Population Association of America, 2006

Cohort Process to the Lowest Fertility in Japan: Estimation and Projection of Lifetime Measures of First Marriage and Birth*

Ryuichi Kaneko**

Abstract

In this study, the cohort processes to the recent decline of the Japanese fertility rate to a historical low are analyzed in terms of lifetime measures of first marriage and birth by birth order. The measures include timing and prevalence indices of those life events estimated and projected with empirically adjusted Coale-McNeil model for the cohorts born in 1935-1970. The results indicate three distinct cohort phases to the lowest fertility in the society;(1) simple delay in marriages and birth due to compositional changes such as prevalence of high educational attainment in cohorts born in 1952 and after, (2) followed by the diffusion of never marrying caused by the further postponement among cohorts born in and after 1959, and (3) finally continuing diffusion of never-marrying at an accelerating pace caused by intentional retreat among cohorts born in and after 1965. These results suggest a general process to the lowest low fertility.

Introduction

The present study aims at developing a better understanding of the rapidly transforming Japanese marriage and birth statistics in terms of cohort behavioral changes. To this end, we reconstructed the post-war trends of various lifetime measures of first marriages and birth for female birth cohorts born after 1935. Two types of measures, i.e., timing indices (mean, mode, median, and sd of age at first marriage, and first birth, etc.) and eventual occurrence levels (proportions of never-married, childless, and only-child women at age 50, etc.) are of primary interest.

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

* This is a very preliminary version of the paper presented to the Annual Meeting of the Population Association of America, 2006 (Los Angels, Murch 30-April 1, 2006). The section of fertility analysis are to be revesed in final version.

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

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. The Coale-McNeil standard model schedule for first marriages is the most widely used tool for this purpose (Bloom, 1982, Bloom and Bennett, 1990, Goldstein and Kenney, 2001, etc.). We developed a practical modification to the model to capture the regularities with further precision (Kaneko, 2003), since it is critical when used in prediction of future life course[1]. With the new model we analyze the long-term trends of the lifetime measures of first marriages and births over cohorts born from 1935 to 1970. As a result, with a combination of timing and prevalence measures of first marriages, the history of first marriage behavior over those cohorts can be divided into five phases, the last three of which are relevant to the unprecedented nuptiality and fertility decline since the mid 1970s in Japan. In these latter three phases, the change in first marriage behavior began with a delay in timing in the cohort born in 1952, followed by an onset of a steep increase in the proportion never marrying after the cohort of 1959. Then the timing shift gradually fades and begins to level off after the cohort of 1965, while the proportion never marrying continues to rise at an accelerating pace.

Based on these findings on changing patterns in the lifetime measures for Japanese women, the general transition pattern of societies to reduced fertility in terms of cohort compositional and behavioral changes is hypothesized. Among cohorts in the onset, mere delay of marriage and birth initiates the whole process. The delay is mainly caused by structural change such as educational upgrading of the cohorts. Period fertility starts to decline due to the tempo effects. Then the delay is succeeded by intentional postponement among following cohorts, spreading in any category of educational level for instance. At the same time unintended retreats from marriage and reproduction due to the excessive postponement spread. The quantum factor of fertility starts to decline in this phase. Finally the retreats itself become intentional in succeeding cohorts reducing probability of having nuptials and births even in advanced ages. Reduction of marital fertility accompanies. The hypothesized cohort process suggests the presence of quite different mechanisms by phase behind seemingly monotonous track to the lowest fertility.

Models: Empirically Adjusted Coale-McNeil Model

Coale-McNeil Model and Generalized Log-Gamma Distribution

The Coale-McNeil model specifies the probability density function (PDF) for the age distribution of first marriages as:

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

[1] It has been pointed out that the Coale-McNeil model schedule bears substantial deviations from observed schedules, even in the maximally flexible free-shape form, especially when it is applied to a non-European society such as Japan (Takahashi, 1978, Kojima, 1985, Kaneko, 1991).

where Γ denotes the gamma function[2], $\alpha(>0)$, $\beta(>0)$, and $\mu(-\infty<\mu<\infty)$ are three parameters (Coale and McNeil, 1972). A fixed-shape version of this model derived from Swedish female cohort data with two free dimensions, i.e. location and scale parameters is called the Coale-McNeil (CM) standard schedule[3], and has been widely used both for estimating the underlying distribution from defective data and projecting a halfway-completed process to the end of the schedule (Bloom, 1982, Bloom and Bennett, 1990, Goldstein and Kenney, 2001, etc.).

The CM distribution given by (1) is mathematically identical to the generalized log gamma (GLG) distribution with a somewhat different parameter space (Kaneko 1991, 2003). According to Prentice's parameterization (1974), the CM distribution is expressed in PDF form of the GLG distribution by:

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

where $\lambda\ (-\infty<\lambda<0)$, $u\ (-\infty<u<\infty)$, $b\ (>0)$ are three parameters[4], Γ denotes the gamma function defined above. With the age distribution of first marriages $g(x)$, the corresponding age schedule $f(x)$ (age specific first marriage rate at age *x*) is given as:

$$f(x;C,u,b,\lambda)=C\ g(x;u,b,\lambda). \tag{3}$$

where *C* denotes the proportion eventually marrying in the cohort.

Performance of the GLG model (equivalently CM model) to trace the observed data is generally good. However, for cohorts of some countries such as Japan, it shows visible discrepancies even with allowing a free-shape (4-parameter model) (Kaneko 1991, 2003). In order to improve the fit, an empirical adjustment is devised according to Kaneko (2003). The resulting GLG model with the adjustment, $\bar{F}(x;\mathbf{\theta}), \mathbf{\theta}=\left(C,\lambda,u,b\right)$, is expressed as:

$$\bar{F}(x;C,\lambda,u,b)=\hat{F}(x;C,\lambda,u,b)+\hat{\xi}\left(\frac{x-u}{b}\right), \tag{4}$$

where $\hat{F}(x;\mathbf{\theta})$ is the GLG model, and $\hat{\xi}(\ )$ is the average error function of the standardized age[5].

---

2 $\Gamma(x)=\int_0^\infty t^{x-1}e^{-t}dt$

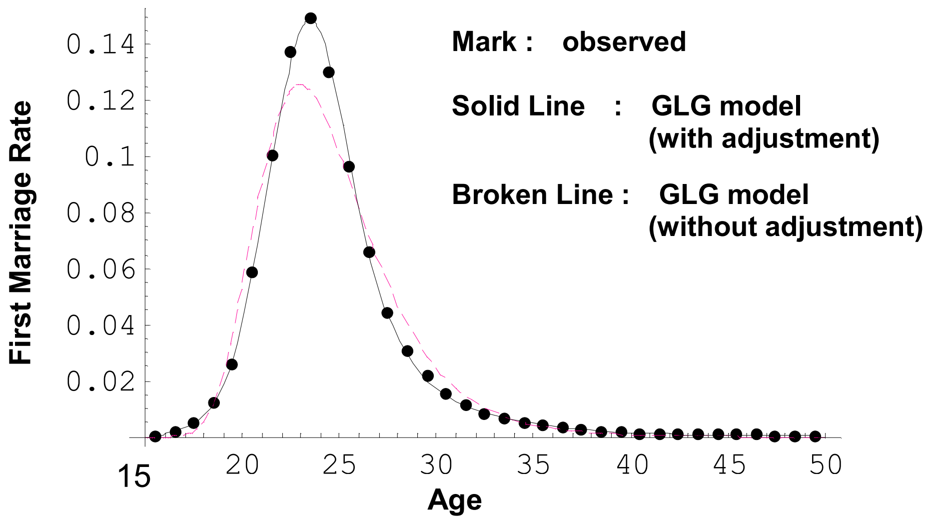
3 Rodriguez and Trussell (1980) proposed parameter values as $\alpha=1.145, \beta=1.896, \mu=-0.805$ to have mean 0 and variance 1.

