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Assumptions on fertility

A study on the short-term fertility projection method using marriage rate - Population projections for the Republic of Korea, 2017-2067

Note by Statistics Korea*

Summary

The Republic of Korea (South Korea) has one of the lowest fertility rates in the world. South Korea's fertility rate hit a record low of 1.05 in 2017 and 0.98 last year, and the decline has continued in 2019. In addition, the decrease in the working age population began in 2019, and the number of elderly population increased from 2017 over the number of child population.

To reflect this trend of ultra - low fertility rates, the Statistics Korea published "Population Projections for Korea (2017~2067)" in March 2019 and will shorten the revision period from five years to two years.

In particular, in this projection, a new short-term projection method for fertility was developed that reflected various demographic factors, such as changes in the patterns of fertility rates or marriage rates, in order improve the short-term predict ability of births. Below, we would like to share fertility projection results and details of short-term and long-term projection methods of the Statistics Korea.

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I. Introduction

1. The population projection in Korea was planned to be conducted every five years and to be published in 2021, but the 『Special Population Projections for Korea (2017~2067)』 was carried out in March 2019 to reflect the recent ultra-low fertility rate. The birth rate in South Korea has been rapidly declining in a globally unprecedented pace resulting in a significant estimation error in the 2016 projection for the number of live births, which heightened the calls for the special projection. This paper illustrates the short-term fertility model being newly adopted in the special projection and provides an overview of its results.

2. In the 2016 projections, the completed cohort fertility was calculated using a time series model, and the age-specific fertility rates were estimated using the Generalized Log Gamma (GLG). However, such a time series model based solely on the trend of fertility could not reflect the recent sharp declines in the prevalence of marriage and childbirth. In this special projection, we used different models in short-term and long-term projections. The short-term model reflects the effect of a marriage on childbirth by using the recent years' marriage rates and childbirth-to-marriage ratios. The long-term model reflects the long-term trends in the cohort fertility rate.

Table 1. Comparison of Fertility Projection Models

2016 Projection	A time series model based on the completed cohort fertility	
	⇩	
2019 Projection	**Short-term**	**Long-term**
	Reflected changing trends in marriage and childbirth by married couples	A time series model based on the completed cohort fertility * Expanding the basic data coverage to include recent cohorts in order to reflect the rapid changes in childbirth

II. Review of the 2016 Projections

3. (Projection Method) In the 2016 fertility projection (2017-2065), a time series model was used to estimate the completed cohort fertility rate and the Generalized Log Gamma Distribution was applied to calculate the age-specific fertility rates. The target cohort was defined as women born in 2000 who reached childbearing age (age 15) in 2015. The completed fertility rate for this cohort was drawn from the completed fertility rate for cohorts born in 1945 through 1970 by using a time series estimation method.

- Time Series Model

$$y_t = b_0 + b_1 \ln(t) + e_t (e_t = \emptyset_1 e_{t-1})$$

y_t : completed fertility rate at the time of t, b_0 : intercept, b_1 : slope

e_t: error at the time of t (assuming the first-order auto-regressive error model)

Generalized Log Gamma Distribution Model

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

- $f(x)$: fertility rate at the age of x, C: level of fertility, u: average age at childbirth, b: standard deviation in the average age at childbirth, λ: distribution pattern

4. (Result of projection) According to the 2016 Projection results, the total fertility rate (TFR) was expected to increase from 1.18 in 2016 to 1.38 in 2050 which was expected to be maintained thereafter. However, the gaps between the estimates and the actual values have widened due to the magnifying ultra-low fertility rate. It plunged to 1.05 in 2017 which was a 13.2 percent decrease from the 10-year average fertility rate (2006-2015) and further decreased to 0.98 in 2018. The actual fertility rate in 2017 was lower than the estimated fertility rate under the low-growth scenario in the 2016 projections.

