Japan and Germany, with assumptions of super-low fertility rate and low mortality rate, the population pyramid will shift its shape to an inverted triangle with a very narrow bottom, basically looking like a vase. In case of Japan, in particular, the proportion of the child population will fall below 10% (8.6%) in 2050, the proportion of the working-age population will be approximately 50% (51.8%) and the elderly proportion will comprise approximately 40% (39.6%) of the total population, which means that the Japanese population will show the most advanced degree

Figure 3-22 Population Pyramids of Major Countries

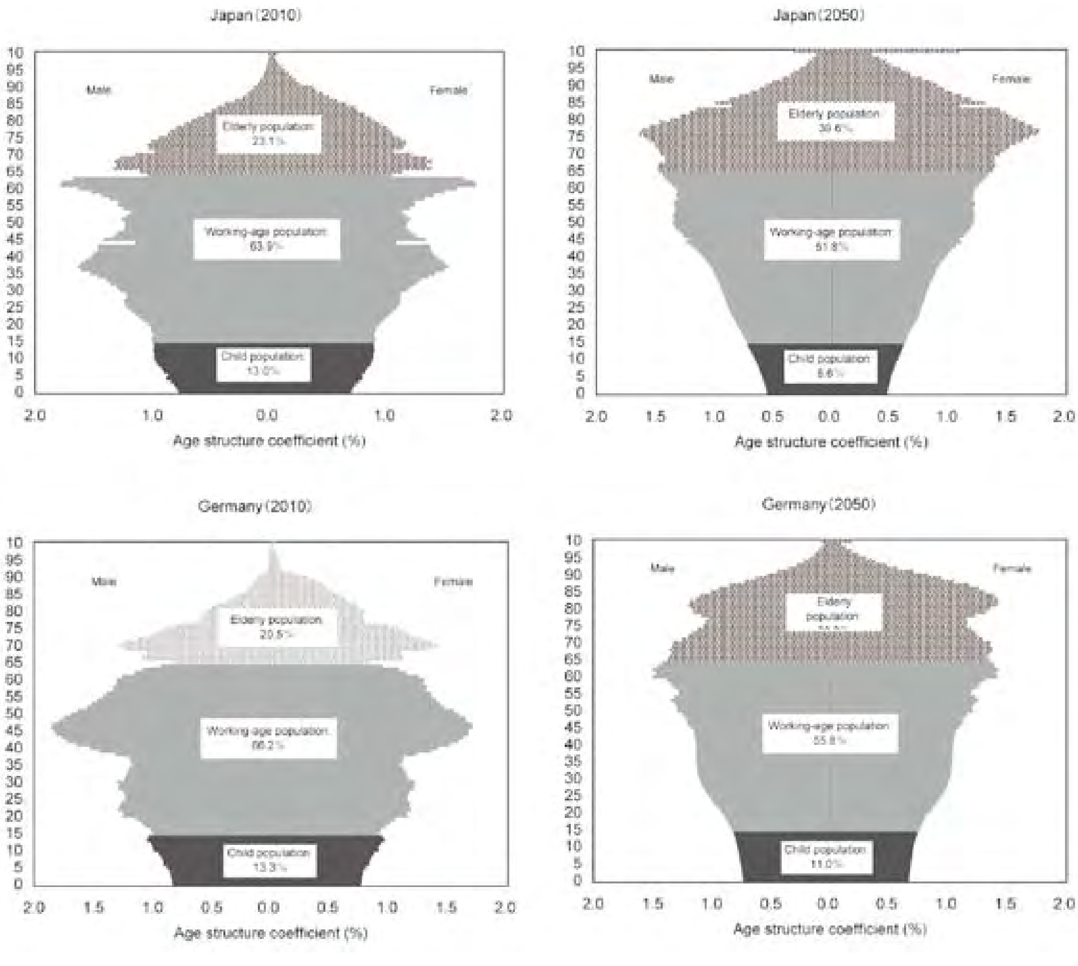
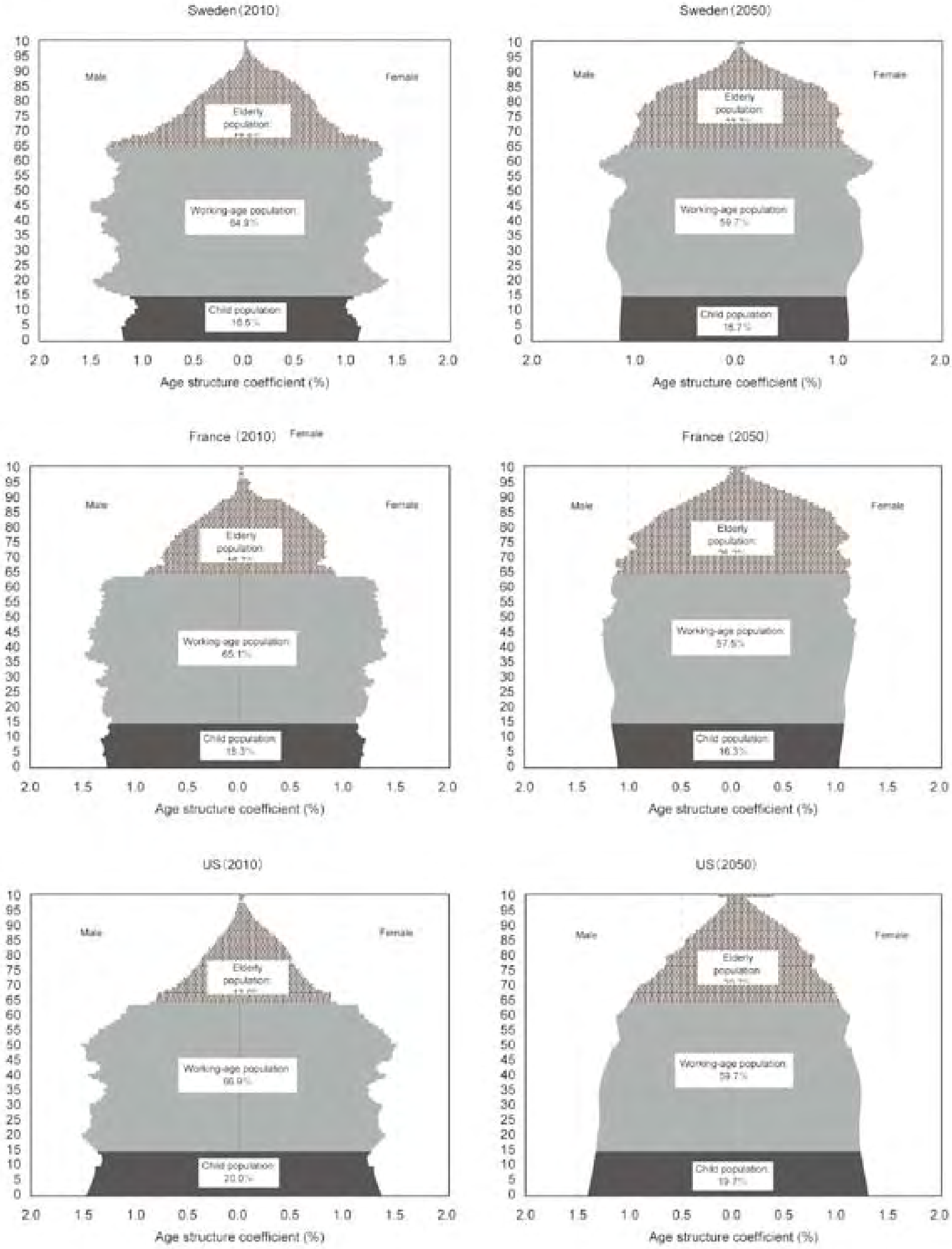


Figure 3-22 Population Pyramids of Major Countries (Continued)



of population aging in the world, combined with an ever-diminishing number of children. In contrast, Sweden, France and the US, whose current fertility rates are higher than those of Japan and Germany, will not suffer from a similar decrease of the proportions of young populations, and their population pyramids as of 2050 will be shaped more like cylindrical bells. The proportions of the elderly populations will remain between 20% and 26%, which means that these countries will maintain far more stable age compositions than Germany and Japan, whose indexes exceed 30% and 40%, respectively.

By comparing the future population demographics of each country of the world via population projections, it becomes clear that the Japanese population is heading in a rather unique direction in terms of depopulation, declining fertility rate and aging population. Even among industrialized countries, where sharp changes in the same indexes are observed, Japan is unique in both the pace of change and the ultimate level these changes are moving towards. Until the beginning of the 1990s, Japan occupied a fairly average position both in terms of the fertility rate and aging society, but in just a few decades, it ended up splitting entirely away from the rest. If Japan does indeed follow the route indicated by the population projections in the future, there will be no model case studies like it that can be found in other countries. Thus, it will be necessary to develop entirely new mechanisms while searching for original ways to handle the situation in every aspect of the society.

(5) Course of Life among Japanese People Depicted by the Population Projections

So far, this report has commented on how to interpret each of the assumptions on the vital events (birth, death and international migration), which serve as premises for the population projections. Through the combinations of such assumptions, the size and sex/age structures of the future population are determined and, in turn, we are able to picture the trends of how the population is changing, including the depopulation and aging tendencies discussed above. Having such information as a baseline, we are also able to discuss other topics, such as how a particular socio-economic system may be viable if imposed on the country, or what general policies to pursue in the nation's best interest. In this respect, it should be remembered that the population trends encompass aspects of the future that are beyond the scope of macro-changes such as depopulation and aging population. Indeed, they are a reflection of life in general and the course of life we individual citizens lead.

This section attempts to depict the future course of life of the Japanese citizen based on the assumption settings for the "Population Projections for Japan (December 2006)." Note that, since the fertility assumptions for the projections are limited to females, the discussion here is limited to the female population as well, and we will only examine the medium-fertility/medium-mortality variant assumptions.

1) Creation of Multistate Life Table on Marriage and Childbearing of Women

In the projections made in December 2006, fertility assumptions are given for each birth cohort of women (according to the year they were born), which means the marriage/childbearing processes are already given along the course of life of each cohort. Table 3-3 shows the total fertility rate and

Table 3-3 Total Fertility Rate and Components of Female Birth Cohorts Assumed for the Medium-Fertility Variant

Cohort index		Female birth cohort (birth year)										
		1955	1960	1965	1970	1975	1980	1985	1990	1995	2000	2005
Lifetime proportion of never married (%)		5.8	9.3	12.0	16.2	20.0	22.6	23.3	23.5	23.6	23.6	23.6
Mean age of first marriage (years)		24.9	25.7	26.5	27.0	27.5	27.9	28.1	28.2	28.2	28.3	28.3
Cohort TFR		1.96	1.81	1.61	1.39	1.28	1.23	1.21	1.20	1.20	1.20	1.20
Completed number of births of first-married couples		2.16	2.06	1.93	1.84	1.78	1.74	1.71	1.70	1.69	1.69	1.69
Distribution of children born (%)	None	12.7	17.5	22.7	30.0	34.3	36.4	37.4	37.4	37.4	37.5	37.5
	One	11.8	13.8	16.9	19.0	18.9	18.3	18.1	18.2	18.2	18.2	18.2
	Two	47.1	43.5	40.8	36.0	33.9	33.4	33.1	33.1	33.1	33.1	33.2
	Three	23.4	20.5	15.8	11.8	10.2	9.5	9.4	9.4	9.4	9.4	9.4
	Four or more	5.0	4.7	3.9	3.3	2.7	2.3	2.1	1.9	1.8	1.8	1.8
Average age of childbearing	All	28.2	28.7	29.3	29.7	30.0	30.2	30.3	30.3	30.3	30.3	30.3
	First child	26.3	27.0	27.8	28.4	28.7	29.0	29.1	29.1	29.1	29.1	29.1
	Second child	28.8	29.4	30.1	30.5	30.9	31.0	31.1	31.1	31.2	31.2	31.2
	Third child	31.3	31.6	32.0	32.3	32.6	32.7	32.9	33.0	33.1	33.1	33.1
	Fourth child or more	33.7	34.0	34.3	34.4	34.5	34.6	34.7	34.7	34.7	34.8	34.8

Note: This table considers only Japanese females. The figures for 1955-cohort are from the actual statistics.

Table 3-4 Proportions of Married/Unmarried Females and the Number of Children Borne in a Lifetime by Cohort

(%)

Distribution of probabilities of first marriage/childbearing and the number of children borne	Female birth cohort (birth year)								
	Actual statistics		Projection						
	1950	1955	1960	1965	1970	1975	1980	1985	1990
Probabilities of first marriage/childbearing by cohort									
Marriage	86.4	88.8	87.1	85.6	82.1	78.3	76.4	75.7	75.7
Birth of the first child	81.6	82.3	79.2	75.2	68.6	64.5	63.6	62.1	61.9
Birth of the second child	70.4	71.1	65.8	58.6	49.8	45.7	44.8	43.9	43.9
Birth of the third child	23.6	26.7	24.1	19.1	14.7	12.8	11.7	11.3	11.2
Birth of the fourth and subsequent child	4.2	4.7	4.5	3.8	3.2	2.7	2.3	2.0	1.9
Never married	13.6	11.2	12.9	14.4	17.9	21.7	23.6	24.3	24.3
No children	18.4	17.7	20.8	24.8	31.4	35.5	36.4	37.9	38.1
No second child	29.6	28.9	34.2	41.4	50.2	54.3	55.2	56.1	56.1
No third child	76.4	73.3	75.9	80.9	85.3	87.2	88.3	88.7	88.8
No forth or subsequent child	95.8	95.3	95.5	96.2	96.8	97.3	97.7	98.0	98.1
Distribution of number of children borne in a lifetime by cohort									
Proportion of females bearing 0 children (proportion of those who remain childless for life)	18.4	17.7	20.8	24.8	31.4	35.5	36.4	37.9	38.1
Never married	13.6	11.2	12.9	14.4	17.9	21.7	23.6	24.3	24.3
Married with no children	4.8	6.5	7.9	10.5	13.5	13.8	12.8	13.6	13.8
Proportion of females with one child	11.2	11.2	13.3	16.5	18.7	18.8	18.8	18.1	18.0
Proportion of females with two children	46.8	44.4	41.8	39.5	35.2	32.9	33.0	32.6	32.8
Proportion of females with three children	19.4	22.0	19.6	15.3	11.5	10.1	9.4	9.3	9.3
Proportion of females with four or more children	4.2	4.7	4.5	3.8	3.2	2.7	2.3	2.0	1.9
Net reproduction rate	87.5	90.0	84.5	76.3	66.3	61.2	59.6	58.1	57.9
Ratio of females without grandchildren	22.2	21.2	25.6	31.6	41.2	46.8	48.1	50.0	50.2

components of female birth cohorts assumed for the medium-fertility variant.

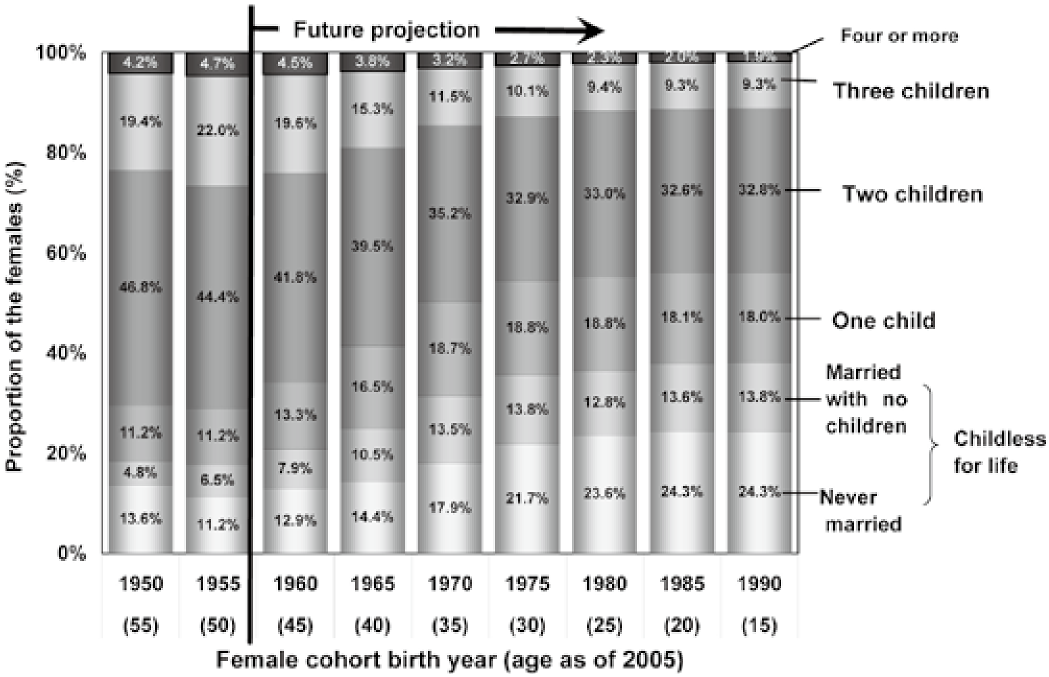
Mortality assumptions, on the other hand, are given as yearly life tables. Life tables refer to tables that list death and survivorship ratios of each year, by sex and age.[25] In this section, we construct a life course of females related to marriage and childbearing, based on the assumptions used for the projections. As a basis for generating such a life course, we first needed to obtain the number of females surviving at each stage of life. To this end, we created a life table for individual cohorts by reorganizing the life table sorted by year into that sorted along the course of life. We then used the multistate life table method to create a cohort multistate life table, which reflects the marriage/childbearing assumptions for each cohort. This table allows us to depict statistically how the females in each cohort go through the course of marriage and childbearing, while experiencing mortality risks.

2) Trends Concerning Marriage and Childbearing during the Course of Life by Cohort

Table 3-4 shows the proportions of unmarried and married females and the probability of bearing a given number of children by the age of 50, calculated by organizing data obtained from the multistate life table into 5-year interval cohorts according to the year of birth. On the assumption that women no longer get married or give birth after the age of 50, these figures can be interpreted as the proportions of females who never married in their "entire lives" versus those who married at least once, along with the probability of bearing one or more children.[26]

Among those studied here, the female population belonging to the 1950 and 1955 cohorts, respectively, have already reached the age of 50, and thus the corresponding figures in the table indicate actual statistical data. The proportions of Japanese females born in those years who have been married at least once by the age of 50 are 86.4% and 88.8%, respectively. To put it the other way around, the proportions of females in those two cohorts who have never been married by the age of 50 (lifetime proportion of never married) account for 13.6% and 11.2%, respectively. It should be noted that this table includes those who died before reaching the age of 50; thus, a certain number of females who died before getting married are included in the denominator as well when

Figure 3-23 Lifetime Proportion of Never Married and Number of Children Borne by Cohort

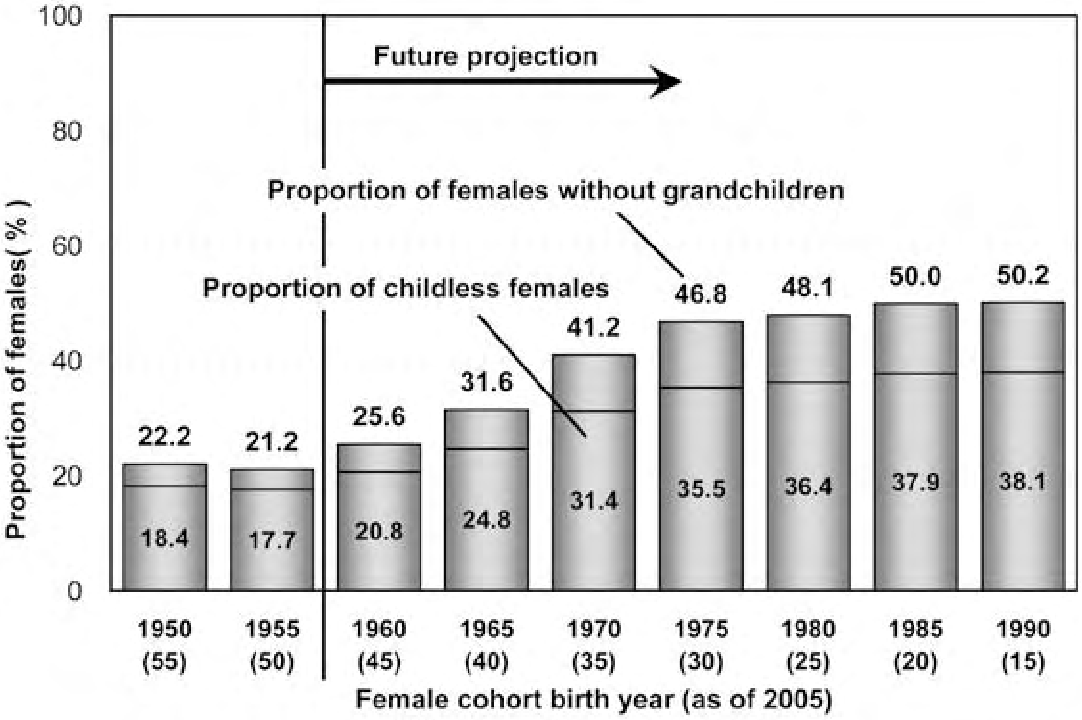


calculating these lifetime proportion of never married. Furthermore, looking at the corresponding figures for the younger generations calculated based on the assumed values of fertility and mortality used in the projections, it is seen that the proportion of the never married is likely to increase rapidly, reaching 24.3% for the generation belonging to the 1990 cohort. It should be noted here that the proportion of the never married used for the fertility assumption (Table 3-3, 23.5%) is slightly lower, due to the fact that mortality rates are not taken into consideration in its calculation.

Similarly, looking at the proportion of females who remain childless for life, the actual statistics for the 1950 and 1955 cohorts were 18.4% and 17.7%, respectively, and this value rose up to 38.1% for the 1990 cohort. Similarly, the proportion of females who bore only one child increased from 11.2% for the 1955 cohort to 18.0% for the 1990 cohort. In contrast, the proportion of females bearing two children shrunk from 44.4% to 32.8%. Figure 3-23 depicts the distribution of the number of children borne in a lifetime by cohort. It is clear from the figure that the proportion of childless females increases in concert with the increase of the lifetime proportion of never married and that the proportion of those with two children, who accounted for slightly less than 50% in the past, decreased to less than one third of the population in the 1990 cohort.

Table 3-4 and Figure 3-24 show the proportion of females who remain childless for life, as well as those who do not have any grandchildren. Women who do not bear children naturally will not have direct grandchildren and so on, but even in the case of women with children, there is no guarantee that their children will give birth to the next generation. The probability of having a grandchild was calculated here on the assumption that the child's generation will marry and give birth according to the same fertility assumptions as for the 1990 cohort.[27] According to the actual data, the proportion of females without grandchildren is around one in five women for the 1950 and 1955 cohorts. This proportion increases gradually in the succeeding generations, and from the 1985 cohort and onward, approximately 50% of the female population would not have any grandchildren. Hence, if the survivorship conditions and trends of childbearing of the current Japanese population are projected into future generations, one in every two women belonging to generations now under 20 years of age will not have any direct descendants (grandchildren and after). In such generations, traditional lifestyle aspects such as several generations living under one roof, etc., must necessarily undergo a complete change. The traditional functions that families used to play in the society so far will be significantly weakened. The obvious question is, when these generations grow old, how will the roles of families in terms of economic support, nursing care and other forms

Figure 3-24 Proportions of Females without Children/Grandchildren (Based on Medium-Variant Fertility Assumptions)



of assistance be made up for in the shrinking networks of family/relatives?

The future projections of the number of households, which were based on this projection, also show that these trends will manifest themselves as an increase in the number of solitary households of elderly people. In the "Household Projections for Japan," the trends of Japanese households until 2030 are revealed (NIPSSR.[28] According to the projections, the number of solitary householders of 65 years of age and over will increase by 86%, from 3.78 million to 7.17 million in the coming 25 years. Moreover, looking at solitary householders of 75 years of age and over, the number will swell by a factor of 2.18 from 1.97 million to 4.29 million households, i.e., the number of solitary households of older elderly people in the Japanese population is projected to more than double.

Next, using the multistate life table created based on the fertility/mortality assumptions, the composition of survival periods of females related to marriage and childbearing is examined (Table 3-5 and Figure 3-25). The table and figure indicate a breakdown of the survival period of each generation expressed as the life expectancy at birth, into unmarried periods, childless periods and so on. In a way, they tell us how the life of the average woman is spent. According to the table, the 1950 and 1955 cohorts who have already reached 50 years of age reflect the high mortality rate of babies in their babyhood/childhood and have significantly shorter life expectancies than succeeding generations, i.e., 80.8 years and 84.2 years, respectively. Among these cohorts, the unmarried period was 25.3 years and 27.2 years, respectively. That is, the proportion of the unmarried period out of the life expectancy at birth was 31% and 32%, respectively, which are a little less than one third of the entire life span. In case of later cohorts, the life expectancy grows gradually to 89.8 years in the 1990 cohort. In the same cohort, the unmarried period increases to 42.5 years, corresponding to 47% or slightly under half of the life expectancy at birth.[29]

It is more appropriate to interpret these figures in terms of the course of life of each generation as a group, rather than the course of life of individuals. That is, females in the 1990 cohort include both women who get married at least once and women who never get married, but if the lives of all the people in the cohort are taken together, they spend 47% of their lives unmarried. Similarly, the average childless period is 51.7 years, which means that women in this cohort spend 58% of their lives without children. Figure 3-25 clearly illustrates that the younger the cohort, the longer the unmarried and childless periods. Moreover, the period of living with at least one child is shortened from 51.7 years (61%) in the 1955 cohort to 38.1 years (42%) among the 1990 cohort. These

Table 3-5 Married/Unmarried Period, Period with Children (By Number of Surviving Children) and Their Proportions within Life Expectancy at Birth

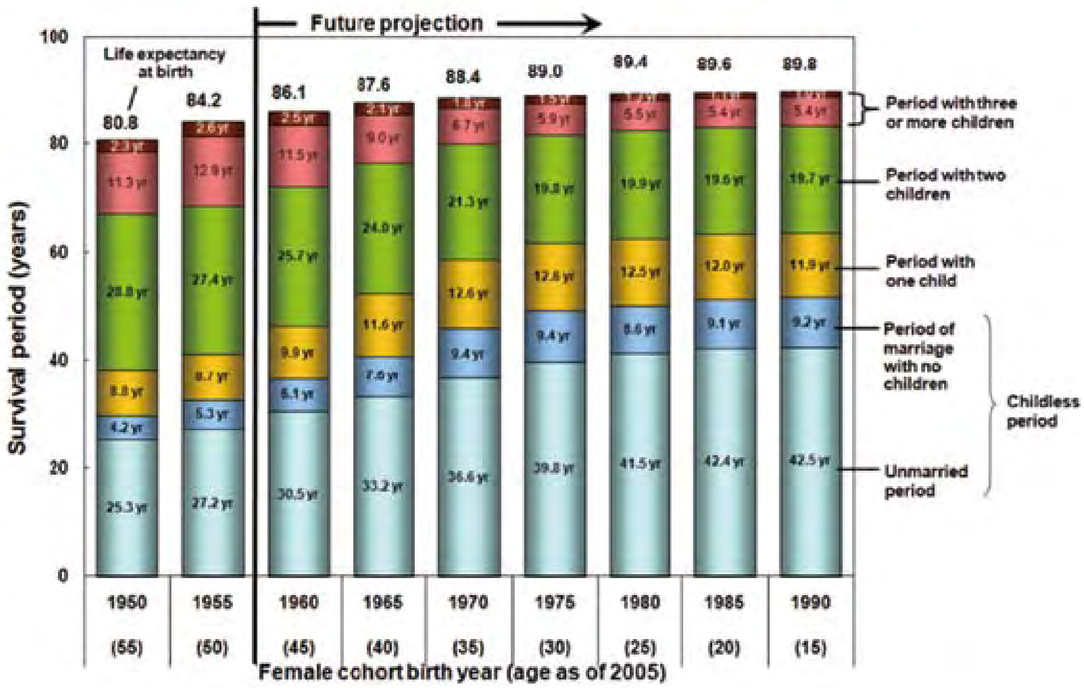
(Year)

Period/proportion by marriage/childbearing status	Female birth cohort (birth year)								
	Actual statistics		Projection						
	1950	1955	1960	1965	1970	1975	1980	1985	1990
Period by marriage/birth status									
Life expectancy at birth	80.8	84.2	86.1	87.6	88.4	89.0	89.4	89.6	89.8
Average unmarried period	25.3	27.2	30.5	33.2	36.6	39.8	41.5	42.4	42.5
Average childless period	29.5	32.5	36.5	40.9	46.0	49.2	50.2	51.4	51.7
Average period with one child	38.3	41.2	46.4	52.5	58.7	61.8	62.7	63.5	63.7
Average period with two children	67.1	68.7	72.1	76.5	79.9	81.6	82.6	83.1	83.4
Average period with three or more children	78.5	81.5	83.6	85.5	86.7	87.5	88.1	88.5	88.8
Average married period	55.4	57.0	55.6	54.3	51.8	49.2	47.8	47.3	47.3
Average period with children	51.2	51.7	49.6	46.7	42.4	39.8	39.2	38.2	38.1

(%)

Proportion of the period by marriage/birth status	1950	1955	1960	1965	1970	1975	1980	1985	1990
Life expectancy at birth	100	100	100	100	100	100	100	100	100
Average unmarried period	31	32	35	38	41	45	46	47	47
Average childless period	37	39	42	47	52	55	56	57	58
Average period with one child	47	49	54	60	66	69	70	71	71
Average period with two children	83	82	84	87	90	92	92	93	93
Average period with three or more children	97	97	97	98	98	98	99	99	99
Average married period	69	68	65	62	59	55	54	53	53
Average period with children	63	61	58	53	48	45	44	43	42

Figure 3-25 Breakdown of Lifespan (Life Expectancy at Birth) of Women into Average Period of Parity State by Cohort



figures also indicate how the realities of marriage and family structure in Japan will change in the future to come.

Depicting and presenting an overall picture of the course of lives of people based on the first marriage rate, fertility rate, mortality rate and other vital rates, as in this section, are expected to illustrate the implications of assumptions more clearly and help in the general understanding of the projections. This section, in particular, made it evident that various severe hypotheses that may be difficult to understand from the assumptions regarding the ever-changing fertility rate (which had mostly leveled off), exist behind the assumptions. We must be fully aware that under the deep layers of the macro-scale changes known as rapid depopulation and aging population, the courses of individual people's lives are simultaneously undergoing a historical transformation.

Note

1) Among the future projections based on the population survey in the 2005 Population Census, a projection of the population in each prefecture in Japan was published in May 2007 (National Institute of Population and Social Security Research "Population Projections by Prefecture for Japan: 2005-2035" [projection as of May 2007], August 2007). Moreover, on the subject of number of households in Japan, "Household Projection for Japan" was published in March 2008 (projection as of March 2008).
2) "Projected population" refers to a population projected into the future, and the process of projecting the population in this way is known as population projection. Population projections are one type of numerical simulations that provide quantitative information regarding future population size and structural changes from a technical point of view. The projections can largely be classified into two types: projections for official use and experimental projections conducted based on arbitrary premises for the purposes of research or demonstration of hypothetical situation. This report only considers population projections of the former type.
3) This type of analysis is conducted in Section 2 (3).
4) Since it is a fact that population movement and socio-economic factors influence each other and form a system, it is important to clarify their interaction and carry out investigations aiming to solve the aforementioned three issues.
5) Refer to the parameter (called the *kt* parameter in general) in the Lee-Carter model.
6) The proportion elderly in projections based on assumptions for the medium variants of both fertility and mortality is 40.5%.
7) The net number of international migrations is very small compared to the total population of Japan. For example, during the period from October 1, 2005, to September 30, 2006, the net international migration rate (the number of entries minus the number of exits, divided by the total population) was only 0.49%, that is, five in every ten thousand people. Therefore, considering the current situation in Japan, the assumption of setting entries and exits to zero is not too far from the actual condition.
8) In 2006, the mortality level expressed in terms of life expectancy, for example, is 79.00 years for men and 85.81 years for women (cf. "Abridged Life Table" by the Statistics and Information Department, the Ministry of Health, Labour and Welfare).
9) As shown here, the strength of the population momentum at a given time can be expressed by obtaining the level to which the population finally converges when the fertility rate at the time and afterwards is set to the population replacement level, and dividing this value by the initial population (this index is called ratio of stationary population or population momentum). If this ratio is larger than 1, the population has inertia in the upward direction. If it is less than 1, the population has inertia in the downward direction.
10) Looking at the effects of different mortality assumptions, there are no significant differences between the high- and low-variant projections in the population size of 25 years of age and up in 2030; the difference is only 1.1% and -1.1%, respectively, compared to the medium-variant mortality projections. Similarly, the differences in the population size of 50 years of age and up in 2055 are only 3.1% and -3.2%, respectively. Essentially, the shape of the population pyramid does not largely differ from Figure 2-3 in any of the years due to difference of mortality assumptions.
11) The immigration examination was made stricter; for instance, Chinese citizens are now required to submit certificates of balance in the past 3 years (showing a credit balance of \3 million or more in principle) as a condition for admitting Chinese students into the Japanese education system.
12) As a matter of fact, the differences between

assumed values and actual statistics from 2000 to 2005 in the 2002 projections are not necessarily reflected completely in the actual population in 2005 (Population Census). This is because there are unavoidable, albeit small, differences in the precision of the actual condition surveys between the 2000 and 2005 Population Census. For this reason, it is more appropriate to say that the differences here are "caused by differences in the starting populations."

13) The main changes made to the projection system from the 2002 projections to the 2006 projections can be summarized as follows: (1) The upper limit of age cohorts (open end) was changed from the conventional "100 years of age or over" to "120 years of age or over." (2) Separate fertility rates are given for the Japanese and non-Japanese population segments. (3) Intra-system calculations are made separately for the Japanese and non-Japanese population segments; the total population is obtained by combining these population segments, in order to more precisely express the impact of structural changes on the vital rates of the population (fertility and international migration rates in case of the 2006 projections) by nationality (Japanese or non-Japanese).

14) The high-mortality and low-mortality variant assumptions of the projections made in December 2006 are set based on the 99% confidence interval of the actual values of the parameter (kt), which indicates the mortality level of the Lee-Carter model used to set the assumptions.

15) The high-fertility and low-fertility variant assumptions of the projections made in December 2006 are projected by investigating and combining the fluctuation range of actual statistics for each index comprising the fertility rate (marriage, couples' reproductive behavior, and behavior pertaining to divorce, bereavement and remarriage).