4 This parameterization is one proposed by Prentice (1974).

5 $\hat{\xi}(z)$ is to be zero as z goes to plus or minus infinity to keep parameter C intact in the adjustment. Definite integral of $\hat{\xi}(z)$ over the domain of z should be zero to keep the mean age of the schedule intact. We slightly adjust the average pattern to derive $\hat{\xi}(z)$ so that these properties of schedule are

The function $\hat{\xi}(z)$ should be treated as a continuous function of age by means of spline interpolation, for example. In Figure 1, we see an improvement of the model's fit as a consequence of the adjustment :in the adjusted model traces the observed rates almost exactly, while the model with no adjustment (broken line) shows visible deviations.

Figure 1. Observed Age Specific First Marriage Rates and Fitted GLG Model (with Adjustment): Japanese Female Cohort born in 1950



Data: Estimation of the Annual Number of First Marriages

Since vital statistics are the only source that annually covers all of Japan, we rely on first marriage rates derived from vital statistics to produce estimates which represent the entire country. However, the statistics exhibit a major drawback from the perspective of this endeavor. There are a substantial number of delayed registrations, and the annually reported number of marriages is subject to omission errors if the dates of the delayed registrations are not corrected. Fortunately, the delayed registrations are reported with information on date and age at the time of marriage in later annual reports for a portion of our target period. Therefore, it is possible to sum them up to obtain the eventual number of marriage occurrences. Nevertheless, information on delayed registrations is not available for the earlier period. Also, for recent years there is no following period long enough to accumulate the delayed registrations to produce the actual number. Hence, evaluation and estimation of the delayed registrations is also required to obtain reliable numbers of marriage occurrences. We looked for systematic phenomena in the delayed registrations by age at marriage data observed over a period for which enough information was available. We found that a measure of moderation of delay ("average hazard of same year registration") is useful to capture the pattern and to project it into periods which lack sufficient information. We modeled the age pattern of delayed registrations in terms of this measure, and applied it to estimate the delay in years for which information on delayed registrations is unavailable. Intercensal numbers of first marriages by age were estimated from census

---

kept.

results on population by marital status, and were used for guidance in determining levels of delayed registrations. This process yielded estimates for the annual numbers of first marriages by wives aged 15-49 in the years 1950 to 2000 (tentatively with 1948, 1949). Further details of the evaluation and estimation procedures are described in the Appendix.

After the numbers of first marriages were estimated by age and year, the age specific first marriage rates corresponding to cohort diamonds on the Lexis diagram were calculated with populations by age and year from censuses as denominators.

Parametric Estimation of Cohort Marriage Schedules

Censoring Effects on Parameter Estimation

We estimated a set of parameters of the adjusted-GLG model applied for the observed first marriage rates of Japanese female cohorts via the maximum likelihood procedure following Kaneko (2003). When the data available does not conform to the specifications of the model,, parameter estimation can be affected by censoring. For instance, this occured in our research for cohorts which have not completed the marriage process (right censoring). Censoring causes problems when we attempt to perform demographic projections of the future course of young cohort experiences. The extent of the censoring effects on parameter estimation depends both on the exactness of model specification and data adequacy. To understand this phenomenon in our specific situation, we conducted some experiments in which censoring was artificially performed during parameter estimation using the data of non-censored cohorts. The resulting parameters were then compared to the "correct" parameters computed using uncensored data to assess the effect of censoring on the estimated value of parameters.

The estimated values of λ with artificial censoring show chaotic fluctuations under standardized age zero (age range before the mode). However, the values become stable and close to the estimates of the uncensored data at around and after standardized age 5.0, which approximately corresponds to normal age 36-40. Hence we may trust estimates of λ for cohorts who completed the marriage process at least up to age 40. Similarly parameters C, u and b indicate that estimates with censoring after standardized age 5.0 are mostly trustworthy.

Close examination of estimates of C (proportion eventually marrying) reveals that the differences between estimated and true value (estimates without censor) are within a range of –1.5% to 1.0% around and after standardized age 2.0, which corresponds to normal age 28-32 according to cohorts in Japan. Therefore we may expect that we can estimate the proportion eventually marrying (and consequently the proportion never marrying) for cohorts which have completed the marriage process up to age 32 with an error of $\pm 2\%$.

When true values of some parameters are given, one expects that other parameters can be more reliably estimated. Parameter λ is supposed to be stable in value. In fact, the widely accepted CM standard schedule is nothing more than a λ-fixed version (= -1.287) of the GLG schedule according to Swedish experiences. Estimation experiments with simulated censoring giving the true value of λ (estimated value without censoring) were conducted. The results show that the reliability of estimated values of C, u and b are improved, and the reliable range expands to younger ages as well.

As for *C*, differences between estimated and true value are within a range of –0.4% to 0.2% with censored data at standardized age 2.0 and older. In this case we can reasonably expect that we are able to predict the proportion never married for cohorts who are above age 30 with an error of $\pm 1\%$.

Not only *C*, but also parameter *u* and *b* are estimated more accurately all together if the true λ is given. Parameter *u,* the location parameter that appoints location of the mode, is estimated within a range of –0.015 to 0.01 of the target when using censored data at standardized age 2.0 and older. For the same condition, parameter *b* is estimated within a range of –0.05 to 0.01 around the target value. These are adequately accurate for most demographic applications. Parameter *u* and *b* are only determinants of the first two moments, i.e. the mean and variance of age at first marriage, if λ is fixed. Similar stability is expected for the other moments.

Hence identifying plausible values of λ for young cohorts is essential to predict demographic measures of their marriage behavior. Thus it seems imperative to inquire how values of λ are determined. In previous work, we found that a mixture of different marriage types with different timing, in particular an admixture of arranged marriages, makes λ large (small in absolute value). (Kaneko 1991). However, other forces affecting λ are also known to exist.

Parametric Estimation of Cohort Marriage Schedules

From the estimated first marriage rates by age and year from 1950-2000, the lifetime first marriage experiences of 16 single year cohorts from 1935-1950 were reconstructed over ages 15-49. However, the relevant cohorts involved in the unprecedented nuptiality and fertility decline in Japan since the mid 1970s are mostly those born after the 1950s. We make use of the adjusted GLG model on Japanese females described above to study these cohorts. The model is fitted to cohort first marriage processes to estimate the lifetime behavioral measures.

The model schedule was fitted to each cohort experience by estimating model parameter values specific to the cohort through the maximum likelihood method, which is applicable to censored data generated by young cohorts. First, parameter estimations were performed without any constraint on parameter values in order to obtain estimated and projected marriage trajectories for cohorts that both have fully and substantially completed first marriage schedules (cohorts 1935-60). Then we extended estimation to younger cohorts which are at relatively early stages in the process by fixing the parameter λ at feasible values.

For cohorts which have completed the marriage process, i.e. those born in years up to 1950, predicted measures by the model agree almost exactly to the observed, since the model schedules fit the actual experiences quite well. However, censoring effects on estimates are apparent in younger cohorts born after the mid 1960s, making estimation results increasingly implausible afterward. According to the criterion of reliability in the estimated value of *C* assessed above, we employ free estimation up to cohorts with a censor at standardized age 5.0 (approximate normal age 36-40). The boundary corresponds to cohorts born in 1960 in our data set.

For cohorts born after 1960, the value of the shape parameter λ was fixed while the other parameters are freely estimated. According to free estimation, values of λ become anomalous starting from the cohort of 1969 after a short plateau during 1965-68, and should be discarded. The criteria for reliable estimation with fixed λ described above also suggests that the border of feasible estimation is around the cohort of 1970. Hence we limit our observations up to the cohort born in 1970.