Table 2. Result of 2016 projection and Actual observation - Total Fertility Rate

(Unit: Number of children per woman aged 15 to 49)

Total Fertility Rate		2015	2016	2017	2018	2019	2020
2016 Projections scenario	Medium-growth	1.24	1.18	1.20	1.22	1.23	1.24
	Low-growth	1.24	1.16	1.14	1.13	1.11	1.10
Actual observation		1.24	1.17	1.05	0.98	-	-

III. Analysis for Fertility Projection

A. The Period Fertility Rate Analysis

5. The number of live births has been on a steady decline since it peaked in 1970 at 1.01 million births. The number stabilized and remained close to 400,000 for 15 years since 2002 before it fell by 11.8 percent to 358,000 in 2017. The number dropped further to 325,000 in 2018, and the decline has continued this year approaching 300,000 live births.

6. The total fertility rate (TFR) continued to fall from 4.53 in 1970 to as low as 1.08 in 2005, which continue to increase and decrease around 1.30 for many years. In 2017, the TFR

recorded 1.05, a 13.2 percent plunge from the average of the previous 10 years (2006-15). The TFR reached a record low of 0.98 in 2018, and is expected to be even lower in 2019.

7. Korean women's average age at childbirth was 32.8 years old in 2018, which has grown each year by around 0.2. Due to the postponement of marriage, the fertility rate of women in their late 20s was declining while the rate of women in their early 30s grew. Since 2016, the pattern of low fertility has been aggravated as the fertility rate of women in their early 30s started declining and the growth of fertility rate for women in their late 30s has slowed.

8. The sex ratio at birth recorded its peak at 116.5 in 1990 and kept declining thereafter. From 2007, it stayed within the range of its natural level and its averages have been close to 105.5 since 2011.

Table 3. Fertility Indicators in Korea
(in ten thousand births, # of childbirth per woman of childbearing ages, # of males per 100 females at birth)

	1970	**1980**	**1990**	**2000**	**2005**	**2010**	**2015**	**2016**	**2017**	**2018**
# of births	101	86	65	64	44	47	44	41	36	33
Total fertility rate	4.53	2.82	1.57	1.48	1.09	1.23	1.24	1.17	1.05	0.98
Mean age at birth	-	-	-	29.0	30.2	31.3	32.2	32.4	32.6	32.8
Sex ratio at birth	109.5	105.3	116.5	110.1	107.8	106.9	105.3	105.0	106.3	105.4

B. The Cohort Fertility Rate Analysis

9. (The Cohort Completed Fertility Rate) The birth cohort analysis reveals that a cohort of women born in 1945 gave birth to an average of 3.57 children, which kept declining thereafter to the average of 2.92 among a cohort of women born in 1950, 2.08 among a cohort born in 1960, and 1.65 among a cohort born in 1975. The completed fertility rate of cohorts born in 1946 through 1955 decreased by an annual average of 0.13. The level of decrease in the completed fertility rate notably slowed among cohorts born in 1956 through 1970 which went back up for cohorts born after 1978.

10. (Age at Childbirth) The birth cohort analysis of women's average age at childbirth reveals that women's age at birth had gone down from 26.6 to 25.8 for the cohorts born during 1945 through 1954. The average age at childbirth kept growing ever since, recording an age of 28.3 for the cohort born in 1970 and an age of 31.0 for the cohort born in 1980. The age went up by an annual average of 0.14 among the cohorts born in the years 1956 through 1965, by an annual average of 0.19 among the cohorts born in the years 1966 through 1970.

Table 4. Cohort Completed Fertility Rate (CFR) & Average Age at Childbirth (AAB)
(in # of live births per woman from each birth cohort, age)

Cohort born in	**1945**	**1950**	**1955**	**1960**	**1965**	**1970**	**1975**	**1980**	**1983**
CFR	3.57	2.92	2.23	2.08	1.99	1.81	1.65	1.48	1.33
AAB	26.6	26.1	26.0	26.5	27.4	28.3	29.6	31.0	31.4

AAB was derived from the age-specific fertility rate data by using a weighted average method

C. Analysis of Marriage and Childbirth

11. In Korea, marriage is a leading factor of birth. The ratio of married couple's childbirth to total childbirth during the past 10 years recorded an average of 98%. The average age at first marriage was 26.5 years old in 2000 which continued to increase by 0.1 through 0.2 each year to record an average of 30.4 years old in 2018. The nuptiality patterns by age group and the age-specific cumulative marriage rate were both steadily decreasing. On average, women were married for 1.8 years at the time of their first childbirth. They were married 4.5 years for their second childbirth and 7.6 years for their third childbirth. The average marriage duration at childbirth during the past 10 years was 3.4 years.