16) The coefficient of variance of the population size in the probabilistic projections is 1.5% in 2030 and 5.2% in 2055, indicating that the uncertainty increases sharply during the latter half of the projection period.

17) Looking only at the difference in fertility assumption (high or low variant), with the mortality fixed at the medium variant assumption of the projections made in December 2006, the span is 13.67 million (84.11 million to 97.77 million), which is approximately two-thirds of the 95% confidence interval of the probabilistic projections.

18) The span between the results of projections with different fertility assumptions, either high-variant or low-variant, along with the medium-variant mortality assumptions, is 1.8 percentage points (50.1% to 51.9%), which is narrower than the 50% confidence interval.

19) To be exact, this figure is the average number of children assuming there is no impact of death and international migration of women from 15 to 49 years of age in the generation. Note that since childbearing by women under 15 and over 50 is not considered here; for the sake of simplicity the experience of childbearing by women from 15 to 49 years of age is referred to as childbearing in their "entire lives."

20) In the projections, three variant assumptions were set for the mortality level. In the high-variant projections, where the mortality rate remains higher than the other two assumptions, the life expectancy in 2055 is 82.41 years for men and 89.17 years for women, implying that the growth in life expectancy is limited to little less than 4 years. Conversely, in the low-variant projections, where the mortality rate develops at the lower level, the life expectancy is projected to grow to 84.93 years for males and 91.51 years for females, meaning that the growth exceeds 6 years.

21) Based on the result of calculating the number of Japanese net international migration in the one-year period from October 1 to September 30 the following year, based on the numbers of people entering and exiting the county obtained from the "Immigration Control Statistics" (Ministry of Justice) as reported in the "Annual Report on Current Population Estimates" by the Statistics Bureau of the Ministry of Internal Affairs and Communications.

22) The statistics summarize the long-term (three month or longer) stays and permanent residencies among the Japanese (with Japanese nationality) living overseas as of October 1, recorded through diplomatic establishments throughout the world.

23) Countries belonging to each area are defined according to the "Annual Report of Statistics on Japanese Nationals Overseas" by the Consular and Migration Policy Division of the Consular Affairs Bureau, the Ministry of Foreign Affairs, Japan. The "Annual Report of Statistics on Japanese Nationals Overseas" divides the countries in the world into 10 regions (Asia, Oceania, North America,

Central America, South America, Western Europe, Central/Eastern Europe and the former Soviet Union, Middle East, Africa and Antarctic Pole), which is partly different from the regional division in the "Immigration Control Statistics" (Ministry of Justice), which was cited in the previous section. Note that the "Immigration Control Statistics" (Ministry of Justice) uses the regional division of Asia, Europe, Africa, North America, South America and Oceania.

24) The referenced materials are as follows: *Japan* (NIPSSR 2007), *Austria* (Statistic Austria 2006), *Germany* (Statistisches Bundesamt 2006), *Italy* (Instituto Nazionale di Statistica 2006), *Switzerland* (Bundesamt für Statistik 2006), t*he United Kingdom* (Government Actuary's Department 2006), *France* (Institut National de la Statistique et des Etudes Economique 2006), *Sweden* (Statistics Sweden 2007), *Norway* (Statistics Norway 2005), *Australia* (Australian Bureau of Statistics 2006), *the United States of America* (U.S. Census Bureau 2004)

25) The report contains life tables from 2005 to 2055, in 5-year interval cohorts.

26) For this and other reasons, as well as for the sake of simplicity, the percentages of unmarried women and women with no children at the age of 50 are generally referred to as lifetime proportion of the never married, and lifetime proportion of childlessness in the demographics statistics.

27) The same assumptions were made for males in the child's generation as well.

28) See footnote 1) above

29) Note that it is assumed here as well that females aged 50 years and over neither get married nor give births for simplicity.

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Population Projections for Japan: 2006-2055
Outline of Results, Methods, and Assumptions

Ryuichi Kaneko, Akira Ishikawa, Futoshi Ishii, Tsukasa Sasai, Miho Iwasawa, Fusami Mita, and Rie Moriizumi

Introduction

The National Institute of Population and Social Security Research in Japan announced a new population projection for Japan in December 2006, based on the results of 2005 Census. This is the summary report on major results of the projections with outline of methods and assumptions.

Population Projections for Japan project size and structure of the population into future, based on assumptions on future fertility, mortality, and international migration levels. Given that future changes in fertility and mortality are inherently uncertain, this document provides a range of population projections based on alternative assumptions.

The projection covers the total population living in Japan, including non-Japanese residents. This is the same framework used by the Population Census of Japan. The period of projection begins with the 2005 Population Census and continues until 2055, projecting the population as of October 1 for each year. It also includes longer-term results up to 2105.

The method of projection is as follows: assumptions are made by age for population process components such as birth, death, and international migration, and population by sex and age in the future is projected through the cohort-component method. Assumptions are made based on actual statistics for each component through the demographic-projective method. (For further details, refer to section “III. Summary of the Method Used for Projecting Population”.)

I Summary of the Results; Projected Population

The Population Projection for Japan is based on three alternate assumptions about future fertility: low variant, medium variant and high variant. In this latest projection, the same high-, medium-, and low-variant assumptions are also set for changes in mortality. Hereafter, the outline of the results of the three projections, which combine the three assumptions on fertility and medium-variant assumptions for mortality, will be presented first, followed by an outline of the results of the three assumptions of fertility combined with low- and high-variant mortality assumptions. In the following descriptions, each projection is referred to by the combination of its respective fertility and mortality assumptions (e.g. medium-fertility (medium-mortality) projection).

The Results of Projections Using the Three Fertility Variant Assumptions with Medium-Variant Mortality

1. Total Population Trends

According to the 2005 Population Census, the base year of this projection, the total population of Japan was 127.77 million. Based on the results of the medium-variant projection, the population is expected to enter a long period of depopulation. The population is expected to decrease to about 115.22 million in 2030, fall below 100 million to 99.38 million in 2046, and drop to 89.93 million by 2055 (see **Table 1-1**, **Figure 1-1**).

Based on the results of the high-fertility-variant projection, the total population is expected to fall below 100 million by 2046 to 99.44 million, and will decrease to 97.77 million in 2055 (see **Table 1-2**, **Figure 1-1**).

On the other hand, based on the results of the low-fertility-variant projection, the total population is expected to fall below 100 million by 2042, and decline to 84.11 million by 2055. (see **Table 1-3**, **Figure 1-1**).

2. Population Trends and the Proportion of the Population in Three Major Age Groups

(1) Trends in the Number of Children under 15 and Its Share of the Population

The annual number of births in Japan has declined from 2.09 million in 1973 to 1.06 million in 2005. Consequently, the population of children under the age of 15 has decreased from 27 million in the early 1980s to 17.52 million in the population census of 2005 (excluding the age-unknown, same below for census populations).

According to the medium-variant projection, the population size of this age group will fall to 16 million in 2009 (see **Table 1-1** and **Figure 1-3**).

The decline will continue, and the population of this age group is expected to fall below 10 million in 2039, eventually decreasing to around 7.52 million by 2055.

According to the trends in the number of children based on the difference of the high- and low-variant future fertility assumptions, this age group is expected to be on the decline even in the high-variant projection (due to longstanding low fertility) and will reach 10.58 million in 2055 (see **Table 1-2**). The low-variant assumptions lead to a projection of a more rapid decline in the size of this age group. It is projected that this demographic group will shrink from its current size of 17.59 million to below 10 million in 2027, and eventually decrease to 5.51 million by 2055 (see **Table 1-3**).

Likewise, the share represented by this demographic group, according to the medium-variant projection, is expected to shrink from 13.8% as of 2005 to 10.0% in 2025, to 9.0% in 2045, and eventually down to 8.4% in 2055 (see **Table 1-1** and **Figure 1-4**).

The high-variant projection shows a slower decline in the number of children, falling below the 13% range in 2012 and reaching 10.8% by 2055 (see **Table 1-2**).

The decline in the children's share of the population is rapid in the low-variant projection, breaking the 13% mark in 2010, falling below 10% in 2019, and ultimately dropping to 6.6% by 2055 (see **Table 1-3**).

(2) Trends in the Working-Age Population (aged from 15 to 64 years) and Its Share of the Population

The population of the working-age group (from 15 to 64 years of age) consistently increased during the post-war years, reaching its peak in the 1995 Population Census at 87.17 million. However, it subsequently entered a period of decline and the population has fallen to 84.09 million, according to the 2005 Population Census.

According to the results of the medium-variant projection, the population of this age group is expected to fall below 80 million in 2012 and eventually drop to 45.95 million by 2055 (see **Table 1-1** and **Figure 1-3**).

Up until 2020, the projections of working-age population trends based on the high- and low-variant assumptions are equivalent to those based on medium-variant assumptions. After 2020, the depopulation of this age group is expected to be rather slow according to the high-variant projection, and the population is expected to decline to 50.73 million by 2055 (see **Table 1-2**). According to the low-variant projection, the working-age population is expected to decrease more rapidly, falling below 70 million in 2026, below 50 million in 2046, and eventually to 42.13 million by 2055 (see **Table 1-3**).

According to the medium-variant projection, the proportion of the population in the working-age group will continue to fall from its 2005 share of 66.1%. It is expected to decline to 60.0% in 2020, reaching 56.4% (approximately ten percentage points lower than the current level) in 2036, and will eventually decline to 51.1% by 2055 (see **Table 1-1** and **Figure 1-4**).

Using the high-variant projection, the population share of the working-age group also shows a constant decline from the start of the projection period. The proportion of the population in this age group is expected to be 51.9% in 2055, 0.8 percentage points higher than the projected proportion using medium-variant assumptions.

In the low-variant projection, the proportion of the population in this age group shows a slow period of decline, due primarily to the sharp decline in the number of children. Therefore, the timing of the percentage falling to 60.0% will be later in 2026 than in the projection based on medium-variant assumptions. However, the subsequent decline accelerates, and the population share will reach 50.1% in 2055, one percentage point lower than the projection based on medium-variant assumptions.

(3) Trends in the Elderly Population (65 years of age and over) and Its Share of the Population

The trend of elderly population will be identical for the three-variant fertility projections throughout the projection period of 50 years if the assumption on mortality is the same. That is, this age group will grow from 25.76 million as of 2005 to over 30 million in 2012 when the baby-boom generation (born between 1947 and 1949) enters this group, and to 35.9 million by 2020 (see **Table 1-1**, **Table 1-2**, **Table 1-3**, and **Figure 1-3**). It will thereafter follow a modest period of increase for some time, reaching 36.67 million in 2043, and will peak in 2043, reaching the 38.63 million mark in 2042 when the second baby-boom generation enters this age group. A steady decrease will follow, and the group will ultimately reach 36.46 million by 2055.

The proportion of the elderly is expected to grow from 20.2% as of 2005 to 25.2% in 2013, already accounting for more than one-quarter of the population of Japan at this stage. According to the medium-variant projection, it will then reach

33.7%, or more than one-third of the population, in 2035. It will reach 40.5% by 2055, which means that 1 out of 2.5 persons will be in the aged category in Japan 50 years from now (see **Table 1-1**, **Figure 1-2**).

The variant in the aging trend due to the difference in the assumptions of fertility rate, derived from a comparison of the results of the high- and low-variant projections, shows a difference of 1.6 points in 2030, between 32.6% based on low-variant projection of birth and 31.0% based on high-variant projection. This difference grows wider thereafter, and for 2055, the low-variant figure is 43.4% whereas the high variant figure is 37.3%, a difference of 6.1 points (see **Figure 1-2**).

As the above report shows, the growth rate of the aging population itself will decrease from around 2020, and the population will peak at 2042 and will decrease thereafter. Nevertheless, the proportion of the aged generation will continue to rise for 50 years from now, according to all three assumptions on fertility. This is because the percentage of this age group will continue to increase against the declining trend other age groups, namely children and working-age population.

3. Trend of the Population Dependency Ratio

The population dependency ratio is used as an index to indicate the level of support of the working-age group, through comparison of the relative size of the child population and aged population groups to that of the working-age group. The old-age dependency ratio (calculated by dividing the aged population by the population of the working-age group) based on the medium-variant projection of birth increases from 31% (that is, 3.3 workers supporting one senior resident) as of 2005 to the 50% range (that is, two workers supporting one senior resident) in 2020. The ratio will continue to rise, and eventually reach 79% (that is, 1.3 workers supporting one senior resident) by 2055 (see **Table 1-4**).

In contrast, the child dependency ratio (calculated by dividing the child population by the population of the working-age group), which is 21% (that is, 4.7 workers supporting one child) as of 2005, is expected to maintain a level of 16 to 20% in the future. Despite the decrease in the child population due to low fertility, the child dependency ratio is not expected to decrease considerably below a certain level, because the working-age group, the generation of their parents, will simultaneously shrink in size.

The child dependency ratio and the old-age dependency ratio added together is referred to as the overall dependency ratio, and this ratio is used to show the degree of support for the entire working-age population. According to the medium-variant projection of birth, the overall dependency ratio is expected to increase to 70.9% in 2030 from 51.3% in 2005, and will eventually reach 95.7% by 2055.

The overall dependency ratio based on the high-variant projection of birth will initially follow a trend that is higher than that of the medium-variant projection, because the child population will be larger. However, this ratio will become lower than that of the medium-variant projection in 2045 and beyond, and is expected to reach 92.7% by 2055. In contrast, the overall dependency ratio based on the low-variant projection of birth will initially maintain a level lower than projections based on the medium-variant projection. This, however, will reverse in 2041, and will reach 99.6% by 2055.

4. Changes in the Population Pyramid

The population pyramid in Japan has significant irregularities due to acute fluctuation in past fertility rates. For example, there was a decrease in the number of live births from 1945 to 1946 in line with the termination of war, an increase in the first baby boom from 1947 to 1949, a subsequent decrease from 1950 to 1957 and in 1966, which was known as the Hinoe-Uma (fire horse) year in the traditional Japanese calendar, a subsequent increase during the second baby boom from 1971 to 1974, and a steady decrease thereafter (see **Figure 1-5**).

In the population pyramid as of 2005, the members of first baby-boomer generation are at the end of their 50s and those of the second baby-boomer generation at the beginning of their 30s. By looking at the evolution of this pyramid according to the projection, the first baby-boomers will be at the beginning of their 80s and the second baby-boomers at the end of their 50s by 2030. It can therefore be concluded that the aging of society toward 2030 is centered on the aging of the first baby-boomer generation (see **Figure 1-5(2)**).

The progression of aging society thereafter will reflect the fact that after the second baby-boomer generation enters the elderly population; the population size of all age brackets will decrease among younger generation, due to the low fertility rate (see **Figure 1-5 (3)**).

The Results of Projections of the Three Fertility Variant Assumptions with High- and Low-Variant Mortality

1. Summary of the Results of Projection with High-Variant Mortality

The high-variant mortality projection is a projection that assumes higher mortality rates compared to the medium-variant mortality projection, which means slower advance in mortality improvement, and life expectancy remaining at a relatively low level. Therefore, number of deaths will be relatively large, and the population will maintain a lower level under the same assumptions on fertility. Compared to the total population estimate of 89.93 million in 2055 based on the medium-fertility (medium-mortality) projection, the total population in the same year based on the medium-fertility (high-mortality) projection will be lower at 88.19 million. In contrast, the trend of the population and the proportion of the three major age groups based on the medium-fertility (high-mortality) projection are as follows: the child population (and the proportion thereof) will be 7.51 million (8.5%), the working-age population (proportion) will be 45.85 million (52.0%), and elderly population (and the proportion thereof) will be 34.83 million (39.5%) in 2055. Compared to the results of the medium-fertility (medium-mortality) projection, the size of the elderly population is smaller and the proportion of the elderly population is also lower (see **Table 2-1**).

The trend in the size of total population and that in the size and proportion of the three major age groups will also differ between the three assumptions on fertility under the high-variant mortality assumption (see **Figure 2-1**, **Figure 2-2**). In 2055, the total population will be 96.03 million based on the high-fertility projection, and 82.38 million based on the low-fertility projection. The elderly population proportion in the same year will be 36.3% based on the high-fertility projection and 42.3% based on the low-fertility projection (see **Table 2-2**, **Table 2-3**). In particular, total population based on low-fertility (high-mortality) projection will be the smallest among the nine projections (combination of the three fertility assumptions and three mortality assumptions), and the proportion of elderly population is the lowest for the high-fertility (high-mortality) projection.

2. Summary of the Results of Projection with Low-Variant Mortality

The low-variant mortality projection is a projection that assumes lower mortality rate as compared with the medium-variant mortality projection, which means a faster advance in mortality improvement, and life expectancy reaching a relatively high level. Therefore, number of deaths will be relatively small, and the population will maintain a higher level under the same assumption on fertility. That is, compared to the total population as of 2055 based on the medium-fertility (medium-mortality) projection, which is 89.93 million, the total population in the same year based on the medium-fertility (low-mortality) projection will be 91.67 million. On the other hand, the trend of the size and the proportion of the three major age groups based on the medium-fertility (low-mortality) projection are as follows: child population (and the proportion thereof) will be 7.52 million (8.2%), working-age population (and the proportion thereof) will be 46.04 million (50.2%), and elderly population (and the proportion thereof) will be 38.1 million (41.6%) in 2055. Compared to the results of the medium-fertility (medium-mortality) projection, the size of the elderly population is larger and the proportion of the elderly population is also higher (see **Table 3-1**).

The trend in the size of total population and that in the size and the proportion of the three major age groups will also differ between the three assumptions on fertility under the low-variant mortality assumption (see **Figure 3-1**, **Figure 3-2**). In 2055, the total population will be 99.52 million based on the high-fertility projection, and 85.84 million based on the low-fertility projection. The elderly population proportion in the same year will be 38.3% based on the high-fertility projection and 44.4% based on the low-fertility projection (see **Table 3-2**, **Table 3-3**). In particular, the total population based on the high-fertility (low-mortality) projection will be the largest among the nine projections (combination of the three fertility assumptions and three mortality assumptions), and the proportion of elderly population is the highest for the low-fertility (low-mortality) projection.

II Summary of the Method Used for Projecting Population

The cohort component method is used for Population Projections for Japan, as with the previous projections. This is a method for forecasting future population by calculating the yearly changes due to the aging of individuals by each age bracket for each component (death, birth and international migration). As for the already existing individuals, the future population is calculated by subtracting the number of deaths due to aging and international migration. The new born population will be determined by calculating the number of live births from the female population in the reproductive age, and the number of babies remaining from death and international migration, and will be added to the population of the following year.

Projecting the population using the cohort component method requires the following information: (1) base population, (2) future fertility rate (and the sex ratio at birth), (3) future survival rate, and (4) future international migration rates (numbers), all classified by sex and age. This projection method requires a set of assumptions by implementing projection techniques based on actual statistics for each component. Given that future changes in fertility and mortality are inherently uncertain, this routine provides a range of population projections based on alternative assumptions.

1. Base Population

As for the base population, or the starting point of the projection, this set of projections uses data on the total population by age and sex as of October 1, 2005, in the Population Census of Japan, compiled by the Statistics Bureau of Ministry of Internal Affairs and Communications. However, the population of "unknown" age is included through its even distribution over all age groups. (The distribution of "unknown" age population is done by prefecture, and the population of Japan is obtained by summing up for all prefectures.)

2. Assumptions of Fertility Rates and Sex Ratio at Births

Projecting the future number of births in this projection requires female age-specific fertility rate of the year in question. This projection uses the cohort-fertility method to estimate future fertility rate. The cohort-fertility method observes the birth process per female birth cohort over the course of their lives, and forecasts the level of completed fertility and the birth timing for cohorts in which the birth process is incomplete. The future age-specific fertility rates and total fertility rates on an annual basis can be obtained by converting the per-cohort rate into annual data. In this projection, the fertility trend for the whole population, including foreigners, is obtained by a conversion of this rate for Japanese, from the perspective of further precision in the determination of fertility rate trend. Therefore, the assumed index figures in relation to marriage and childbirth described hereafter are all those of Japanese females.

Cohort age-specific fertility rates are statistically estimated and/or assumed by each order of birth by way of models that use lifetime birth probability and age of childbearing as index. The lifetime birth process is statistically estimated from the actual figures derived in the birth process for cohort that is going through the birth process. As for young cohorts that have only small or no actual figures, the index at the completion of birth process is calculated based on indexes projected separately for the reference cohort. The reference cohort refers to those born in 1990. The index in question is projected based on actual statistics on first marriage behavior, couples' reproductive behavior, and behavior pertaining to divorce, bereavement and remarriage. The cohort total fertility rate and the distribution by birth orders are calculated as the result of such indexes.

Because future fertility is an unknown, three assumptions (medium, high, and low-variant projections) are set and population is projected based on each assumption. This allows adding fluctuation range assumed for future population, brought by changes in birth viewed from the current state.

(1) Assumption for the Medium Variant of Fertility

(i) The mean age of first marriage of females by cohort will rise from 24.9 for the cohort born in 1955 to 28.2 for the cohort born in 1990. It eventually reaches 28.3 for the cohort born in 2005 and remains unchanged thereafter.

(ii) The proportion of never married increases from 5.8% for the cohort born in 1955 to 23.5% for the cohort born in 1990. It eventually reaches 23.6% for the cohort born in 2005, remaining unchanged thereafter.

(iii) Delayed marriage, delayed childbearing, and changes in the reproductive behavior of couples affect the completed number of births from married couples Index showing changes in reproductive behavior of couples (marital fertility variation index), observed by establishing couples with wife in the cohorts born from 1935 to 1954 as a benchmark (1.0), declines to 0.906 for the cohort born in 1990. It reaches 0.902 for the cohort born in 2005 and remains unchanged thereafter. The number of births from married couples is obtained from this index and change in first marriage behavior shown in (i) and (ii) above as follows: 2.19 for the cohorts born from 1953 to 1957 decreases to 1.70 for the cohort born in 1990, and to 1.69 for the cohort born in 2005, remaining unchanged thereafter.

(iv) The effects of divorce, bereavement and remarriage on fertility rates are ascertained based on the number of births from females with previously mentioned experiences and the trend of structural changes in marital status. As a result, by setting the birth level of a first-married couple as a benchmark (1.0), the effect of divorce and bereavement and remarriage decrease from the actual figure of 0.952 for the cohort born in 1955 to 0.925 for the cohort born in 1990. It remains unchanged thereafter.

From the results of above (i) to (iv), the total fertility rate of Japanese females decreases from the observed figure of 1.964 for the cohort born in 1955 to 1.202 for the cohort born in 1990. It reaches 1.198 for the cohort born in 2005 and remains unchanged thereafter.

Cohort age-specific fertility rates calculated as above are converted into the annual fertility rate. Subsequently, the fertility rate of the entire population including foreigners is obtained by assuming that the relationships between moments of the age-specific fertility rate functions of non-Japanese and Japanese females, estimated from actual figures, is unchanging. It is possible to calculate the fertility rate of the same definition with the Vital Statistics (fertility rate also counting children of Japanese nationality born from females of non-Japanese nationality; see the formula below) corresponding with the population composition by nationality upon making a projection. The results of such calculations show that the total fertility rate increased from the actual figure of 1.26 as of 2005 to 1.29 in 2006, and then will gradually decline to 1.21 in 2013. It is then expected to turn upward to 1.24 in 2030, and eventually to 1.26 in 2055 (see **Table 4-1**, **Figure 4-1**).

Definition of the total fertility rate of the Vital Statistics

$$(\text{Total fertility rate}) = \sum_{\substack{\text{Sum for ages}\\(15\text{-}49)}} \frac{(\text{Number of births by Japanese females}) + (\text{Number of births with Japanese nationality born from non-Japanese females}^*)}{(\text{Population of Japanese females})}$$

* A child with Japanese nationality born from a non-Japanese female is a child whose father is Japanese.

(2) Assumptions for the High Variant of Fertility

(i) The mean age of first marriage of females by cohort will advance to 27.8 for the cohort born in 1990, which will maintain the almost same level up to the cohort born in 2005, and remains unchanged thereafter.

(ii) The proportion of the never married demographic increases to 17.9% for the cohort born in 1990, ultimately reaching 17.1% for the cohort born in 2005, remaining unchanged thereafter.

(iii) The marital fertility variation index, an index showing changes in reproductive behavior of couples, observed by establishing the couple with wife in the cohorts born from 1935 to 1954 as a benchmark (1.0), declines temporarily but will return to 1.0 before the cohort born in 1990. The completed number of births from married couples derived from this index and change in first marriage behavior shown above will be 1.91 for the cohort born in 1990, and it will remain unchanged for cohorts born in 2005 and after.

(iv) The effects of divorce, bereavement and remarriage on fertility rate will decrease from the actual figure of 0.952 for the cohort born in 1955 to 0.938 for the cohort born in 1990, remaining unchanged thereafter.

From the results of above (i) to (iv), the total fertility of Japanese females decreases from the actual figure of 1.964 for the cohort born in 1955 to 1.467 for the cohort born in 1990, eventually reaching 1.478 for the cohort born in 2005, remaining unchanged thereafter.

The fertility rate of the same definition with the Vital Statistics corresponding with the above will increases from the actual figure of 1.26 as of 2005 to 1.32 in 2006 and to 1.53 in 2030, eventually reaching 1.55 in 2055 (see **Table 4-1**, **Figure 4-1**).

(3) Assumption for the Low Variant of Fertility

(i) The mean age of first marriage of females by cohort will increase to 28.7 for the cohort born in 1990 and to 28.8 for the cohort born in 2005, which remains unchanged thereafter.

(ii) The proportion of the never married demographic increases to 27.0% for the cohort born in 1990, and eventually reaches 27.4% for the cohort born in 2005, which remains unchanged thereafter.

(iii) Marital fertility variation index, a index showing changes in the reproductive behavior of couples, observed by establishing couples with wives in the cohorts born from 1935 to 1954 as a benchmark (1.0), declines thereafter to 0.838 for the cohort born in 1990. It will eventually reach 0.825 for the cohort born in 2005, remaining unchanged thereafter. Completed number of births from married couples derived from this index and change in first marriage behavior shown above will decrease to 1.52 for the cohort born in 1990, and will reach 1.49 for cohorts born in 2005, which remains unchanged thereafter.

(iv) The effects of divorce, bereavement and remarriage on fertility rates will decrease from the actual figure of 0.952 for the cohort born in 1955 to 0.918 for the cohort born in 1990, remaining unchanged thereafter.

Based on the results of (i) to (iv) above, the cohort total fertility of Japanese females decreases from the actual figure of 1.964 for the cohort born in 1955 to 1.022 for the cohort born in 1990, eventually reaching 0.999 for the cohort born in 2005, which remains unchanged thereafter.

The fertility rate of the same definition with the Vital Statistics corresponding with the above will increase from the actual figure of 1.26 as of 2005 to 1.27 in 2006. However, it will decline to the order of 1.03 in 2026, following which it will marginally increase to 1.06 by 2055 (see **Table 4-1**, **Figure 4-1**).

As regards sex ratio at birth (the number of male children compared with 100 female children) that is used when the future number of newborns is divided into male and female, the actual figure of 105.4 for five years from 2001 to 2005 is used as remaining consistent from 2006 and thereafter.

3. Assumption of the Survivorship Ratio (Future Life Table)

In order to project the population from one year to the next, survivorship ratios by age and sex are needed, and, in order to obtain future survivorship ratios, it is necessary to construct future life tables. This projection has adopted the Lee-Carter model, which is internationally recognized as the standard model, to construct future life tables. This projection modifies the model by adding new features that properly respond to life expectancy trends in Japan, which is the highest in the world. The Lee-Carter model describes change in mortality rates for each age according to the general level of mortality changes, by decomposing a matrix of age-specific death rates into the “average” mortality age schedule, the general level of mortality (mortality index), the age-specific changes “when the general level of mortality changes,” and an error term. In this projection, logistic curves are applied for past mortality curves so as to estimate their parameters on significance of age shifts and gradients, and the Lee-Carter model is applied by considering the age shift of advanced age mortality rate, in order to suit the mortality state of Japan, where mortality rate improvement is notable.

Upon projecting the future mortality index, data after 1970 is used in order to reflect changes in the level of mortality that remained slow and gradual over the past 35 years. From the perspective of ensuring consistency in terms of the mortality rate of males and females, curve fittings were applied simultaneously for both males and females. Future amounts of age shift were projected using linear relations with the mortality index in the past ten years, and gradient was fixed for the future using the latest mean value (covering the past ten years for males and past the 15 years for females).

Because the improvement in mortality levels for recent years is showing trends beyond the assumptions of existing theory, it is assumed that future mortality rate transitions and levels reached will be highly uncertain. Therefore, in this projection, it was decided that a projection with a selected range based on several assumptions would be implemented. To obtain the variants in mortality index parameters for the standard mortality rate trend, the bootstrap method is used to estimate the 99% confidence interval. The “high variant of death” assumption is the projection with a high mortality rate in which the mortality index maintains the upper limit level of the confidence interval, and “low variant of death” assumption is the projection with low mortality rate in which the mortality index maintains the lower limit of the confidence interval.

The future life tables were constructed from the assumed age- and sex-specific mortality rates up until 2055, based upon the parameters obtained through the above procedures.

(1) Assumptions for the Medium Variant of Mortality

According to the standard future life tables, life expectancy, which was 78.53 years for males and 85.49 years for females in 2005, is expected to extend to 79.51 years for males and 86.41 years for females in 2010, 81.88 years for males and 88.66 years for females in 2030, and, in 2055, 83.67 years for males and 90.34 years for females (see **Table 4-2**, **Figure 4-2**).

(2) Assumptions for the High Variant of Mortality

According to the assumption for the high variant of death, the mortality rate will increase, and therefore life expectancy will be shorter as compared to the medium-variant assumption. As a result, life expectancy in 2055 according to this assumption will be 82.41 years for males and 89.17 years for females.

(3) Assumptions for the Low Variant of Mortality

According to the assumption for the medium variant of death, the mortality rate will be lower, and therefore the life expectancy will be longer as compared to the medium-variant assumption. As a result, the life expectancy in 2055 according to this assumption will be 84.93 years for males and 91.51 years for females.

4. Assumptions in regards to the International Migration Rate (Numbers)

International migration varies largely in line with processes in globalization and changes in the economic conditions of Japan. Additionally, it is also affected by the policies and regulations concerning international migration in Japan, and by the economic and social conditions of other countries as well. Other temporary circumstances that could affect the international migration rate include terrorist attacks and the epidemics such as SARS (Severe Acute Respiratory Syndrome).

The actual figures show that international migration trends differ between Japanese and non-Japanese populations. Additionally, in theory, the number of non-Japanese entering Japan can be unrelated to the population size or age structure of Japan. Therefore, in this projection international migration figures are analyzed and projected separately for the Japanese and non-Japanese populations. The report calls them the “net international migration rate for Japanese” and the “net migrants of non-Japanese,” respectively.

The overall trend in international migration of the Japanese population shows exits exceeding entries. This trend is relatively stable, thus the assumptions are made as follows: first, obtain the average value of the age- and sex-specific annual net international migration rate between 1995 and 2005 (excluding 2001-2004, which were the years affected by terrorist attacks and SARS), and then smooth the rate to remove random fluctuation, and set the result as the net international migration rate of Japanese for 2006 and after.

As for international migration of the non-Japanese population, the figure for net migrants is showing an overall increasing trend, although some significant fluctuation therein has been observed in recent years. The number for future net migrants for non-Japanese by sex was projected for the period from 2006 to 2025 by ascertaining actual trends of net migrants by major countries of origin. The figure was assumed to be unchanged beyond 2026. In addition, because the proportion of sex-specific non-Japanese entries by age has been relatively stable since 2000, the average value for 2000-2005 is adjusted and is assumed as unchanged beyond 2006 (see **Tables 4-3** through 4-5, **Figures 4-3** through 4-5).

[Results of Projections Based on Medium-Variants of Mortality]

Table 1-1 Projected future population, proportion by the major three age groups (under 15, 15-64 and 65 and over) and age structure coefficient: [Medium-variant fertility (with Medium-variant mortality)]

Year	Population（thousand）by age group				Proportion（%）by age group		
	Total	0-14	15-64	65+	0-14	15-64	65+
2005	127,768	17,585	84,422	25,761	13.8	66.1	20.2
2006	127,762	17,436	83,729	26,597	13.6	65.5	20.8
2007	127,694	17,238	83,010	27,446	13.5	65.0	21.5
2008	127,568	17,023	82,334	28,211	13.3	64.5	22.1
2009	127,395	16,763	81,644	28,987	13.2	64.1	22.8
2010	127,176	16,479	81,285	29,412	13.0	63.9	23.1
2011	126,913	16,193	81,015	29,704	12.8	63.8	23.4
2012	126,605	15,880	79,980	30,745	12.5	63.2	24.3
2013	126,254	15,542	78,859	31,852	12.3	62.5	25.2
2014	125,862	15,201	77,727	32,934	12.1	61.8	26.2
2015	125,430	14,841	76,807	33,781	11.8	61.2	26.9
2016	124,961	14,486	76,025	34,450	11.6	60.8	27.6
2017	124,456	14,133	75,346	34,977	11.4	60.5	28.1
2018	123,915	13,803	74,732	35,380	11.1	60.3	28.6
2019	123,341	13,488	74,199	35,655	10.9	60.2	28.9
2020	122,735	13,201	73,635	35,899	10.8	60.0	29.2
2021	122,097	12,892	73,141	36,064	10.6	59.9	29.5
2022	121,430	12,622	72,678	36,131	10.4	59.9	29.8
2023	120,735	12,381	72,144	36,210	10.3	59.8	30.0
2024	120,015	12,159	71,549	36,307	10.1	59.6	30.3
2025	119,270	11,956	70,960	36,354	10.0	59.5	30.5
2026	118,502	11,769	70,363	36,371	9.9	59.4	30.7
2027	117,713	11,597	69,728	36,388	9.9	59.2	30.9
2028	116,904	11,438	69,028	36,438	9.8	59.0	31.2
2029	116,074	11,290	68,274	36,510	9.7	58.8	31.5
2030	115,224	11,150	67,404	36,670	9.7	58.5	31.8
2031	114,354	11,017	66,835	36,502	9.6	58.4	31.9
2032	113,464	10,888	65,896	36,681	9.6	58.1	32.3
2033	112,555	10,762	64,942	36,851	9.6	57.7	32.7
2034	111,627	10,637	63,949	37,041	9.5	57.3	33.2
2035	110,679	10,512	62,919	37,249	9.5	56.8	33.7
2036	109,714	10,384	61,832	37,498	9.5	56.4	34.2
2037	108,732	10,253	60,699	37,779	9.4	55.8	34.7
2038	107,733	10,118	59,528	38,087	9.4	55.3	35.4
2039	106,720	9,978	58,387	38,354	9.4	54.7	35.9
2040	105,695	9,833	57,335	38,527	9.3	54.2	36.5
2041	104,658	9,682	56,358	38,619	9.3	53.8	36.9
2042	103,613	9,526	55,455	38,632	9.2	53.5	37.3
2043	102,560	9,366	54,589	38,605	9.1	53.2	37.6
2044	101,503	9,202	53,779	38,522	9.1	53.0	38.0
2045	100,443	9,036	53,000	38,407	9.0	52.8	38.2
2046	99,382	8,868	52,268	38,245	8.9	52.6	38.5
2047	98,321	8,701	51,541	38,079	8.8	52.4	38.7
2048	97,261	8,535	50,792	37,934	8.8	52.2	39.0
2049	96,205	8,373	50,038	37,794	8.7	52.0	39.3
2050	95,152	8,214	49,297	37,641	8.6	51.8	39.6
2051	94,102	8,061	48,588	37,453	8.6	51.6	39.8
2052	93,056	7,914	47,894	37,248	8.5	51.5	40.0
2053	92,013	7,774	47,224	37,014	8.4	51.3	40.2
2054	90,971	7,641	46,577	36,753	8.4	51.2	40.4
2055	89,930	7,516	45,951	36,463	8.4	51.1	40.5

Current population as of October 1 of each year. Indices for 2005 are based on the “Population Census Report” by the Statistics Bureau, Ministry of Internal Affairs and Communications (the population of “unknown” age adjusted by equally distributing over all age groups).