Which value should we fix λ to for cohorts born from 1961 to 1970? Free estimation suggests that the value of λ increases during the years 1961 to 1970. It is not clear if this trend is real or is just an artifact of the censoring. Previously, we found that the shape value becomes larger (smaller in absolute value) when marriages are a mixture of different types of marriages with distinct time schedules, in particular with the coexistence of non-arranged and arranged marriages (Kaneko, 1991). Since arranged marriages have been diminishing throughout the postwar period, we expect the value of λ to decrease rather than increase. . Thus, first we fix λ at the level of 1960.

However, since an upward turn is also observed in the trend of λ for the previous cohorts with supposedly reliable estimates (i.e. cohorts of 1952-55), we cannot fully exclude the possibility that λ is in fact rising for the younger cohorts of 1961-68. In particular, if there exists an upper bound on marriage propensity in later ages, delay in marriage could result in a more symmetric shape of the marriage schedule and thus in a rise in λ. Hence, we provide an alternative prediction in which a free estimation is employed for cohorts of 1961-68, and then λ is fixed at the level of 1968 for cohorts of 1969 and 1970.

The results of parameter estimation are presented in Table 1 with five other measures of marriage behavior derived from predicted schedules generated by estimated parameters. These include the proportion never married at age 50 (γ), the mean, two types of median, and standard deviation (SD) of age at first marriage. We provide two of median measures : median1, the median of age at first marriage (age under which a half of those eventually marrying have got married), and median2, the median of first marriage schedule (age at which the proportion married attains 50%).

Table 1 Estimated Parameter Values and Some Measures of First Marriage Schedules of Japanese Female Cohorts

a. Free Estimation

Cohort	Estimated Parameter Values				Measures of Schedule				
(Birth Year)	λ	u (mode)	b	C	γ (%)	mean	SD	median1	median2
1933	-0.848	22.78	3.46	0.958	4.6	24.38	4.21	23.83	24.00
1934	-0.832	22.89	3.31	0.952	5.1	24.39	4.04	23.87	24.07
1935	-0.835	22.93	3.16	0.955	4.7	24.37	3.90	23.87	24.04
1936	-0.838	22.92	3.04	0.948	5.3	24.33	3.80	23.83	24.03
1937	-0.839	22.90	2.95	0.960	4.1	24.26	3.71	23.78	23.92
1938	-0.843	22.89	2.88	0.956	4.4	24.24	3.65	23.76	23.91
1939	-0.855	22.91	2.84	0.958	4.2	24.27	3.61	23.78	23.92
1940	-0.863	22.90	2.80	0.947	5.3	24.25	3.59	23.76	23.94
1941	-0.859	22.90	2.80	0.960	4.0	24.24	3.58	23.75	23.89
1942	-0.843	22.95	2.81	0.959	4.1	24.27	3.57	23.79	23.93
1943	-0.831	23.00	2.80	0.971	2.9	24.29	3.54	23.83	23.92
1944	-0.835	22.99	2.78	0.946	5.4	24.28	3.52	23.82	24.00
1945	-0.854	23.00	2.77	0.930	7.0	24.32	3.54	23.84	24.08
1946	-0.888	23.03	2.76	0.977	2.3	24.41	3.56	23.90	23.98
1947	-0.911	23.01	2.74	0.942	5.8	24.42	3.57	23.90	24.10
1948	-0.945	22.99	2.72	0.945	5.5	24.45	3.59	23.90	24.08
1949	-0.982	22.96	2.70	0.938	6.2	24.49	3.63	23.90	24.11
1950	-1.006	22.93	2.73	0.940	6.0	24.51	3.69	23.90	24.10
1951	-1.012	22.93	2.77	0.938	6.2	24.55	3.76	23.92	24.14
1952	-0.984	23.01	2.88	0.937	6.3	24.63	3.85	24.01	24.24
1953	-0.949	23.14	2.98	0.940	6.1	24.74	3.90	24.15	24.37
1954	-0.923	23.32	3.05	0.950	5.1	24.89	3.92	24.32	24.51
1955	-0.915	23.48	3.08	0.936	6.5	25.05	3.94	24.48	24.73
1956	-0.927	23.60	3.09	0.940	6.1	25.20	3.96	24.62	24.85
1957	-0.956	23.70	3.10	0.943	5.8	25.36	4.02	24.75	24.97
1958	-0.987	23.75	3.14	0.943	5.9	25.49	4.10	24.84	25.07
1959	-1.015	23.78	3.20	0.926	7.5	25.61	4.21	24.93	25.23
1960	-1.024	23.86	3.31	0.924	7.8	25.77	4.34	25.06	25.39

Table 2 Estimated Parameter Values and Some Measures of First Marriage Schedules of Japanese Female Cohorts (continued)

b. λ is fixed after 1961

Cohort (Birth Year)	Estimated Parameter Values				Indices of Schedule				
	λ	u (mode)	b	C	γ (%)	mean	s.d.	median1	median2
1961	-1.024	23.98	3.44	0.925	7.8	25.95	4.46	25.23	25.56
1962	-1.024	24.10	3.57	0.924	7.9	26.13	4.57	25.40	25.75
1963	-1.024	24.25	3.70	0.915	8.9	26.33	4.64	25.59	26.00
1964	-1.024	24.40	3.79	0.912	9.2	26.52	4.62	25.77	26.21
1965	-1.024	24.51	3.84	0.894	11.1	26.65	4.58	25.90	26.44
1966	-1.024	24.61	3.85	0.907	9.8	26.75	4.53	26.00	26.47
1967	-1.024	24.66	3.84	0.874	13.1	26.80	4.50	26.05	26.71
1968	-1.024	24.69	3.87	0.877	12.8	26.83	4.50	26.09	26.73
1969	-1.024	24.71	3.92	0.858	14.8	26.88	4.52	26.13	26.91
1970	-1.024	24.74	3.97	0.840	16.6	26.92	4.54	26.17	27.08

