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# Total number of births shrinking faster than fertility rates: fertility quantum decline and shrinking generation size in South Korea

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**ABSTRACT**
South Korea's total fertility rate reached 1.3 in 2001 and hit a record low (0.92) in 2019. The total number of births shrank even faster, recording a 45.9 per cent drop between 2001 and 2019. To understand the declining births and the contributing demographic factors, I decompose the change in the birth rate into mean generation size, fertility quantum, and tempo distortions, and evaluate their relative contributions to the decline. The remarkable birth decline since 2001 is largely explained by fertility quantum decline, especially for second births, and shrinking generation size caused by the decline in female population size. Tempo distortions were strong, but given the marginal change since 2001, they contributed less and only in recent years. This study highlights unique features of East Asia's low fertility, such as continued fertility decline and the long-term negative effects of reproducing generations' low fertility. Findings might have implications for developing countries experiencing rapid fertility decline.

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## Introduction

The total number of births, which determines the size of new cohorts in a society, is one of the ways to understand fertility trends. A rise or fall in cohort size affects many aspects of society, such as public schooling, the labor market, the housing market, public pensions, and social security systems. For example, the post-war baby-boomers in developed countries contributed to labor supply and economic growth in the past, but as they began to retire, public concern has been raised over social security programs like the pension system ('The Next Crisis', 2012). Despite its significance, prior research has paid less attention to the total number of births than to period fertility (e.g., total fertility rate [TFR]), probably because the total number of births is affected by the size and age structure of the childbearing female population, as well as the period fertility level.

This study focuses on the declining number of births in the era of lowest-low fertility in South Korea (hereafter, 'Korea'). Korea provides an interesting setting for analysing the total number of births. The Korean period TFR fell below 2.1 in 1983 and reached 1.31

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in 2001 (see Figure 1). Since then, the TFR has remained below 1.3. In recent years, the period TFR began to decline further, reaching a record low of 0.92 births per woman in 2019, which is the lowest among the Organization for Economic Cooperation and Development (OECD) countries (Statistics Korea, 2020), whereas women's mean age at childbearing has continued to rise since the early 1980s.

What is even more surprising is the dramatic fall in the total number of births, which outpaced the declining TFRs. While the TFR fell 29.8 per cent between 2001 and 2019, the total number of births declined by 45.9 per cent, from 559,934 births in 2001 to 302,676 births in 2019 (Statistics Korea, 2020). The tempo distortion-free fertility quantum has also declined in the last couple of decades (Yoo & Sobotka, 2018). One may suspect that the female population's age structure has contributed to such a remarkable drop in the total number of births. Sustained low fertility since the 1980s has resulted in a gradual reduction in the size of the young population and facilitated population aging (Figure 2). Therefore, it is interesting to determine whether and to what extent the demographic changes in the female population have contributed to the declining total number of births in South Korea.

This study is to understand the demographic factors affecting the changing number of births since the onset of lowest-low fertility and to identify unique features of Korean fertility as distinct from Western countries. I decompose the changing number of births into fertility quantum, fertility timing, and the size and age structure of the female population to evaluate these demographic factors' relative contributions to the decline in the total number of births. The Korean experience enriches our understanding of fertility dynamics in East Asia and suggests implications for other developing countries that have experienced rapid fertility decline.

## Quantum, tempo, & age structure effects

Trends in fertility levels and the number of births can move in different directions, depending on the childbearing female population's size and age structure. For instance,