Table 1-2 Projected future population, proportion by the major three age groups (under 15, 15-64 and 65 and over) and age structure coefficient: [High-variant fertility (with Medium-variant mortality)]

Year	Population（thousand）by age group				Proportion（%）by age group		
	Total	0-14	15-64	65+	0-14	15-64	65+
2005	127,768	17,585	84,422	25,761	13.8	66.1	20.2
2006	127,777	17,451	83,729	26,597	13.7	65.5	20.8
2007	127,761	17,305	83,010	27,446	13.5	65.0	21.5
2008	127,703	17,158	82,334	28,211	13.4	64.5	22.1
2009	127,603	16,971	81,644	28,987	13.3	64.0	22.7
2010	127,463	16,766	81,285	29,412	13.2	63.8	23.1
2011	127,285	16,566	81,015	29,704	13.0	63.6	23.3
2012	127,072	16,347	79,980	30,745	12.9	62.9	24.2
2013	126,824	16,112	78,859	31,852	12.7	62.2	25.1
2014	126,543	15,883	77,727	32,934	12.6	61.4	26.0
2015	126,232	15,643	76,807	33,781	12.4	60.8	26.8
2016	125,890	15,415	76,025	34,450	12.2	60.4	27.4
2017	125,519	15,196	75,346	34,977	12.1	60.0	27.9
2018	125,119	15,006	74,732	35,380	12.0	59.7	28.3
2019	124,690	14,837	74,199	35,655	11.9	59.5	28.6
2020	124,234	14,700	73,635	35,899	11.8	59.3	28.9
2021	123,750	14,530	73,156	36,064	11.7	59.1	29.1
2022	123,241	14,365	72,744	36,131	11.7	59.0	29.3
2023	122,706	14,218	72,278	36,210	11.6	58.9	29.5
2024	122,148	14,086	71,755	36,307	11.5	58.7	29.7
2025	121,567	13,967	71,245	36,354	11.5	58.6	29.9
2026	120,964	13,860	70,734	36,371	11.5	58.5	30.1
2027	120,340	13,760	70,193	36,388	11.4	58.3	30.2
2028	119,696	13,664	69,595	36,438	11.4	58.1	30.4
2029	119,032	13,570	68,952	36,510	11.4	57.9	30.7
2030	118,347	13,477	68,200	36,670	11.4	57.6	31.0
2031	117,643	13,383	67,758	36,502	11.4	57.6	31.0
2032	116,919	13,287	66,951	36,681	11.4	57.3	31.4
2033	116,176	13,188	66,137	36,851	11.4	56.9	31.7
2034	115,415	13,087	65,287	37,041	11.3	56.6	32.1
2035	114,636	12,981	64,406	37,249	11.3	56.2	32.5
2036	113,842	12,872	63,472	37,498	11.3	55.8	32.9
2037	113,032	12,758	62,495	37,779	11.3	55.3	33.4
2038	112,208	12,640	61,482	38,087	11.3	54.8	33.9
2039	111,373	12,517	60,502	38,354	11.2	54.3	34.4
2040	110,529	12,391	59,611	38,527	11.2	53.9	34.9
2041	109,676	12,261	58,796	38,619	11.2	53.6	35.2
2042	108,817	12,129	58,057	38,632	11.1	53.4	35.5
2043	107,954	11,994	57,355	38,605	11.1	53.1	35.8
2044	107,090	11,860	56,708	38,522	11.1	53.0	36.0
2045	106,225	11,725	56,092	38,407	11.0	52.8	36.2
2046	105,362	11,593	55,524	38,245	11.0	52.7	36.3
2047	104,502	11,462	54,961	38,079	11.0	52.6	36.4
2048	103,645	11,335	54,375	37,934	10.9	52.5	36.6
2049	102,793	11,212	53,787	37,794	10.9	52.3	36.8
2050	101,947	11,094	53,212	37,641	10.9	52.2	36.9
2051	101,106	10,980	52,672	37,453	10.9	52.1	37.0
2052	100,269	10,872	52,148	37,248	10.8	52.0	37.1
2053	99,435	10,769	51,652	37,014	10.8	51.9	37.2
2054	98,605	10,672	51,180	36,753	10.8	51.9	37.3
2055	97,775	10,579	50,733	36,463	10.8	51.9	37.3

Current population as of October 1 of each year. Indices for 2005 are based on the “Population Census Report” by the Statistics Bureau, Ministry of Internal Affairs and Communications (the population of “unknown” age adjusted by equally distributing over all age groups).

Table 1-3 Projected future population, proportion by the major three age groups (under 15, 15-64 and 65 and over) and age structure coefficient: [Low-variant fertility (with Medium-variant mortality)]

Year	Population（thousand）by age group				Proportion（%）by age group		
	Total	0-14	15-64	65+	0-14	15-64	65+
2005	127,768	17,585	84,422	25,761	13.8	66.1	20.2
2006	127,754	17,429	83,729	26,597	13.6	65.5	20.8
2007	127,625	17,170	83,010	27,446	13.5	65.0	21.5
2008	127,416	16,871	82,334	28,211	13.2	64.6	22.1
2009	127,149	16,518	81,644	28,987	13.0	64.2	22.8
2010	126,829	16,132	81,285	29,412	12.7	64.1	23.2
2011	126,458	15,738	81,015	29,704	12.4	64.1	23.5
2012	126,037	15,312	79,980	30,745	12.1	63.5	24.4
2013	125,569	14,858	78,859	31,852	11.8	62.8	25.4
2014	125,059	14,399	77,727	32,934	11.5	62.2	26.3
2015	124,508	13,920	76,807	33,781	11.2	61.7	27.1
2016	123,920	13,445	76,025	34,450	10.8	61.4	27.8
2017	123,296	12,973	75,346	34,977	10.5	61.1	28.4
2018	122,637	12,525	74,732	35,380	10.2	60.9	28.8
2019	121,946	12,093	74,199	35,655	9.9	60.8	29.2
2020	121,224	11,690	73,635	35,899	9.6	60.7	29.6
2021	120,471	11,273	73,133	36,064	9.4	60.7	29.9
2022	119,690	10,949	72,610	36,131	9.1	60.7	30.2
2023	118,881	10,678	71,993	36,210	9.0	60.6	30.5
2024	118,047	10,436	71,305	36,307	8.8	60.4	30.8
2025	117,190	10,220	70,615	36,354	8.7	60.3	31.0
2026	116,309	10,028	69,910	36,371	8.6	60.1	31.3
2027	115,408	9,856	69,163	36,388	8.5	59.9	31.5
2028	114,485	9,700	68,348	36,438	8.5	59.7	31.8
2029	113,542	9,556	67,476	36,510	8.4	59.4	32.2
2030	112,578	9,420	66,488	36,670	8.4	59.1	32.6
2031	111,594	9,291	65,801	36,502	8.3	59.0	32.7
2032	110,589	9,164	64,744	36,681	8.3	58.5	33.2
2033	109,562	9,038	63,674	36,851	8.2	58.1	33.6
2034	108,516	8,911	62,564	37,041	8.2	57.7	34.1
2035	107,448	8,780	61,419	37,249	8.2	57.2	34.7
2036	106,361	8,644	60,219	37,498	8.1	56.6	35.3
2037	105,254	8,502	58,974	37,779	8.1	56.0	35.9
2038	104,130	8,352	57,691	38,087	8.0	55.4	36.6
2039	102,989	8,196	56,439	38,354	8.0	54.8	37.2
2040	101,834	8,032	55,275	38,527	7.9	54.3	37.8
2041	100,666	7,861	54,187	38,619	7.8	53.8	38.4
2042	99,488	7,684	53,173	38,632	7.7	53.4	38.8
2043	98,303	7,502	52,196	38,605	7.6	53.1	39.3
2044	97,112	7,316	51,274	38,522	7.5	52.8	39.7
2045	95,918	7,128	50,383	38,407	7.4	52.5	40.0
2046	94,724	6,941	49,538	38,245	7.3	52.3	40.4
2047	93,530	6,755	48,696	38,079	7.2	52.1	40.7
2048	92,338	6,572	47,831	37,934	7.1	51.8	41.1
2049	91,149	6,395	46,961	37,794	7.0	51.5	41.5
2050	89,966	6,224	46,101	37,641	6.9	51.2	41.8
2051	88,787	6,062	45,271	37,453	6.8	51.0	42.2
2052	87,612	5,909	44,454	37,248	6.7	50.7	42.5
2053	86,441	5,766	43,660	37,014	6.7	50.5	42.8
2054	85,273	5,633	42,887	36,753	6.6	50.3	43.1
2055	84,106	5,510	42,133	36,463	6.6	50.1	43.4

Current population as of October 1 of each year. Indices for 2005 are based on the “Population Census Report” by the Statistics Bureau, Ministry of Internal Affairs and Communications (the population of “unknown” age adjusted by equally distributing over all age groups).

Table 1-4 Mean age and age structure index of population [Medium, high and low-variant fertility (with Medium-variant mortality)]

Year	Medium fertility (medium mortality)				High fertility (medium mortality)				Low fertility (medium mortality)			
	Mean Age (yr.)	Age Dependency Ratio(%)			Mean Age (yr.)	Age Dependency Ratio(%)			Mean Age (yr.)	Age Dependency Ratio(%)		
		Total	Children 0-14	Old-age 65+		Total	Children 0-14	Old-age 65+		Total	Children 0-14	Old-age 65+
2005	43.3	51.3	20.8	30.5	43.3	51.3	20.8	30.5	43.3	51.3	20.8	30.5
2006	43.7	52.6	20.8	31.8	43.7	52.6	20.8	31.8	43.7	52.6	20.8	31.8
2007	44.0	53.8	20.8	33.1	44.0	53.9	20.8	33.1	44.0	53.7	20.7	33.1
2008	44.4	54.9	20.7	34.3	44.3	55.1	20.8	34.3	44.4	54.8	20.5	34.3
2009	44.7	56.0	20.5	35.5	44.6	56.3	20.8	35.5	44.8	55.7	20.2	35.5
2010	45.1	56.5	20.3	36.2	45.0	56.8	20.6	36.2	45.2	56.0	19.8	36.2
2011	45.4	56.7	20.0	36.7	45.3	57.1	20.4	36.7	45.6	56.1	19.4	36.7
2012	45.8	58.3	19.9	38.4	45.6	58.9	20.4	38.4	45.9	57.6	19.1	38.4
2013	46.1	60.1	19.7	40.4	45.9	60.8	20.4	40.4	46.3	59.2	18.8	40.4
2014	46.4	61.9	19.6	42.4	46.2	62.8	20.4	42.4	46.7	60.9	18.5	42.4
2015	46.8	63.3	19.3	44.0	46.5	64.3	20.4	44.0	47.1	62.1	18.1	44.0
2016	47.1	64.4	19.1	45.3	46.8	65.6	20.3	45.3	47.4	63.0	17.7	45.3
2017	47.4	65.2	18.8	46.4	47.0	66.6	20.2	46.4	47.8	63.6	17.2	46.4
2018	47.7	65.8	18.5	47.3	47.3	67.4	20.1	47.3	48.2	64.1	16.8	47.3
2019	48.0	66.2	18.2	48.1	47.6	68.0	20.0	48.1	48.5	64.4	16.3	48.1
2020	48.3	66.7	17.9	48.8	47.8	68.7	20.0	48.8	48.8	64.6	15.9	48.8
2021	48.6	66.9	17.6	49.3	48.0	69.2	19.9	49.3	49.2	64.7	15.4	49.3
2022	48.9	67.1	17.4	49.7	48.3	69.4	19.7	49.7	49.5	64.8	15.1	49.8
2023	49.2	67.4	17.2	50.2	48.5	69.8	19.7	50.1	49.8	65.1	14.8	50.3
2024	49.4	67.7	17.0	50.7	48.7	70.2	19.6	50.6	50.1	65.6	14.6	50.9
2025	49.7	68.1	16.8	51.2	48.9	70.6	19.6	51.0	50.4	66.0	14.5	51.5
2026	49.9	68.4	16.7	51.7	49.1	71.0	19.6	51.4	50.7	66.4	14.3	52.0
2027	50.2	68.8	16.6	52.2	49.3	71.4	19.6	51.8	51.0	66.9	14.3	52.6
2028	50.4	69.4	16.6	52.8	49.5	72.0	19.6	52.4	51.3	67.5	14.2	53.3
2029	50.6	70.0	16.5	53.5	49.6	72.6	19.7	53.0	51.5	68.3	14.2	54.1
2030	50.9	70.9	16.5	54.4	49.8	73.5	19.8	53.8	51.8	69.3	14.2	55.2
2031	51.1	71.1	16.5	54.6	49.9	73.6	19.8	53.9	52.0	69.6	14.1	55.5
2032	51.3	72.2	16.5	55.7	50.1	74.6	19.8	54.8	52.3	70.8	14.2	56.7
2033	51.5	73.3	16.6	56.7	50.2	75.7	19.9	55.7	52.5	72.1	14.2	57.9
2034	51.7	74.6	16.6	57.9	50.4	76.8	20.0	56.7	52.8	73.4	14.2	59.2
2035	51.8	75.9	16.7	59.2	50.5	78.0	20.2	57.8	53.0	74.9	14.3	60.6
2036	52.0	77.4	16.8	60.6	50.6	79.4	20.3	59.1	53.2	76.6	14.4	62.3
2037	52.2	79.1	16.9	62.2	50.7	80.9	20.4	60.5	53.4	78.5	14.4	64.1
2038	52.4	81.0	17.0	64.0	50.8	82.5	20.6	61.9	53.7	80.5	14.5	66.0
2039	52.5	82.8	17.1	65.7	50.9	84.1	20.7	63.4	53.9	82.5	14.5	68.0
2040	52.7	84.3	17.2	67.2	51.1	85.4	20.8	64.6	54.1	84.2	14.5	69.7
2041	52.9	85.7	17.2	68.5	51.2	86.5	20.9	65.7	54.3	85.8	14.5	71.3
2042	53.0	86.8	17.2	69.7	51.2	87.4	20.9	66.5	54.5	87.1	14.5	72.7
2043	53.2	87.9	17.2	70.7	51.3	88.2	20.9	67.3	54.7	88.3	14.4	74.0
2044	53.4	88.7	17.1	71.6	51.4	88.8	20.9	67.9	55.0	89.4	14.3	75.1
2045	53.5	89.5	17.0	72.5	51.5	89.4	20.9	68.5	55.2	90.4	14.1	76.2
2046	53.7	90.1	17.0	73.2	51.6	89.8	20.9	68.9	55.4	91.2	14.0	77.2
2047	53.8	90.8	16.9	73.9	51.7	90.1	20.9	69.3	55.6	92.1	13.9	78.2
2048	54.0	91.5	16.8	74.7	51.8	90.6	20.8	69.8	55.8	93.0	13.7	79.3
2049	54.1	92.3	16.7	75.5	51.8	91.1	20.8	70.3	56.0	94.1	13.6	80.5
2050	54.3	93.0	16.7	76.4	51.9	91.6	20.8	70.7	56.2	95.2	13.5	81.6
2051	54.4	93.7	16.6	77.1	52.0	92.0	20.8	71.1	56.4	96.1	13.4	82.7
2052	54.6	94.3	16.5	77.8	52.1	92.3	20.8	71.4	56.6	97.1	13.3	83.8
2053	54.7	94.8	16.5	78.4	52.1	92.5	20.8	71.7	56.8	98.0	13.2	84.8
2054	54.9	95.3	16.4	78.9	52.2	92.7	20.9	71.8	57.0	98.8	13.1	85.7
2055	55.0	95.7	16.4	79.4	52.3	92.7	20.9	71.9	57.2	99.6	13.1	86.5

Current population as of October 1 of each year. Indices for 2005 are based on the “Population Census Report” by the Statistics Bureau, Ministry of Internal Affairs and Communications (the population of “unknown” age adjusted by equally distributing over all age groups).

Figure 1-1 Actual and projected population of Japan
- Medium, high and low fertility (with medium mortality) variants -

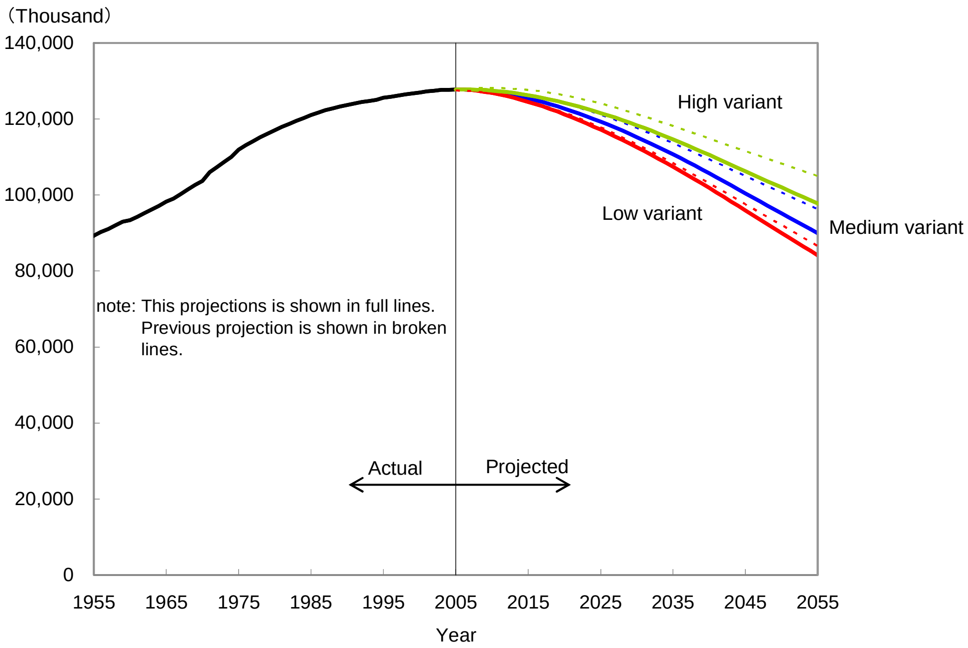


Figure 1-2 Trends in the proportion of elderly
- Medium, high and low fertility (with medium mortality) variants -

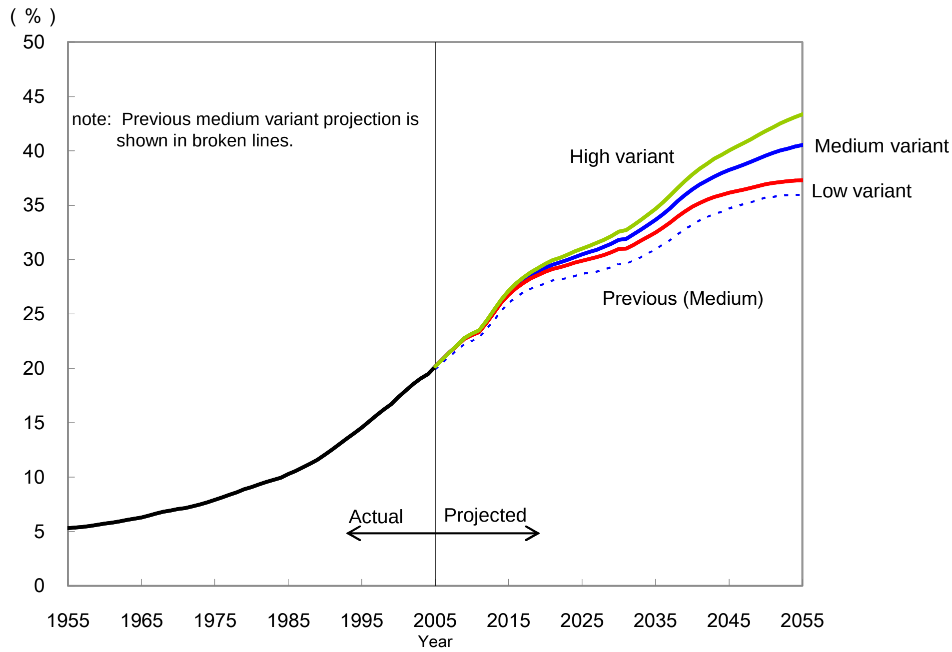


Figure 1-3 Trends in the number of major three age groups
- Medium fertility (with medium mortality) variant -

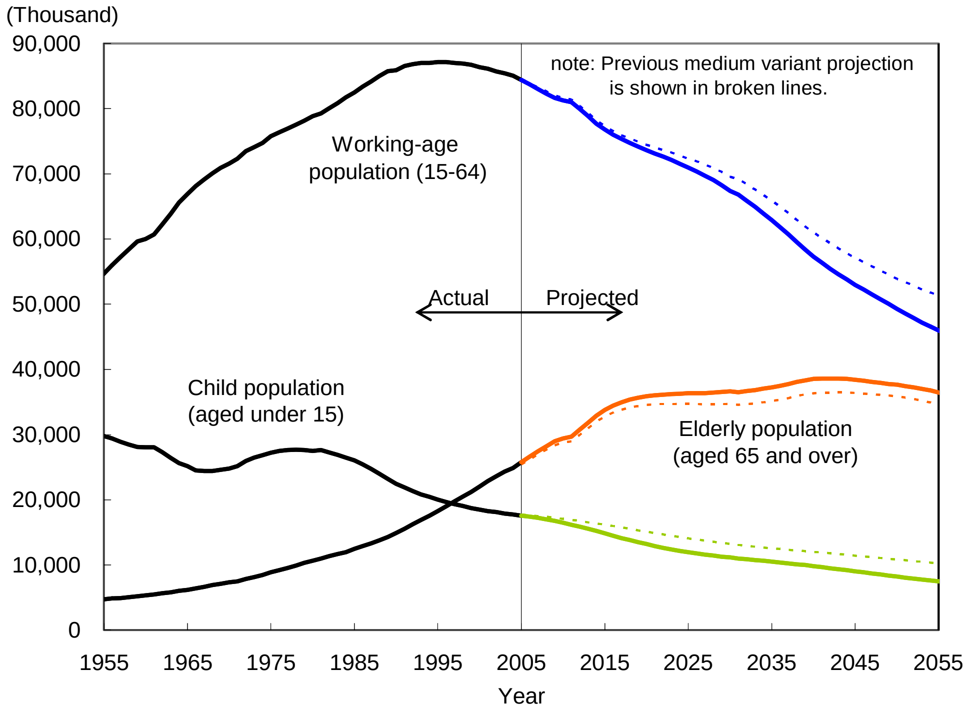


Figure 1-4 Trends in the proportion of major three age groups
- Medium fertility (with medium mortality) variant -

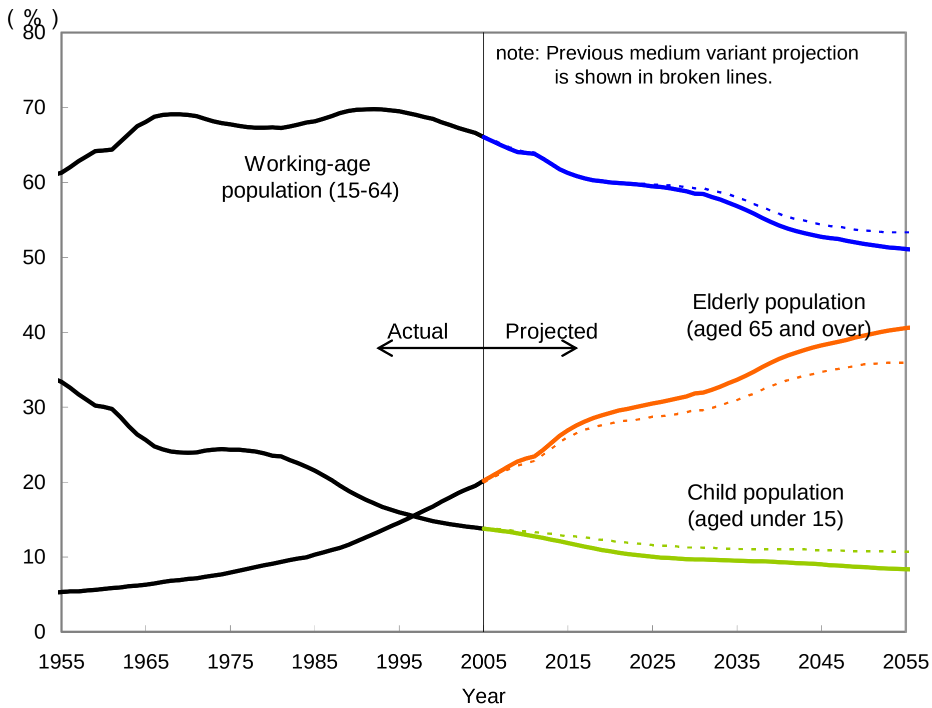
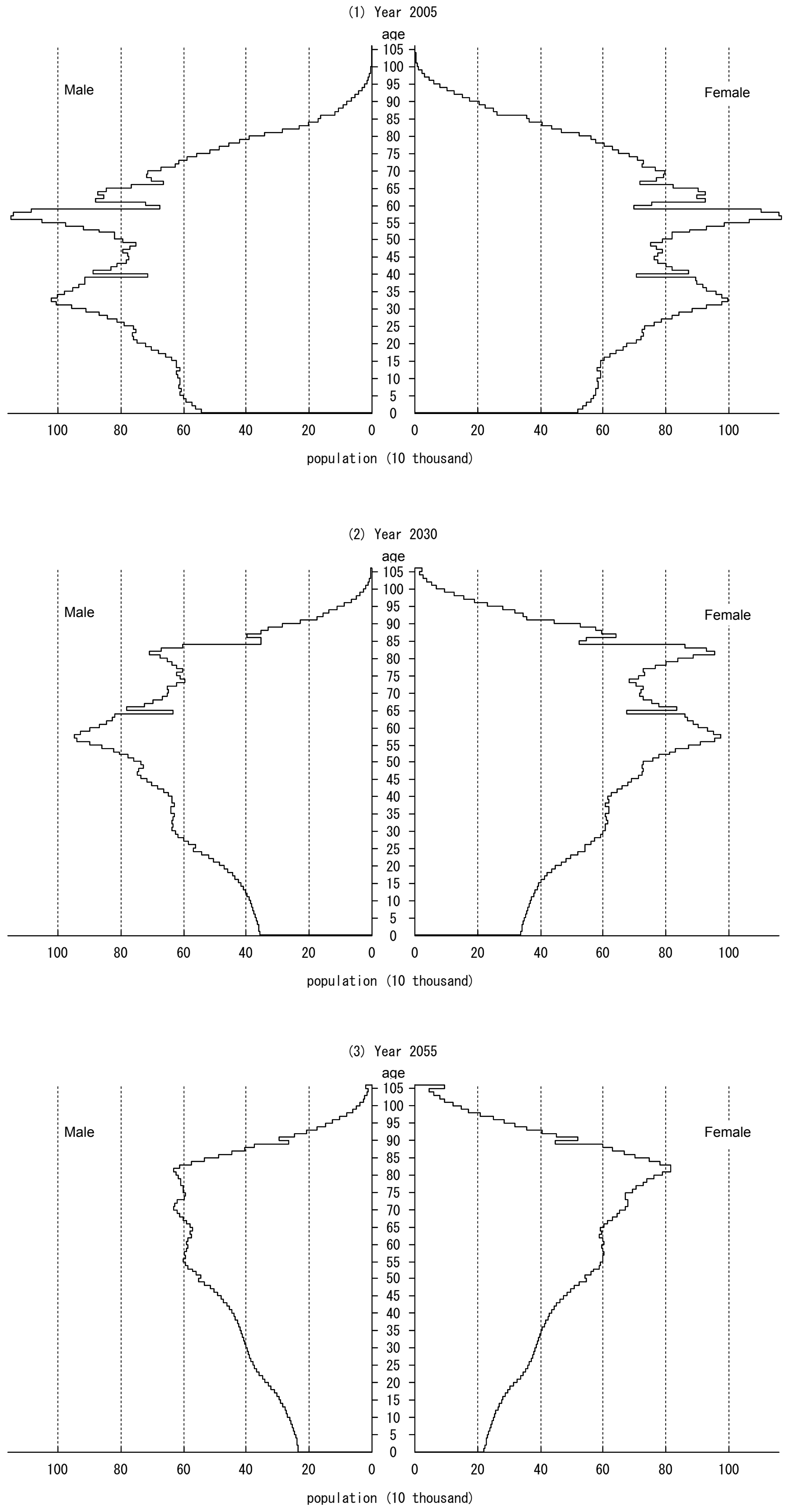


Figure 1-5 Population pyramid: Medium fertility (with Medium mortality) variant



[Results of Projections Based on High and Low Variants of Mortality]

Table 2-1 Projected future population, proportion by the major three age groups (under 15, 15-64 and 65 and over) and age structure coefficient: [Medium-variant fertility (with High-variant mortality)]

Year	Population(thousand) by age group				Proportion(%) by age group		
	Total	0-14	15-64	65+	0-14	15-64	65+
2005	127,768	17,585	84,422	25,761	13.8	66.1	20.2
2006	127,736	17,436	83,725	26,575	13.7	65.5	20.8
2007	127,632	17,237	83,001	27,393	13.5	65.0	21.5
2008	127,469	17,022	82,321	28,125	13.4	64.6	22.1
2009	127,257	16,763	81,627	28,868	13.2	64.1	22.7
2010	126,998	16,478	81,263	29,257	13.0	64.0	23.0
2011	126,693	16,192	80,989	29,513	12.8	63.9	23.3
2012	126,343	15,878	79,950	30,515	12.6	63.3	24.2
2013	125,951	15,540	78,826	31,584	12.3	62.6	25.1
2014	125,517	15,199	77,691	32,627	12.1	61.9	26.0
2015	125,044	14,839	76,768	33,436	11.9	61.4	26.7
2016	124,531	14,483	75,983	34,065	11.6	61.0	27.4
2017	123,981	14,130	75,301	34,551	11.4	60.7	27.9
2018	123,395	13,799	74,684	34,911	11.2	60.5	28.3
2019	122,774	13,484	74,148	35,142	11.0	60.4	28.6
2020	122,121	13,197	73,581	35,343	10.8	60.3	28.9
2021	121,437	12,888	73,084	35,465	10.6	60.2	29.2
2022	120,723	12,618	72,617	35,489	10.5	60.2	29.4
2023	119,983	12,377	72,080	35,526	10.3	60.1	29.6
2024	119,218	12,155	71,482	35,582	10.2	60.0	29.8
2025	118,430	11,951	70,890	35,589	10.1	59.9	30.1
2026	117,618	11,764	70,289	35,565	10.0	59.8	30.2
2027	116,785	11,592	69,652	35,541	9.9	59.6	30.4
2028	115,931	11,433	68,948	35,550	9.9	59.5	30.7
2029	115,057	11,285	68,191	35,581	9.8	59.3	30.9
2030	114,163	11,145	67,319	35,699	9.8	59.0	31.3
2031	113,249	11,012	66,747	35,491	9.7	58.9	31.3
2032	112,317	10,883	65,805	35,630	9.7	58.6	31.7
2033	111,367	10,757	64,850	35,760	9.7	58.2	32.1
2034	110,398	10,632	63,855	35,912	9.6	57.8	32.5
2035	109,412	10,506	62,824	36,083	9.6	57.4	33.0
2036	108,410	10,379	61,736	36,295	9.6	56.9	33.5
2037	107,392	10,248	60,603	36,540	9.5	56.4	34.0
2038	106,359	10,113	59,432	36,814	9.5	55.9	34.6
2039	105,314	9,973	58,292	37,050	9.5	55.4	35.2
2040	104,259	9,827	57,240	37,192	9.4	54.9	35.7
2041	103,194	9,676	56,262	37,256	9.4	54.5	36.1
2042	102,123	9,520	55,359	37,243	9.3	54.2	36.5
2043	101,046	9,360	54,494	37,193	9.3	53.9	36.8
2044	99,967	9,196	53,683	37,088	9.2	53.7	37.1
2045	98,886	9,029	52,903	36,953	9.1	53.5	37.4
2046	97,805	8,862	52,171	36,773	9.1	53.3	37.6
2047	96,726	8,694	51,444	36,589	9.0	53.2	37.8
2048	95,650	8,529	50,694	36,428	8.9	53.0	38.1
2049	94,577	8,366	49,940	36,271	8.8	52.8	38.4
2050	93,508	8,207	49,199	36,102	8.8	52.6	38.6
2051	92,442	8,054	48,490	35,898	8.7	52.5	38.8
2052	91,378	7,908	47,795	35,675	8.7	52.3	39.0
2053	90,316	7,767	47,126	35,423	8.6	52.2	39.2
2054	89,255	7,635	46,478	35,143	8.6	52.1	39.4
2055	88,193	7,509	45,852	34,833	8.5	52.0	39.5

Current population as of October 1 of each year. Indices for 2005 are based on the “Population Census Report” by the Statistics Bureau, Ministry of Internal Affairs and Communications (the population of “unknown” age adjusted by equally distributing over all age groups).