IV. The short-term fertility projection model in 2019

D. Short-term Fertility Projection Method

12. (Methods) As for the short-term projection covering the next three years*, the total fertility rate is projected by using the poly-nominal model of the marriage rate and the marriage-to-fertility ratio. As for the long-term projection for the next decade, the cohort completed fertility rate is projected by using a time-series model. The total fertility rate for the next 4~9 years is projected by a weighted average method which equalizes the short-term and long-term estimates.

Figure 1
Short-term and Long-term Fertility Projection Methods

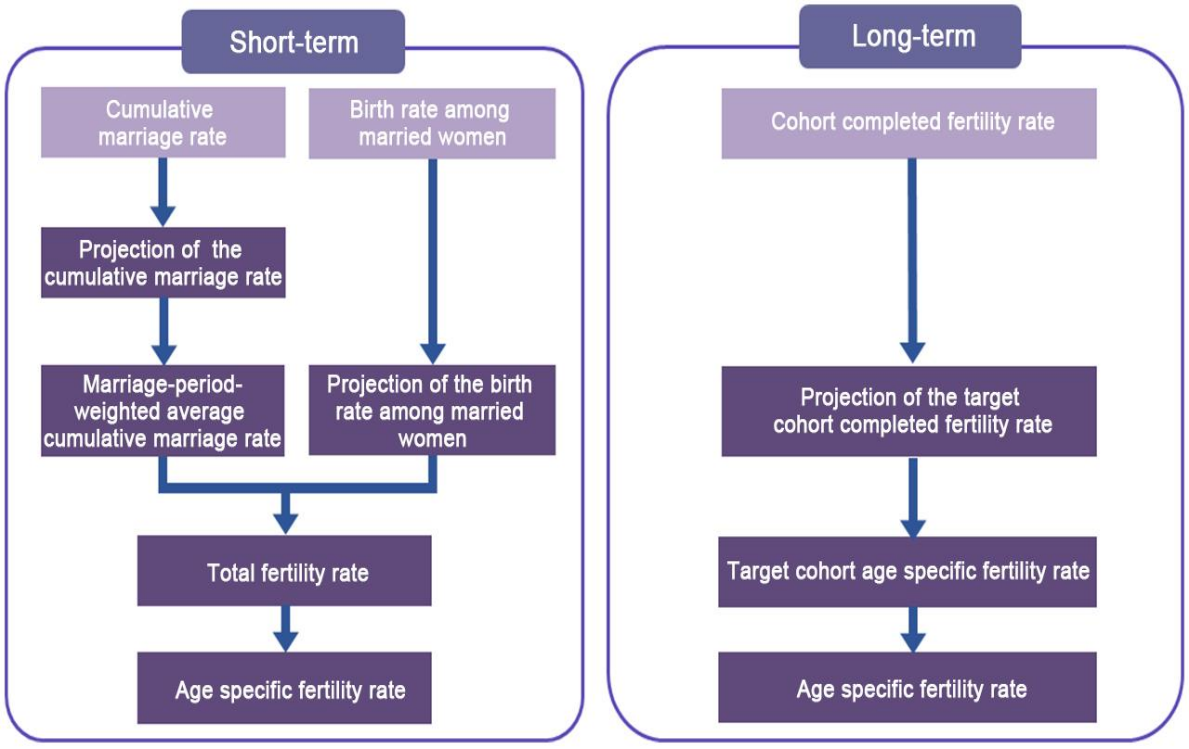

Table 6.
Basic Data for Fertility Projections

Items	Data being used	Period
Cumulative marriage rate*	- Age-specific marriage rates (ages 15 - 39)	2008 - 2018
Childbirth to marriage ratio	- Proportion of childbirth by birth order (1 birth, 2 births, and 3 or more births) relative to the weighted average cumulative marriage rate (under 40) Composition of mothers' marriage period at childbirth by birth order	
Cohort completed fertility rate	- Completed fertility rate of birth cohorts born in 1945 through 1983* * Cohorts should reach the age of 35 in 2018. Age 35: the average age at childbirth for women giving birth to 3 or more children	
Average age at childbirth	- Average age at childbirth for women born in 1945 through 1983	