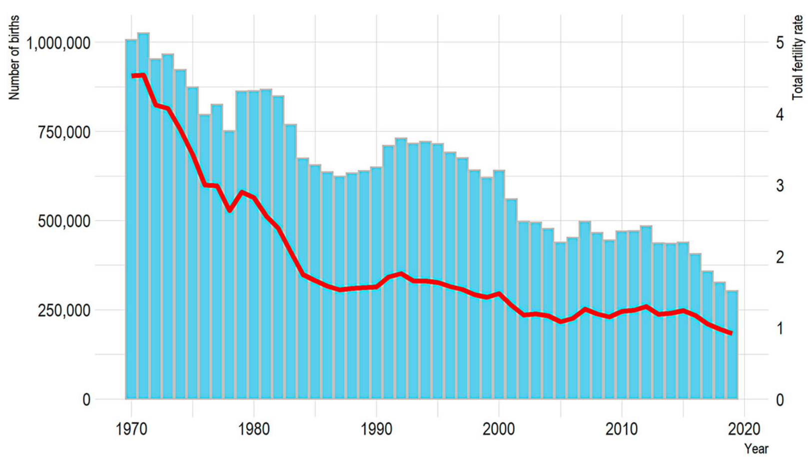


**Figure 1.** Total fertility rates and total number of births, South Korea, 1970–2019. Source: Vital Statistics 1970–2019 (KOSIS, 2020).

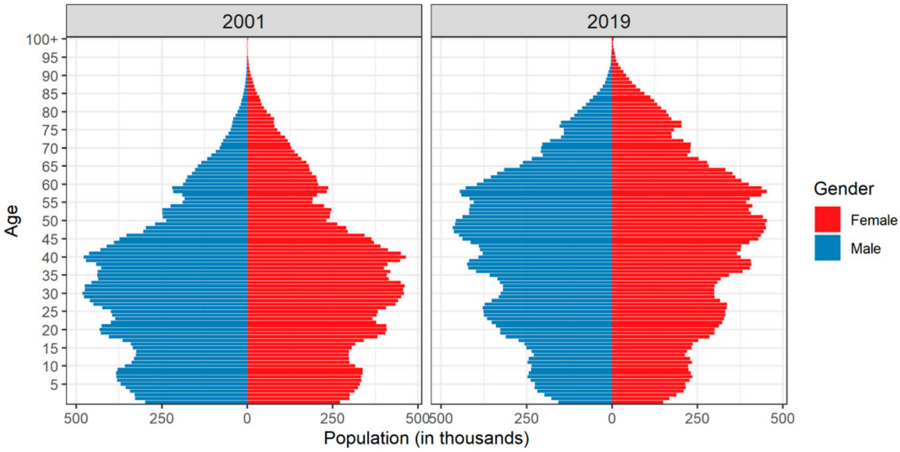


**Figure 2.** Population distribution by age and sex in South Korea, 2001 & 2019. Source: Mid-year population based on resident registration data (KOSIS, 2020).

an increase in the reproductive-age female population can partially compensate for the decline in births caused by falling fertility levels. Therefore, deviation between fertility level and the size of the female population is likely to attenuate a radical change in the number of births. However, the change in the number of births can be rather dramatic once the two factors move in the same direction. For instance, the declining number of births caused by fertility decline might be fueled by a smaller female population.

This idea is similar to what Lutz et al. (2008) described as the self-reinforcing mechanisms of low fertility, 'low-fertility trap hypothesis.' They argued that due to sustained low fertility, fewer potential mothers would result in fewer births in the future. Population growth is conditioned by age structure that is an outcome of past fertility and mortality, as well as current fertility and mortality; it is referred to as population momentum (Preston et al., 2000, p. 136). For instance, population can continue to grow because of its age structure, even if fertility reaches the replacement level. Likewise, the low-fertility trap's demographic pathway implies negative population momentum in that the existing population's age structure contributes to shrinking population size. The negative momentum would be strong if the fertility decline was sharp and current fertility was very low.

Compared to most Western countries, fertility decline to below or far below the replacement level has been much faster in non-Western countries, leading to a rapid reduction of the childbearing female population. If such negative momentum exists, it would be more easily observed in non-Western settings, like Korea, where fertility has declined rapidly and remains at the lowest-low level.

Tempo distortions in period fertility (Bongaarts & Feeney, 1998) also complicate empirical analysis of the changing number of births. It is well known that the rise and fall of many European countries' period TFR is explained by the 'postponement transition' (Kohler et al., 2002). Ideational changes, driven by individualization and self-realization, delay childbearing to later ages (Lesthaeghe, 2010; Lesthaeghe & van de Kaa, 1986). The period TFR began to fall with the onset of childbearing postponement, and then it gradually recovered later with decreases in birth postponement (Goldstein et al., 2009; Sobotka, 2004). Likewise, the annual number of births can shrink due to delayed childbearing without a significant decline in lifetime fertility; it can also rise with an advance in the timing of childbearing. Thus, the postponement of childbearing negatively affects the total number of births.