Table 2-2 Projected future population, proportion by the major three age groups (under 15, 15-64 and 65 and over) and age structure coefficient: [High-variant fertility (with High-variant mortality)]

Year	Population（thousand）by age group				Proportion（%）by age group		
	Total	0-14	15-64	65+	0-14	15-64	65+
2005	127,768	17,585	84,422	25,761	13.8	66.1	20.2
2006	127,751	17,451	83,725	26,575	13.7	65.5	20.8
2007	127,699	17,305	83,001	27,393	13.6	65.0	21.5
2008	127,604	17,157	82,321	28,125	13.4	64.5	22.0
2009	127,465	16,970	81,627	28,868	13.3	64.0	22.6
2010	127,285	16,765	81,263	29,257	13.2	63.8	23.0
2011	127,066	16,564	80,989	29,513	13.0	63.7	23.2
2012	126,810	16,345	79,950	30,515	12.9	63.0	24.1
2013	126,521	16,110	78,826	31,584	12.7	62.3	25.0
2014	126,199	15,880	77,691	32,627	12.6	61.6	25.9
2015	125,845	15,640	76,768	33,436	12.4	61.0	26.6
2016	125,460	15,412	75,983	34,065	12.3	60.6	27.2
2017	125,044	15,193	75,301	34,551	12.1	60.2	27.6
2018	124,598	15,002	74,684	34,911	12.0	59.9	28.0
2019	124,122	14,833	74,148	35,142	11.9	59.7	28.3
2020	123,619	14,696	73,581	35,343	11.9	59.5	28.6
2021	123,089	14,526	73,099	35,465	11.8	59.4	28.8
2022	122,533	14,361	72,684	35,489	11.7	59.3	29.0
2023	121,953	14,213	72,214	35,526	11.7	59.2	29.1
2024	121,351	14,081	71,688	35,582	11.6	59.1	29.3
2025	120,726	13,962	71,175	35,589	11.6	59.0	29.5
2026	120,079	13,855	70,660	35,565	11.5	58.8	29.6
2027	119,411	13,754	70,116	35,541	11.5	58.7	29.8
2028	118,723	13,659	69,515	35,550	11.5	58.6	29.9
2029	118,014	13,565	68,869	35,581	11.5	58.4	30.1
2030	117,285	13,471	68,115	35,699	11.5	58.1	30.4
2031	116,537	13,377	67,669	35,491	11.5	58.1	30.5
2032	115,771	13,281	66,860	35,630	11.5	57.8	30.8
2033	114,986	13,182	66,044	35,760	11.5	57.4	31.1
2034	114,185	13,080	65,193	35,912	11.5	57.1	31.5
2035	113,368	12,975	64,310	36,083	11.4	56.7	31.8
2036	112,535	12,865	63,376	36,295	11.4	56.3	32.3
2037	111,690	12,751	62,398	36,540	11.4	55.9	32.7
2038	110,832	12,633	61,385	36,814	11.4	55.4	33.2
2039	109,965	12,510	60,405	37,050	11.4	54.9	33.7
2040	109,090	12,383	59,515	37,192	11.4	54.6	34.1
2041	108,209	12,253	58,700	37,256	11.3	54.2	34.4
2042	107,324	12,121	57,960	37,243	11.3	54.0	34.7
2043	106,437	11,986	57,258	37,193	11.3	53.8	34.9
2044	105,550	11,851	56,610	37,088	11.2	53.6	35.1
2045	104,664	11,717	55,994	36,953	11.2	53.5	35.3
2046	103,781	11,584	55,425	36,773	11.2	53.4	35.4
2047	102,903	11,454	54,861	36,589	11.1	53.3	35.6
2048	102,029	11,326	54,275	36,428	11.1	53.2	35.7
2049	101,161	11,203	53,686	36,271	11.1	53.1	35.9
2050	100,298	11,085	53,111	36,102	11.1	53.0	36.0
2051	99,439	10,971	52,570	35,898	11.0	52.9	36.1
2052	98,584	10,863	52,046	35,675	11.0	52.8	36.2
2053	97,732	10,760	51,549	35,423	11.0	52.7	36.2
2054	96,881	10,662	51,077	35,143	11.0	52.7	36.3
2055	96,030	10,569	50,628	34,833	11.0	52.7	36.3

Current population as of October 1 of each year. Indices for 2005 are based on the “Population Census Report” by the Statistics Bureau, Ministry of Internal Affairs and Communications (the population of “unknown” age adjusted by equally distributing over all age groups).

Table 2-3 Projected future population, proportion by the major three age groups (under 15, 15-64 and 65 and over) and age structure coefficient: [Low-variant fertility (with High-variant mortality)]

Year	Population（thousand） by age group				Proportion（%） by age group		
	Total	0-14	15-64	65+	0-14	15-64	65+
2005	127,768	17,585	84,422	25,761	13.8	66.1	20.2
2006	127,729	17,428	83,725	26,575	13.6	65.5	20.8
2007	127,564	17,169	83,001	27,393	13.5	65.1	21.5
2008	127,317	16,870	82,321	28,125	13.3	64.7	22.1
2009	127,012	16,517	81,627	28,868	13.0	64.3	22.7
2010	126,651	16,131	81,263	29,257	12.7	64.2	23.1
2011	126,238	15,737	80,989	29,513	12.5	64.2	23.4
2012	125,775	15,310	79,950	30,515	12.2	63.6	24.3
2013	125,267	14,856	78,826	31,584	11.9	62.9	25.2
2014	124,715	14,397	77,691	32,627	11.5	62.3	26.2
2015	124,122	13,917	76,768	33,436	11.2	61.8	26.9
2016	123,490	13,442	75,983	34,065	10.9	61.5	27.6
2017	122,822	12,970	75,301	34,551	10.6	61.3	28.1
2018	122,117	12,522	74,684	34,911	10.3	61.2	28.6
2019	121,380	12,090	74,148	35,142	10.0	61.1	29.0
2020	120,610	11,687	73,581	35,343	9.7	61.0	29.3
2021	119,811	11,270	73,076	35,465	9.4	61.0	29.6
2022	118,984	10,945	72,549	35,489	9.2	61.0	29.8
2023	118,130	10,674	71,929	35,526	9.0	60.9	30.1
2024	117,252	10,432	71,238	35,582	8.9	60.8	30.3
2025	116,350	10,217	70,545	35,589	8.8	60.6	30.6
2026	115,426	10,025	69,837	35,565	8.7	60.5	30.8
2027	114,480	9,852	69,087	35,541	8.6	60.3	31.0
2028	113,514	9,696	68,268	35,550	8.5	60.1	31.3
2029	112,526	9,552	67,394	35,581	8.5	59.9	31.6
2030	111,518	9,416	66,403	35,699	8.4	59.5	32.0
2031	110,490	9,287	65,713	35,491	8.4	59.5	32.1
2032	109,443	9,160	64,653	35,630	8.4	59.1	32.6
2033	108,376	9,034	63,582	35,760	8.3	58.7	33.0
2034	107,289	8,906	62,471	35,912	8.3	58.2	33.5
2035	106,183	8,775	61,325	36,083	8.3	57.8	34.0
2036	105,059	8,639	60,125	36,295	8.2	57.2	34.5
2037	103,916	8,497	58,879	36,540	8.2	56.7	35.2
2038	102,758	8,348	57,596	36,814	8.1	56.1	35.8
2039	101,585	8,191	56,345	37,050	8.1	55.5	36.5
2040	100,400	8,027	55,181	37,192	8.0	55.0	37.0
2041	99,205	7,856	54,093	37,256	7.9	54.5	37.6
2042	98,001	7,679	53,079	37,243	7.8	54.2	38.0
2043	96,792	7,497	52,102	37,193	7.7	53.8	38.4
2044	95,579	7,311	51,180	37,088	7.6	53.5	38.8
2045	94,365	7,123	50,288	36,953	7.5	53.3	39.2
2046	93,151	6,936	49,443	36,773	7.4	53.1	39.5
2047	91,939	6,750	48,601	36,589	7.3	52.9	39.8
2048	90,731	6,567	47,736	36,428	7.2	52.6	40.1
2049	89,526	6,390	46,865	36,271	7.1	52.3	40.5
2050	88,326	6,219	46,005	36,102	7.0	52.1	40.9
2051	87,130	6,057	45,176	35,898	7.0	51.8	41.2
2052	85,938	5,904	44,359	35,675	6.9	51.6	41.5
2053	84,749	5,761	43,565	35,423	6.8	51.4	41.8
2054	83,562	5,628	42,791	35,143	6.7	51.2	42.1
2055	82,375	5,505	42,037	34,833	6.7	51.0	42.3

Current population as of October 1 of each year. Indices for 2005 are based on the “Population Census Report” by the Statistics Bureau, Ministry of Internal Affairs and Communications (the population of “unknown” age adjusted by equally distributing over all age groups).

Figure 2-1 Actual and projected population of Japan
- Medium, high and low fertility (with high mortality) variants -

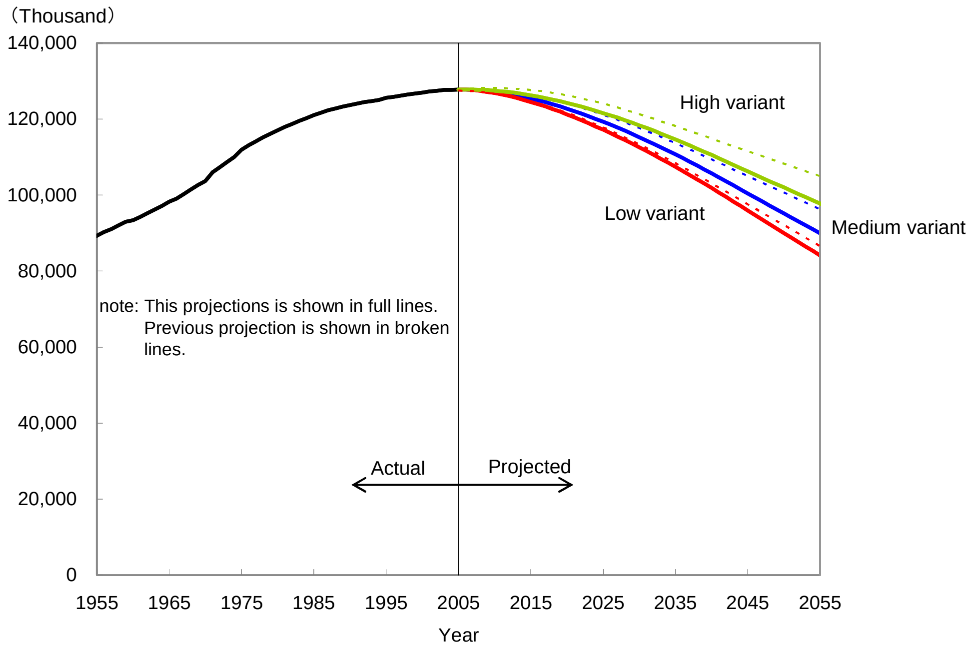


Figure 2-2 Trends in the proportion of elderly
- Medium, high and low fertility (with high mortality) variants -

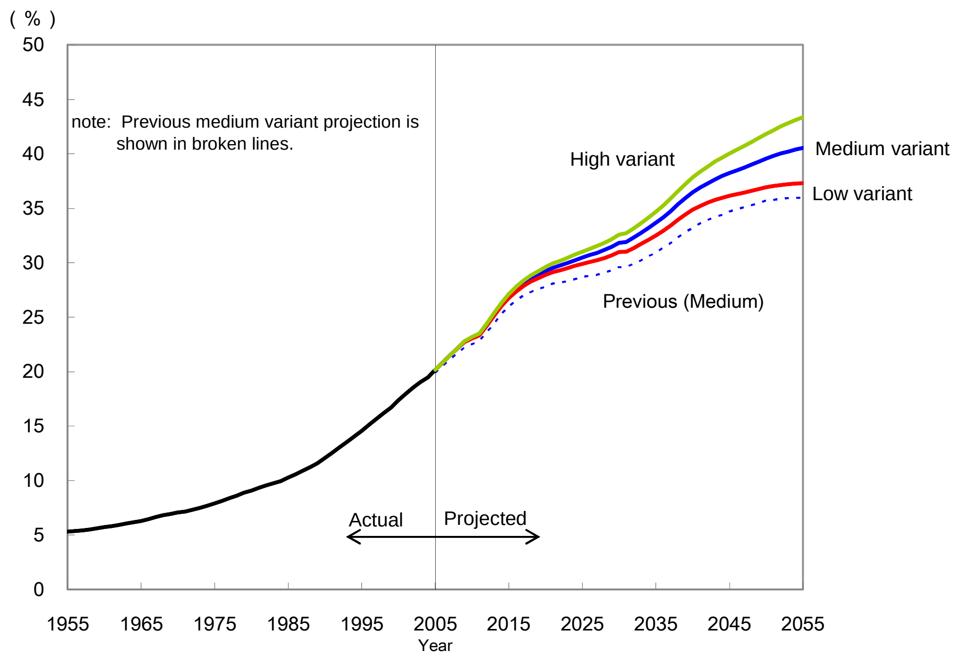


Table 3-1 Projected future population, proportion by the major three age groups (under 15, 15-64 and 65 and over) and age structure coefficient: [Medium-variant fertility (with Low-variant mortality)]

Year	Population（thousand） by age group				Proportion（%） by age group		
	Total	0-14	15-64	65+	0-14	15-64	65+
2005	127,768	17,585	84,422	25,761	13.8	66.1	20.2
2006	127,788	17,437	83,733	26,619	13.6	65.5	20.8
2007	127,756	17,238	83,018	27,500	13.5	65.0	21.5
2008	127,667	17,024	82,346	28,297	13.3	64.5	22.2
2009	127,533	16,764	81,661	29,107	13.1	64.0	22.8
2010	127,352	16,481	81,306	29,565	12.9	63.8	23.2
2011	127,127	16,194	81,041	29,891	12.7	63.7	23.5
2012	126,858	15,881	80,009	30,967	12.5	63.1	24.4
2013	126,548	15,544	78,892	32,112	12.3	62.3	25.4
2014	126,199	15,203	77,762	33,234	12.0	61.6	26.3
2015	125,811	14,844	76,845	34,122	11.8	61.1	27.1
2016	125,386	14,488	76,065	34,832	11.6	60.7	27.8
2017	124,924	14,136	75,389	35,399	11.3	60.3	28.3
2018	124,427	13,806	74,778	35,843	11.1	60.1	28.8
2019	123,897	13,491	74,248	36,158	10.9	59.9	29.2
2020	123,335	13,205	73,687	36,444	10.7	59.7	29.5
2021	122,743	12,895	73,196	36,651	10.5	59.6	29.9
2022	122,122	12,626	72,736	36,761	10.3	59.6	30.1
2023	121,474	12,385	72,206	36,884	10.2	59.4	30.4
2024	120,799	12,163	71,613	37,024	10.1	59.3	30.6
2025	120,100	11,960	71,028	37,113	10.0	59.1	30.9
2026	119,378	11,773	70,433	37,172	9.9	59.0	31.1
2027	118,633	11,601	69,802	37,230	9.8	58.8	31.4
2028	117,866	11,442	69,104	37,320	9.7	58.6	31.7
2029	117,079	11,294	68,353	37,433	9.6	58.4	32.0
2030	116,273	11,154	67,484	37,634	9.6	58.0	32.4
2031	115,445	11,021	66,919	37,505	9.5	58.0	32.5
2032	114,598	10,892	65,981	37,725	9.5	57.6	32.9
2033	113,731	10,767	65,030	37,935	9.5	57.2	33.4
2034	112,844	10,642	64,037	38,165	9.4	56.7	33.8
2035	111,936	10,517	63,008	38,412	9.4	56.3	34.3
2036	111,010	10,389	61,922	38,698	9.4	55.8	34.9
2037	110,064	10,259	60,790	39,016	9.3	55.2	35.4
2038	109,101	10,124	59,618	39,360	9.3	54.6	36.1
2039	108,121	9,984	58,477	39,661	9.2	54.1	36.7
2040	107,127	9,838	57,424	39,865	9.2	53.6	37.2
2041	106,120	9,688	56,446	39,986	9.1	53.2	37.7
2042	105,103	9,532	55,544	40,027	9.1	52.8	38.1
2043	104,076	9,372	54,678	40,026	9.0	52.5	38.5
2044	103,042	9,208	53,868	39,966	8.9	52.3	38.8
2045	102,004	9,042	53,089	39,873	8.9	52.0	39.1
2046	100,963	8,874	52,358	39,731	8.8	51.9	39.4
2047	99,921	8,707	51,631	39,583	8.7	51.7	39.6
2048	98,879	8,541	50,882	39,456	8.6	51.5	39.9
2049	97,839	8,379	50,128	39,332	8.6	51.2	40.2
2050	96,803	8,220	49,387	39,195	8.5	51.0	40.5
2051	95,769	8,067	48,678	39,024	8.4	50.8	40.7
2052	94,740	7,921	47,984	38,835	8.4	50.6	41.0
2053	93,714	7,781	47,315	38,619	8.3	50.5	41.2
2054	92,691	7,648	46,668	38,376	8.3	50.3	41.4
2055	91,669	7,522	46,042	38,104	8.2	50.2	41.6

Current population as of October 1 of each year. Indices for 2005 are based on the “Population Census Report” by the Statistics Bureau, Ministry of Internal Affairs and Communications (the population of “unknown” age adjusted by equally distributing over all age groups).

Table 3-2 Projected future population, proportion by the major three age groups (under 15, 15-64 and 65 and over) and age structure coefficient: [High-variant fertility (with Low-variant mortality)]

Year	Population(thousand) by age group				Proportion(%) by age group		
	Total	0-14	15-64	65+	0-14	15-64	65+
2005	127,768	17,585	84,422	25,761	13.8	66.1	20.2
2006	127,803	17,451	83,733	26,619	13.7	65.5	20.8
2007	127,823	17,306	83,018	27,500	13.5	64.9	21.5
2008	127,802	17,159	82,346	28,297	13.4	64.4	22.1
2009	127,740	16,972	81,661	29,107	13.3	63.9	22.8
2010	127,639	16,767	81,306	29,565	13.1	63.7	23.2
2011	127,499	16,567	81,041	29,891	13.0	63.6	23.4
2012	127,325	16,348	80,009	30,967	12.8	62.8	24.3
2013	127,118	16,114	78,892	32,112	12.7	62.1	25.3
2014	126,880	15,885	77,762	33,234	12.5	61.3	26.2
2015	126,612	15,645	76,845	34,122	12.4	60.7	26.9
2016	126,315	15,417	76,065	34,832	12.2	60.2	27.6
2017	125,987	15,199	75,389	35,399	12.1	59.8	28.1
2018	125,631	15,009	74,778	35,843	11.9	59.5	28.5
2019	125,246	14,840	74,248	36,158	11.8	59.3	28.9
2020	124,834	14,704	73,687	36,444	11.8	59.0	29.2
2021	124,396	14,534	73,211	36,651	11.7	58.9	29.5
2022	123,933	14,370	72,803	36,761	11.6	58.7	29.7
2023	123,445	14,222	72,339	36,884	11.5	58.6	29.9
2024	122,933	14,090	71,819	37,024	11.5	58.4	30.1
2025	122,398	13,972	71,313	37,113	11.4	58.3	30.3
2026	121,840	13,865	70,804	37,172	11.4	58.1	30.5
2027	121,261	13,765	70,266	37,230	11.4	57.9	30.7
2028	120,660	13,669	69,671	37,320	11.3	57.7	30.9
2029	120,039	13,576	69,030	37,433	11.3	57.5	31.2
2030	119,397	13,482	68,281	37,634	11.3	57.2	31.5
2031	118,736	13,388	67,842	37,505	11.3	57.1	31.6
2032	118,054	13,292	67,037	37,725	11.3	56.8	32.0
2033	117,354	13,194	66,225	37,935	11.2	56.4	32.3
2034	116,634	13,092	65,377	38,165	11.2	56.1	32.7
2035	115,895	12,987	64,496	38,412	11.2	55.7	33.1
2036	115,139	12,878	63,563	38,698	11.2	55.2	33.6
2037	114,367	12,764	62,586	39,016	11.2	54.7	34.1
2038	113,579	12,646	61,573	39,360	11.1	54.2	34.7
2039	112,777	12,524	60,592	39,661	11.1	53.7	35.2
2040	111,964	12,398	59,701	39,865	11.1	53.3	35.6
2041	111,141	12,268	58,886	39,986	11.0	53.0	36.0
2042	110,310	12,136	58,147	40,027	11.0	52.7	36.3
2043	109,473	12,002	57,446	40,026	11.0	52.5	36.6
2044	108,632	11,867	56,799	39,966	10.9	52.3	36.8
2045	107,790	11,733	56,184	39,873	10.9	52.1	37.0
2046	106,948	11,600	55,616	39,731	10.8	52.0	37.2
2047	106,106	11,470	55,053	39,583	10.8	51.9	37.3
2048	105,268	11,343	54,468	39,456	10.8	51.7	37.5
2049	104,433	11,221	53,880	39,332	10.7	51.6	37.7
2050	103,603	11,102	53,306	39,195	10.7	51.5	37.8
2051	102,778	10,989	52,765	39,024	10.7	51.3	38.0
2052	101,958	10,881	52,242	38,835	10.7	51.2	38.1
2053	101,143	10,778	51,746	38,619	10.7	51.2	38.2
2054	100,331	10,680	51,275	38,376	10.6	51.1	38.2
2055	99,520	10,588	50,828	38,104	10.6	51.1	38.3

Current population as of October 1 of each year. Indices for 2005 are based on the “Population Census Report” by the Statistics Bureau, Ministry of Internal Affairs and Communications (the population of “unknown” age adjusted by equally distributing over all age groups).

Table 3-3 Projected future population, proportion by the major three age groups (under 15, 15-64 and 65 and over) and age structure coefficient: [Low-variant fertility (with Low-variant mortality)]

Year	Population（thousand） by age group				Proportion（%） by age group		
	Total	0-14	15-64	65+	0-14	15-64	65+
2005	127,768	17,585	84,422	25,761	13.8	66.1	20.2
2006	127,780	17,429	83,733	26,619	13.6	65.5	20.8
2007	127,687	17,170	83,018	27,500	13.4	65.0	21.5
2008	127,515	16,871	82,346	28,297	13.2	64.6	22.2
2009	127,287	16,519	81,661	29,107	13.0	64.2	22.9
2010	127,005	16,133	81,306	29,565	12.7	64.0	23.3
2011	126,671	15,739	81,041	29,891	12.4	64.0	23.6
2012	126,290	15,313	80,009	30,967	12.1	63.4	24.5
2013	125,863	14,860	78,892	32,112	11.8	62.7	25.5
2014	125,396	14,401	77,762	33,234	11.5	62.0	26.5
2015	124,889	13,922	76,845	34,122	11.1	61.5	27.3
2016	124,344	13,447	76,065	34,832	10.8	61.2	28.0
2017	123,764	12,976	75,389	35,399	10.5	60.9	28.6
2018	123,149	12,528	74,778	35,843	10.2	60.7	29.1
2019	122,502	12,096	74,248	36,158	9.9	60.6	29.5
2020	121,823	11,693	73,687	36,444	9.6	60.5	29.9
2021	121,116	11,277	73,188	36,651	9.3	60.4	30.3
2022	120,381	10,952	72,668	36,761	9.1	60.4	30.5
2023	119,619	10,681	72,055	36,884	8.9	60.2	30.8
2024	118,832	10,439	71,369	37,024	8.8	60.1	31.2
2025	118,019	10,224	70,682	37,113	8.7	59.9	31.4
2026	117,184	10,032	69,980	37,172	8.6	59.7	31.7
2027	116,326	9,860	69,236	37,230	8.5	59.5	32.0
2028	115,447	9,704	68,423	37,320	8.4	59.3	32.3
2029	114,547	9,559	67,554	37,433	8.3	59.0	32.7
2030	113,626	9,424	66,568	37,634	8.3	58.6	33.1
2031	112,684	9,295	65,885	37,505	8.2	58.5	33.3
2032	111,721	9,168	64,829	37,725	8.2	58.0	33.8
2033	110,737	9,042	63,760	37,935	8.2	57.6	34.3
2034	109,731	8,915	62,652	38,165	8.1	57.1	34.8
2035	108,704	8,784	61,508	38,412	8.1	56.6	35.3
2036	107,655	8,648	60,309	38,698	8.0	56.0	35.9
2037	106,585	8,506	59,063	39,016	8.0	55.4	36.6
2038	105,496	8,357	57,780	39,360	7.9	54.8	37.3
2039	104,388	8,200	56,527	39,661	7.9	54.2	38.0
2040	103,264	8,036	55,363	39,865	7.8	53.6	38.6
2041	102,126	7,865	54,274	39,986	7.7	53.1	39.2
2042	100,976	7,688	53,261	40,027	7.6	52.7	39.6
2043	99,816	7,506	52,284	40,026	7.5	52.4	40.1
2044	98,649	7,321	51,362	39,966	7.4	52.1	40.5
2045	97,477	7,133	50,471	39,873	7.3	51.8	40.9
2046	96,302	6,945	49,626	39,731	7.2	51.5	41.3
2047	95,127	6,759	48,785	39,583	7.1	51.3	41.6
2048	93,952	6,577	47,920	39,456	7.0	51.0	42.0
2049	92,780	6,399	47,049	39,332	6.9	50.7	42.4
2050	91,613	6,229	46,189	39,195	6.8	50.4	42.8
2051	90,449	6,067	45,359	39,024	6.7	50.1	43.1
2052	89,291	5,914	44,542	38,835	6.6	49.9	43.5
2053	88,138	5,771	43,748	38,619	6.5	49.6	43.8
2054	86,988	5,638	42,974	38,376	6.5	49.4	44.1
2055	85,840	5,515	42,221	38,104	6.4	49.2	44.4

Current population as of October 1 of each year. Indices for 2005 arw based on the “Population Census Report” by the Statistics Bureau, Ministry of Internal Affairs and Communications (the population of “unknown” age adjusted by equally distributing over all age groups).

Figure 3-1 Actual and projected population of Japan
- Medium, high and low fertility (with low mortality) variants -

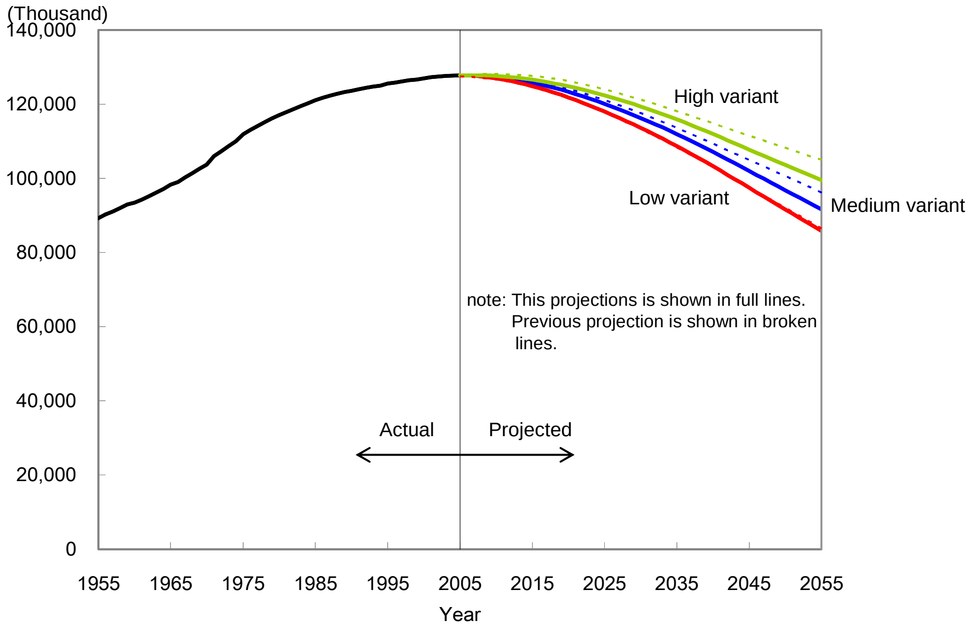
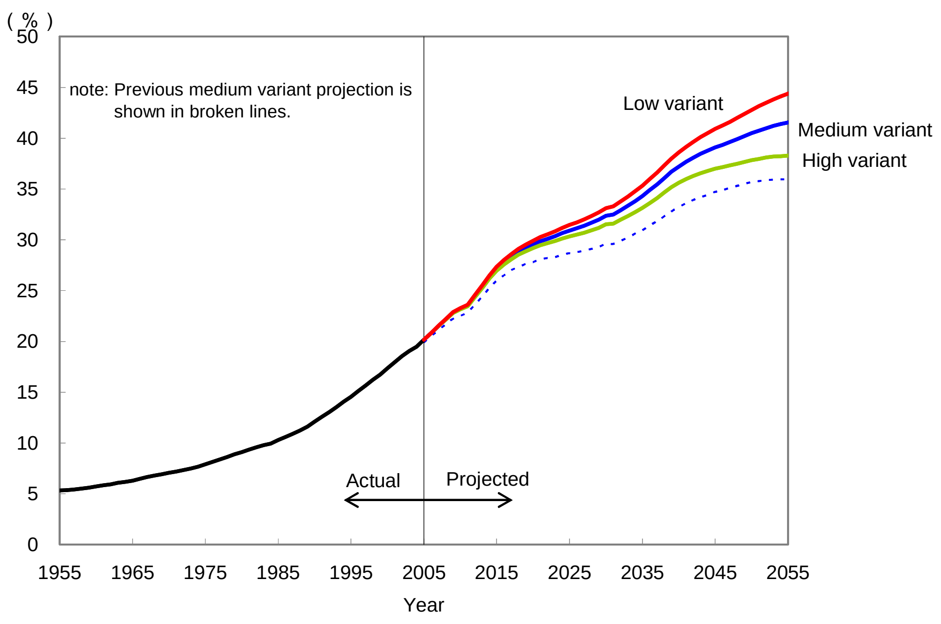


Figure 3-2 Trends in the proportion of elderly
- Medium, high and low fertility (with low mortality) variants -



[Assumptions]

Table 4-1 The total fertility rate: Medium, high and low variants

Year	Medium	High	Low
2005	1.2601	1.2601	1.2601
2006	1.2942	1.3243	1.2662
2007	1.2467	1.3170	1.1626
2008	1.2297	1.3179	1.1185
2009	1.2232	1.3214	1.0980
2010	1.2184	1.3282	1.0806
2011	1.2152	1.3383	1.0666
2012	1.2135	1.3516	1.0560
2013	1.2134	1.3677	1.0486
2014	1.2148	1.3853	1.0441
2015	1.2171	1.4033	1.0418
2016	1.2199	1.4210	1.0410
2017	1.2227	1.4376	1.0411
2018	1.2252	1.4528	1.0415
2019	1.2273	1.4664	1.0421
2020	1.2289	1.4783	1.0425
2021	1.2302	1.4885	1.0426
2022	1.2311	1.4971	1.0423
2023	1.2320	1.5042	1.0417
2024	1.2328	1.5100	1.0409
2025	1.2335	1.5145	1.0400
2026	1.2343	1.5181	1.0393
2027	1.2351	1.5209	1.0386
2028	1.2360	1.5231	1.0383
2029	1.2371	1.5249	1.0382
2030	1.2382	1.5264	1.0384
2031	1.2394	1.5277	1.0389
2032	1.2408	1.5289	1.0397
2033	1.2422	1.5301	1.0407
2034	1.2436	1.5311	1.0419
2035	1.2450	1.5322	1.0433
2036	1.2465	1.5332	1.0448
2037	1.2479	1.5342	1.0463
2038	1.2492	1.5351	1.0478
2039	1.2505	1.5360	1.0491
2040	1.2517	1.5368	1.0504
2041	1.2528	1.5376	1.0516
2042	1.2538	1.5383	1.0527
2043	1.2548	1.5389	1.0538
2044	1.2557	1.5395	1.0547
2045	1.2566	1.5401	1.0556
2046	1.2574	1.5407	1.0564
2047	1.2582	1.5412	1.0571
2048	1.2589	1.5418	1.0578
2049	1.2597	1.5424	1.0584
2050	1.2604	1.5429	1.0591
2051	1.2611	1.5435	1.0598
2052	1.2618	1.5441	1.0605
2053	1.2625	1.5447	1.0613
2054	1.2632	1.5454	1.0622
2055	1.2640	1.5461	1.0630

Figures for 2005 are actual values. Afterwards, figures are based on the projections from medium mortality variant.

Table 4-2 The life expectancy at birth: Medium, high and low variants (continued on next page)

(Years)

Year	Medium mortality		
	Male	Female	Sex difference
2005	78.53	85.49	6.96
2006	78.85	85.78	6.93
2007	79.02	85.94	6.92
2008	79.19	86.10	6.91
2009	79.35	86.25	6.90
2010	79.51	86.41	6.90
2011	79.66	86.55	6.89
2012	79.80	86.69	6.89
2013	79.94	86.82	6.88
2014	80.08	86.95	6.87
2015	80.22	87.08	6.86
2016	80.35	87.20	6.85
2017	80.49	87.33	6.84
2018	80.61	87.45	6.83
2019	80.73	87.57	6.84
2020	80.85	87.68	6.83
2021	80.96	87.78	6.83
2022	81.07	87.89	6.82
2023	81.18	87.99	6.81
2024	81.29	88.09	6.80
2025	81.39	88.19	6.79
2026	81.50	88.28	6.79
2027	81.60	88.38	6.78
2028	81.70	88.48	6.78
2029	81.79	88.57	6.78
2030	81.88	88.66	6.78
2031	81.97	88.74	6.78
2032	82.06	88.83	6.77
2033	82.14	88.90	6.76
2034	82.23	88.98	6.76
2035	82.31	89.06	6.75
2036	82.39	89.14	6.74
2037	82.47	89.21	6.74
2038	82.55	89.28	6.73
2039	82.63	89.36	6.73
2040	82.71	89.43	6.72
2041	82.78	89.50	6.72
2042	82.85	89.57	6.72
2043	82.92	89.64	6.72
2044	82.99	89.71	6.72
2045	83.05	89.77	6.72
2046	83.12	89.83	6.72
2047	83.18	89.89	6.71
2048	83.25	89.95	6.70
2049	83.31	90.01	6.70
2050	83.37	90.07	6.69
2051	83.43	90.12	6.69
2052	83.50	90.18	6.68
2053	83.56	90.24	6.68
2054	83.62	90.29	6.67
2055	83.67	90.34	6.67

Figures for 2005 are actual values.