c. λ is fixed after 1969

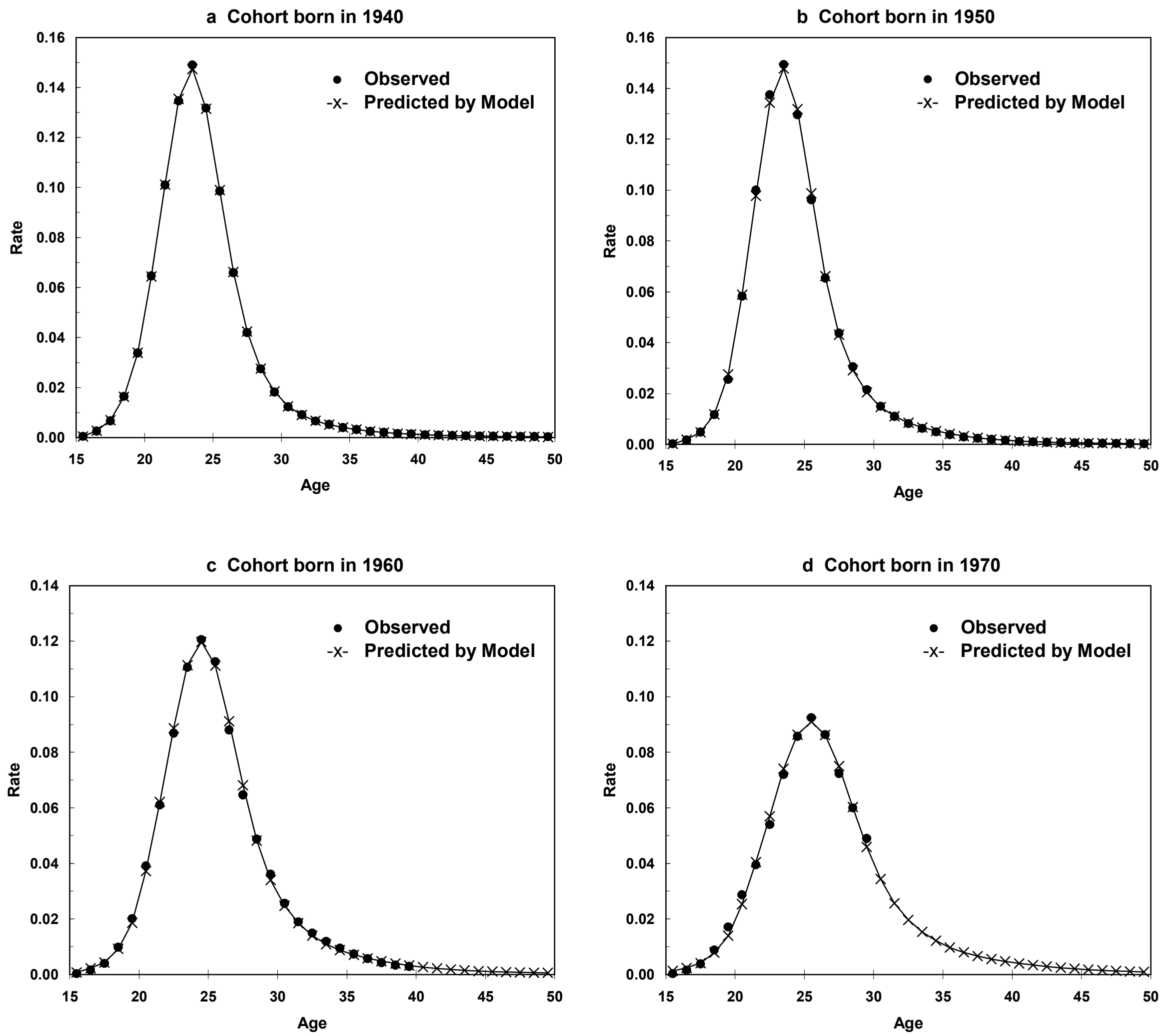
Cohort (Birth Year)	Estimated Parameter Values				Indices of Schedule				
	λ	u (mode)	b	C	γ (%)	mean	s.d.	median1	median2
1961	-1.021	23.98	3.44	0.925	7.8	25.95	4.46	25.23	25.56
1962	-1.013	24.12	3.58	0.924	8.0	26.12	4.57	25.40	25.75
1963	-0.985	24.30	3.70	0.913	9.2	26.28	4.64	25.59	26.01
1964	-0.941	24.50	3.78	0.906	9.9	26.40	4.62	25.76	26.22
1965	-0.897	24.64	3.82	0.882	12.2	26.45	4.58	25.86	26.46
1966	-0.875	24.75	3.82	0.890	11.4	26.50	4.53	25.94	26.49
1967	-0.874	24.80	3.79	0.855	14.9	26.53	4.50	25.98	26.72
1968	-0.868	24.82	3.80	0.854	15.0	26.54	4.50	25.99	26.74
1969	-0.868	24.83	3.83	0.832	17.2	26.56	4.52	26.01	26.90
1970	-0.868	24.83	3.85	0.810	19.4	26.57	4.54	26.02	27.07

In Table 2, alternative results with different settings to λ for cohorts after 1961 are presented in separate tables. The trends show smooth continuous transitions from cohort to cohort except relatively large fluctuations in C for cohorts born at the end of World War II, possibly caused by disturbances in original statistics.

Predicted marriage schedules from the results of parameter estimation are contrasted with those observed in Figure 6. The model follows the actual experiences quite well, though the exactness of fit becomes slightly weaker in younger cohorts[6].

[6] Predicted schedule for the cohort of 1970 in Figure 5-4 is one from estimation with λ fixed at level of 1960. Alternate schedule with λ fixed at level 1968 fits only slightly better.

Figure 2. Observed Age Specific First Marriage Rates and Fitted GLG Model (with Adjustment): Japanese Female Cohort born in 1950



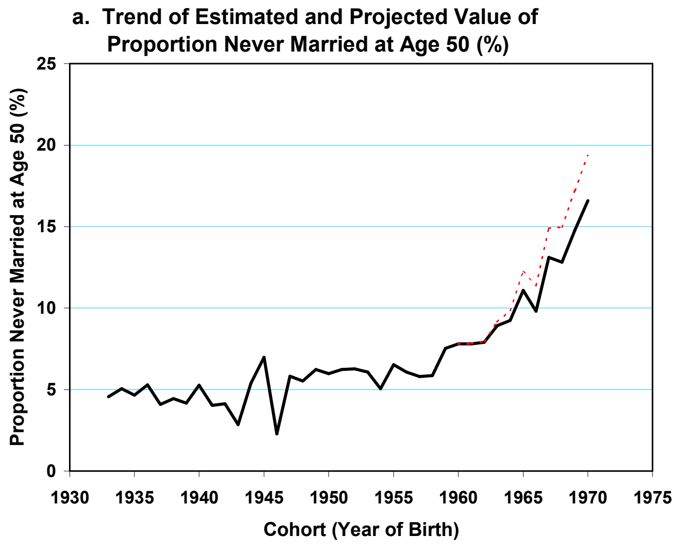
Note: Predicted Schedule for cohort born in 1970 in this figure is from estimation with fixed λ at level of 1960.

Results

For the cohorts of 1935-1970[7], trends of the proportion never married at age 50 (γ), the mean, two types of median and the standard deviation (SD) of age at first marriage are shown in Table 1 and Figure 3. The mode of age at first marriage is also shown as a trend of parameter u in Table 1.

[7] In the figures and tables tentative estimates for cohorts born in 1933 and 1934 are included.

Figure 3. Trends of Estimated and Projected Measures of First Marriage Schedule



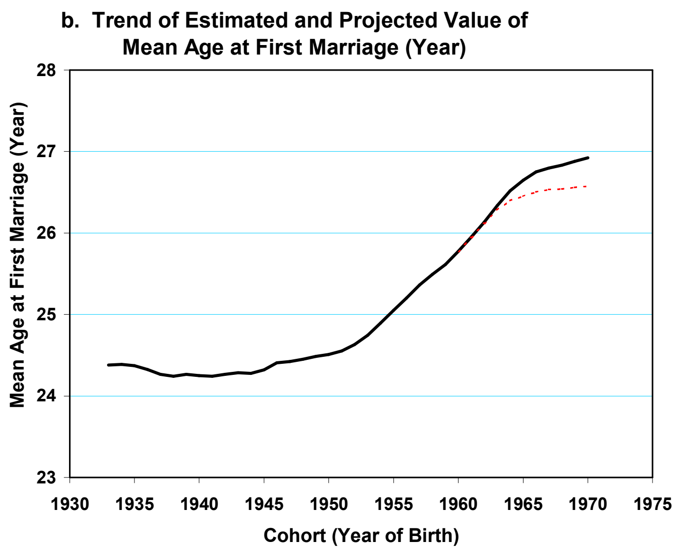
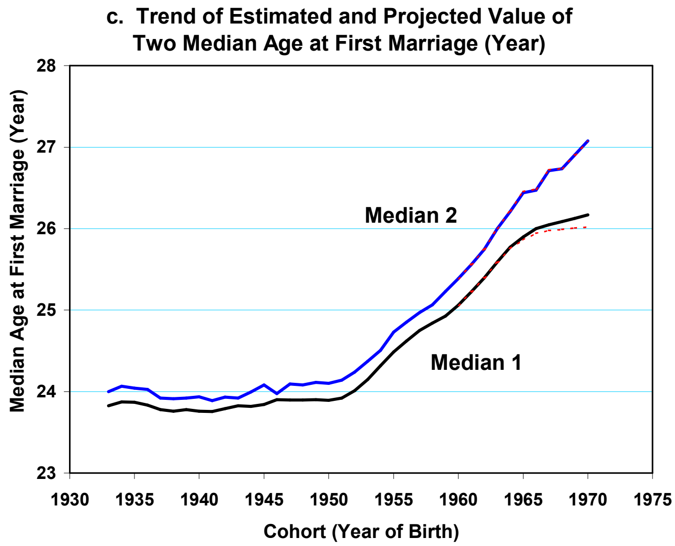
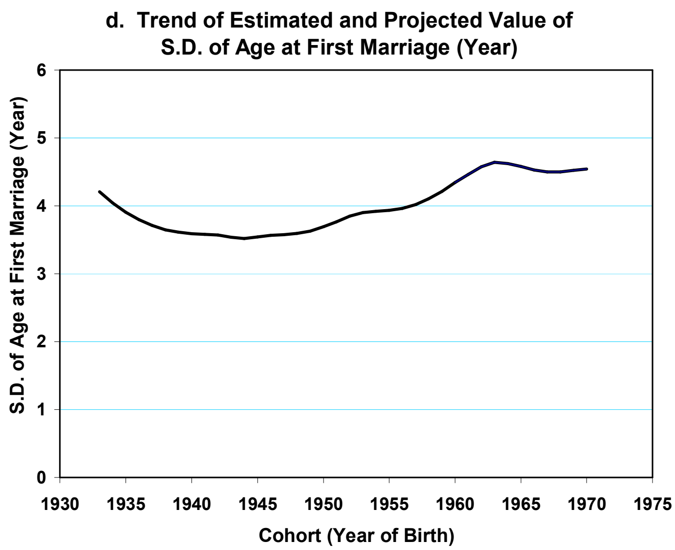