Kohler and Ortega (2002; Ortega & Kohler, 2002) introduced a possible method to decompose the number of births into tempo, quantum, and age structure effects. Extending Kohler and Ortega's approach, Sobotka et al. (2005) analysed the changing number of births in 13 European countries since the onset of the postponement transition. According to their results, tempo distortion was the main factor negatively affecting the number of births, while falling fertility quantum and shifts in the number of childbearing-age women contributed to regional variations. For example, tempo distortions was a primary factor reducing the number of births in Austria, Denmark, Sweden, the Czech Republic, Hungary, and Poland, whereas the negative effect of falling fertility quantum on the size of new cohorts was larger than that of tempo distortions in Italy and Spain. Therefore, it is important to adjust tempo effects to understand fertility trends. Meanwhile, in their study, the mean generation size displayed either positive impacts or negligible negative impacts on the change in the number of births depending on country-specific context.

In East Asia's advanced economies, such as Japan, Singapore, Taiwan, Hong Kong, and South Korea, the TFR fell below 1.3 between the mid-1990s and the 2000s, a phenomenon also known as 'ultra-low fertility' (Straughan et al., 2008). These countries' TFRs have remained below 1.3 and declined even further in recent years. One exception is Japan, where the TFR rebounded to above 1.3 in the late 2000s.

East Asia's low fertility is distinct from the Western experience in several aspects: the rapid decline in fertility, the continued rise in the childbearing age, and the absence of a rebound in period TFRs––though this could still happen later. Fertility decline to below replacement levels and to lowest-low levels has been much faster in East Asian countries, especially in Korea, than in most Western countries. The size of the female population has continued to decline with a time lag. Therefore, the size and age structure of the childbearing female population are likely to negatively influence the total number of births, if the period TFR has been in decline for a few decades prior.

At the same time, the dramatic trend away from marriage has delayed women's mean age at childbearing in East Asian countries, where nonmarital births are still rare (Jones, 2007; Jones & Gubhaju, 2009; Yoo, 2016). The delayed childbearing trend has been prevalent for the last several decades, coupled with the lack of rebounding period TFRs. In particular, the sustained delay in childbearing has generated strong tempo effects on period fertility in Korea (Yoo & Sobotka, 2018). Therefore, unlike European countries where fertility levels, fertility timing, and female population size move in different directions, offsetting the negative impacts of each on the total number of births, demographic factors in Korea may point in the same direction, resulting in a declining number of births.

## Data

Estimating period fertility free from tempo distortions requires detailed information about the age- and parity-specific number of births and the female population. This study uses multiple data sources, such as vital statistics, resident registration data, and the population census. Statistics Korea computes official TFRs using the number of births from vital statistics and the size of the mid-year female population aged 15–49 from resident registration data.

I apply the same analytical approach in this study. Figures representing the total number of births by mother's age and birth order for the period 2001–2019 are directly obtained from vital statistics through the Korean Statistical Information System (KOSIS) website (Statistics Korea, 2020). Births missing mother's age and parity are proportionally distributed based on observed compositions. Figures representing the childbearing female population, sorted by age, for the period 2001–2019 are available in the resident registration data, but parity information is missing. Unfortunately, the parity distribution of the female population is available only in the 2000 population census. Therefore, I reconstruct the age and parity distribution of the female population by updating the distribution observed in the 2000 population census with age-specific fertility rates estimated by birth order for the corresponding birth cohorts and ages. The age- and parity-specific distribution of the female population is extended forward, up to 2019. Then, it is applied to the female population as represented in the resident registration data to obtain the female population by age and parity for the entire period from 2001 to 2019 (please refer to the Appendix for details).