Table 4-2 The life expectancy at birth: Medium, high and low variants (continued)

(Years)

Year	High mortality			Low mortality		
	Male	Female	Sex difference	Male	Female	Sex difference
2005	78.53	85.49	6.96	78.53	85.49	6.96
2006	78.51	85.47	6.96	79.19	86.10	6.90
2007	78.66	85.61	6.96	79.39	86.28	6.89
2008	78.80	85.75	6.95	79.58	86.47	6.88
2009	78.94	85.88	6.94	79.76	86.64	6.88
2010	79.07	86.00	6.93	79.93	86.80	6.87
2011	79.20	86.12	6.92	80.11	86.96	6.86
2012	79.33	86.24	6.92	80.28	87.12	6.84
2013	79.45	86.36	6.91	80.45	87.28	6.83
2014	79.57	86.48	6.90	80.61	87.44	6.82
2015	79.68	86.59	6.91	80.77	87.59	6.82
2016	79.79	86.69	6.90	80.92	87.73	6.82
2017	79.89	86.79	6.89	81.06	87.87	6.81
2018	79.99	86.88	6.89	81.21	88.01	6.79
2019	80.09	86.97	6.88	81.36	88.14	6.78
2020	80.19	87.06	6.87	81.50	88.27	6.77
2021	80.29	87.15	6.87	81.64	88.40	6.76
2022	80.38	87.24	6.86	81.77	88.53	6.76
2023	80.47	87.33	6.86	81.90	88.66	6.76
2024	80.56	87.41	6.85	82.02	88.78	6.76
2025	80.64	87.49	6.85	82.15	88.89	6.75
2026	80.72	87.57	6.85	82.27	89.01	6.74
2027	80.80	87.65	6.85	82.39	89.12	6.73
2028	80.87	87.72	6.85	82.51	89.23	6.72
2029	80.95	87.79	6.84	82.63	89.34	6.71
2030	81.02	87.86	6.84	82.74	89.44	6.70
2031	81.09	87.92	6.83	82.85	89.55	6.70
2032	81.16	87.99	6.83	82.95	89.66	6.71
2033	81.23	88.05	6.82	83.06	89.76	6.70
2034	81.29	88.11	6.82	83.16	89.85	6.69
2035	81.36	88.18	6.82	83.26	89.94	6.68
2036	81.42	88.24	6.81	83.36	90.03	6.68
2037	81.49	88.30	6.81	83.46	90.12	6.67
2038	81.55	88.35	6.80	83.55	90.21	6.66
2039	81.61	88.41	6.80	83.65	90.30	6.65
2040	81.67	88.47	6.80	83.74	90.39	6.64
2041	81.72	88.53	6.80	83.83	90.47	6.64
2042	81.78	88.58	6.80	83.92	90.56	6.64
2043	81.83	88.63	6.80	84.00	90.64	6.64
2044	81.88	88.69	6.80	84.09	90.73	6.64
2045	81.93	88.73	6.80	84.17	90.81	6.64
2046	81.98	88.78	6.80	84.25	90.88	6.63
2047	82.03	88.83	6.79	84.33	90.96	6.63
2048	82.08	88.87	6.79	84.41	91.03	6.62
2049	82.13	88.92	6.79	84.49	91.10	6.61
2050	82.18	88.96	6.78	84.57	91.17	6.60
2051	82.22	89.00	6.78	84.64	91.24	6.60
2052	82.27	89.05	6.78	84.72	91.31	6.59
2053	82.32	89.09	6.77	84.79	91.38	6.58
2054	82.36	89.13	6.77	84.86	91.45	6.58
2055	82.41	89.17	6.77	84.93	91.51	6.58

Figures for 2005 are actual values.

Table 4-3 Age-specific net international migration rates by sex for Japanese

Age at the year end	Male	Female	Age at the year end	Male	Female
0	-0.00435	-0.00441	55	-0.00076	0.00005
1	-0.00340	-0.00341	56	-0.00068	0.00010
2	-0.00223	-0.00224	57	-0.00064	0.00012
3	-0.00118	-0.00121	58	-0.00064	0.00011
4	-0.00054	-0.00058	59	-0.00061	0.00012
5	-0.00034	-0.00036	60	-0.00053	0.00015
6	-0.00035	-0.00034	61	-0.00039	0.00021
7	-0.00020	-0.00016	62	-0.00025	0.00024
8	-0.00008	-0.00007	63	-0.00017	0.00022
9	-0.00001	-0.00002	64	-0.00013	0.00020
10	0.00002	0.00000	65	-0.00009	0.00019
11	0.00004	0.00001	66	-0.00002	0.00021
12	0.00020	0.00020	67	0.00002	0.00021
13	0.00035	0.00031	68	0.00004	0.00018
14	0.00035	0.00013	69	0.00007	0.00015
15	0.00031	-0.00001	70	0.00011	0.00012
16	0.00019	-0.00011	71	0.00014	0.00012
17	-0.00006	-0.00028	72	0.00014	0.00013
18	-0.00047	-0.00078	73	0.00012	0.00013
19	-0.00093	-0.00150	74	0.00009	0.00011
20	-0.00130	-0.00214	75	0.00008	0.00007
21	-0.00134	-0.00237	76	0.00007	0.00004
22	-0.00097	-0.00202	77	0.00005	0.00002
23	-0.00055	-0.00155	78	0.00004	0.00002
24	-0.00033	-0.00122	79	0.00004	0.00002
25	-0.00023	-0.00084	80	0.00005	0.00001
26	-0.00023	-0.00047	81	0.00004	0.00001
27	-0.00023	-0.00011	82	0.00004	0.00001
28	-0.00021	0.00000	83	0.00002	0.00001
29	-0.00022	-0.00009	84	0.00001	0.00001
30	-0.00029	-0.00021	85	-0.00001	0.00001
31	-0.00038	-0.00026	86	-0.00002	0.00001
32	-0.00046	-0.00024	87	-0.00003	0.00000
33	-0.00049	-0.00019	88	-0.00003	0.00001
34	-0.00047	-0.00011	89	-0.00003	0.00001
35	-0.00042	-0.00004	90	0.00000	0.00000
36	-0.00040	0.00004	91	0.00000	0.00000
37	-0.00043	0.00014	92	0.00000	0.00000
38	-0.00052	0.00021	93	0.00000	0.00000
39	-0.00059	0.00028	94	0.00000	0.00000
40	-0.00062	0.00033	95	0.00000	0.00000
41	-0.00062	0.00037	96	0.00000	0.00000
42	-0.00062	0.00037	97	0.00000	0.00000
43	-0.00062	0.00032	98	0.00000	0.00000
44	-0.00063	0.00025	99	0.00000	0.00000
45	-0.00066	0.00016	100	0.00000	0.00000
46	-0.00071	0.00009	101	0.00000	0.00000
47	-0.00076	0.00004	102	0.00000	0.00000
48	-0.00080	0.00002	103	0.00000	0.00000
49	-0.00081	0.00000	104	0.00000	0.00000
50	-0.00081	-0.00002	105+	0.00000	0.00000
51	-0.00082	-0.00003			
52	-0.00085	-0.00004			
53	-0.00086	-0.00004			
54	-0.00084	0.00000			

Rate of net international migration of Japanese to the total Japanese population.

Table 4-4 Non-Japanese net migrants by sex (Persons)

Year at the term end	Male	Female	Year at the term end	Male	Female	Year at the term end	Male	Female
2006	25,890	26,462	2013	30,106	37,518	2020	32,384	40,838
2007	26,677	28,972	2014	30,518	38,263	2021	32,617	41,067
2008	27,390	31,079	2015	30,896	38,891	2022	32,833	41,261
2009	28,038	32,848	2016	31,244	39,421	2023	33,034	41,427
2010	28,627	34,334	2017	31,564	39,869	2024	33,220	41,567
2011	29,165	35,583	2018	31,859	40,247	2025	33,393	41,686
2012	29,656	36,634	2019	32,132	40,567			

Table 4-5 Age distributions of non-Japanese net migrants by sex

Age at the year end	Male	Female	Age at the year end	Male	Female
0	-0.00180	-0.00044	55	-0.00198	-0.00136
1	0.00326	0.00243	56	-0.00222	-0.00153
2	0.00474	0.00309	57	-0.00275	-0.00181
3	0.00304	0.00183	58	-0.00336	-0.00199
4	-0.00004	-0.00005	59	-0.00364	-0.00197
5	-0.00219	-0.00115	60	-0.00340	-0.00185
6	-0.00212	-0.00087	61	-0.00278	-0.00171
7	-0.00102	-0.00012	62	-0.00227	-0.00154
8	0.00045	0.00072	63	-0.00201	-0.00137
9	0.00185	0.00143	64	-0.00197	-0.00119
10	0.00267	0.00182	65	-0.00192	-0.00106
11	0.00283	0.00189	66	-0.00157	-0.00095
12	0.00305	0.00214	67	-0.00118	-0.00090
13	0.00457	0.00297	68	-0.00091	-0.00087
14	0.00626	0.00221	69	-0.00086	-0.00080
15	0.00836	0.00228	70	-0.00083	-0.00068
16	0.01844	0.01240	71	-0.00067	-0.00053
17	0.04253	0.03911	72	-0.00055	-0.00043
18	0.07496	0.07820	73	-0.00049	-0.00040
19	0.10608	0.11587	74	-0.00048	-0.00041
20	0.12761	0.13681	75	-0.00046	-0.00041
21	0.13486	0.13368	76	-0.00037	-0.00036
22	0.12916	0.11243	77	-0.00027	-0.00027
23	0.11464	0.08625	78	-0.00031	-0.00019
24	0.09288	0.06304	79	-0.00044	-0.00014
25	0.06653	0.04632	80	-0.00052	-0.00011
26	0.04411	0.03684	81	-0.00046	-0.00011
27	0.03086	0.03207	82	-0.00034	-0.00013
28	0.02283	0.02817	83	-0.00023	-0.00013
29	0.01665	0.02326	84	-0.00019	-0.00010
30	0.01133	0.01749	85	-0.00018	-0.00007
31	0.00706	0.01187	86	-0.00018	-0.00005
32	0.00418	0.00738	87	-0.00014	-0.00003
33	0.00196	0.00430	88	-0.00009	-0.00002
34	-0.00073	0.00252	89	-0.00004	-0.00001
35	-0.00356	0.00211	90	0.00001	0.00000
36	-0.00551	0.00242	91	0.00000	0.00000
37	-0.00594	0.00277	92	0.00000	0.00000
38	-0.00532	0.00280	93	0.00000	0.00000
39	-0.00438	0.00253	94	0.00000	0.00000
40	-0.00325	0.00225	95	0.00000	0.00000
41	-0.00194	0.00224	96	0.00000	0.00000
42	-0.00083	0.00232	97	0.00000	0.00000
43	-0.00010	0.00198	98	0.00000	0.00000
44	0.00001	0.00134	99	0.00000	0.00000
45	-0.00021	0.00078	100	0.00000	0.00000
46	-0.00043	0.00037	101	0.00000	0.00000
47	-0.00042	0.00003	102	0.00000	0.00000
48	-0.00042	-0.00024	103	0.00000	0.00000
49	-0.00054	-0.00054	104	0.00000	0.00000
50	-0.00075	-0.00082	105+	0.00000	0.00000
51	-0.00107	-0.00108			
52	-0.00150	-0.00129			
53	-0.00177	-0.00136			
54	-0.00185	-0.00134			

Age distributions assuming the total net migrants as 1 for each sex respectively.

Figure 4-1 Trends in the total fertility rate: Medium, high and low variants

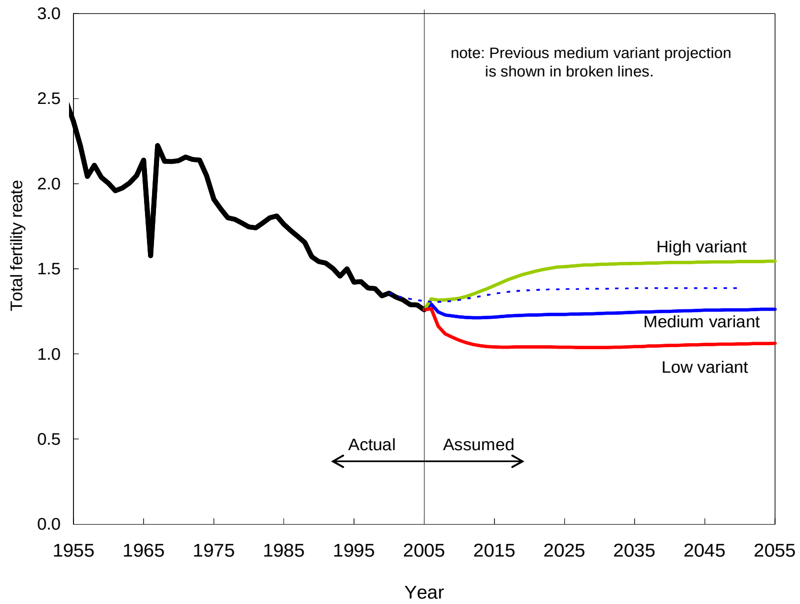


Figure 4-2 Trends in life expectancy: Medium, high and low variants

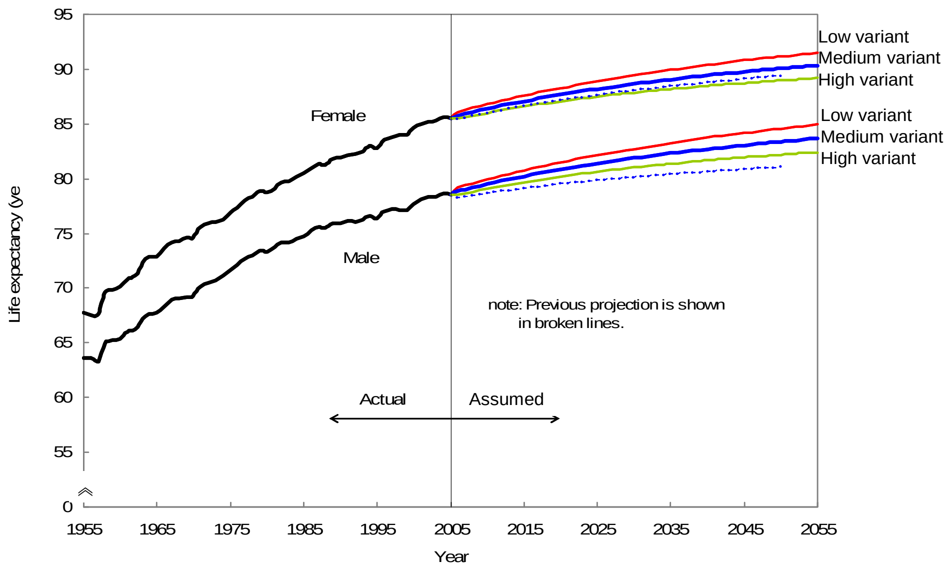


Figure 4-3 Age-specific net international migration rates by sex for Japanese

Figure 4-4 Trends in non-Japanese net migrants by sex

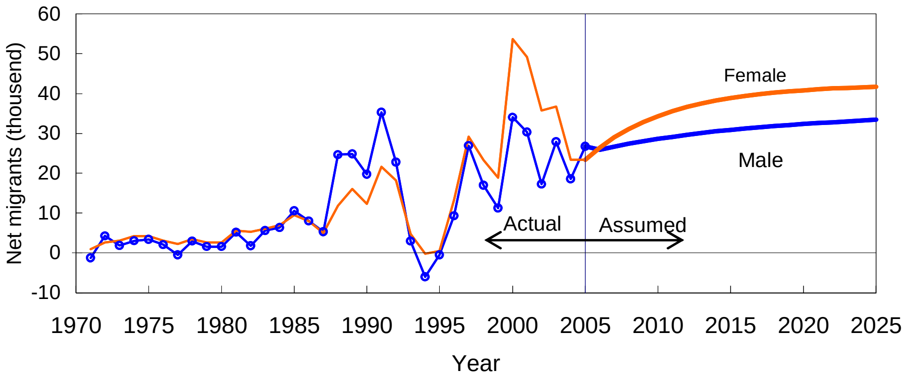
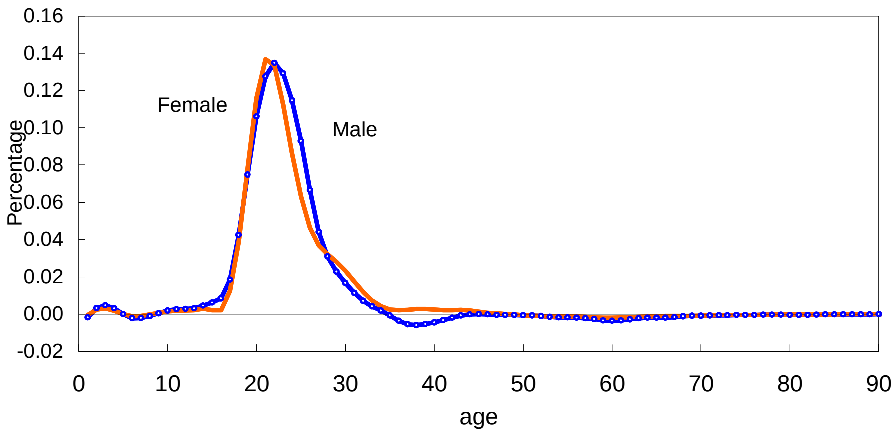


Figure 4-5 Age distributions of non-Japanese net migrants by sex



[Appendix Long-range Population Projections]

In order to be used as a reference for the analysis on population development for the long term, ancillary projections were made for the period from 2056 to 2105. Mortality rate, fertility rate, sex ratio at births, and rate (number) of international net migration are assumed to remain constant for 2056 and thereafter.

Table A-1 Projected future population, proportion by the major three age groups (under 15, 15-64 and 65 and over) and age structure coefficient: [Medium-variant fertility (with Medium-variant mortality)]

Year	Population（thousand） by age group				Proportion（%） by age group		
	Total	0-14	15-64	65+	0-14	15-64	65+
2056	88,882	7,397	45,336	36,149	8.3	51.0	40.7
2057	87,825	7,286	44,707	35,832	8.3	50.9	40.8
2058	86,757	7,181	44,086	35,491	8.3	50.8	40.9
2059	85,679	7,081	43,437	35,161	8.3	50.7	41.0
2060	84,592	6,987	42,778	34,827	8.3	50.6	41.2
2061	83,495	6,897	42,130	34,468	8.3	50.5	41.3
2062	82,390	6,810	41,468	34,112	8.3	50.3	41.4
2063	81,278	6,726	40,795	33,758	8.3	50.2	41.5
2064	80,162	6,644	40,127	33,391	8.3	50.1	41.7
2065	79,043	6,563	39,452	33,028	8.3	49.9	41.8
2066	77,923	6,483	38,788	32,653	8.3	49.8	41.9
2067	76,805	6,402	38,133	32,269	8.3	49.6	42.0
2068	75,691	6,322	37,507	31,863	8.4	49.6	42.1
2069	74,585	6,240	36,901	31,444	8.4	49.5	42.2
2070	73,488	6,158	36,325	31,005	8.4	49.4	42.2
2071	72,403	6,074	35,735	30,594	8.4	49.4	42.3
2072	71,332	5,990	35,185	30,157	8.4	49.3	42.3
2073	70,276	5,904	34,665	29,706	8.4	49.3	42.3
2074	69,237	5,818	34,166	29,253	8.4	49.3	42.3
2075	68,216	5,732	33,686	28,798	8.4	49.4	42.2
2076	67,213	5,645	33,223	28,345	8.4	49.4	42.2
2077	66,229	5,558	32,775	27,896	8.4	49.5	42.1
2078	65,263	5,472	32,341	27,450	8.4	49.6	42.1
2079	64,316	5,387	31,918	27,011	8.4	49.6	42.0
2080	63,387	5,304	31,505	26,578	8.4	49.7	41.9
2081	62,475	5,222	31,100	26,152	8.4	49.8	41.9
2082	61,579	5,143	30,703	25,733	8.4	49.9	41.8
2083	60,699	5,065	30,311	25,322	8.3	49.9	41.7
2084	59,834	4,991	29,925	24,918	8.3	50.0	41.6
2085	58,983	4,919	29,543	24,521	8.3	50.1	41.6
2086	58,146	4,850	29,164	24,132	8.3	50.2	41.5
2087	57,322	4,783	28,789	23,750	8.3	50.2	41.4
2088	56,511	4,720	28,415	23,376	8.4	50.3	41.4
2089	55,712	4,658	28,044	23,010	8.4	50.3	41.3
2090	54,925	4,600	27,674	22,651	8.4	50.4	41.2
2091	54,150	4,543	27,306	22,300	8.4	50.4	41.2
2092	53,386	4,489	26,939	21,958	8.4	50.5	41.1
2093	52,634	4,436	26,575	21,623	8.4	50.5	41.1
2094	51,894	4,384	26,214	21,296	8.4	50.5	41.0
2095	51,165	4,334	25,855	20,976	8.5	50.5	41.0
2096	50,449	4,285	25,501	20,663	8.5	50.5	41.0
2097	49,746	4,236	25,152	20,357	8.5	50.6	40.9
2098	49,055	4,188	24,809	20,057	8.5	50.6	40.9
2099	48,377	4,140	24,473	19,764	8.6	50.6	40.9
2100	47,712	4,093	24,144	19,475	8.6	50.6	40.8
2101	47,061	4,045	23,824	19,192	8.6	50.6	40.8
2102	46,424	3,998	23,512	18,914	8.6	50.6	40.7
2103	45,800	3,951	23,209	18,640	8.6	50.7	40.7
2104	45,189	3,903	22,916	18,371	8.6	50.7	40.7
2105	44,592	3,856	22,631	18,105	8.6	50.8	40.6

Current population as of October 1 of each year.

Table A-2 Projected future population, proportion by the major three age groups (under 15, 15-64 and 65 and over) and age structure coefficient: [High-variant fertility (with Medium-variant mortality)]

Year	Population（thousand）by age group				Proportion（%）by age group		
	Total	0-14	15-64	65+	0-14	15-64	65+
2056	96,938	10,490	50,299	36,149	10.8	51.9	37.3
2057	96,091	10,405	49,854	35,832	10.8	51.9	37.3
2058	95,234	10,324	49,420	35,491	10.8	51.9	37.3
2059	94,367	10,245	48,961	35,161	10.9	51.9	37.3
2060	93,489	10,168	48,495	34,827	10.9	51.9	37.3
2061	92,602	10,093	48,041	34,468	10.9	51.9	37.2
2062	91,706	10,017	47,576	34,112	10.9	51.9	37.2
2063	90,802	9,942	47,102	33,758	10.9	51.9	37.2
2064	89,893	9,866	46,636	33,391	11.0	51.9	37.1
2065	88,980	9,789	46,162	33,028	11.0	51.9	37.1
2066	88,066	9,711	45,702	32,653	11.0	51.9	37.1
2067	87,153	9,632	45,252	32,269	11.1	51.9	37.0
2068	86,244	9,551	44,830	31,863	11.1	52.0	36.9
2069	85,341	9,468	44,428	31,444	11.1	52.1	36.8
2070	84,448	9,385	44,058	31,005	11.1	52.2	36.7
2071	83,566	9,300	43,659	30,607	11.1	52.2	36.6
2072	82,697	9,214	43,266	30,218	11.1	52.3	36.5
2073	81,844	9,127	42,889	29,828	11.2	52.4	36.4
2074	81,006	9,041	42,527	29,439	11.2	52.5	36.3
2075	80,187	8,954	42,177	29,055	11.2	52.6	36.2
2076	79,385	8,868	41,838	28,679	11.2	52.7	36.1
2077	78,601	8,783	41,506	28,312	11.2	52.8	36.0
2078	77,836	8,700	41,179	27,957	11.2	52.9	35.9
2079	77,088	8,618	40,854	27,615	11.2	53.0	35.8
2080	76,356	8,538	40,532	27,287	11.2	53.1	35.7
2081	75,641	8,460	40,210	26,971	11.2	53.2	35.7
2082	74,941	8,385	39,889	26,667	11.2	53.2	35.6
2083	74,255	8,312	39,568	26,375	11.2	53.3	35.5
2084	73,583	8,241	39,248	26,093	11.2	53.3	35.5
2085	72,922	8,173	38,927	25,822	11.2	53.4	35.4
2086	72,273	8,107	38,607	25,559	11.2	53.4	35.4
2087	71,635	8,043	38,287	25,305	11.2	53.4	35.3
2088	71,006	7,982	37,966	25,059	11.2	53.5	35.3
2089	70,387	7,921	37,646	24,820	11.3	53.5	35.3
2090	69,776	7,862	37,326	24,587	11.3	53.5	35.2
2091	69,173	7,804	37,008	24,361	11.3	53.5	35.2
2092	68,578	7,747	36,690	24,140	11.3	53.5	35.2
2093	67,990	7,691	36,375	23,924	11.3	53.5	35.2
2094	67,410	7,635	36,063	23,712	11.3	53.5	35.2
2095	66,836	7,579	35,754	23,503	11.3	53.5	35.2
2096	66,269	7,523	35,450	23,297	11.4	53.5	35.2
2097	65,710	7,466	35,150	23,094	11.4	53.5	35.1
2098	65,157	7,410	34,855	22,893	11.4	53.5	35.1
2099	64,612	7,353	34,566	22,694	11.4	53.5	35.1
2100	64,074	7,296	34,282	22,496	11.4	53.5	35.1
2101	63,543	7,238	34,005	22,300	11.4	53.5	35.1
2102	63,019	7,180	33,734	22,105	11.4	53.5	35.1
2103	62,502	7,123	33,468	21,911	11.4	53.5	35.1
2104	61,992	7,065	33,209	21,719	11.4	53.6	35.0
2105	61,489	7,007	32,955	21,528	11.4	53.6	35.0

Current population as of October 1 of each year.

Table A-3 Projected future population, proportion by the major three age groups (under 15, 15-64 and 65 and over) and age structure coefficient: [Low-variant fertility (with Medium-variant mortality)]

Year	Population（thousand）by age group				Proportion（%）by age group		
	Total	0-14	15-64	65+	0-14	15-64	65+
2056	82,934	5,396	41,389	36,149	6.5	49.9	43.6
2057	81,752	5,291	40,629	35,832	6.5	49.7	43.8
2058	80,562	5,194	39,877	35,491	6.4	49.5	44.1
2059	79,362	5,104	39,097	35,161	6.4	49.3	44.3
2060	78,154	5,020	38,307	34,827	6.4	49.0	44.6
2061	76,937	4,940	37,528	34,468	6.4	48.8	44.8
2062	75,712	4,864	36,736	34,112	6.4	48.5	45.1
2063	74,482	4,791	35,933	33,758	6.4	48.2	45.3
2064	73,247	4,719	35,138	33,391	6.4	48.0	45.6
2065	72,011	4,647	34,335	33,028	6.5	47.7	45.9
2066	70,774	4,576	33,545	32,653	6.5	47.4	46.1
2067	69,540	4,505	32,766	32,269	6.5	47.1	46.4
2068	68,312	4,432	32,017	31,863	6.5	46.9	46.6
2069	67,091	4,358	31,289	31,444	6.5	46.6	46.9
2070	65,881	4,283	30,594	31,005	6.5	46.4	47.1
2071	64,684	4,206	29,891	30,587	6.5	46.2	47.3
2072	63,502	4,128	29,278	30,095	6.5	46.1	47.4
2073	62,336	4,050	28,717	29,569	6.5	46.1	47.4
2074	61,189	3,970	28,187	29,032	6.5	46.1	47.4
2075	60,060	3,890	27,683	28,487	6.5	46.1	47.4
2076	58,952	3,811	27,203	27,938	6.5	46.1	47.4
2077	57,864	3,732	26,744	27,388	6.4	46.2	47.3
2078	56,796	3,654	26,302	26,841	6.4	46.3	47.3
2079	55,749	3,577	25,873	26,298	6.4	46.4	47.2
2080	54,721	3,503	25,455	25,763	6.4	46.5	47.1
2081	53,712	3,431	25,046	25,235	6.4	46.6	47.0
2082	52,722	3,361	24,644	24,716	6.4	46.7	46.9
2083	51,750	3,294	24,248	24,207	6.4	46.9	46.8
2084	50,795	3,231	23,857	23,707	6.4	47.0	46.7
2085	49,858	3,171	23,469	23,218	6.4	47.1	46.6
2086	48,936	3,113	23,085	22,738	6.4	47.2	46.5
2087	48,031	3,059	22,703	22,268	6.4	47.3	46.4
2088	47,141	3,008	22,323	21,809	6.4	47.4	46.3
2089	46,266	2,959	21,946	21,360	6.4	47.4	46.2
2090	45,407	2,913	21,571	20,922	6.4	47.5	46.1
2091	44,562	2,870	21,199	20,494	6.4	47.6	46.0
2092	43,733	2,828	20,829	20,077	6.5	47.6	45.9
2093	42,920	2,787	20,462	19,671	6.5	47.7	45.8
2094	42,122	2,749	20,099	19,275	6.5	47.7	45.8
2095	41,341	2,711	19,742	18,889	6.6	47.8	45.7
2096	40,577	2,673	19,390	18,513	6.6	47.8	45.6
2097	39,830	2,637	19,046	18,147	6.6	47.8	45.6
2098	39,101	2,601	18,709	17,791	6.7	47.8	45.5
2099	38,390	2,565	18,382	17,443	6.7	47.9	45.4
2100	37,697	2,529	18,065	17,103	6.7	47.9	45.4
2101	37,024	2,493	17,759	16,772	6.7	48.0	45.3
2102	36,369	2,457	17,465	16,448	6.8	48.0	45.2
2103	35,734	2,421	17,182	16,131	6.8	48.1	45.1
2104	35,117	2,385	16,910	15,821	6.8	48.2	45.1
2105	34,518	2,350	16,650	15,518	6.8	48.2	45.0

Current population as of October 1 of each year.

Table A-4 Projected future population, proportion by the major three age groups (under 15, 15-64 and 65 and over) and age structure coefficient: [Medium-variant fertility (with High-variant mortality)]

Year	Population（thousand）by age group				Proportion（%）by age group		
	Total	0-14	15-64	65+	0-14	15-64	65+
2056	87,125	7,390	45,236	34,499	8.5	51.9	39.6
2057	86,049	7,279	44,607	34,163	8.5	51.8	39.7
2058	84,964	7,174	43,985	33,805	8.4	51.8	39.8
2059	83,871	7,074	43,336	33,461	8.4	51.7	39.9
2060	82,770	6,980	42,678	33,113	8.4	51.6	40.0
2061	81,663	6,889	42,029	32,744	8.4	51.5	40.1
2062	80,550	6,803	41,368	32,379	8.4	51.4	40.2
2063	79,434	6,719	40,695	32,020	8.5	51.2	40.3
2064	78,316	6,637	40,029	31,651	8.5	51.1	40.4
2065	77,199	6,556	39,354	31,290	8.5	51.0	40.5
2066	76,085	6,475	38,691	30,919	8.5	50.9	40.6
2067	74,976	6,395	38,038	30,544	8.5	50.7	40.7
2068	73,875	6,314	37,412	30,149	8.5	50.6	40.8
2069	72,785	6,233	36,807	29,745	8.6	50.6	40.9
2070	71,706	6,150	36,232	29,323	8.6	50.5	40.9
2071	70,642	6,067	35,643	28,932	8.6	50.5	41.0
2072	69,593	5,982	35,094	28,516	8.6	50.4	41.0
2073	68,561	5,897	34,575	28,089	8.6	50.4	41.0
2074	67,547	5,811	34,077	27,660	8.6	50.4	40.9
2075	66,551	5,724	33,597	27,230	8.6	50.5	40.9
2076	65,574	5,637	33,135	26,802	8.6	50.5	40.9
2077	64,615	5,551	32,688	26,376	8.6	50.6	40.8
2078	63,674	5,465	32,255	25,955	8.6	50.7	40.8
2079	62,751	5,380	31,832	25,538	8.6	50.7	40.7
2080	61,844	5,297	31,420	25,128	8.6	50.8	40.6
2081	60,954	5,215	31,016	24,723	8.6	50.9	40.6
2082	60,079	5,135	30,619	24,325	8.5	51.0	40.5
2083	59,219	5,058	30,228	23,933	8.5	51.0	40.4
2084	58,374	4,984	29,842	23,548	8.5	51.1	40.3
2085	57,542	4,912	29,460	23,170	8.5	51.2	40.3
2086	56,723	4,842	29,082	22,798	8.5	51.3	40.2
2087	55,916	4,776	28,707	22,433	8.5	51.3	40.1
2088	55,122	4,712	28,334	22,075	8.5	51.4	40.0
2089	54,340	4,651	27,963	21,725	8.6	51.5	40.0
2090	53,570	4,593	27,594	21,383	8.6	51.5	39.9
2091	52,811	4,536	27,227	21,048	8.6	51.6	39.9
2092	52,065	4,482	26,861	20,722	8.6	51.6	39.8
2093	51,330	4,429	26,497	20,404	8.6	51.6	39.8
2094	50,607	4,378	26,136	20,093	8.7	51.6	39.7
2095	49,897	4,327	25,779	19,791	8.7	51.7	39.7
2096	49,199	4,278	25,425	19,495	8.7	51.7	39.6
2097	48,514	4,229	25,077	19,207	8.7	51.7	39.6
2098	47,842	4,181	24,735	18,926	8.7	51.7	39.6
2099	47,183	4,134	24,399	18,650	8.8	51.7	39.5
2100	46,538	4,086	24,072	18,381	8.8	51.7	39.5
2101	45,907	4,039	23,752	18,116	8.8	51.7	39.5
2102	45,288	3,991	23,441	17,856	8.8	51.8	39.4
2103	44,683	3,944	23,139	17,601	8.8	51.8	39.4
2104	44,091	3,897	22,846	17,349	8.8	51.8	39.3
2105	43,512	3,849	22,561	17,101	8.8	51.9	39.3

Current population as of October 1 of each year.