Figure 3. Trends of Estimated and Projected Measures of First Marriage Schedule (continued)





Note that the observation of trends over cohorts born in 1951 up to 1970 is made possible only via the application of the effective model. When relying solely on observed statistics the lifetime measures are available only for cohorts of 1935-1950, which have little relevance to the recent drastic decline in fertility and nuptiality in Japan.

As for the proportion never married, the trend for cohorts born in the mid 1930s through 1970 can be divided into three phases. First, for the cohort born before the end of the World War II, the proportion had stayed at a level slightly below five percent. From the oldest in our data set, at least 10 cohorts are included in this phase until the measure is disturbed in cohorts born in the years at the end of the war. In the second phase, the proportion rose across the five percent line to about six percent and stayed there until the cohort born in 1958, involving 12 single year cohorts. In the third, for the following cohorts starting from 1959, the proportion started to increase very steeply until the cohort of

1970, which is the last cohort for which we safely estimate the value. The alternative projection from estimation with a relaxed shape suggests an even steeper proportional rise. This change has persisted through at least 12 cohorts so far and seems to continue into the following cohorts judging from the trend at the end.

The mean age at first marriage for those who are eventually marrying in each cohort is also characterized by a sharp increase in the latter half of the target span. However timing of the onset of the change differs from that of the proportion never married. The mean had been at halfway of 24 years of age until the cohort born in the early 1950s. Then it showed a remarkable increase for some thirteen cohorts until it decelerated in the cohort born in the late 1960s. It seems that the mean is roughly leveling off afterward. This new trend is even clearer in the alternative projection.

The steep increase in the mean indicates that first marriage schedules have rapidly shifted toward older values on the age axis. The shift is also represented by a change in the mode, whose values are carried by parameter u. The trend of u presented in Table 1 shows similar development to that of the mean with even clearer turning points. It started to increase with the cohort of 1952, and started to decelerate with the cohort of 1965, and almost ceased to increase after the cohort of 1968. In the alternative projection, the leveling off is clearly observed after the cohort of 1968. In Figure 3-c, Median1 (for those eventually marrying) and median2 (for all women) shows almost parallel trends with the mean and mode until the mid 1960's, but afterward median1 still follows the parallel path with the mean and mode and levels off, while median2 alone continues to rise. All these indices are measures of marriage timing, and in aggregate indicate that a rapid timing shift started with the cohort of 1952, and slowly ended after the mid 1960s. Only median2, which conveys quantum factor of cohort nuptiality as well as timing, takes a different course after the mid 1960s.

The trend of the standard deviation (SD) of age at first marriage (Table 1 and Figure 3-d) demonstrates a somewhat different course from the other measures in cohorts born before World War II. It decreased at first until the cohort of 1944, then reversed course to increase moderately throughout postwar cohorts until 1963, followed by a leveling off or even minor decrease afterward. The recent leveling off of SD also suggests even more clearly that the rapid timing transformation of first marriage schedules from the viewpoint of dispersion is about to end.

In summary, the demographic history of lifetime first marriage behavior among Japanese women can be divided into five phases represented by the following groups of cohorts:

Group A (cohort born in 1933–1944 (age 56-67 as of 2000), 10 cohorts);

First marriage behavior is stable except for minor reduction of variance of marriage timing.

Group B (cohort born in 1947–1951 (49-53 year-olds), 4 cohorts);

The proportion never married shifted to a slightly higher level by 1.5 %.

Group I (cohort born in 1952–1958 (42-48 year-olds), 7 cohorts);

The mean age at first marriage (and the mode) started to rise, while the proportion never married is unchanged.

Group II (cohort born in 1959–1964 (36-41 year-olds), 5 cohorts);

The proportion never married started to increase, while the mean, mode and SD continued to rise in similar rates as before.

Group III (cohort born in 1965–1970 (30-35 year-olds), 6 cohorts);

The rise in mean, mode and SD decelerated and seems about to level off, while the proportion never married continues to increase even at an accelerated pace.

Cohorts born in 1945 and 1946 are regarded as a transitional generation between Group A and B, and can be included in either of the groups; their placement is uncertain due to their radical cohort size changes leading to a disturbance in their statistical features.

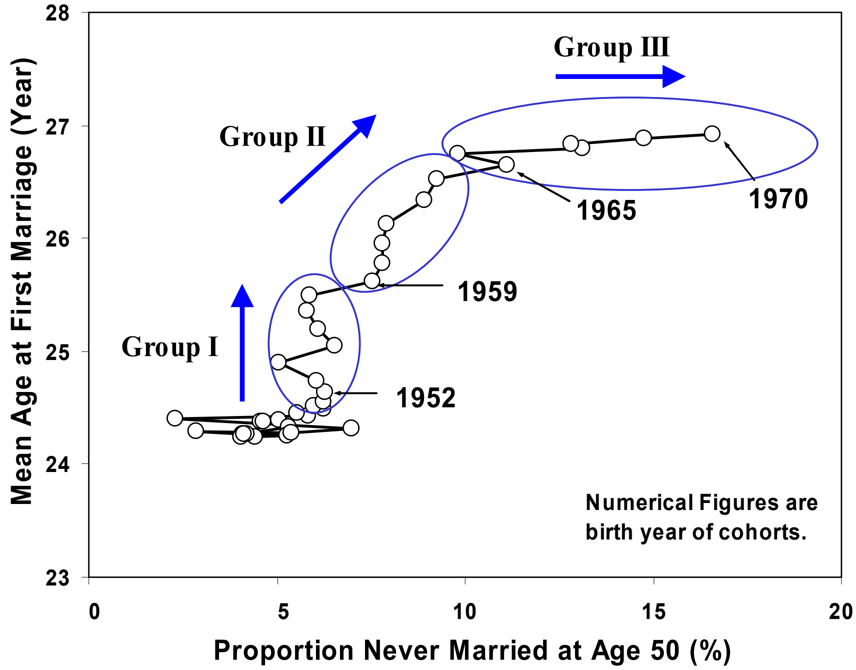
Among those phases, behavioral changes relevant to the prolonged period of fertility decline since the mid 1970s are observed in Group I and after. These changes in female marriage behavior in Japan were initiated with a timing delay by Group I (born in 1952-58). It was followed by a new tendency of gradual diffusion of those who stay unmarried throughout reproductive ages in addition to continuing marriage postponement, in Group II (born in 1959-64). Then the timing shift decelerates and seems about to end in Group III[8], while the diffusion of lifetime never married behavior continues at an even more accelerated pace.