## Methods

This study disentangles factors associated with the declining total number of births into period fertility tempo (timing) and quantum (level), as well as age structure effects, focusing on the fact that the period TFRs have remained below 1.3. I use the decomposition method proposed in prior studies (Kohler & Ortega, 2002; Ortega & Kohler, 2002; Sobotka et al., 2005). Based on Kohler and Ortega's (2002) method, Sobotka et al. (2005) decomposed the total number of births into tempo, quantum, and age structure effects, and found that the tempo distortions were the main force negatively affecting the total number of births in European countries.

Prior research taken a similar approach (Lee, 2013; Min & Yoo, 2020) are commonly based on the decomposition method suggested by Sobotka et al. (2005), but they examined fertility change in earlier periods (1981–2009) and focused on the tempo effect (Lee, 2013) or used the Bongaarts-Feeney method to adjust the tempo effect (Min & Yoo, 2020); this revealed considerable year-to-year fluctuations, especially in places like Korea, where changes in the childbearing age occur rapidly (Sobotka, 2003).

In essence, I apply the approach introduced in prior research (Kohler & Ortega, 2002; Ortega & Kohler, 2002; Sobotka et al., 2005) to the Korean context, but I employ an improved adjustment method and simplify the indexes of relative differences for intuitive interpretation. As stated, Sobotka et al. (2005) used the Kohler-Ortega adjustment, which was one of the most sophisticated methods to adjust tempo distortions at the time the authors conducted their research; however, the present study uses the latest adjustment methods proposed by Bongaarts and Sobotka (2012). Among a range of alternatives, the Bongaarts-Sobotka method provides the most stable and closest values to completed fertility (Bongaarts & Sobotka, 2012). As details on the adjustment method and decomposition approach can be found elsewhere (see Bongaarts & Sobotka, 2012; Sobotka et al., 2005), I only briefly introduce their approach to decomposition here and describe the method I use in this study.

### *Estimation of tempo-adjusted TFR*

The tempo effect in fertility indicates a distortion in period TFR caused by shifts in childbearing timing (Bongaarts & Feeney, 1998). Period TFRs are depressed when women's childbearing age increases in a society. Bongaarts and Feeney (1998) proposed a way to adjust tempo distortions in period TFR. In their approach, tempo-adjusted TFR (*adjTFR*) can be easily computed by dividing the period TFR by $1 - r$, where $r$ indicates the annual rate of change in women's mean childbearing age. This adjustment can be extended to birth-order components. While this approach is simple and intuitive, it also has several shortcomings. For instance, fertility schedules are assumed to be constant, but this assumption is frequently violated in real-world settings. The adjustment also cannot reflect shifts in the female population's parity distribution (Imhoff & Keilman, 2000; Kohler & Ortega, 2002; Ní Bhrolcháin, 2011). Simply put, Bongaarts and Feeney's (1998) *adjTFR* is unstable, with considerable fluctuations in countries like Korea where the change in the mean childbearing age is dramatic and rapid (Bongaarts & Sobotka, 2012).

To address these issues, demographers began to use alternative indicators of period fertility based on fertility tables (rates of the first kind) instead of conventional TFR (rates of the second kind). In this approach, tempo adjustment is applied to age- and parity-specific fertility probabilities, which are then converted into period fertility quantum. For example, Kohler and Ortega (2002) proposed a tempo distortion-free period fertility indicator based on increment-decrement fertility tables of different birth orders. Here, births are treated as repeatable events, as introduced by Park (1976) and Rallu and Toulemon (1993), while the tempo adjustment is also derived from the rate of change in the probability mean (rates of the first kind). The Kohler-Ortega method is considered to be an improvement compared to the Bongaarts-Feeney method, but fertility probabilities tend to be too high at higher birth orders to display stable trends.