Table A-5 Projected future population, proportion by the major three age groups (under 15, 15-64 and 65 and over) and age structure coefficient: [High-variant fertility (with High-variant mortality)]

Year	Population (thousand) by age group				Proportion (%) by age group		
	Total	0-14	15-64	65+	0-14	15-64	65+
2056	95,173	10,480	50,194	34,499	11.0	52.7	36.2
2057	94,307	10,395	49,748	34,163	11.0	52.8	36.2
2058	93,433	10,314	49,313	33,805	11.0	52.8	36.2
2059	92,549	10,235	48,853	33,461	11.1	52.8	36.2
2060	91,658	10,158	48,387	33,113	11.1	52.8	36.1
2061	90,759	10,082	47,933	32,744	11.1	52.8	36.1
2062	89,854	10,007	47,468	32,379	11.1	52.8	36.0
2063	88,945	9,931	46,994	32,020	11.2	52.8	36.0
2064	88,034	9,855	46,528	31,651	11.2	52.9	36.0
2065	87,123	9,778	46,055	31,290	11.2	52.9	35.9
2066	86,213	9,700	45,594	30,919	11.3	52.9	35.9
2067	85,309	9,621	45,144	30,544	11.3	52.9	35.8
2068	84,412	9,540	44,723	30,149	11.3	53.0	35.7
2069	83,524	9,457	44,321	29,745	11.3	53.1	35.6
2070	82,648	9,373	43,951	29,323	11.3	53.2	35.5
2071	81,785	9,288	43,552	28,945	11.4	53.3	35.4
2072	80,938	9,202	43,159	28,577	11.4	53.3	35.3
2073	80,107	9,116	42,782	28,209	11.4	53.4	35.2
2074	79,294	9,029	42,420	27,845	11.4	53.5	35.1
2075	78,498	8,942	42,071	27,485	11.4	53.6	35.0
2076	77,720	8,856	41,732	27,132	11.4	53.7	34.9
2077	76,960	8,771	41,400	26,789	11.4	53.8	34.8
2078	76,217	8,688	41,073	26,457	11.4	53.9	34.7
2079	75,491	8,606	40,748	26,137	11.4	54.0	34.6
2080	74,781	8,526	40,426	25,829	11.4	54.1	34.5
2081	74,085	8,448	40,104	25,533	11.4	54.1	34.5
2082	73,404	8,373	39,783	25,248	11.4	54.2	34.4
2083	72,735	8,300	39,463	24,973	11.4	54.3	34.3
2084	72,079	8,229	39,142	24,708	11.4	54.3	34.3
2085	71,435	8,161	38,822	24,452	11.4	54.3	34.2
2086	70,801	8,095	38,502	24,204	11.4	54.4	34.2
2087	70,176	8,031	38,181	23,964	11.4	54.4	34.1
2088	69,561	7,969	37,861	23,731	11.5	54.4	34.1
2089	68,955	7,909	37,541	23,505	11.5	54.4	34.1
2090	68,357	7,850	37,222	23,285	11.5	54.5	34.1
2091	67,766	7,792	36,903	23,071	11.5	54.5	34.0
2092	67,183	7,735	36,586	22,862	11.5	54.5	34.0
2093	66,607	7,678	36,272	22,657	11.5	54.5	34.0
2094	66,039	7,622	35,960	22,457	11.5	54.5	34.0
2095	65,477	7,566	35,651	22,260	11.6	54.4	34.0
2096	64,923	7,510	35,347	22,066	11.6	54.4	34.0
2097	64,376	7,454	35,047	21,875	11.6	54.4	34.0
2098	63,835	7,397	34,753	21,686	11.6	54.4	34.0
2099	63,302	7,340	34,464	21,498	11.6	54.4	34.0
2100	62,776	7,283	34,181	21,313	11.6	54.4	33.9
2101	62,257	7,225	33,904	21,128	11.6	54.5	33.9
2102	61,745	7,168	33,633	20,945	11.6	54.5	33.9
2103	61,240	7,110	33,368	20,763	11.6	54.5	33.9
2104	60,742	7,052	33,109	20,581	11.6	54.5	33.9
2105	60,250	6,995	32,855	20,401	11.6	54.5	33.9

Current population as of October 1 of each year.

Table A-6 Projected future population, proportion by the major three age groups (under 15, 15-64 and 65 and over) and age structure coefficient: [Low-variant fertility (with High-variant mortality)]

Year	Population（thousand）by age group				Proportion（%）by age group		
	Total	0-14	15-64	65+	0-14	15-64	65+
2056	81,183	5,391	41,293	34,499	6.6	50.9	42.5
2057	79,983	5,286	40,533	34,163	6.6	50.7	42.7
2058	78,776	5,189	39,781	33,805	6.6	50.5	42.9
2059	77,561	5,099	39,001	33,461	6.6	50.3	43.1
2060	76,340	5,015	38,212	33,113	6.6	50.1	43.4
2061	75,113	4,935	37,434	32,744	6.6	49.8	43.6
2062	73,881	4,859	36,643	32,379	6.6	49.6	43.8
2063	72,646	4,785	35,841	32,020	6.6	49.3	44.1
2064	71,411	4,714	35,047	31,651	6.6	49.1	44.3
2065	70,177	4,642	34,245	31,290	6.6	48.8	44.6
2066	68,947	4,571	33,457	30,919	6.6	48.5	44.8
2067	67,724	4,500	32,680	30,544	6.6	48.3	45.1
2068	66,508	4,427	31,932	30,149	6.7	48.0	45.3
2069	65,304	4,353	31,206	29,745	6.7	47.8	45.5
2070	64,114	4,278	30,512	29,323	6.7	47.6	45.7
2071	62,938	4,201	29,812	28,925	6.7	47.4	46.0
2072	61,779	4,123	29,200	28,455	6.7	47.3	46.1
2073	60,639	4,045	28,641	27,953	6.7	47.2	46.1
2074	59,517	3,965	28,111	27,441	6.7	47.2	46.1
2075	58,415	3,885	27,609	26,921	6.7	47.3	46.1
2076	57,334	3,806	27,130	26,398	6.6	47.3	46.0
2077	56,272	3,727	26,672	25,874	6.6	47.4	46.0
2078	55,230	3,649	26,230	25,351	6.6	47.5	45.9
2079	54,208	3,572	25,802	24,833	6.6	47.6	45.8
2080	53,205	3,498	25,385	24,322	6.6	47.7	45.7
2081	52,220	3,426	24,977	23,817	6.6	47.8	45.6
2082	51,253	3,356	24,575	23,321	6.5	47.9	45.5
2083	50,303	3,290	24,180	22,833	6.5	48.1	45.4
2084	49,370	3,226	23,789	22,354	6.5	48.2	45.3
2085	48,453	3,166	23,402	21,885	6.5	48.3	45.2
2086	47,552	3,109	23,018	21,425	6.5	48.4	45.1
2087	46,667	3,055	22,637	20,975	6.5	48.5	44.9
2088	45,797	3,004	22,258	20,536	6.6	48.6	44.8
2089	44,943	2,955	21,882	20,106	6.6	48.7	44.7
2090	44,104	2,909	21,508	19,687	6.6	48.8	44.6
2091	43,280	2,865	21,136	19,279	6.6	48.8	44.5
2092	42,473	2,823	20,767	18,883	6.6	48.9	44.5
2093	41,681	2,783	20,401	18,497	6.7	48.9	44.4
2094	40,906	2,744	20,039	18,122	6.7	49.0	44.3
2095	40,147	2,706	19,683	17,758	6.7	49.0	44.2
2096	39,406	2,669	19,332	17,405	6.8	49.1	44.2
2097	38,683	2,633	18,988	17,062	6.8	49.1	44.1
2098	37,979	2,597	18,653	16,729	6.8	49.1	44.0
2099	37,293	2,561	18,327	16,405	6.9	49.1	44.0
2100	36,625	2,525	18,010	16,090	6.9	49.2	43.9
2101	35,977	2,489	17,705	15,783	6.9	49.2	43.9
2102	35,347	2,453	17,412	15,482	6.9	49.3	43.8
2103	34,736	2,417	17,129	15,189	7.0	49.3	43.7
2104	34,142	2,381	16,859	14,902	7.0	49.4	43.6
2105	33,566	2,346	16,600	14,621	7.0	49.5	43.6

Current population as of October 1 of each year.

Table A-7 Projected future population, proportion by the major three age groups (under 15, 15-64 and 65 and over) and age structure coefficient: [Medium-variant fertility (with Low-variant mortality)]

Year	Population (thousand) by age group				Proportion (%) by age group		
	Total	0-14	15-64	65+	0-14	15-64	65+
2056	90,640	7,404	45,428	37,808	8.2	50.1	41.7
2057	89,599	7,292	44,799	37,508	8.1	50.0	41.9
2058	88,548	7,187	44,178	37,183	8.1	49.9	42.0
2059	87,485	7,088	43,529	36,869	8.1	49.8	42.1
2060	86,412	6,993	42,870	36,548	8.1	49.6	42.3
2061	85,327	6,903	42,221	36,202	8.1	49.5	42.4
2062	84,231	6,816	41,559	35,856	8.1	49.3	42.6
2063	83,127	6,732	40,885	35,509	8.1	49.2	42.7
2064	82,014	6,650	40,217	35,147	8.1	49.0	42.9
2065	80,896	6,569	39,541	34,786	8.1	48.9	43.0
2066	79,773	6,489	38,876	34,408	8.1	48.7	43.1
2067	78,649	6,409	38,221	34,020	8.1	48.6	43.3
2068	77,526	6,328	37,593	33,605	8.2	48.5	43.3
2069	76,407	6,247	36,986	33,174	8.2	48.4	43.4
2070	75,294	6,164	36,410	32,719	8.2	48.4	43.5
2071	74,190	6,081	35,819	32,290	8.2	48.3	43.5
2072	73,097	5,996	35,268	31,833	8.2	48.2	43.5
2073	72,018	5,911	34,747	31,361	8.2	48.2	43.5
2074	70,955	5,825	34,247	30,883	8.2	48.3	43.5
2075	69,909	5,738	33,766	30,404	8.2	48.3	43.5
2076	68,880	5,651	33,302	29,926	8.2	48.3	43.4
2077	67,870	5,565	32,854	29,451	8.2	48.4	43.4
2078	66,879	5,479	32,419	28,981	8.2	48.5	43.3
2079	65,907	5,394	31,996	28,517	8.2	48.5	43.3
2080	64,954	5,310	31,582	28,061	8.2	48.6	43.2
2081	64,018	5,229	31,177	27,612	8.2	48.7	43.1
2082	63,100	5,149	30,779	27,172	8.2	48.8	43.1
2083	62,199	5,072	30,387	26,740	8.2	48.9	43.0
2084	61,313	4,997	30,000	26,316	8.2	48.9	42.9
2085	60,443	4,925	29,618	25,900	8.1	49.0	42.9
2086	59,587	4,856	29,239	25,493	8.1	49.1	42.8
2087	58,745	4,790	28,863	25,093	8.2	49.1	42.7
2088	57,917	4,726	28,489	24,702	8.2	49.2	42.7
2089	57,100	4,665	28,117	24,319	8.2	49.2	42.6
2090	56,297	4,606	27,747	23,944	8.2	49.3	42.5
2091	55,504	4,550	27,378	23,577	8.2	49.3	42.5
2092	54,724	4,495	27,011	23,218	8.2	49.4	42.4
2093	53,955	4,442	26,646	22,867	8.2	49.4	42.4
2094	53,198	4,391	26,284	22,523	8.3	49.4	42.3
2095	52,452	4,340	25,925	22,186	8.3	49.4	42.3
2096	51,718	4,291	25,570	21,857	8.3	49.4	42.3
2097	50,996	4,242	25,220	21,533	8.3	49.5	42.2
2098	50,286	4,194	24,877	21,215	8.3	49.5	42.2
2099	49,590	4,146	24,540	20,903	8.4	49.5	42.2
2100	48,906	4,099	24,210	20,596	8.4	49.5	42.1
2101	48,235	4,051	23,889	20,295	8.4	49.5	42.1
2102	47,578	4,004	23,577	19,998	8.4	49.6	42.0
2103	46,935	3,957	23,273	19,705	8.4	49.6	42.0
2104	46,305	3,909	22,979	19,417	8.4	49.6	41.9
2105	45,689	3,862	22,693	19,134	8.5	49.7	41.9

Current population as of October 1 of each year.

Table A-8 Projected future population, proportion by the major three age groups (under 15, 15-64 and 65 and over) and age structure coefficient: [High-variant fertility (with Low-variant mortality)]

Year	Population（thousand） by age group				Proportion（%） by age group		
	Total	0-14	15-64	65+	0-14	15-64	65+
2056	98,702	10,499	50,395	37,808	10.6	51.1	38.3
2057	97,874	10,415	49,951	37,508	10.6	51.0	38.3
2058	97,034	10,333	49,517	37,183	10.6	51.0	38.3
2059	96,182	10,255	49,058	36,869	10.7	51.0	38.3
2060	95,319	10,178	48,592	36,548	10.7	51.0	38.3
2061	94,444	10,102	48,139	36,202	10.7	51.0	38.3
2062	93,557	10,027	47,675	35,856	10.7	51.0	38.3
2063	92,661	9,951	47,200	35,509	10.7	50.9	38.3
2064	91,756	9,876	46,734	35,147	10.8	50.9	38.3
2065	90,845	9,799	46,260	34,786	10.8	50.9	38.3
2066	89,929	9,721	45,799	34,408	10.8	50.9	38.3
2067	89,010	9,642	45,349	34,020	10.8	50.9	38.2
2068	88,093	9,561	44,927	33,605	10.9	51.0	38.1
2069	87,178	9,479	44,526	33,174	10.9	51.1	38.1
2070	86,270	9,395	44,156	32,719	10.9	51.2	37.9
2071	85,370	9,310	43,756	32,304	10.9	51.3	37.8
2072	84,481	9,224	43,363	31,894	10.9	51.3	37.8
2073	83,606	9,138	42,985	31,483	10.9	51.4	37.7
2074	82,746	9,051	42,623	31,071	10.9	51.5	37.6
2075	81,902	8,965	42,274	30,664	10.9	51.6	37.4
2076	81,076	8,879	41,934	30,263	11.0	51.7	37.3
2077	80,268	8,794	41,602	29,872	11.0	51.8	37.2
2078	79,478	8,710	41,275	29,493	11.0	51.9	37.1
2079	78,707	8,628	40,951	29,128	11.0	52.0	37.0
2080	77,953	8,549	40,628	28,777	11.0	52.1	36.9
2081	77,217	8,471	40,306	28,440	11.0	52.2	36.8
2082	76,497	8,396	39,985	28,116	11.0	52.3	36.8
2083	75,792	8,323	39,664	27,805	11.0	52.3	36.7
2084	75,101	8,252	39,344	27,505	11.0	52.4	36.6
2085	74,424	8,184	39,023	27,217	11.0	52.4	36.6
2086	73,759	8,118	38,703	26,938	11.0	52.5	36.5
2087	73,105	8,054	38,382	26,669	11.0	52.5	36.5
2088	72,462	7,993	38,061	26,409	11.0	52.5	36.4
2089	71,829	7,932	37,741	26,156	11.0	52.5	36.4
2090	71,205	7,873	37,421	25,911	11.1	52.6	36.4
2091	70,590	7,816	37,102	25,672	11.1	52.6	36.4
2092	69,982	7,759	36,785	25,439	11.1	52.6	36.4
2093	69,382	7,702	36,469	25,211	11.1	52.6	36.3
2094	68,789	7,646	36,157	24,987	11.1	52.6	36.3
2095	68,204	7,590	35,848	24,766	11.1	52.6	36.3
2096	67,625	7,534	35,543	24,548	11.1	52.6	36.3
2097	67,053	7,477	35,243	24,333	11.2	52.6	36.3
2098	66,489	7,421	34,948	24,120	11.2	52.6	36.3
2099	65,931	7,364	34,658	23,909	11.2	52.6	36.3
2100	65,380	7,307	34,374	23,699	11.2	52.6	36.2
2101	64,837	7,249	34,097	23,491	11.2	52.6	36.2
2102	64,301	7,192	33,825	23,284	11.2	52.6	36.2
2103	63,772	7,134	33,559	23,079	11.2	52.6	36.2
2104	63,251	7,076	33,299	22,875	11.2	52.6	36.2
2105	62,736	7,019	33,045	22,673	11.2	52.7	36.1

Current population as of October 1 of each year.

Table A-9 Projected future population, proportion by the major three age groups (under 15, 15-64 and 65 and over) and age structure coefficient: [Low-variant fertility (with Low-variant mortality)]

Year	Population（thousand）by age group				Proportion（%）by age group		
	Total	0-14	15-64	65+	0-14	15-64	65+
2056	84,685	5,401	41,476	37,808	6.4	49.0	44.6
2057	83,521	5,296	40,717	37,508	6.3	48.8	44.9
2058	82,347	5,199	39,965	37,183	6.3	48.5	45.2
2059	81,162	5,109	39,184	36,869	6.3	48.3	45.4
2060	79,967	5,024	38,394	36,548	6.3	48.0	45.7
2061	78,761	4,945	37,614	36,202	6.3	47.8	46.0
2062	77,546	4,869	36,821	35,856	6.3	47.5	46.2
2063	76,322	4,795	36,018	35,509	6.3	47.2	46.5
2064	75,091	4,723	35,221	35,147	6.3	46.9	46.8
2065	73,854	4,652	34,417	34,786	6.3	46.6	47.1
2066	72,614	4,581	33,625	34,408	6.3	46.3	47.4
2067	71,374	4,509	32,845	34,020	6.3	46.0	47.7
2068	70,135	4,437	32,094	33,605	6.3	45.8	47.9
2069	68,901	4,363	31,364	33,174	6.3	45.5	48.1
2070	67,674	4,287	30,667	32,719	6.3	45.3	48.3
2071	66,457	4,211	29,963	32,283	6.3	45.1	48.6
2072	65,253	4,133	29,349	31,771	6.3	45.0	48.7
2073	64,063	4,054	28,787	31,222	6.3	44.9	48.7
2074	62,890	3,975	28,255	30,661	6.3	44.9	48.8
2075	61,736	3,895	27,751	30,090	6.3	45.0	48.7
2076	60,600	3,815	27,270	29,515	6.3	45.0	48.7
2077	59,485	3,736	26,810	28,939	6.3	45.1	48.6
2078	58,391	3,658	26,367	28,366	6.3	45.2	48.6
2079	57,317	3,581	25,938	27,798	6.2	45.3	48.5
2080	56,264	3,507	25,519	27,237	6.2	45.4	48.4
2081	55,230	3,435	25,110	26,686	6.2	45.5	48.3
2082	54,216	3,365	24,707	26,144	6.2	45.6	48.2
2083	53,221	3,299	24,310	25,612	6.2	45.7	48.1
2084	52,244	3,235	23,918	25,090	6.2	45.8	48.0
2085	51,284	3,175	23,530	24,579	6.2	45.9	47.9
2086	50,342	3,117	23,145	24,079	6.2	46.0	47.8
2087	49,415	3,063	22,763	23,590	6.2	46.1	47.7
2088	48,505	3,012	22,382	23,111	6.2	46.1	47.6
2089	47,610	2,963	22,005	22,642	6.2	46.2	47.6
2090	46,731	2,917	21,629	22,184	6.2	46.3	47.5
2091	45,866	2,873	21,255	21,737	6.3	46.3	47.4
2092	45,017	2,832	20,885	21,300	6.3	46.4	47.3
2093	44,182	2,791	20,517	20,874	6.3	46.4	47.2
2094	43,363	2,752	20,154	20,457	6.3	46.5	47.2
2095	42,560	2,714	19,796	20,050	6.4	46.5	47.1
2096	41,773	2,677	19,443	19,652	6.4	46.5	47.0
2097	41,002	2,641	19,098	19,264	6.4	46.6	47.0
2098	40,249	2,604	18,761	18,884	6.5	46.6	46.9
2099	39,513	2,568	18,433	18,513	6.5	46.6	46.9
2100	38,796	2,532	18,115	18,149	6.5	46.7	46.8
2101	38,098	2,496	17,808	17,793	6.6	46.7	46.7
2102	37,418	2,460	17,512	17,445	6.6	46.8	46.6
2103	36,758	2,425	17,229	17,104	6.6	46.9	46.5
2104	36,116	2,389	16,957	16,771	6.6	47.0	46.4
2105	35,494	2,353	16,696	16,445	6.6	47.0	46.3

Current population as of October 1 of each year.

Figure A-1 Actual and projected population of Japan: Comparison of the nine projections three fertility assumptions with three mortality assumptions

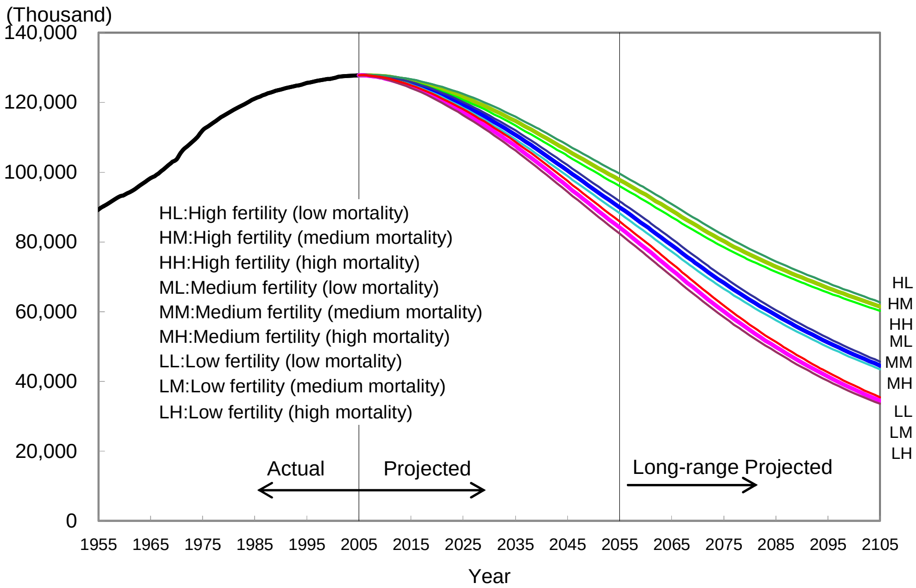
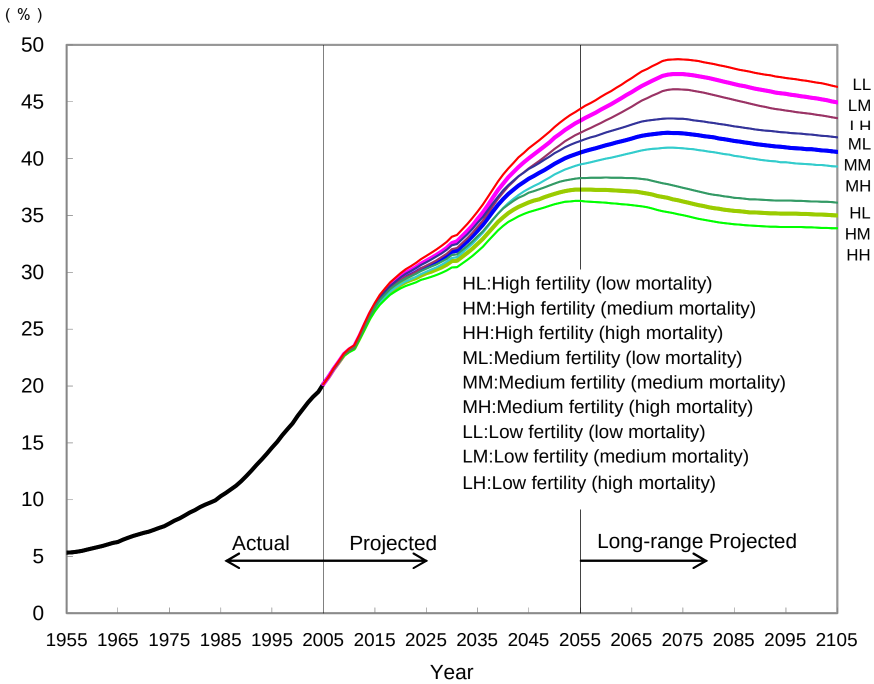


Figure A-2 Trends in the proportion of elderly: Comparison of the nine projections three fertility assumptions with three mortality assumptions



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Research Article

Elaboration of the Coale-McNeil Nuptiality Model as the Generalized Log Gamma Distribution: A New Identity and Empirical Enhancements

Ryuichi Kaneko

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Elaboration of the Coale-McNeil Nuptiality Model as the Generalized Log Gamma Distribution: A New Identity and Empirical Enhancements

Ryuichi Kaneko [1]

Abstract

The Coale-McNeil nuptiality model is a particular case of the generalized log gamma distribution model. In this paper, we demonstrate that recognition of this connection allows an expansion of the possible applications of the Coale-McNeil model. As examples, we propose a procedure to develop country specific standard schedules, and illustrate the utility in regression analysis (directly and via the competing risk framework). In addition, we employ this identification to enhance the ability of the models with empirical adjustment to trace the trajectory of the lifetime schedule for cohorts which have not completed the process. We illustrate an application to Japanese female cohorts. We also propose an application to fertility projection by modeling the fertility schedule by birth order.

[1] National Institute of Population and Social Security Research, Hibiya-kokusai Bldg. 6F, 2-2-3, Uchisaiwai-cho, Chiyoda-ku, Tokyo 100-0011, Japan. E-mail: r-kaneko@ipss.go.jp

1. Introduction

The Coale-McNeil (CM) nuptiality model is a mathematical expression of regularity in age patterns of first marriage. It is a standard demographic tool for the estimation and projection of age schedules of first marriage and birth by birth order. However, it is not generally recognized by researchers that the CM model without a prevalence parameter is precisely the log version of the generalized gamma distribution with limited parameter space (Kaneko 1991a). Clear recognition of this connection is useful because it enables the utilization of the rich body of knowledge about the statistical properties of the generalized gamma distribution when pursuing demographic applications. Conversely, some of the analysis of the structure of the CM model (such as the interpretation of the convolution structure) can be applied to understanding the generalized log gamma distribution. The first purpose of this article is to demonstrate some of the demographic applications that benefit from this new description of the CM framework. We present algorithms for formalized development of country-specific standard schedules. In addition, we provide an analysis of the effects of covariates on marriage timing, both with and without application of the competing risk framework for different types of marriages.

The second purpose of this article is to present enhancements to the ability of the model to trace the trajectories of lifetime marriage and fertility schedules by incorporating an empirical model of the residual pattern. This provides more precise estimation even for cohort experiences of the processes that have not been completed. Period measures of nuptiality and fertility are subject to compositional and distributional "distortions" such as those from flux in marital and parity composition and tempo effects. Although some effective remedies have been proposed to correct for these distortions (Bongaarts and Feeney 1998, Kohler and Philipov 2001, Kohler and Ortega 2002, Ryder 1964, 1980), cohort nuptiality and fertility measures which are free from those effects are of primary importance in understanding what is taking place in people's life course in the demographic sense. The only drawback of cohort measures is that they cannot be evaluated until the life course processes of the events are completed, and therefore they do not provide information on the current situation of uncompleted phenomena. It is impossible to “measure” cohort experiences that are not completed (Ryder 1964, van Imhoff 2001). However, a model embodying lifetime regularities of the events (i.e. the "law" of nuptiality and fertility) may provide useful predictions of the current situation. Our empirical enhancement of the GLG model is a very practical effort in this line. We demonstrate its usage in estimation and prediction of first marriage schedules by providing long-term estimations of lifetime measures for marriage behavior relevant to recent marriage and fertility developments in Japan. We also discuss fertility projection as an application of the empirically enhanced model.

2. Coale-McNeil Model and the Generalized Log Gamma Distribution

2.1 Coale-McNeil Model

Following the finding by Coale (1971) that age specific rates of first marriages for female cohorts from different countries showed virtually identical patterns if location, scale, and eventual proportion of ever marrying are adjusted, Coale and McNeil derived a statistical distribution that described observed distributions of age at first marriage (Coale and McNeil 1972). The closed form description of the probability density function (PDF) for this distribution is:

$$g(x) = \frac{\beta}{\Gamma(\alpha/\beta)} \exp\left[-\alpha(x-\mu) - \exp\left\{-\beta(x-\mu)\right\}\right] \tag{1}$$

where Γ denotes the gamma function ($\Gamma(x) = \int_0^\infty t^{x-1} e^{-t} dt$), $\alpha(>0)$, $\beta(>0)$, and $\mu(-\infty < \mu < \infty)$ are three parameters (Coale and McNeil 1972). For practical application, they provided a standard marriage schedule model from a location-scale family of this distribution by fixing the shape according to the experiences of Swedish female cohorts. The following is an adjusted version of the standard model with mean zero, and variance unity by Rodriguez and Trussell (1980), obtained by setting $\alpha = 1.145, \beta = 1.896$, and $\mu = -0.805$ in equation (1):

$$g_s(z) = 1.2813 \exp\left[-1.145(z+.805) - \exp\left\{-1.896(z+.805)\right\}\right]. \tag{2}$$

Let $g(x)$ denote a distribution of age at first marriage of any female cohort with its observed mean, u, standard deviation, *b*. Using the standard model above, it is given by:

$$g(x; u, b) \cong \frac{1}{b} g_s\left(\frac{x-u}{b}\right) \tag{3}$$

The marriage schedule that embodies the probability density of marrying at exact age *x* for all members of the cohort (Note 1), $f(x)$, is represented by:

$$f(x) = C\ g(x) \tag{4}$$

where C denotes proportion eventually marrying in the cohort. Thus, the age distribution underlies the age schedule (the age specific rate) with parameter of prevalence measure, C.

Clear definition of terms is essential. In this paper, the probability density $f(x)$ given by (4) is called first marriage schedule, the underlying distribution $g(x)$ in the same equation is called distribution of age at first marriage, and the normalized distribution with fixed shape $g_s(x)$ given by (2) is the (global) standard distribution of age at first marriage. Thus, $C\ g_s(x)$ is the (global) standard schedule.

An interesting feature of the CM distribution is that it is a limiting probability distribution of convolution of infinite set of mean-related exponential distributions. Thus, it is regarded as a convolution of distribution of its own form and some numbers of related exponential distributions as well. This structure provides a mathematical model for the multistage process, by which we mean a process that consists of multiple processes required for the target event to happen. In fact, Coale and McNeil (1972), inspired by Feeney (1972), viewed first marriage as a multistage process in which entry into marriageable state, meeting of the eventual spouse, and engagement are required to take place prior to the marriage.

Suppose we form the convolution of the m exponential distribution with parameter α, $\alpha+\beta$, $\alpha+2\beta$, …, $\alpha+m\beta$, where α and β are two parameters with positive real values, and let $h_T(t;m)$ denote PDF of the resulting distribution, then the CM distribution given in equation (1) is the convolution of two distributions whose PDFs are:

$$g_X(x;m) = \frac{\beta}{\Gamma(\alpha/\beta+m)} \exp\left[-(\alpha+m\beta)(x-\mu) - \exp\{-\beta(x-\mu)\}\right] \tag{5}$$

$$h_T(t;m) = \frac{\beta\Gamma(\alpha/\beta+m)}{\Gamma(\alpha/\beta)(m-1)!}\{1-\exp(-\beta t)\}^{m-1} \exp(-\alpha t) \tag{6}$$

where α, β, and μ are three parameters of the CM distribution found in (1) (Coale and McNeil, 1972). Here $g_X(x;m)$ represents the distribution of times of entering a stage from when the process starts, and $h_T(t;m)$ is the distribution of the waiting time that is composed of *m* exponentially distributed waiting times. The mean and variance of distribution $g_X(x;m)$ are respectively $\mu - \frac{1}{\beta}\psi\left(\frac{\alpha}{\beta}+m\right)$, and $\frac{1}{\beta^2}\psi'\left(\frac{\alpha}{\beta}+m\right)$, where ψ and ψ' are the digamma and trigamma functions. Those of distribution $h_T(x;m)$ are respectively $\sum_{j=1}^{m}\{\alpha+(m-1)\beta\}^{-1}$, and $\sum_{j=1}^{m}\{\alpha+(m-1)\beta\}^{-2}$.

The exponential distribution with the three largest means convoluted in distribution $h_T(t;m)$ have the parameters α, $\alpha+\beta$, and $\alpha+2\beta$. For the first marriage process, Coale and McNeil supposed that these are distributions of duration from entry into the marriage market to the meeting of future husband, dating duration, and engagement duration. According to parameter values of the CM standard age distribution (2), which are derived from the experiences of Swedish female cohorts, the mean duration from entry into the marriage market to the meeting of future husband is estimated as ($1/0.174$) or 5.75 years. Similarly, means of the second and third waiting durations are 2.16 years ($1/(0.174+0.2881)$) and 1.33 years ($1/(0.174+2\times 0.2881)$) respectively (Coale and McNeil, 1972). However, empirical evidence on female first marriage process in Japan indicates that age at the meeting and durations between meeting and marriage are highly correlated (Kaneko 1991a) (Note 2). This implies that the assumption of independence of the convolved distributions is violated in actual processes, and the estimated mean durations above should be biased. Nonetheless, the convolution structure of the CM distribution may provide a structured approximation of the complicated multistage model. Moreover, it should serve as an important prototype in developing models with process dependences which make parameters of sub-processes dependent on the timing of the outcomes of previous stages.

2.2 Coale-McNeil Model as The Generalized Log Gamma Distribution

Some authors have discussed relationships of the Coale-McNeil distribution to other well-known probability distributions. Coale and McNeil themselves pointed out that the CM distribution is the extreme value distribution (of type I, or equivalently the Gompertz distribution for non-negative random variables) when $\alpha = \beta$ (Coale and McNeil, 1972). Rodriguez and Trussell discussed its relationships with the gamma distribution (Rodriguez and Trussell, 1980). Liang (2000) discussed its relationships to the extreme value, log-gamma, and the normal distribution based on discussion of the log-gamma distribution by Johnson et al. (1994). The conclusive observation on these relationships is that the CM distribution is precisely equivalent to the *generalized* log gamma (GLG) distribution with a somewhat different parameter space (Kaneko 1991a). This explains the relationships of the CM distribution to the extreme, the log gamma, and the normal distributions, since these arise as special cases of the generalized log gamma distribution.

The generalized gamma (GG) distribution was defined by Stacy (1962), introducing an additional parameter into the gamma distribution (Note 3). If a random variable follows the GG distribution, then the log-transform of the random variable follows the GLG distribution (some authors such as Johnson et al. 1994, call it the log generalized gamma distribution), which is a mirror image of the CM distribution reflected at the origin ($x = 0$). Prentice (1974) proposed an alternative parameterization of the GLG distribution which extends the parameter space so as to express both mirror images of the distribution corresponding to random variable X and -X by one model. Hence, it includes the CM distribution as a constrained version with half of the extended parameter space. Here we refer to Prentice's extended version simply as the GLG distribution.