In contrast with common belief, female baby boomers did not change their marriage behavior in terms of aggregate features as compared to those of preceding generations. Instead, the onset of all changes started from the cohort of 1952, members of which are a few years younger than the baby boomers, and a substantial part of which is supposed to be partners of male baby-boomers.

One of our new findings is that there was a time lag of seven years between the onset of the timing shift in marriages and the diffusion of never married behavior. We have also observed in very recent cohorts that the timing shift seems about to end while the retreat from marriage has accelerated. Although this delay and retreat are expected to be closely related, we have confirmed that either may take place in a cohort in isolation. The relationship between the mean and proportion seen in Japanese female cohorts is illustrated in Figure 4 as a sequential scatter gram, where the change started with a vertical rise (phase I) followed by a diagonal rise (II) and then by a horizontal shift (III). The delay and retreat occurred together only during the diagonal rise.

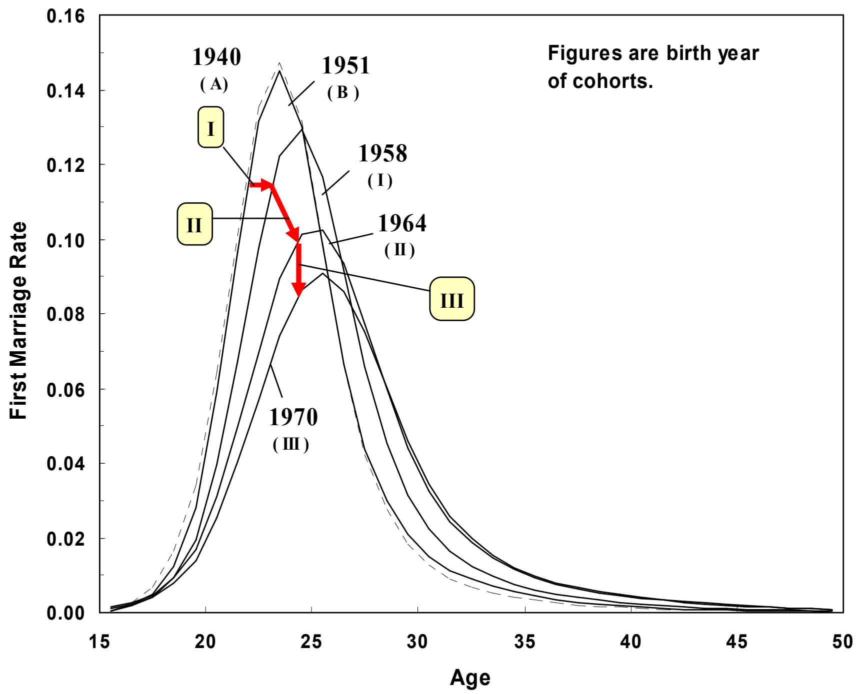
[8] Deceleration of increase in SD of age at first marriage already stated from late cohorts in Group II. The boundary of the trend in timing shift is somewhat ambiguous.

Figure 4. Relationships between Proportion Never Married and Mean Age at First Marriage



Implication of these combined changing patterns on marriage schedules are illustrated as arrows in Figure 9. Before cohort of 1951, no visible change is found in marriage schedules. From cohort 1951 (Group B) to 1958 (I) only a horizontal shift took place (with some horizontal dispersion). Then toward cohort 1964 (II) a combined change of horizontal shift and reduction in area under the curves occurred, followed by a change from reduction alone to cohort 1970 (III).

Figure 5. Changes in Cohort First Marriage Rate by Age of Japanese Women

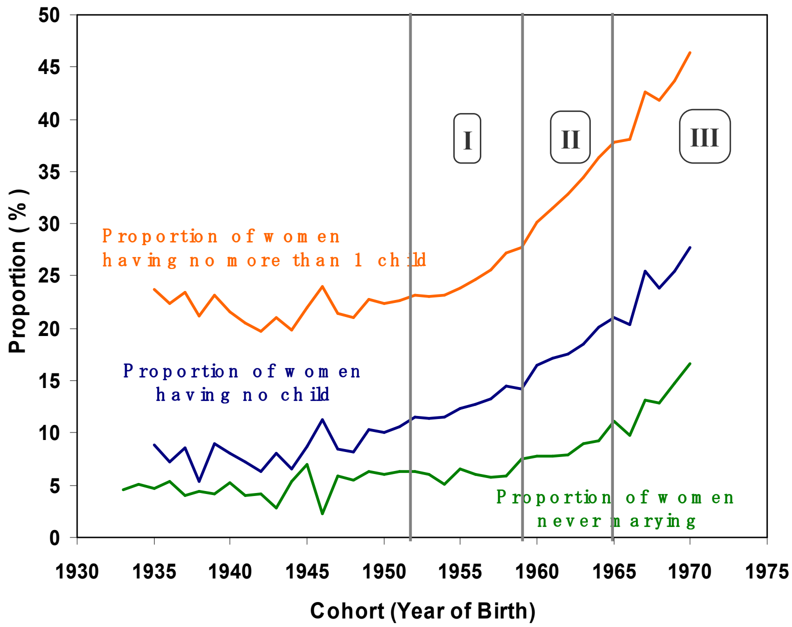


As a result of the timing shift, the mean age at first marriage of Japanese female cohorts has increased from 24.6 in cohort 1951 (end of Group B) to 26.9 in cohort 1970 (most recent in Group III) by 2.4 years in 20 years (2.0 years in the alternative estimation). The corresponding figures in the mode are 1.8 years between cohort 1951 and 1970

The proportion never married was 5.9% (or equivalently one out of 17 women) in the 1958 cohort, the last cohort before the rise stated. Since then it has increased up to 16.6% (or one out of 6 women) in the cohort 1970. This threefold increase took place over only 12 years. Furthermore, judging from the slope at the end of the observation, an even higher proportion of women are anticipated to never marry in the following generations. It is feasible to assert that one woman out of five amongst the generation now in their 20s will remain unmarried throughout her life.

We conducted estimation and projection of lifetime measures of first and second birth with the same procedure. The resulted cohort trends of the proportion of women by fertility status (parity) are illustrated in Figure 5. The onset of the clear rise in the proportion of women having no children and no more than one child are observed among the cohort Group I. Subsequently, those measures have kept rising at an accelerated pace. Distinct phases are not so clear as in the measures of first marriage, probably because fertility is influenced by both timing and prevalence of first marriage which are observed throughout the cohorts among Group I to III.

Figure 6　Trends of Proportion of Japanese Women by Fertility Status



Discussion and Conclusion

The present study aims at developing a better understanding of the rapidly transforming marriage and birth statistics in terms of cohort behavioral changes in Japan. For this purpose, we reconstructed the post-war trends of some lifetime measures of first marriages and birth for female birth cohorts born after 1935. However, when relying only on observed statistics in our data set, the lifetime measures are available only for cohorts born in 1935-1950. Hence the generalized log gamma (GLG) model, as an alternative parameterization of the Coale–McNeil (CM) model, coupled with an empirical adjustment for the Japanese situation, was applied to estimate and project the cohort first marriage schedule so as to provide long-term estimates of the lifetime measures for the cohorts that have yet to complete the marriage process. We obtained estimates of the measures for cohorts born in 1951-70, the years which are relevant to the massive decline in fertility and nuptiality since mid 1970's in Japan.