Bongaarts and Sobotka (2012) proposed an alternative adjustment method that is an extension of the Bongaarts-Feeney approaches (Bongaarts & Feeney, 1998, 2008). This method, also known as tempo- and parity-adjusted TFR (*adjTFRp*), also uses fertility tables of different birth orders, but births are treated as non-repeatable. Therefore, all women who have not reached parity $i$ are considered in estimating age-specific birth hazard rates for having the *i-th* birth. This method is distinguished from the Kohler-Ortega method that only uses women with the *i-th* birth. However, adjustment to the age-specific birth hazard rates is directly derived from the change in mean childbearing age (rate of the second kind), as in the Bongaarts-Feeney method. From among a range of alternative approaches, including the Kohler-Ortega method, this approach provides more stable period fertility that is free from tempo distortions and is also the closest to completed fertility. Therefore, in this study, I use the Bongaarts-Sobotka method to estimate TFR free from tempo distortions (*adjTFRp*).

### *Decomposition of the total number of births*

Utilizing tempo-free fertility indicators, Kohler and Ortega (2002; Ortega & Kohler, 2002) developed a way to decompose the total number of births into quantum, tempo, and age structure effects. Sobotka et al. (2005) extended the decomposition technique and applied it to analyse trends in the total number of births in European countries. Here, I briefly describe the core of the decomposition method they used, but I substitute the Kohler-Ortega adjustment with the latest adjustment proposed by Bongaarts and Sobotka (2012). Their approach decomposes a change in the total number of births into three factors: age structure effects, fertility quantum, and tempo distortions.

### *Age structure effects*

As stated, the total number of births is influenced by the size of the reproductive-age female population. However, because of fertility schedules, the impact of the female population on the total number of births varies by age. For instance, the extent to which the members of the female population who are in their late twenties contribute to the total number of births is different from the extent of the contribution of those members who are in late adolescence. To reflect this circumstance, the concept of *mean generation size* ($G$), originally proposed by Calot (1984), is employed. $G$ can be interpreted as the mean of the female population weighted by age-specific fertility rate at each age. This can be represented as follows:

$$G = \frac{\sum_x (f_x \cdot N_x)}{\sum_x f_x} = \frac{\sum_x (f_x \cdot N_x)}{TFR} = \frac{B}{TFR} \tag{1}$$

where $f_x$ and $N_x$ represent age-specific fertility rates and age-specific mid-year female population at age $x$, respectively. Put simply, $G$ is equal to the total number of births ($B$) divided by a conventional TFR.

### *Fertility quantum*

Period fertility quantum indicates the level of tempo-distortion-free period TFR. Again, I use the Bongaarts-Sobotka method to compute period TFRs free from tempo distortions based on fertility tables of each birth order up to the third birth or higher. Assuming that all women are exposed to having a birth of any parity, survivorship is computed for each parity independent of the other parities (Bongaarts & Sobotka, 2012). In the formula below, $p_{x,t,i}$ represents conditional fertility probabilities (*first kind*) at the women's age at $x$ for birth order $i$ in time $t$, while $r_{t,i}$ indicates the rate of annual change in the women's mean childbearing age of birth order $i$ in time $t$ (*second kind*). For the tempo adjustment factor $1 - r_{t,i}$, I used the average change in the women's mean childbearing age between time $t - 1$ and $t + 1$. This measure adjusts tempo distortions caused by changes in the women's mean childbearing age and partial changes in the parity distribution of the female population.

$$adjTFRp = \sum_i \left\{ 1 - \exp\left[ -\sum_x \frac{p_{x,t,i}}{1 - r_{t,i}} \right] \right\} \tag{2}$$

### *Tempo distortions*

The extent to which period TFR is distorted can be measured in two different ways: absolute and relative terms. Tempo distortion usually indicates the absolute difference between conventional TFR and tempo-adjusted TFR. However, one of the goals of decomposition analysis is to evaluate the relative significance among factors of interest. Therefore, we can also measure the tempo distortions as a ratio of the conventional TFR to tempo- and parity-adjusted TFR, *adjTFRp*. I provide both here, but I use the relative measure of tempo distortions for decomposition analysis, which is the primary interest in this study. The relative size of tempo distortions ($T$) can be expressed as follows:

$$T = TFR/adjTFRp \tag{3}$$

### *Decomposition of the total number of births*

As described above, $G$ is equal to the total number of births *(B)* divided by a conventional TFR (see Eq. 1). Based on this relationship, we can estimate the total number of births when $G$ and conventional TFR are known. Then, the conventional TFR can be further divided into two components: fertility quantum (*adjTFRp*) and tempo distortions, where the tempo distortions are measured in relative terms. Thus, the total number of births can be represented by a product of three components: $G$, fertility quantum ($Q$), and tempo distortion ($T$).