The PDF and the cumulative distribution function (CDF) of the GLG distribution are given by:

$$g(x) = \frac{|\lambda|}{b\Gamma(\lambda^{-2})} (\lambda^{-2})^{\lambda^{-2}} \exp\left[\lambda^{-1}\left(\frac{x-u}{b}\right) - \lambda^{-2} \exp\left\{ \lambda \left(\frac{x-u}{b} \right) \right\} \right] \qquad (7)$$

$$G(x) = 1 - I\left(\lambda^{-2}, \lambda^{-2} \exp\left(\lambda \frac{x-u}{b} \right) \right) \qquad (8)$$

where $\lambda\,(-\infty < \lambda < \infty, \neq 0), u\,(-\infty < u < \infty), b\,(>0)$ are three parameters, and Γ and I denote the gamma function and the incomplete gamma function respectively (Note 4). Parameter λ determines the shape of the distribution; if it is positive, the distribution is skewed to the left, and if it is negative, it is skewed to the right. The distribution is not defined for $\lambda = 0$, but as $\lambda \to 0$, the distribution approaches the normal distribution. u is a location parameter which determines the location of the mode of the distribution. b is the scale parameter of the distribution.

The following alternative parameterization of the CM distribution allows representation of the full range of the parameter space as the GLG distribution:

$$g(x) = \frac{|\beta|}{\Gamma(k)} \exp\left[-k\beta\left(x-\mu\right) - \exp\left\{-\beta\left(x-\mu\right)\right\}\right] \tag{9}$$

where $k\,(>0)$ is a new parameter, and β is now allowed to take a negative value (Note 5).

Since the original CM distribution corresponds to the GLG distribution with a negative value of λ, and we consider only situations in which λ takes on a negative value, we can regard the GLG distribution as equivalent to the CM distribution throughout the paper.

One of the advantages of the GLG formulation is that it has only one shape parameter, i.e. λ. Describing the shape of the distribution by a single value is quite useful in applications. Since it identifies a distribution once location and scale are controlled for, it can be regarded as an index of schedule shape specific to cohorts of a country or region, for instance. In fact, the essential nature of the CM global standard nuptiality schedule is constancy across population groups of the shape parameter at a value of λ –1.287. Substantial implication of the shape value is discussed later. In the next section, we describe a simple procedure to develop country specific standard schedules which takes advantage of the single shape parameter. The single shape parameter is quite effective in developing fertility schedules by birth order as well, since the shape value varies by birth order.

The mean and variance of the GLG distribution are respectively given as:

$$u + (b/\lambda)\{\psi(\lambda^2) + \ln\lambda^2\} \tag{10}$$

$$(b/\lambda)^2\psi'(\lambda^{-2}) \tag{11}$$

The mode is simply *u*, with the maximum of PDF given by: $\hat{g} = \frac{|\lambda|}{b\Gamma(\lambda^{-2})}(\lambda^{-2})^{\lambda^{-2}} e^{-\lambda^{-2}}$.

As mentioned earlier, the GLG distribution includes many of the fundamental distributions as special cases. Specifically, it specializes to the extreme value distribution when $\lambda = 1$, the (standard) log-gamma distributions when $\lambda = b, u = -2\ln\lambda$, and even the normal distribution as a limiting case when $\lambda \to 0$. These relations are a reflection of relationships between the GG distribution and the exponential, the Weibull, the gamma, and the log normal distributions, and it guarantees that the GLG distribution describes age distribution of first marriages better than those specialized distributions.

The correspondence between the parameters of the CM and GLG distributions can be expressed as:

$$\alpha = -\frac{1}{b\lambda},\ \beta = -\frac{\lambda}{b},\ \mu = u - \frac{b}{\lambda}\ln\lambda^2 \tag{12}$$

or equivalently,

$$\lambda = -\left(\frac{\alpha}{\beta}\right)^{-\frac{1}{2}},\ b = (\alpha\beta)^{-\frac{1}{2}},\ u = \mu - \frac{1}{\beta}\ln\left(\frac{\alpha}{\beta}\right), \tag{13}$$

where α, β, and μ are parameters of the CM formulation in (1) (Kaneko 1991a). The revised version of the CM standard distribution of age at first marriage by Rodriguez and Trussell given by (2) is expressed by the GLG with parameters $\lambda = -1.287$, $u = -0.5390$, $b = 0.6787$.

The identification of the CM distribution as the GLG distribution allows many important properties previously explored separately for each of the distributions to be unified. For instance, since the GLG distribution includes as special cases some important distributions as noted above, so does the CM distribution. Conversely, the characterization of the CM distribution as a convolution of an infinite number of mean related exponential distributions applies to the GLG distribution as well. In other words, the convolution representation of the CM distribution as expressed in formulations (5) and (6) holds for the GLG distribution as:

$$g_X(x;m) = \frac{|\lambda|}{b\Gamma(\lambda^{-2}+m)} (\lambda^{-2})^{\lambda^{-2}+m} \exp\left[\left(\lambda^{-2}+m\right) \lambda \left(\frac{x-u}{b} \right) - \lambda^{-2} \exp\left\{ \lambda \left(\frac{x-u}{b} \right) \right\} \right] \quad (14)$$

$$h_T(t;m) = \frac{|\lambda| \Gamma(\lambda^{-2}+m)}{b\Gamma(\lambda^{-2})(m-1)!} \left\{ 1 - \exp\left(\frac{\lambda t}{b} \right) \right\}^{m-1} \exp\left(\frac{t}{b\lambda} \right) \quad (15)$$

where the parameters are the same as given above and *m* is the number of the mean-related exponential distributions that compose the waiting time distribution $h_T(x;m)$.

Theories, application frameworks, and computer software packages developed for either distribution can be applied to the other. This is particularly useful in view of the wide array of utilities for working with the GG and GLG distributions. In the following section, we first demonstrate the usefulness of the GLG formulation as an analytic tool for studying first marriage behavior, and then we conduct empirical enhancement of the applicability of the model to predict trajectories of marriage and fertility schedules.

3. The GLG Model as an Analytic Tool for First Marriage

3.1 Development of Country Specific Standard Schedules

The first demonstration of the usefulness of the new identification of the CM model exploits the feature that it has only one shape parameter (λ). This enables us to make country specific standard schedules through undemanding procedure. Country specific standards are sometimes required and often desirable, since the global standard schedule derived from Swedish experiences might be inappropriate for some populations. In addition, identifying the specific shape value to apply for a schedule is crucial for predicting the fertility by birth order, since the value for each order varies from that of the nuptiality standard. In the following, we illustrate the development of a country specific schedule using Japanese female cohorts.

Some authors have reported that the CM standard marriage schedule does not fit Japanese experiences as well as those of Western countries (Takahashi 1978, Kojima 1985, Kaneko 1991b). Kaneko (1991b) examined shape parameter values of the GLG model fitted to cohort and period marriage schedules of Japanese females, and found substantial deviations from the shape value λ of the CM standard schedule, i.e. -1.287.

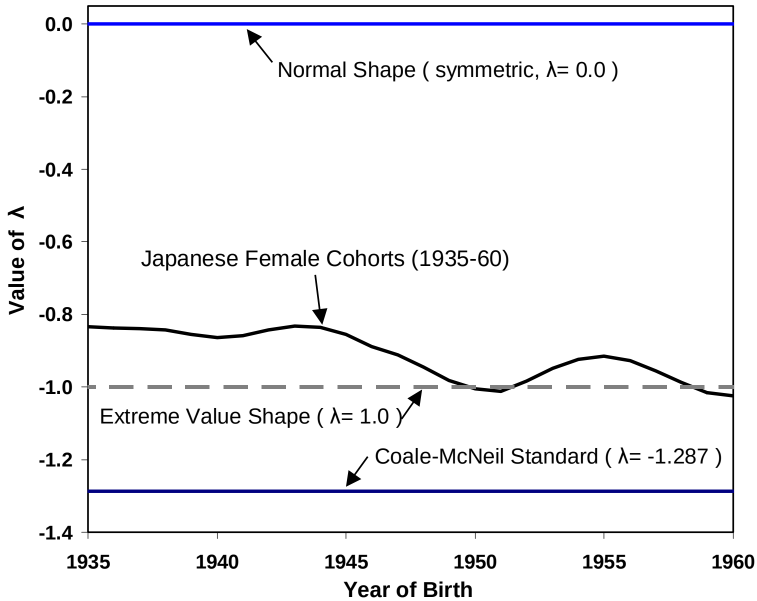


Figure 1: *Estimated Shape Parameter Values (λ) of The GLG Model For Japanese Female Cohorts born in 1935-60*

Figure 1 shows the trend of parameter λ estimated for Japanese female cohorts born in 1935-1960 who have attained at least age 40 at the time of evaluation. The figure indicates deviations in the shape values of Japanese cohorts from the value of the CM standard schedule, which is derived from Swedish experiences. The shape values of Japanese cohorts fall in the range from –1.0 to –0.8, while it is at –1.287 for the CM standard. Other particular values correspond to well-known underlying distributions. The value zero corresponds to the normal distribution, and the value unity to the extreme value distribution. The shape values of Japanese cohorts are located in the middle of the CM standard and the normal distribution near the extreme value model, implying that the Japanese schedule is more symmetric than the CM standard. It seems a little more feasible to use the extreme value distribution to describe Japanese cohorts. We consider some of reasons for the symmetry seen in Japanese cohorts later. A mild decline in the shape value over cohorts is also identified in the figure.

Coale's original finding about first marriage schedules is, in our translation, that the shape parameter of the age distribution is common over countries and periods (Coale 1971). It has been validated by the wide use of the shape-fixed CM standard schedule as a practical tool in various demographic applications. However, the stability of shape is, of course, an approximation. Our close examination indicates that it varies across countries (Japan is not the same as Sweden), and undergoes changes over time to some extent as well. Thus, a schedule with a shape value specific to Japanese women is expected to be more accurate. On the grounds that the shape characterizes the first marriage process of a nation, developing country specific standard schedule with an appropriate shape value is quite beneficial. Such a specific schedule offers more accuracy with the same general form. We now describe the procedure for producing a country specific shape-fixed standard schedule with mean zero and standard deviation of unity.

Let λ_s denote shape parameter of the GLG model which is specific to cohorts of a country. The following parameters are to be calculated for the new standard:

$$k_s = \lambda_s^{-2},$$
$$\alpha_s = k_s\sqrt{\psi'(k_s)}, \quad \beta_s = \sqrt{\psi'(k_s)}, \quad \mu_s = \frac{\psi(k_s)}{\sqrt{\psi'(k_s)}}, \tag{16}$$

where ψ and ψ' denote the digamma and trigamma function. Using these parameters, the underlying distribution of age at first marriage in the new standard schedule is given by:

$$g_s(z) = \frac{\beta_s}{\Gamma(\alpha_s/\beta_s)}\exp\left[-\alpha_s\left(z-\mu_s\right)-\exp\left\{-\beta_s\left(z-\mu_s\right)\right\}\right] \tag{17}$$

The country specific shape value λ_s can be obtained by averaging values of λ of the GLG model fitted to source schedules. Then any first marriage or fertility distribution $g(x)$ and corresponding schedule $f(x)$ among the location-scale family of the standard are given by:

$$g(x)=\frac{1}{s_x}g_s(\frac{x-\overline{x}}{s_x}), \tag{18}$$

$$f(x)=C\ g(x), \tag{19}$$

where $\overline{x}$ and s_x are the mean and standard deviation of the distribution, and *C* is the proportion eventually marrying, of a target cohort.

For Japanese female cohorts born between 1935-60, the average of the estimated λ of the GLG model is -0.9123. With this value for λ_s, and following the formulas (16) and (17), our new Japanese female standard marriage schedule $g_j(z)$ is given by:

$$g_J(z)=1.226\exp\left[-1.351\left(z+0.2553\right)-\exp\left\{-1.125\left(z+0.2553\right)\right\}\right]. \tag{20}$$

In Figure 2 the Japanese standard schedule developed here is compared with the CM standard. Substantial difference in shape is observed. The Japanese standard is more symmetrical than the CM standard. In fact, the shape value indicates that the Japanese standard is only a little more symmetrical than the extreme distribution. Besides Japanese cohorts, Liang (2000) reported that the first marriage distribution of a Chinese female cohort was close to the normal distribution rather than the CM standard.

Why are the distributions from these countries more symmetrical than the CM standard? What determines the shape of the distribution in the first place? Kaneko (1991a), using national representative survey results, examined the shape of first marriage schedule by type of marriage in Japan, and concluded that a rather symmetric shape in the Japanese schedule was formed by presence of arranged marriages. Namely, when the competing risk models were applied to age distributions of marriage by the types of marriage (arranged marriage and others), the shape of each distribution by disaggregated by type was less symmetric than the aggregate, and each shape value was closer to that of the CM standard (arranged –1.065, non-arranged–0.965, while the aggregate –0.644). This implies that the major part of the deviation of the shape in Japan from that of the CM standard is caused by mixture of types of marriage whose timing is distinctively different. In addition, the shape values of schedules of non-arranged and all marriages become even closer to the CM global standard if socioeconomic covariates are controlled for. Therefore, the skewed shape exhibited by the CM global standard may represent schedules of homogeneous marriage behaviors. Comparison of the shape values associated to different marriage types with covariates controlled through the competing risk framework is given in the following section.

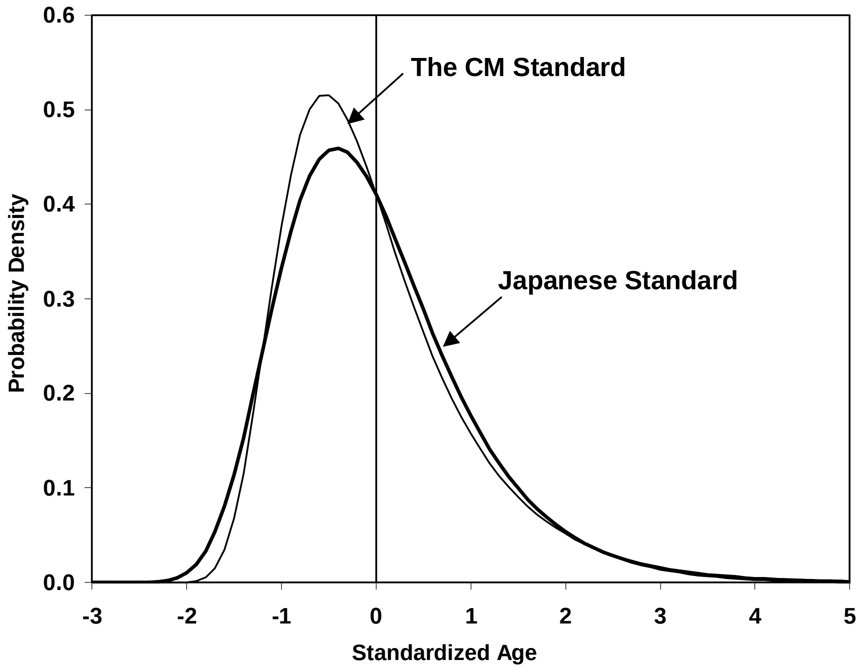


Figure 2: *Comparison of Japanese Standard Schedule with The Coale-McNeil Standard for First Marriage of Female Cohort*

Searching for the determinants of the shape is essential for many applications of the model. As shown later, it is crucial to identify the shape in predicting the schedules of young cohorts that have yet to complete their process. As seen in Figure 1, the shape value changes over time. For example, if presence of arranged marriage makes the shape symmetric and proportion of arranged marriage decreases over time, the shape value is expected to approach that of the CM standard.

3.2 Estimation of Covariate Effects on First Marriage Timing with/without Competing Risk Framework

Though extensions to incorporate covariates into the CM model have been conducted by several authors (Trussell and Bloom 1983, Sørensen and Sørensen 1986, Liang, 2000), the GLG specification has some advantages for this purpose in both theoretical and practical developments since it is one of the standard parametric regression models in survival analysis (Lawless 1982, Johnson et al. 1994 1995, Klein and Moeschberger 1997). Here, we demonstrate the effectiveness of the model in analysis of covariate effects on age at first marriage, and the effect of heterogeneity on shape parameter value, which is significant in predicting the parameter required for nuptiality and fertility projection described later in this paper.

In the standard specification of the GLG regression model, a vector of covariates for individual *i*, $\mathbf{X}_i$, are incorporated into the model in linear form with regression parameters $\boldsymbol{\theta}$, so that the parameter *u* of equation (7) and (8) for individual *i* should be $u_i = \mathbf{X}_i^t\boldsymbol{\theta}$ where $\mathbf{X}_i^t$ denotes the transpose of vector $\mathbf{X}_i$. Since the parameter *u* determines the location of the schedules (the mode), the specification implies that individuals have underlying probabilities that differ in marriage or reproduction timing depending on their characteristics. This formulation is particularly useful for analysis of the current fertility decline to below replacement level in many countries, since the decline is firmly connected with delay in timing of marriage and childbearing.

We conduct the GLG regression for age at first marriage with some demographic and socio-economic characteristics using survey data for illustrative purposes (Note 6) (The source is the national representative sample in the Ninth National Fertility Survey conducted in 1987 in Japan). The results are presented in Table 1 in the far left two columns ("All Marriage"), where estimated parameter values and regression coefficients for two different model specifications (model 1 and 2) are shown.

The coefficients listed indicate the amount of marriage delay (year) in relation to timing in reference category (marked with #) if variables are categorical, or to unit change of covariates if they are quantitative (here only "Number of Sibling"). Model 1 incorporates only "cohort" as covariates, and shows no significant difference in marriage timing among them, though slight delay is observed in younger cohorts. However, Model 2, in which all other covariates at hand are incorporated, reveals that the delay in younger cohorts is fully attributable to the effects of other covariates than "cohort", mainly due to the expansion of higher educational groups, since coefficient values of cohorts are reversed when those effects are controlled in this model (Note 7). It is worth noting that the value of λ tends to decrease when more covariates are introduced, which supports the view that the symmetric shape of schedule is caused by heterogeneity in marriage timing.

Table 1: *Effects of Covariates on Age at First Marriage of Japanese Women: The GLG Regression by Type of Marriage with Competing Risk Model*

Covariates	All Marriage Model 1 (N=4682)	All Marriage Model 2 (N=4682)	Non-Arranged (N=4682) (n=2878)	Arranged (N=4682) (n=1804)
Intercept	23.34	22.43	23.86	23.33
Cohort (Birth Year)			****	****
# 1938-39	0.00	0.00	0.00	0.00
1940-44	0.04	-0.05	-0.36	0.30
1945-49	0.17	-0.11	-0.72 ***	0.75 ***
1950-54	0.20	-0.18	-1.02 ****	1.29 ****
Educational Background		****	****	****
# Junior College		0.00	0.00	0.00
High School		0.87 ****	0.82 ****	0.89 ****
Junior College		1.49 ****	1.69 ****	1.00 ****
University		2.48 ****	2.61 ****	2.05 ****
Father's Occupation		**	**	***
# Agriculture		0.00	0.00	0.00
Self-employed		0.13	-0.10	0.50 **
White-colalr		0.17	-0.16	0.70 ****
Blue-collar		-0.13	-0.49 **	0.48 *
Not working/ temporary		-0.44 *	-0.69 **	0.02
Area of Residence		****		****
# Rural		0.00	0.00	0.00
Urban		0.42 ****	0.13	0.98 ****
Co-residence with			***	****
# Living seperately		0.00	0.00	0.00
Living together		0.09		
Heiress				
# Not heiress		0.00	0.00	0.00
heiress		-0.16	-0.06	-0.22
Number of Sibling		-0.07 **	-0.12	0.04
Scale Parameter (b)	2.614	2.460	3.082	3.453
Shape Parameter (λ)	-0.673	-0.761	-1.161	-1.054

N : Sample Size n : Number of Samples without Censor # : Reference Category
* P<0.05 ** P<0.01 ***P<0.001 ****P<0.0001
Data Source: The Ninth National Fertility Survey in Japan, Female cohorts born in 1938-54.

While the effects of heterogeneity of individual characteristics in relation to first marriage timing are measured above, we next view the effects of heterogeneity of characteristics of marriage itself. There occur several different types of marriage such as non-arranged and arranged marriages, registered marriage and cohabitation, or inter-racial and intra-racial marriages, and so forth. For instance, consider a situation in which the marriage processes of non-arranged and arranged marriages are to be compared. One plausible supposition here is that the same person goes through different processes simultaneously and ends up in either of these different types of marriage, whichever comes first. According to the survival analysis framework, this type of situation can be dealt with by the competing risk model, in which several different events have their own mutually independent probabilities of taking place at a given time.

We illustrate the use of the competing risk framework by applying it to analysis on determinants of first marriage timing in Japan taking into account the type of marriage, i.e. non-arranged and arranged marriage. The results are presented in the right two columns of Table 1. Here, some interesting tendencies hidden in the analysis of all over marriage appear. First, age at first marriage decreased by cohort for non-arranged marriages, while it increased for arranged marriages. These changes in opposite directions are both statistically significant and substantial in amount. On the other hand, as described before, the trend as a whole for all marriages indicates no significant change by cohort. The analysis by type of marriage here revealed active changes behind the seeming stability over the cohorts. Similar opposite effects by type of marriage are seen for some other covariates. Co-residence with parent(s) before marriage significantly affects marriage timing of each type in opposite directions (delay in the non-arranged, and accelerated in the arranged marriage) while that of over all marriage appears to be unaffected. Residence in urban areas delays only arranged marriage. Only non-arranged marriage is accelerated by the presence of siblings. The analysis illustrates that examination by type of marriage with the competing risk framework provides us with information about detailed features of the process which are otherwise not observable.

Again, it should be noted that the values of shape parameter λ for each type of marriage are substantially smaller in absolute value than that of overall marriages, approaching the value of the CM global standard schedule derived from the Swedish experience. This confirms the view that a mixture of different processes such as type of marriage makes the shape of the age distribution of overall marriages more symmetric than the CM standard, while shape of each underlying process tends to follow the standard.

4. Empirical Enhancement

4.1 Empirical Adjustment of the GLG Model

No model fits actual data perfectly. Discrepancies consist of two types of errors; one is random error induced by exogenous factors such as measurement error, and the other is systematic error derived from simplification or insufficiency in model specification. The latter may be corrected by exploiting regularity in the pattern of error. Here we introduce empirical adjustments of the GLG model, seeking a better fit to actual experiences in first marriage of Japanese female cohorts.

The GLG model does not satisfactorily describe the first marriage experiences of Japanese female cohorts. This issue is partly discussed above, where the shape of the standard schedule is inappropriate and therefore is to be set to a specific value to create a country-specific schedule. But even allowing the shape parameter to take value specific to a target cohort, the model schedule deviates noticeably from the observed data. Figure 3 shows observed (dots) and modeled (broken line) first marriage rates for Japanese female cohorts born in 1950. Although the model is best-fitted by optimizing all parameter values including the shape value, the discrepancy is sizable. A similar error pattern is found for every cohort that completed the marriage process in our data set, and therefore the errors can be regarded as systematic. The discrepancy causes serious distortion in estimated parameter values especially when the model is applied to censored cohorts that have not completed their marriage processes. Therefore, seeking better fit for the model is critical in predicting eventual schedule of nuptiality and fertility for cohorts that have not completed the process.

To improve the predictive power of the model in this circumstance, we should capture regularity in the error pattern to be modeled. Difference in the cumulative first marriage rates by age between actual and fitted experiences for 16 cohorts (born in 1935 through 1950) that completed the marriage process are examined. We adjust the cumulative rate function instead of the first marriage rate function because the former is used in parameter estimation, as describe later.

Figure 4 shows the errors for the cohorts. In the figure, the horizontal coordinate is calibrated by standardized age z in terms of parameter u and b, i.e. with usual age x: $z = (x-u)/b$. The origin (0) of the axis indicates the location of mode, since parameter u designates the mode of the GLG schedule. Let $\xi(z)$ denote the error as: $\xi(z) = F(u+bz) - \hat{F}(u+bz; C, \lambda, u, b)$, where $F(x)$ and $\hat{F}(x;\boldsymbol{\theta})$,

$\boldsymbol{\theta} = (C, \lambda, u, b)$ are the cumulative function of the first marriage rate of observed and model (the latter is alternatively represented by $\hat{F}(z;\boldsymbol{\theta}), \boldsymbol{\theta} = (C, \lambda, 0, 1)$.)

As mentioned above, a highly systematic age pattern of error exists. It is reasonable to assume that there is a particular cause for the very persistent age pattern of discrepancy seen in Figure 4. However, here we just model the pattern empirically. We return to a discussion of underlying causes of the error pattern later.

The straightforward way to incorporate the error pattern into the model is to add an average error pattern to the model. The resulting model $\overline{F}(x;\boldsymbol{\theta}), \boldsymbol{\theta} = (C, \lambda, u, b)$ is expressed as:

$$\overline{F}(x;C,\lambda,u,b) = \hat{F}(x;C,\lambda,u,b) + \hat{\xi}\left(\frac{x-u}{b}\right), \tag{21}$$

where $\hat{F}(x;\boldsymbol{\theta})$ is the GLG model, and $\hat{\xi}(z)$ is the average error at standardized age *z*, called the adjustment function (Note 8). We call this model the empirically adjusted GLG model. Although incorporating empirical residual pattern into the mathematical model is not an elegant solution, the simple way out is of practical efficacy.

Here, $\hat{\xi}(z)$ is obtained by averaging the errors of the model applied for Japanese cohorts (born in 1935-50) described above, and is presented in numerical form in Table A-1 in the Appendix. The function is also shown in Figure 4 in a continuous curve along with error dots. To obtain the average error pattern on standardized ages, and to evaluate $\hat{\xi}(z)$ in the new model $\overline{F}(x;\boldsymbol{\theta})$, some interpolation method is required. Although here the cubic spline interpolation technique is employed, linear interpolation may be adequate for most purposes. There are some constraints on the adjustment function $\hat{\xi}(z)$. First, it is to be zero as *z* goes to plus or minus infinity to keep parameter C intact as is in the original GLG model. Secondly, integration of $\hat{\xi}(z)$ over the full domain of *z* should be zero to keep the mean age of the schedule intact. Therefore, we slightly adjust the average error pattern to derive $\hat{\xi}(z)$ so that these properties of schedule are preserved.

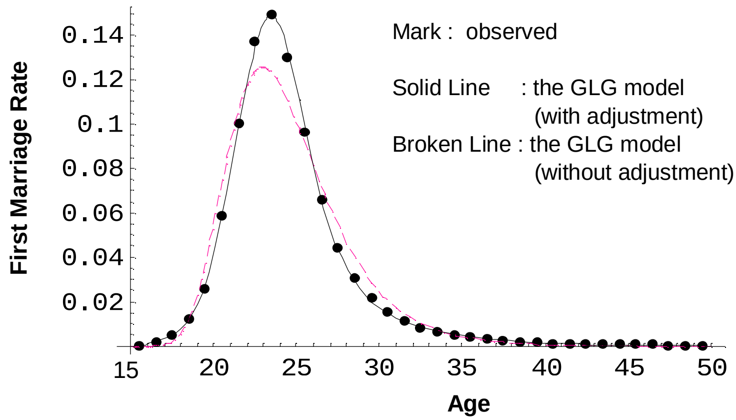


Figure 3: *Observed Age Specific First Marriage Rates and Fitted GLG Model (with and without Adjustment): Japanese Female Cohort born in 1950*

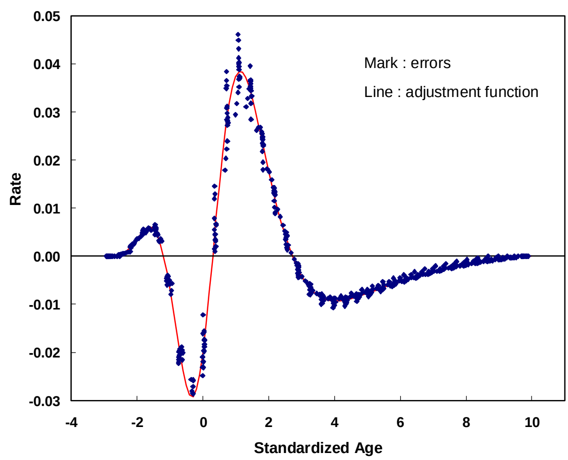
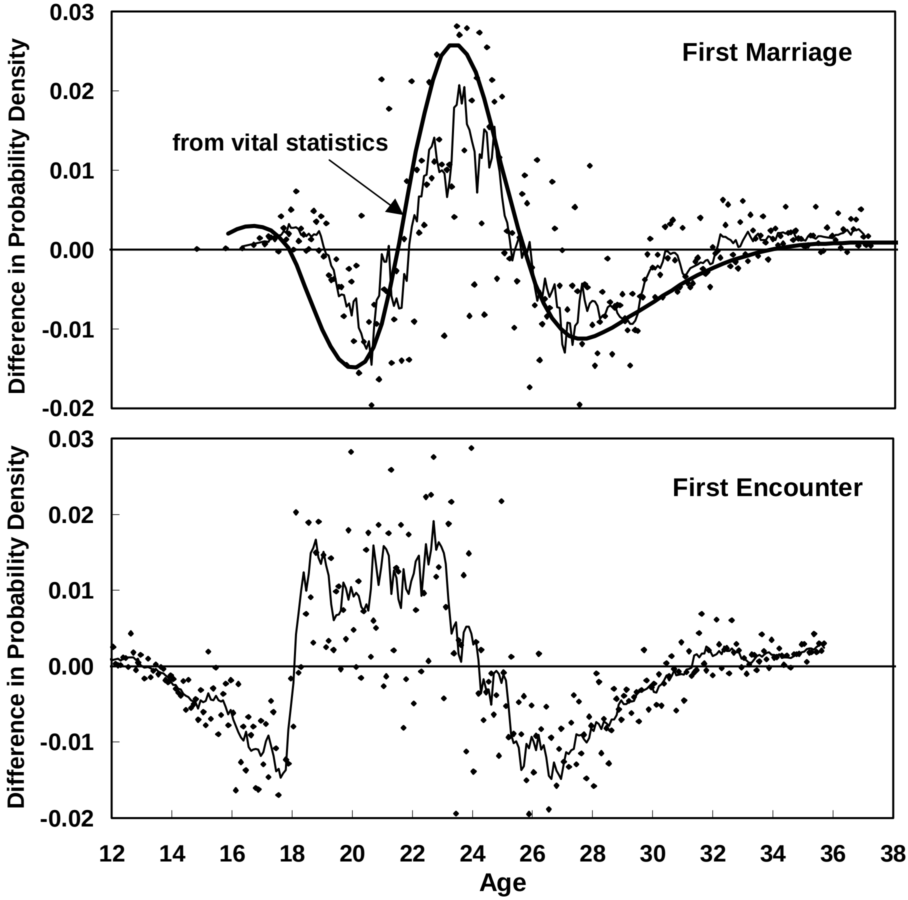


Figure 4: *Errors of the GLG Model in Cumulative Fist Marriage Rate for Japanese Female Cohort (1935-50) and Adjustment Function*

In Figure 3, we see an improvement in the results produced by the adjusted model (solid line). The curve produced by the adjusted GLG model traces almost exactly the observed rates, while, as already mentioned, the GLG model without adjustment (broken line) does not (Note 9).

Now we briefly discuss the cause of the error pattern. The upper graph of Figure 5 shows the average error pattern in the first marriage rate of the Japanese female cohorts from vital statistics and from a national representative sample. Both patterns indicate that first marriages concentrate on the mode (age 23-24) more than is predicted by the GLG model. A similar error pattern is reported in attempts to fit the Coale-McNeil model to cohort experiences in other countries (for the U.S., Bloom and Bennett 1990, for Swedish male, Ewbank 1974). If the model should represent the “natural” course of first marriage schedule, people should exert a certain kind of regulation on age at marriage resulting in the error pattern. Since in the US, the actual rate exceeds the prediction of the model in the late teens, where the mode locates, Bloom and Bennett speculate that there is a threshold age of 18 before which marriage is hindered by laws or cultural norms. In our case in Japan, however, excess marriages concentrate on age 23-24. Inquiring as to the cause of this residual pattern, we might ask if age at marriage is regulated directly by couples or if the pattern is formed spontaneously in course of marriage process. We observe the error pattern of distribution of age at first encounter with eventual spouse through a national representative survey (the National Fertility Survey) in Japan. The lower graph of Figure 5 indicates that there is a similar deviation pattern in distribution of age at first encounter from the GLG model, which suggests that the regulation is exerted largely on the timing of first encounter, although a difference in the error pattern between first encounter and marriage, especially in their dispersion, indicates that duration from encounter to marriage is partly regulated as well. A sharp rise in deviation of the actual rates of first encounter around age 18 from the model prediction seen in the lower graph of Figure 5 suggests that graduation from high school may be a threshold of behavioral change in first meeting, which supports the view of Bloom and Bennett(1990) that the residual pattern is formed by interference of some social activities.

Hereafter we exclusively use the empirically adjusted version of the model for the first marriage schedule. Notation $F(x)$ instead of $\bar{F}(x)$ is used for simplicity.



Note: Dots stand for residual that are obtained as difference between the Kaplan-Meyer estimates and the GLG model prediction. Thin lines represent their moving average. Thick lines represent the residual pattern from vital statistics. Data is from the National Fertility Survey, round 9, 10, and 11, for married cohorts born during 1937-1959, from the vital statistics for cohorts born in 1935-1950.

Figure 5: *PDF Residual Pattern of the GLG Model of First Marriage and First Encounter with Spouse by Age*

4.2 Method of Parameter Estimation

The Parameter Estimation Method for the adjusted GLG model is no different from the standard method as long as the proper interpolation technique is used for the adjustment term. In a simple situation where age at first marriage of the married people and age at survey of the never married are measured, the likelihood function $L(\boldsymbol{\theta})$ is constructed as:

$$L(\boldsymbol{\theta}) = \prod_{i \in P} f(x_i;\boldsymbol{\theta})^{\delta_i} \left[1 - F(x_i;\boldsymbol{\theta})\right]^{1-\delta_i} \tag{22}$$

where $f(x;\boldsymbol{\theta})$ and $F(x;\boldsymbol{\theta})$ are respectively the density function (age specific first marriage rate) and the cumulative function of first marriage schedule at age x with parameter set $\boldsymbol{\theta}$, which includes C, λ, u, b in our model (21), x_i is age at marriage or age at survey (consor) of individual i depending on whether i is married or never married, δ_i is a indicator variable that takes value one if individual i is married at age x_i and zero otherwise, and P denotes the sample set as a whole. We estimate a set of parameters $\boldsymbol{\theta}$ so as to maximize $L(\boldsymbol{\theta})$, although its logarithm is to be maximized in practice for the sake of ease of calculation.