* Cumulative marriage rate is the sum of age-specific nuptialities for a specified age range

13. (Details of Short-term Method) The short-term total fertility rate is estimated by using the marriage rates in recent years and the fertility-to-marriage ratio.

$$TFR_t = \sum_s M_{s,t}\, b_{s,t} + e_t$$

- TFR_t : Total fertility rate at time t
- $M_{s,t}$: Marriage-period-weighted average cumulative marriage rate* for birth order s(1, 2, 3+) at time t*
- $b_{s,t}$: Birth rate by birth order s(1, 2, 3+) at time $t$per married woman**

$$M_{s,t} = \sum_k m_k\, w_{s,k}$$

- m_k : Cumulative marriage rate until age 39 during time $k$of marriage period
- $w_{s,k}$: Weight of percentage of birth at time $k$of marriage period by birth order s(1, 2, 3+)

- k : Marriage period, $\begin{cases} [t-2,\ t\ ] & (\text{if } s=1\ ) \\ [t-6, t-2\ ] & (\text{if } s=2\ ) \\ [t-9, t-4\ ] & (\text{if } s=3+) \end{cases}$

$$w_{s,\,k} = \frac{p_{s,\,k}}{\sum_k p_{s,\,k}}$$

- $p_{s,k}$: Percentage at time $k$of marriage period by birth order s(1, 2, 3+)

① Calculating the cumulative marriage rates by year:

- The cumulative marriage rates by age are projected by using the Lee-Carter model (1992) after a conversion to the Gompit model.
- The high- and low-growth scenarios are calculated at the 99% confidence intervals of the Lee-Carter model.

② Calculating the time-weighted average of cumulative marriage rates:

- The weighted average of cumulative marriage rates of women under 40 by birth order is calculated by using the shares of childbirth by birth order and marriage period as weights.

③ The fertility-to-marriage ratio by birth order is projected by using the Lee-Carter model.

- The high and low scenarios are calculated at the 99% confidence intervals of the Lee-Carter model .

④ The total fertility rates by year are calculated as the sum of the timed-weighted averages of cumulative marriage rates by birth order multiplied by the fertility-to-marriage ratios.

⑤ The distribution of the fertility rates by age is calculated by using the Generalized Log Gamma

.

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

・C: Probability of childbirth by birth order (provided the birth order is not considered, the value will be same as TFR)

・u: average age at childbirth

・b: standard deviation of the average age at childbirth

・λ: distribution pattern

* In the short-term model, the average age at childbirth reflects the recent fluctuation trends

* In the long-term model, the cohort average age at childbirth was calculated in a log regression model

$\hat{y_t} = 292.12 \ln(t) - 2187.24$; R^2 (0.858)

14. Assumptions (Medium-growth Scenario)

① The cumulative marriage rate of women under 40 will decrease from 0.70 in 2017 to 0.65 in 2021.

Table 7. Cumulative Marriage Rates for Women Under 40, 2000-2022
(unit: number of events per woman)

2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022
0.75	0.72	0.78	0.80	0.75	0.70	0.68	0.67	0.66	0.65	0.62

② The total fertility rates relative to the time-weighted average cumulative marriage rates for women under 40 will decline from 1.39 in 2017 to 1.27 in 2021.

③ The average age of women at childbirth will increase from 32.6 in 2017 to 33.5 in 2067.

Table 8. Childbirth-to-marriage Ratio, 2009-2022
(in number of live births per marriage, cumulative of women under 40)

median value	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
total	1.62	1.66	1.50	1.53	1.57	1.51	1.39	1.33	1.31	1.29	1.27	1.26
1 birth	0.83	0.86	0.78	0.81	0.85	0.84	0.79	0.78	0.78	0.78	0.77	0.77
2 births	0.61	0.63	0.57	0.57	0.58	0.54	0.48	0.45	0.44	0.42	0.41	0.40
3 or more	0.18	0.17	0.16	0.15	0.14	0.14	0.12	0.10	0.09	0.09	0.09	0.08

Table 9. Average age at childbirth, 2000-2067
(in ages)

2000	2005	2010	2015	2017	2018	2025	2035	2045	2067
29.0	30.2	31.3	32.2	32.6	32.8	33.0	33.2	33.5	33.5

V. Results of the 2019 Fertility Projection

15. Unlike the 2016 projection results, which forecasted a steady increase of the total fertility rate, this projection using a short-term model forecasts that the fertility rate will decline in the next three years before starting to increase again. In other words, the total fertility rate of 0.98 in 2018 will continue to fall to its lowest of 0.86 in 2021 before a recovery which will bounce back to 1.0 in 2025 and continue to rise to 1.14 in 2030 and 1.27 in 2040.