$$\mathrm{B} = G \cdot TFR = G \cdot adjTFRp \cdot \frac{TFR}{adjTFRp} = G \cdot Q \cdot T \tag{4}$$

Eq. 4 above, which is a product of three factors ($G$, $Q$, and $T$), can be utilized to compare the total number of births between two time points, a base year (reference, 0) and year $t$. Any change in the total number of births between the base year (0) and time $t$ is necessarily caused by a change in one or more of the three factors on the right-hand side. The trend in the number of births can be expressed as shown below:

$$\frac{B_t}{B_0} = \frac{G_t \cdot Q_t \cdot T_t}{G_0 \cdot Q_0 \cdot T_0} \tag{5}$$

In Eq. 5 above, the ratio can be replaced with a relative difference or rate of change. The relative change is usually applicable when studying change over time in multiplicative models (Bongaarts & Potter, 1983; Romo, 2003, pp. 39–42). Then, the relative difference in the number of births can be expressed in additive terms as:

$$Bgrave; = Ggrave; + Qgrave; + Tgrave; + \epsilon \tag{6}$$

where the grave accent denotes the relative difference. To evaluate a relative change over time, I use a *rate of change* for each factor in comparison with the value in a base year 0. Therefore, the index of each factor becomes zero in the base year, unlike in Sobotka et al. (2005). The two approaches are basically identical, but interpretation is more intuitive when using rates of change. Rates of change for the number of births and the three factors are expressed as shown below:

$$IB_t = \frac{B_t - B_0}{B_0} \tag{7}$$

$$IG_t = \frac{G_t - G_0}{G_0} \tag{8}$$

$$IQ_t = \frac{Q_t - Q_0}{Q_0} \tag{9}$$

$$IT_t = \frac{T_t - T_0}{T_0} \tag{10}$$

We can decompose the index of the total number of births (*IB*) into effects of mean generation size (*IG*), fertility quantum (*IQ*), tempo distortions (*IT*), and possible interactions between these three effects. If we consider the interactions between the three effects as residuals ($\varepsilon$), then this can be expressed in additive terms, as shown below:

$$IB_t = IG_t + IQ_t + IT_t + \varepsilon \tag{11}$$

Eq. 11 above can be easily transformed into the number of births by multiplying both sides by the total number of births at the selected baseline year ($B_0$). Therefore, we can estimate the change in the number of births attributable to each factor between the baseline year and year *t:*

$$B_0 \cdot IB_t = B_0 \cdot (IG_t + IQ_t + IT_t + \varepsilon) \tag{12}$$

Sobotka et al. (2005) selected the year in which fertility postponement was initiated as a reference. However, in this study, I use 2001 as the base year to explore the extent to which the three factors contributed to the decline in the total number of births in the era of lowest-low fertility. The reasoning is that Korea's period TFR first reached 1.3 during that year and has never risen above that level. The tempo-adjusted TFRs and decomposition analysis are conducted by birth order, that is, first, second, and third or higher.

### *Extended decomposition of mean generation size (G)*

In the decomposition above, the change in mean generation size (*G)* captures the impact of change in the female population on the change in the total number of births. However, strictly speaking, it is an indirect measure. An additional decomposition analysis of *G* enables us to estimate the effects of the change in female population size directly (Sobotka et al., 2005, pp. 11–15). As seen in Eq. 1, *G* is the mean of the female population weighted by age-specific fertility rate at each age. If we disregard the distinction between fertility quantum and tempo distortion, the mean generation size, *G*, can be expressed as

$$\mathrm{G} = \frac{\sum_x (f_x \cdot N_x)}{\sum_x f_x} = \sum_x (\pi_x \cdot N_x) \tag{13}$$

where $\pi_x$ corresponds to the relative distribution of fertility schedule at age *x*, $\pi_x = \frac{f_x}{\sum_x f_x}$.