We found that the history of Japanese cohort first marriage behavior starting from the cohort born in 1935 can be divided into five phases. First, among cohorts born in 1933-1944 (Group A), the measures are stable except for a minor reduction in the variance of marriage timing. Secondly, among the cohort born in 1947-1951 (Group B), which are the baby boomers and a few successive cohorts, the proportion never married shifted to a slightly higher level by 1.5 %, but otherwise little changes were found. Then in the cohort born in 1952-1958 (Group I), the mean age at first marriage (along with the mode and median) started to rise, while the proportion never married remained unchanged. In the cohort born in 1959-1964 (Group II), the proportion never married also started to rise, while delay in marriage timing continued to increase at the same pace as before. Finally, in the cohort born in 1965-1970 (Group III), the mean, mode, median (of the first kind) and SD decelerated and seem about to level off, while the proportion never married continued to increase at an even more accelerated pace.

Preliminary indications are that the behavioral tendencies of Group III persist into the following cohorts.

The important findings about changes in cohort marriage behavior are summarized as follows;

(1) The cohort that started the delay and therefore initiated the whole process of the historical marriage and fertility transfiguration is the one which was born in 1952. This is younger than the baby boomers (1947-49) by three to five years, and many members of this cohort had partnerships with male baby boomers.

(2) There is a time lag between the onset of delaying marriage timing and the wholesale retreat from marriage. The delay in marriage timing started by the cohort of 1952 and the retreating from marriage started to move toward diffusion by the cohort of 1959. So the time lag is roughly seven years.

(3) The delay decelerated after the cohort of 1965, while the retreat continues to diffuse at an even faster pace. According to the trend up to the cohort of 1970, the timing shift appeared to cease in the following cohorts that are in their 20s today. Instead, the proportion never marrying continues to increase at an unprecedented level. It is possible that the proportion will exceed 20 percent amongst these current cohorts.

The finding (1) raises the question concerning causes of the first marriage delay, the onset of the major prolonged transformation in nuptiality and fertility in Japan. The author examined causes of delay in first marriage process in Japanese female cohorts within the Group B, I and II above by decomposing the increase in mean age at first marriage (Kaneko 2004). Using nationally representative survey data, it is found that the substantial part of the delay in the Japanese marriage process in Group I is derived from compositional changes in individual characteristics such as educational attainment (increases in proportion of women with higher educational level of younger cohorts), In other words, the timing of first marriage of the younger cohorts shifted toward later in Group I mostly because proportion of those who are highly educated, and who tended to marry later increased in the cohorts. Therefore the cohort changes leading to the major transformation in nuptiality and fertility in Japan are mainly initiated by unintended changes[9]. However, the mechanism of delaying marriage seen in Group II seemed quite different from the previous group, since the compositional changes stabilized in Group II, and so their effects on marriage timing are reduced. Instead, the marriage timing showed delay over the cohorts irrespective of categories of individual characteristics.

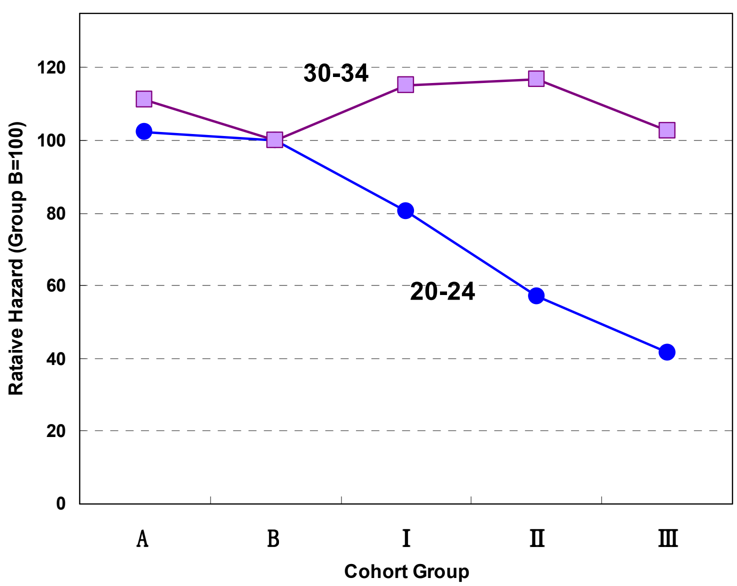
As for the findings (2) and (3), we offer some hypotheses about the mechanism of behavioral change in first marriage behavior. The presence of the time lag between onsets of postponement and retreat in marriage behavior suggests that when adaptation in marriage behavior to new situations is required, cohorts tend to start adjusting the timing at first because of its lower impact on their life. Then they start to resort to a substantive alteration of life by retreating from marriage itself when

[9] To the extent that the marriage delay in Group I is not completely explained by the compositional changes, a further pinpointed investigation at or around the cohort of 1952 would be informative for factors affecting this significant behavioral change. For example, effects of the radical cohort size changes in these cohorts might affect their marriage behavior by causing favorable conditions of marriage market for women.

further adaptation is required. There are two mechanisms hypothesized here. First, there may be a certain limit for marriage propensity to rise in later ages so that some postponed marriages will be lost for life, when the limit is attained by prolonged postponement. Second, postponement and retreat may be somewhat independent behavioral adaptations to resolve somewhat different difficulties so that they could exhibit uncoupled emergence.

In order to test these hypotheses, we derived the hazard rate for each of the cohort group by age group. Figure 10 indicates relative hazards of two age groups, young (20-24) and late (30-34) for the cohort groups. The relative hazards are chosen so as to be 100 for Group B, which is those before the behavioral changes started. According to examination on the hazard pattern, the first hypothesis seems applicable to Phase II. In cohorts of Phase I, the hazard to marry in young ages decreased, while it increased in late twenties through early thirties. This pattern of hazard change implies that those who postponed their marriage in young ages among cohort group I got married later. On the contrary, in cohorts of Phase II, the hazard rates in late ages lie around the same levels as Phase I, although it continued to decrease in young ages. It implies that some of those who tried to postpone their marriage in this cohort group have not married at all even at later ages keeping hazard in these ages at the same level as level of the previous group. These patterns are predicted by the hypothesis that there is a certain limit in the propensity to marry in these late ages, and postponement brings about a rise in the proportion never marrying, which we actually observed in Phase II.

Figure 7　Cohort Changes in Relative Hazard to Marry in Two Age Groups:

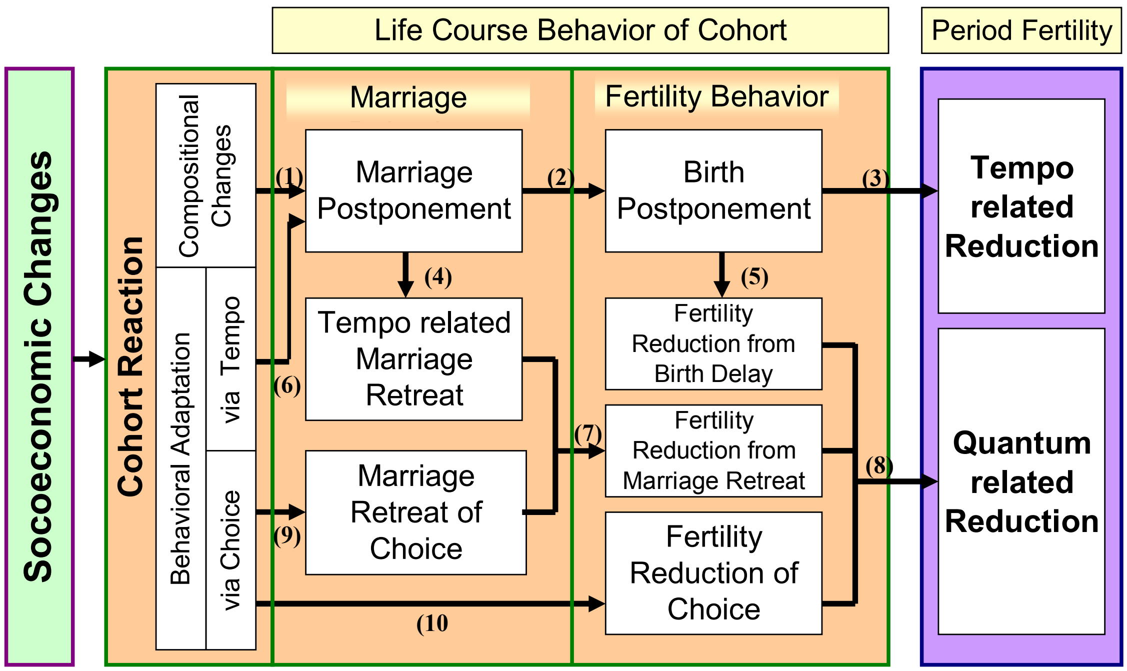


However, in cohorts in Phase III, the hazard in the early thirties is found to decline slightly, while it continued to decline in early twenties. These patterns are predicted by the second hypothesis that retreat from marriage could take place somewhat independently of postponement, because decline in hazard in late ages could not be explained either by simple postponement or by the first hypothesis.

Consequently, our simplified conclusions concerning results (2) and (3) are as follows: the rise in the proportion never marrying in Phase II mainly resulting from prolonged marriage postponement that had started earlier in the previous cohorts, because of the presence of an upper limit in marriage propensity in later ages. In other words, the spread of marriage retreat in this group of cohorts was mostly unintentional. On the contrary, the further rise in the proportion never marrying in Phase III was from somewhat independent cause of postponement, and was a genuine decline in marriage propensity throughout an individual's lifetime as a new behavioral adaptation. That is, we suggest that the change is caused by intentional shifts in the behavior of cohort members.

The emergence of the non-postponement-related rise in the proportion never marrying in the recent female cohorts (Group III) in Japan leads to a prospect of further substantive decline in nuptiality and fertility, which would be unbearable to a society already among the world's least reproductive.

Figure 8 Paths to Period Fertility Reductions from Compositional and Behavioral Changes of Female Cohorts in Japan



Main paths of effect to period fertility by cohort groups:

Group I : (1 → (2 → (3 → **T**
(2 → (5 → (8 → **Q** *(minor effect)*

Group II : (6 → (2 → (3 → **T**
(2 → (5 → (8 → **Q**
(6 → (4 → (7 → (8 → **Q**

in addition to paths of Group II,

Group III : (9 → (7 → (8 → **Q**
(10 → (8 → **Q**

Based on these findings on changing patterns in the lifetime measures for Japanese women, the general transition pattern of societies to reduced fertility in terms of cohort compositional and behavioral changes is hypothesized. We summarized the Japanese experiences in the Figure 8, where various paths to fertility reduction through changes in marriage and child-bearing behaviors are illustrated. As noted with the figure, each group of cohort has a different path to contribute to period fertility of the lowest according to their phase in the process.

Among cohorts in the onset (Group I in Japanese case), mere delay of marriage and birth initiates the whole process. The delay is mainly caused by structural change such as educational upgrading of the cohorts. Period fertility starts to decline due to the tempo effects. Then the delay is succeeded by intentional postponement among following cohorts (II), spreading in any category of educational level for instance. At the same time unintended retreats from marriage and reproduction due to the excessive postponement spread. The quantum factor of fertility starts to decline in this phase. Finally the retreats itself become intentional in succeeding cohorts (III) reducing probability of having nuptials and births even in advanced ages. Reduction of marital fertility accompanies.

The hypothesized cohort process suggests the presence of quite different mechanisms by phase behind seemingly monotonous track to the lowest fertility. Typically unintentional changes substantiate by transforming to intentional behavioral changes of succeeding cohorts in response to the aggregate changes of the forerunner. In this process, period fertility starts to decline due to the tempo effect from unintentional delays in reproductive process, yet preserving potential to recover. However the driving effect is progressively replaced by the quantum factor from deliberate changes of new cohorts beneath the monotonous change perpetuating the low fertility setting. This tricky process may have provided slippery ground for fertility forecasters leading to wide miscount in the past few decades.

References

Bloom, David E., 1982, What's happening to the age at first birth in the United States? A study of recent cohorts, *Demography*, Vol. 19(3): 351-370.

––, and Bennett, Neil G., 1990, Modeling American marriage patterns, *Journal of The American Statistical Association*, Vol. 85, No. 412:1009-1017.

Bongaarts, J. and G. Feeney. 1998. "On the Quantum and Tempo of Fertility." *Population and Development Review* 24: 271-292.

—, 1971, "Age Patterns of Marriage", *Population Studies*, Vol. 25(2): 193-214.

Coale, A.J., McNeil, D. R., 1972, "The Distribution by Age of the Frequency of First Marriage in Female Cohorts", *Journal of American Statistical Association*, Vol. 67: 743-749.

Goldstein, J. R. and Kenney, C. T. (2001). "Marriage delayed or marriage foregone? New cohort forecasts of first marriage for U.S. women. " *American Sociological Review 66*: 506–519.

Kaneko, R., 1991, "Demographic Analysis of the First Marriage Process," *The Journal of Population Problems*, Vol.47, No. 3: 3-27 (in Japanese with English summary)

––, 2003, "Transformations in first marriage behavior of Japanese female cohorts: estimation and projection of lifetime measures via empirically adjusted Coale-McNeil model," Presented at Annual Meeting of Population Association of America, Minneapolis.

––, 2003, "Elaboration of the Coale-McNeil Nuptiality Model as The Generalized Log Gamma Distribution: A New Identity and Empirical Enhancements," *Demographic Research*, Vol. 9-10:223-262. http://www.demographic-research.org/Volumes/Vol9/10/9-10.pdf

—, 2004, "On Changing Factors of Marriage Transformation in Japan: Decomposition of Delay in Women's First Marriage Process," paper presented at the Annual Meeting of the Population Association of America, Boston, Massachusetts.

Kohler, H.-P. and D. Philipov. 2001. "Variance Effects in the Bongaarts-Feeney Formula." *Demography* 38(1): 1-16.

––, and J. A. Ortega. 2002. "Tempo-Adjusted Period Parity Progression Measures, Fertility Postponement and Completed Cohort Fertility." *Demographic Research* 6(6): 91-144. http://www.demographic-research.org/Volumes/Vol6/6/6-6.pdf

Kojima, H., 1985, "Coale-McNeil no Kekkon Model ni Tuite (About the Coale-McNeil Nuptiality Model)," *Jinkou Mondai Kenkyu*, No. 175: 36-47.

Rodriguez, G., Trussell, J., 1980, *Maximum Likelihood Estimation of the Parameters of Coale's Model Nuptiality Schedule from Survey Data*, World Fertility Survey, Technical Bulletins, No.7.

Ryder, N. B. 1964. "The Process of Demographic Translation." *Demography* 1(1): 74-82.

––, 1980. "Components of temporal variations in American fertility." In R. W. Hiorns (ed.), *Demographic Patterns in Developed Societies.* pp. 15-54. Taylor and Francis: London.

Takahashi, S., 1978, "Kekkon model schedule no Nihon eno Tekiyouni Tuite (Application of the Nuptiality Model Schedule to Japan)," *Kokumin Keizai Zasshi*, Vol. 138, No. 6: 80-95.

van Imhoff, E. 2001. "On the Impossibility of Inferring Cohort Fertility Measures from Period Fertility Measures." *Demographic Research* 5(2): 23-64. http://www.demographic-research.org/Volumes/Vol5/2/5-2.pdf