In the situation above, x_i, age at marriage or at survey is to be exact age. If only aggregated information, such as numbers of marriage classified by age group or even by completed age of single year, is available, the maximum likelihood method with interval censoring is appropriate. Most data of the national level is available only in this form. Suppose that a female cohort of size N at exact age x had m_a marriages in each completed age a ($a<x$), and n_x is left as never married, i.e. $N = \sum_{a=a_0}^{x-1} m_a + n_x$, where a_0 is age at onset of first marriages. Assuming marriages take place independently, the probability of having such a sample follows the multinomial distribution with $x - a_0 + 1$ parameters (m_a $(a = a_0, a_0 + 1, \cdots, x-1)$, n_x). Let $F(x;\boldsymbol{\theta})$ denote the cumulative first marriage rate function. Then the probability (L) is given by:

$$L(\boldsymbol{\theta}) = \frac{N!}{m_{a_0}!m_{a_0+1}!\cdots m_{x-1}!n_x!} \left[\prod_{a=a_0}^{x-1} \left(F(a+1;\boldsymbol{\theta}) - F(a;\boldsymbol{\theta})\right)^{m_a}\right] \left(1 - F(x;\boldsymbol{\theta})\right)^{n_x}. \tag{23}$$

Eliminating the constant factors from the log-transform of L, we maximize the following function to obtain an estimate of $\boldsymbol{\theta}$:

$$\sum_{a=a_0}^{x-1} m_a \ln\left(F(a+1;\boldsymbol{\theta})-F(a;\boldsymbol{\theta})\right)+n_x \ln\left(1-F(x;\boldsymbol{\theta})\right) \tag{24}$$

The estimation procedure described above requires number of marriages and population never married as inputs. But in most applications with aggregate data, it is desirable to input rates rather than numbers for the estimation, since numbers are subject to direct influences of death and migration. Here we use the age specific first marriage rate in completed age a as input for m_a, and the proportion never married at exact age x for n_x so as to focus on behavioral aspects of first marriage free from influences of death and migration (Note 10).

4.3 Censoring Effects on Parameter Estimation

Parameter estimation is affected by censoring. This takes place in our research for cohorts that have not completed the marriage process (right censoring). The extent of censoring effects on parameter estimation depends both on the exactness of model specification and data adequacy. Here, we conduct some experiments in which censoring is artificially performed on non-censored cohorts to assess the effects of censoring at various ages on estimated value of parameters.

Examination of estimated values of parameters with artificial censoring shows that the values are quite stable and close to the "true" values that are estimated without censoring when the censoring takes place after standardized age 5.0, which approximately corresponds to normal age 36-40 in the case of Japanese females. It is suggested, therefore, that estimates with censoring after standardized age 5.0 are mostly trustworthy. Examination of estimates of C indicates that the differences between estimated and the true values are within a range of –1.5% to 1.0% for those censored around and after standardized age 2.0, which corresponds to normal age 28-32 in Japan. Therefore, we may expect that we can estimate the proportion eventually marrying for the cohort that has completed the marriage process up to around age 30 with error of less than $\pm 2\%$.

If the values of some parameters are known a priori, it is observed that the prediction of other parameters for young cohorts are more accurate, and with the same accuracy the target range can be extended to younger cohorts. Since parameter λ is expected to be stable in value, it is reasonable to fix it at a certain value such as the global standard (-1.287) or a country specific value in order to obtain a better prediction for younger cohorts in first marriage schedule. According to our examination, differences of *C* between estimated and the true values are within a range of –0.4% to 0.2% with censor at standardized age 2.0, if true value of λ is known. In this case we may reasonably expect to be able to predict the proportion never married for cohorts who are above age 30 with an error of less than $\pm 1\%$. In the same condition, parameter *u*, the location parameter that designates location of the mode, is estimated within a range of –0.015 to 0.01 of the target when censored at standardized age 2.0, and parameter *b* is estimated within range of –0.05 to 0.01 around the target value. This is adequate accuracy for most demographic applications. Since *u* and *b* are only determinants of the mean and standard deviation of age at first marriage if λ is fixed, similar stabilities are expected for those moments.

5. Application of the Adjusted GLG Model

5.1 Estimation and Projection of First Marriage

Now we apply the empirically adjusted GLG model described above to estimate and predict first marriage schedules for female birth cohorts including those that have yet to complete the marriage process. Annual first marriage rates derived from the vital statistics with correction of delayed registration are used as the source data so that the results represent overall Japan (the correction procedure is described elsewhere, Kaneko 2002).

From the estimated annual first marriage rates through the ages and years of 1950-2000, the full lifetime first marriage experiences over ages 15-49 can be extracted only for 16 single year cohorts born during 1935-1950. However, the relevant cohorts to the unprecedented nuptiality and fertility decline in Japan since the mid 1970s are mostly those born after the 1950s. Hence, some reliable predictive tool is required to identify the changes seen in the contemporary nuptiality and fertility reduction. We employ the GLG model adjusted for Japanese females described in the previous chapter for this purpose. We apply it to the cohort first marriage processes to estimate lifetime behavioral measures such as mean age at first marriage, or proportion never married at age 50.

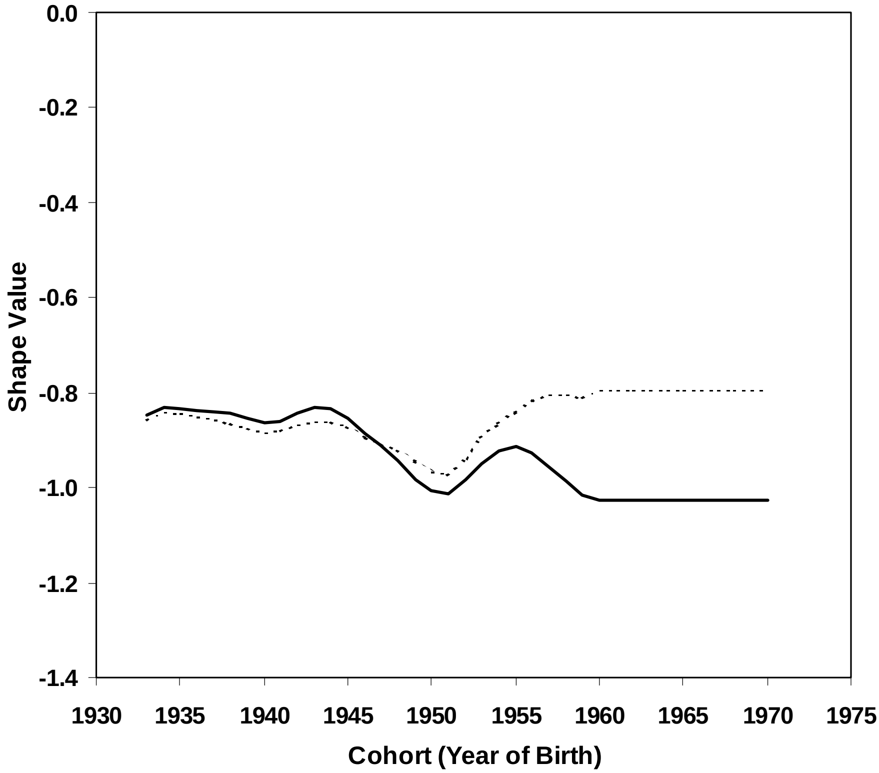
The model schedule is fitted to each cohort experience by estimating model parameter values specific to the cohort through the maximum likelihood method described in the previous section. First, parameter estimation is performed without constraint on parameter for cohorts that have fully and substantially completed their lifetime first marriage schedules. Then, we extend the estimation to younger cohorts that are undergoing various stages in the process, by keeping the shape parameter constant at feasible values as described in the following.

For cohorts that have completed the marriage process, i.e. those born in the years up to 1950, predicted measures by the model agree almost exactly to the observed, since model schedules fit the actual experiences quite well. However, censoring effects on estimates are apparent in younger cohorts born after the mid 1960s, causing estimation results to be increasingly implausible. According to our criterion of reliability in the estimated value of *C* assessed in the censoring experiments described above, we employ free estimation for cohorts with censoring at standardized age 5.0, which corresponds to cohorts born in 1960 in our data set. For cohorts born after 1960, the value of λ is to be fixed while the other parameters are freely estimated. The criteria for reliable estimation with fixed λ described in the previous section suggests that the border of feasible estimation is around the cohort of 1970. Hence, we limit our observation up to cohorts born in 1970.

Which value should we fix λ to for cohorts born from 1961 to 1970? According to the free estimation, the value of λ shows upward development during 1961 to 1970. It is not certain if the trend is actually happening or is just an artifact due to the censoring effect. Previously we found that the shape value becomes larger (smaller in absolute value) when marriages are a mixture of non-arranged and arranged marriages. Since arranged marriages have been diminishing through the postwar period, the value of λ is expected to decrease instead of increase as seen in the results of free estimation. Thus, here we fix λ at the level of 1960 so as not to let λ increase.

Estimated and fixed values of λ are shown in Figure 6. In the figure, we added the graph of estimated λ for the model without empirical adjustment in a broken line to see effect of the adjustment. Its values after 1960 are fixed at the level of 1960 again. Shape values of the non-adjustment model deviate from that of the adjusted particularly in later cohorts with earlier truncation of the marriage process, tending to be larger which implies a more symmetric shape.

Predicted marriage schedules for the cohort of 1970 are contrasted with those observed in Figure 7. The model schedule follows the actual experiences quite well, even though the cohort is the youngest and its exactitude of the fit is supposed to be the weakest in our data set.



Notes: Solid line: Estimates with empirical adjustment, Broken line: Estimates without empirical adjustment.

Figure 6: *Trends of Estimated Value of Parameter λ (Shape Value): Japanese Female Cohorts born in 1933-70*

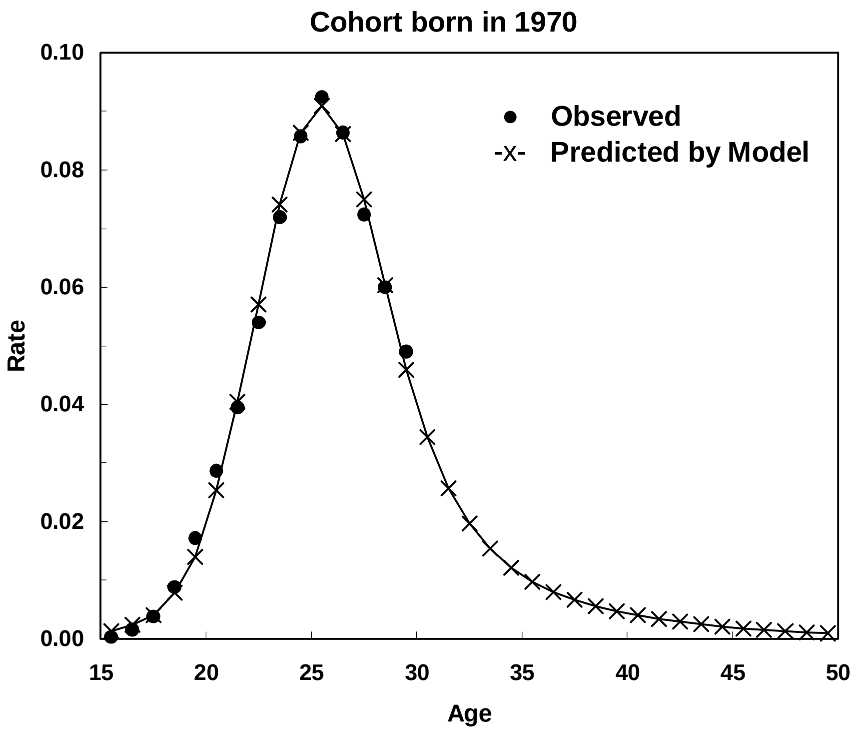


Figure 7: *Observed and Predicted Age Specific First Marriage Rate: Japanese Female Cohort born in 1970*

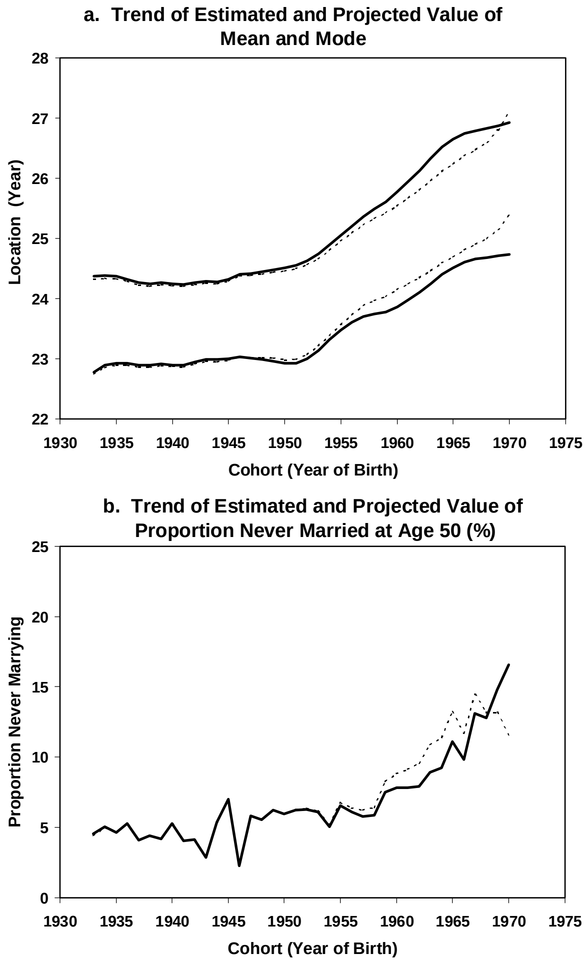
The results of estimation for the mean and the mode of age at first marriage, and the proportion never married at age 50 (γ) are portrayed (solid lines) in Figure 8-a and -b along with estimates for the non-adjustment model (broken lines) again. The trends show a smooth continuous transition from cohort to cohort except the relatively large fluctuation in C for cohorts born at the end of the World War II, probably caused by a flaw in raw statistics. For these indices, the original GLG model without adjustment yields similar estimates to those from the adjusted model for older cohorts. But the results from the former show somewhat different paths from the latter for younger truncated cohorts. These are expected from differences in the abilities of the models to trace age schedules of first marriage (see Figure 3, for instance).

What are the findings from the estimated trends of lifetime measures of first marriage by the empirically adjusted GLG model? The results for cohorts born in 1935-1970 indicate that there are five phases of behavioral change, of which the last three are relevant to the recent unprecedented nuptiality and fertility decline. The change was initiated with a delay in marriage by the cohort born in 1952, followed by a diffusion of never-marrying in cohorts born after 1959 along with prolonged delaying. Then there is an emerging new phase in which the timing shift of marriage is gradually ending in cohorts born after 1965, while the diffusion of never-marrying is rather accelerated. Close examination of hazard rates revealed that the diffusion of never-marrying in the second phase is related to the delaying behavior since marriage propensity in later ages seems to have a bound on increase, and some of postponed marriage have been foregone. On the contrary the diffusion of never-marrying in the third phase is caused by a decline in the propensity to marry even in higher ages as well as early ages. The results suggest that a new phase of marriage behavior is emerging among Japanese women born in and after 1965, which will result in steep increase in lifetime proportion never-marrying (Kaneko 2002).

Note that observation of the trends over cohorts born in from 1952 to 1970 is possible only via the application of some model, and a high level of accuracy in model is required to draw substantive conclusion. The original GLG model (CM model) seems not sufficient in the Japanese case for the recent period described above.

5.2 Application for Fertility Projection

As mentioned before, a model of first marriage schedules also serves for modeling fertility schedules by birth order. Those processes of first marriage and birth by birth order share common structures. The application of the GLG model to birth by order is theoretically expected because of the convolution structure of the GLG model described



Note: Solid line : Estimates with empirical adjustment Broken line : Estimates without empirical adjustment

Figure 8: *Trends of Estimated and Projected Lifetime Measures of First Marriage: Japanese Female Cohorts born in 1933-70*

in this paper (Note 11). We briefly illustrate an immediate application of the GLG model to fertility in a system of fertility projection, following Kaneko (1993).

Let $F_n(x; C_n, \boldsymbol{\theta})$ be a function of age specific cumulative fertility rate of the *n*-th child at age *x* with proportion eventually having *n*-th child C_n and a set of other parameters $\boldsymbol{\theta}_n$, then:

$$F_n(x; C_n, \boldsymbol{\theta}_n) = C_n G(x; \boldsymbol{\theta}_n) \tag{25}$$

where G denotes the distribution function of the GLG distribution. The function of age specific fertility rate of the *n*-th birth $f_n(x; C_n, \boldsymbol{\theta}_n)$ is given by:

$$f_n(x; C_n, \boldsymbol{\theta}_n) = \frac{dF_n(x; C_n, \boldsymbol{\theta}_n)}{dx} = C_n g(x; \boldsymbol{\theta}_n) \tag{26}$$

where *g* denotes PDF of the GLG distribution. However, the observed age specific fertility rate in completed age a should be given by $F_n(a+1) - F_n(a)$.

The estimation scheme is also identical to that for first marriages except substituting observed frequencies of *n*-th birth for those of first marriages. If schedules for all birth order are estimated, then the overall age specific cumulative birth rate $F(x)$ is given simply by summing them up to the highest birth order as:

$$F(x) = \sum_{n=1}^{L} F_n(x; C_n, \boldsymbol{\theta}_n) \tag{27}$$

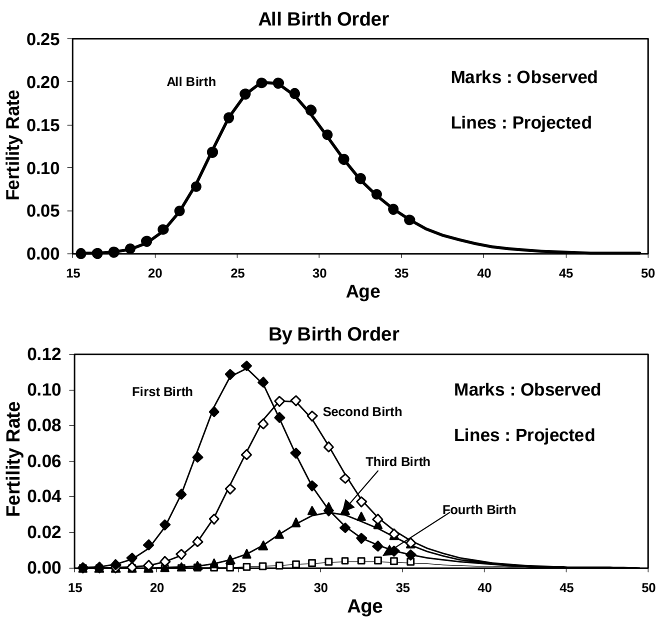
where *L* denotes the highest birth order. In practice, the class of highest birth order may include certain order of births (e.g. 5-th birth) and higher together so that the summation in (27) includes all births.

In general, the higher the birth order is, the more the shape of the schedule becomes symmetric. There is difficulty for the GLG model to describe the schedule whose shape approaches perfect symmetry. The distribution underlies the perfect symmetric GLG model is the normal distribution. Therefore, the normal distribution model (with extra parameter for prevalence level, *C*) is to be used as an approximation for the case in which the shape is highly symmetric, or value of parameter λ is near zero.

The model (27) contains $4 \times L$ parameters, which seem to be many more than required to describe overall fertility schedules. Parameters for subsequent birth orders should be correlated and the relationships might be modeled so that we could reduce the number of parameters for parsimony. However, the maximum precision is attained in the original form as long as fertility rate by birth order are available, which is mostly the case with national data.

The empirical adjustment technique employed for first marriage schedule developed in the previous section is applicable to the model of fertility as well. Kaneko (1993) examined the error pattern of the model for each birth order with regard to Japanese female cohorts, and presented the adjustment functions in table form (see Table A-2 in the Appendix).

We now provide an illustration of the application of the model to cohort fertility. In Figure 9, the observed and predicted age specific fertility rates by birth order for Japanese female cohorts born in 1955 with data up to age 35 are plotted together. The model schedules follow the observed rates quite well for all birth orders.



Note: Fifth and higher birth order is not shown

Figure 9: *Observed (as of 1991) and projected Cohort Fertility Rates: Japanese Female Cohort born in 1955*

The model projects the schedule of this cohort beyond age 35 (the point after which data was not available) to conclude the processes. Applying this projection procedure to every relevant cohort with some assumptions of future fertility behavior for very young cohorts, we obtain a prediction of the period fertility schedule. Using fertility data of cohorts born in 1935-75, the period age specific fertility rates for the year 1985 through 1990 are reconstructed by the model system. The fits are visually presented in Figure 10, which indicates that the system is capable of generating period fertility schedules with adequate precision for most practical purposes (Note 12).

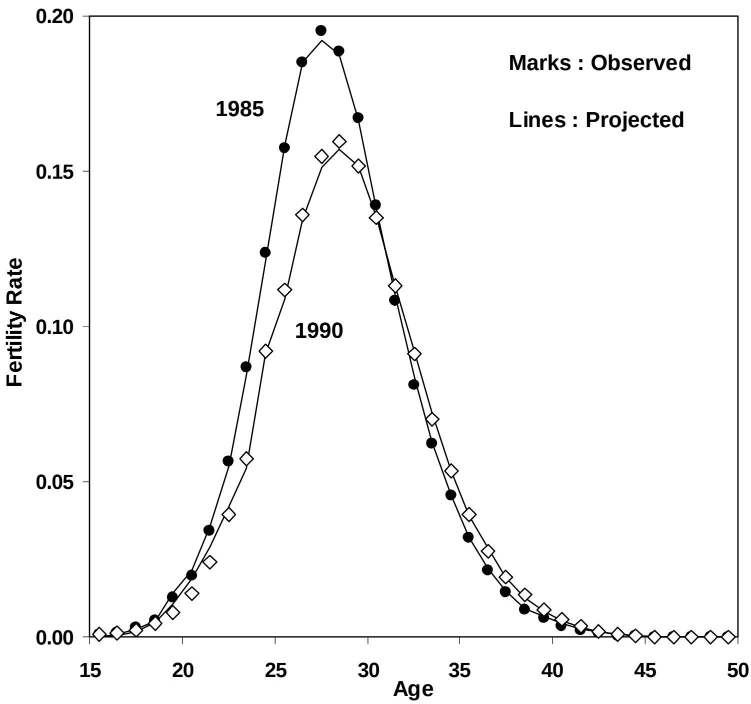


Figure 10: *Observed and Projected Period Fertility Rates: Japanese Female, 1985, 1990*

6. Summary and Conclusion

The first purpose of the present paper is to show that recognition that the Coale-McNeil (CM) nuptiality model is equivalent to the generalized log gamma (GLG) distribution model allows an expansion of possible application of the model. Some of these applications are illustrated. First, by taking advantage of single parameter representation for the shape of the GLG model, a simple method to derive a country specific standard schedule is proposed. In this course, the significance of the shape specific to a country or region, represented by single value by the GLG model, is indicated. Second, we demonstrated a regression analysis of the effects of covariates on marriage timing. Immediate application of the theories, techniques and software packages of the GLG statistical model to analyze first marriage is main advantage of the new recognition. Here the effects of individual characteristics on first marriage timing were measured with the GLG regression technique, taking account of types of marriage, such as arranged and non-arranged marriages, with the competing risk framework. In our illustration of analysis on Japanese female experiences, we found interesting hidden effects of covariates that would not be found otherwise. These applications revealed also some mechanisms that determine the shape of distribution underlying the first marriage schedule. Heterogeneities of the marriage processes depending both on individual characters and types of marriage (presence of arranged marriage) in Japanese case promote symmetry in shape, which is significantly different from the shape of the Coale-McNeil global standard derived from Swedish experiences. When both types of heterogeneity are controlled, the shape of the schedule of each underlying process tends to follow the global standard.

The second purpose of the present study is to enhance the ability of the model to trace trajectories of the lifetime marriage schedule by incorporating an empirical model of residual error so as to ensure precise estimation results for cohort processes that have not been completed. Employing our findings about stability of residual error patterns for Japanese female cohorts, we successfully incorporated the empirical residual pattern, adjusting its location and scale into the GLG model. The behavioral foundation of the residual pattern was examined, and confirmed to be mainly caused by adjustment in the time of first encounter with future spouse, though there seems an adjustment of dating duration. We conducted a long-term estimation of cohort lifetime measures of first marriages including cohort behavior relevant to the recent drastic reduction in nuptiality and fertility observed in Japan, finding that a new phase of marriage behavior where the proportion never-marrying will drastically increase is emerging. The predictive power of the GLG model allows estimation for behavior of young cohorts, and the empirical adjustment ensures the precision, otherwise quite different schema is drawn, as illustrated.

It should be noted that every aspect of arguments on the GLG model for the first marriage schedule can be directly applied for the fertility schedule by birth order, because of the formal equivalence in structures of those processes. Finally, we demonstrated an application of the enhanced model to the fertility projection system. The performance of the system to predict cohort and period age specific fertility rates seems satisfactory so that it is utilized for country specific precise fertility projection.

7. Acknowledgements

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Notes

1. This may be regarded as a continuous version of the age specific first marriage rate that is in the strict sense defined by a definite integral of $f(x)$ over the relevant age range.

2. Pearson's correlation coefficient between meeting and waiting time to first marriage is -0.48 (that of meeting and time to engagement is -0.45, and of meeting and engagement period is -0.22) for Japanese women born in 1938-54. Partial correlation coefficient between the age at meeting and the waiting time to first marriage with cohort effect controlled is virtually not affected (-0.45). The analysis was carried out on the data from the Ninth National Fertility Survey in 1987 conducted by National Institute of Population and Social Security Research.

3. PDF of the Gamma distribution with two parameters, k and δ, is: $f(t)=\frac{\delta(\delta t)^{k-1}}{\Gamma(k)}\exp[-\delta t] \quad t>0$ while that of the GG distribution with additional parameter, η, is; $f(t)=\frac{\delta\eta(\delta t)^{k\eta-1}}{\Gamma(k)}\exp\left[-(\delta t)^{\eta}\right] \quad t>0$

4. The gamma function and the incomplete gamma function are here defined as: $\Gamma(y)=\int_0^{\infty}u^{y-1}e^{-u}du$ and $I(y,t)=\frac{1}{\Gamma(y)}\int_0^{t}u^{y-1}e^{-u}du$) respectively.

5. k is corresponding to $\alpha/|\beta|$ in equation (1).

6. Some of statistical packages include regression application with the generalized gamma distribution. We here utilized LIFEREG procedure in SAS/STAT. Constant term of *u*, *b*, and λ are respectively correspond to INTECEPT, SCALE, and SHAPE in the SAS output of the procedure with option NOLOG.

7. We here present only a naïve analysis for examination of covariates effects on marriage processes, because of its illustrative purpose for the use of GLG model. Raymo (2003) closely examined the effects of individual characteristics, educational attainment in particular, on transition probability to first marriage among Japanese women, finding higher educational attainment is increasingly associated with later and less marriage by cohort.

8. It seems possible to introduce an additional parameter as a coefficient of ξ to seek further flexibility. However, it may distort the estimation of the other parameters due to identification problem.

9. The empirical adjustment proposed here is primarily aimed to improve model's ability to trace the age schedules in macro level (demographic) applications, in which the improved accuracy is crucial for predictive use. Though it improves accuracy of estimates in the regression analysis as well, the adjustment is mostly surplus for the regression analysis in the cost of giving up application of the techniques and prevailing software packages. For instance, the cohort effects on first marriage timing presented in Table 1 (Model 1) revised with the adjustment are respectively 0.00, 0.09, 0.16, 0.24 with intercept 23.14 (log-likelihood -11475.3), while original estimates are 0.00, 0.04, 0.17, 0.20 with intercept 23.34 (log-likelihood -11491.0). As seen in this example, changes in regression coefficients are usually not significant, though likelihood is slightly improved.

10. For the parameter estimation of the empirically adjusted GLG model in this study, specific software (written in C and C++) is developed. To obtain the software, contact the author.

11. If age at (n-1)-th birth (or first marriage if n=1) follows the GLG model, then age at n-th birth that is expressed as a convolution of age at (n-1)-th birth (or marriage) and birth interval to n-th birth follows the GLG distribution. This convolution structure, however, holds only approximately in practice, since it is valid only if age at (n-1)-th birth (or marriage) and birth interval to n-th birth are independent of each other.

12. This system of fertility projection with some modifications has been employed in the official population projection in Japan conducted in 1992, 1997, and 2002.

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Appendix

Table A-1: Adjustment Function of the GLG Model for First Marriage of Japanese Female Cohorts: $\xi(z)$

Standardized Age (z)	Adjustment Function	Standardized Age (z)	Adjustment Function
-3.0	0.00000	3.6	-0.00859
-2.8	0.00000	3.8	-0.00912
-2.6	0.00011	4.0	-0.00931
-2.4	0.00069	4.2	-0.00926
-2.2	0.00188	4.4	-0.00901
-2.0	0.00358	4.6	-0.00864
-1.8	0.00513	4.8	-0.00821
-1.6	0.00600	5.0	-0.00774
-1.4	0.00478	5.2	-0.00724
-1.2	0.00006	5.4	-0.00673
-1.0	-0.00713	5.6	-0.00623
-0.8	-0.01573	5.8	-0.00573
-0.6	-0.02372	6.0	-0.00524
-0.4	-0.02885	6.2	-0.00478
-0.2	-0.02761	6.4	-0.00436
0.0	-0.02014	6.6	-0.00395
0.2	-0.00728	6.8	-0.00356
0.4	0.00756	7.0	-0.00319
0.6	0.02134	7.2	-0.00284
0.8	0.03183	7.4	-0.00252
1.0	0.03737	7.6	-0.00222
1.2	0.03830	7.8	-0.00192
1.4	0.03542	8.0	-0.00164
1.6	0.03027	8.2	-0.00138
1.8	0.02393	8.4	-0.00115
2.0	0.01766	8.6	-0.00092
2.2	0.01178	8.8	-0.00071
2.4	0.00669	9.0	-0.00051
2.6	0.00234	9.2	-0.00033
2.8	-0.00127	9.4	-0.00016
3.0	-0.00408	9.6	-0.00004
3.2	-0.00616	9.8	-0.00001
3.4	-0.00763	10.0	0.00000

Note: These are the adjustment values for the cumulative function of the GLG model for first marriage schedule by standardized age prepared for Japanese female cohorts.

Table A-2: *Adjustment Function of the GLG Model for Fertility of Japanese Female Cohorts by Birth Order:* $\xi(z)$

Standardized Age (z)	Birth Order (n)				
	1	2	3	4	5 and over
-3.6	0.00000	0.00001	-0.00001	-0.00001	-0.00004
-3.4	0.00000	0.00002	-0.00001	-0.00003	-0.00009
-3.2	0.00000	0.00006	0.00001	-0.00008	-0.00012
-3.0	0.00000	0.00012	0.00007	-0.00012	-0.00009
-2.8	0.00011	0.00027	0.00024	-0.00010	-0.00023
-2.6	0.00041	0.00057	0.00062	0.00007	-0.00075
-2.4	0.00097	0.00110	0.00117	0.00043	-0.00131
-2.2	0.00185	0.00188	0.00171	0.00082	-0.00187
-2.0	0.00291	0.00260	0.00192	0.00100	-0.00198
-1.8	0.00386	0.00280	0.00162	0.00054	-0.00171
-1.6	0.00381	0.00199	0.00058	-0.00045	-0.00173
-1.4	0.00213	-0.00015	-0.00156	-0.00150	-0.00147
-1.2	-0.00142	-0.00321	-0.00459	-0.00289	-0.00070
-1.0	-0.00667	-0.00626	-0.00740	-0.00394	0.00158
-0.8	-0.01246	-0.00913	-0.00905	-0.00414	0.00565
-0.6	-0.01713	-0.01163	-0.00886	-0.00310	0.00829
-0.4	-0.01836	-0.01164	-0.00649	-0.00064	0.00888
-0.2	-0.01562	-0.00854	-0.00240	0.00256	0.00953
0.0	-0.00982	-0.00323	0.00254	0.00423	0.00840
0.2	-0.00128	0.00317	0.00707	0.00481	0.00534
0.4	0.00845	0.00906	0.00943	0.00605	-0.00010
0.6	0.01640	0.01321	0.00989	0.00744	-0.00558
0.8	0.02127	0.01503	0.00952	0.00694	-0.00925
1.0	0.02286	0.01437	0.00861	0.00412	-0.01156
1.2	0.02157	0.01162	0.00701	0.00108	-0.01133
1.4	0.01817	0.00772	0.00457	-0.00101	-0.00855
1.6	0.01364	0.00386	0.00175	-0.00292	-0.00586
1.8	0.00890	0.00075	-0.00065	-0.00406	-0.00334
2.0	0.00449	-0.00154	-0.00228	-0.00394	-0.00048
2.2	0.00064	-0.00314	-0.00326	-0.00378	0.00203
2.4	-0.00248	-0.00410	-0.00369	-0.00337	0.00386
2.6	-0.00474	-0.00446	-0.00377	-0.00367	0.00411
2.8	-0.00617	-0.00438	-0.00350	-0.00189	0.00346
3.0	-0.00689	-0.00404	-0.00295	-0.00106	0.00269
3.2	-0.00708	-0.00354	-0.00235	-0.00039	0.00185
3.4	-0.00689	-0.00298	-0.00182	0.00006	0.00123
3.6	-0.00645	-0.00242	-0.00135	0.00032	0.00076
3.8	-0.00581	-0.00188	-0.00095	0.00042	0.00040
4.0	-0.00506	-0.00139	-0.00063	0.00040	0.00010
4.2	-0.00428	-0.00099	-0.00039	0.00030	0.00000
4.4	-0.00352	-0.00068	-0.00021	0.00021	0.00000
4.6	-0.00285	-0.00044	-0.00010	0.00015	0.00000
4.8	-0.00225	-0.00026	-0.00004	0.00010	0.00000
5.0	-0.00172	-0.00015	-0.00001	0.00005	0.00000
5.2	-0.00126	-0.00008	0.00000	0.00002	0.00000
5.4	-0.00090	-0.00003	0.00001	0.00000	0.00000
5.6	-0.00062	0.00000	0.00000	0.00000	0.00000
5.8	-0.00041	0.00001	0.00000	0.00000	0.00000
6.0	-0.00025	0.00001	0.00000	0.00000	0.00000
6.2	-0.00013	0.00001	0.00000	0.00000	0.00000
6.4	-0.00005	0.00001	0.00000	0.00000	0.00000
6.6	0.00000	0.00001	0.00000	0.00000	0.00000
6.8	0.00002	0.00001	0.00000	0.00000	0.00000
7.0	0.00003	0.00000	0.00000	0.00000	0.00000

Note: These are the adjustment values for the cumulative function of the GLG model for fertility schedules by birth order by standardized age prepared for Japanese female cohorts.