Table 10. Total Fertility Rates, 2017 ~ 2067
(Unit: Number of births per woman aged 15 to 49)

scenario	2017	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2067
Medium growth	1.05	0.90	1.00	1.14	1.22	1.27	1.27	1.27	1.27	1.27	1.27	1.27
High growth	1.05	1.06	1.23	1.38	1.44	1.45	1.45	1.45	1.45	1.45	1.45	1.45
Low growth	1.05	0.81	0.84	0.97	1.03	1.09	1.10	1.10	1.10	1.10	1.10	1.10

16. The number of live births will also drop in the next three years followed by a re-bounce between 2022 and 2028, peaking at a high of 361,000 births in 2028, before declining again thereafter. An anticipated recovery between 2022 and 2028 is supported by the facts that the total fertility rate is expected to go up after 2022, or after its lowest rate of 0.86 in 2021, and the number of women in their early 30s (ages 30-34), or most prevailing childbearing ages, will also increase after 2021.

Table 11. 2016 and 2019 Projection results

Year	**Number of Births (**in thousand)			**Total Fertility Rate**		
	2016 (A)	**2019 (B)**	**(A-B)**	**2016 (C)**	**2019 (D)**	**(C-D)**
2017	413	348	-65	1.2	1.05	-0.15
2018	411	325	-86	1.22	0.98	-0.24
2019	410	309	-101	1.23	0.94	-0.29
2020	409	292	-117	1.24	0.9	-0.34
2021	410	290	-120	1.25	0.86	-0.39
2022	411	300	-111	1.26	0.9	-0.36
2023	413	312	-101	1.27	0.93	-0.34
2024	415	324	-91	1.27	0.97	-0.3
2025	417	335	-82	1.28	1.0	-0.28
2026	418	346	-72	1.29	1.04	-0.25
2027	417	356	-61	1.3	1.08	-0.22
2028	415	361	-54	1.3	1.11	-0.19
2029	412	360	-52	1.31	1.13	-0.18
2030	406	358	-48	1.32	1.14	-0.18
2031	399	354	-45	1.33	1.16	-0.17
2032	391	349	-42	1.34	1.17	-0.17
2033	382	342	-40	1.35	1.19	-0.16
2034	372	335	-37	1.36	1.21	-0.15
2035	362	327	-35	1.36	1.22	-0.14
2040	322	295	-27	1.38	1.27	-0.11
2045	306	275	-31	1.38	1.27	-0.11
2050	291	240	-51	1.38	1.27	-0.11
2055	282	210	-72	1.38	1.27	-0.11
2060	277	214	-63	1.38	1.27	-0.11
2065	263	216	-47	1.38	1.27	-0.11

VI. Conclusion

17. Although predicting fertility is a difficult task in Korea, especially against its unprecedentedly low rate of fertility in recent years, this study suggests a development of a new projection model intending to adapt to this new reality. We also aim to

improve the validity and reliability of the projection's methods and results by strengthening the participation of experts in the study.

References

Statistics Korea (2019). "Population Projections for Korea (2017~2067)"

Bongaarts, J., & Feeney, G. (1998). "On the quantum and tempo of fertility." Population and Development Review, 24(2), 271-291.

Bongaarts, J., & Feeney, G. (2008). "The quantum and tempo of life-cycle events." In E. Barbi, J. Bongaarts, & J. W. Vaupel (Eds.), How Long Do We Live? Demographic Models and Reflections on Tempo Effects (pp. 29-65). Rostock: Springer.

Kaneko, R. (2003). " Elaboration of the Coale-McNeil Nuptiality Model as The Generalized Log Gamma Distribution: A New Identity and Empirical Enhancements." Demographic Research, 9(10), 223-262. Retrieved from https://www.demographic-research.org/volumes/vol9/10/