Then, the change in *G* can be decomposed into two component effects. The change in *G* between time *0* and time *t* is attributable to changes in the relative distribution of fertility schedule ($\Delta\pi_x$), changes in the age structure and size of female population ($\Delta N_x$), and residuals ($\varepsilon$), as below.

$$G_t - G_0 = \sum_x (\pi_{xt} \cdot N_{xt}) - \sum_x (\pi_{x0} \cdot N_{x0}) = \sum_x (\Delta[\pi_x] \cdot N_{xt}) + \sum_x (\pi_{xt} \cdot \Delta[N_x]) + \varepsilon \quad (14)$$

The residuals indicate the difference between observed and estimated change in $G$. By dividing both sides with the mean generation size at time $0$ ($G_0$), we get the rate of change in the mean generation size, $IG_t$ as in Eq. 12. Therefore, we can evaluate the contributions of two components, shifts in fertility schedule ($S$) and changes in female population size ($N$), to the changes in mean generation size ($G$) and then, to the changes in the total number of births ($B$) in turn. This work can be done for total births or by birth order separately. Again, I conduct this decomposition for each birth order up to third or higher order births and then summate order-specific results to illustrate the results for total births.

## Results

### *Descriptive analysis*

Since the TFR reached 1.3 in 2001, the number of births has declined in all birth orders (Figure 3). The number of first births decreased from 267,664 in 2001 to 168,565 in 2019, a decline of 37.0 per cent (99,099 births). However, the pace of the decline was faster in both second and third or higher births. Compared to 2001, the number of births for the second and third or higher order in 2019 shrank by 54.0 per cent, from 235,671 to 108,391, and by 54.6 per cent, from 56,486 to 25,660, respectively. Thus, the decline between 2001 and 2019 was more pronounced among second and third or higher births than in first births.

In this study, the age structure and size of the childbearing female population is captured by the concept of $G$. Figure 4 displays the trends in the average for the age-specific

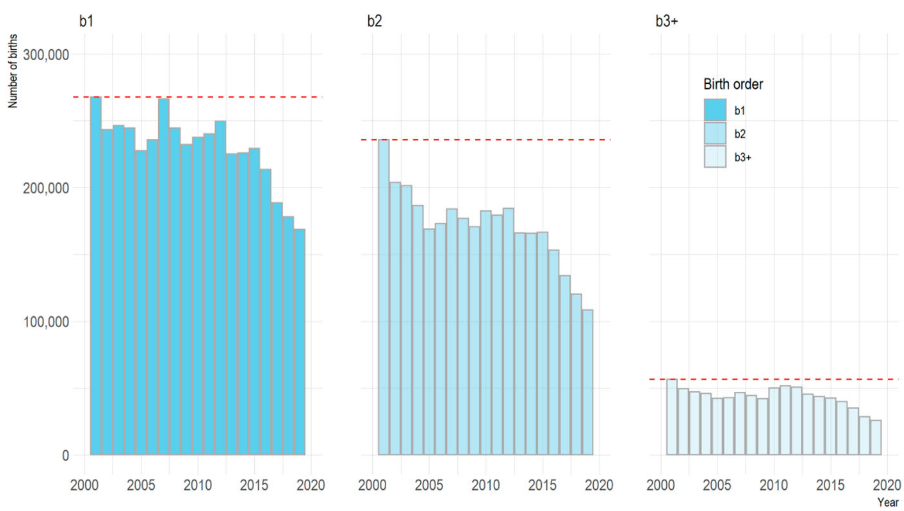


**Figure 3.** Total number of births by birth order, South Korea, 2001–2019. *Note*. The dotted line indicates the number of births for each birth order in 2001. Source: Vital Statistics 1970–2019 (KOSIS, 2020).

female population and mean generation size (*G*) for each birth order. Weighted by fertility schedule, the mean generation size varies with birth order. Given that the fertility schedule for higher-order births tends to be concentrated on older ages with a larger female population, the mean generation size for third or higher births is larger than that of both first and second births. While the average for the age-specific female population moderately declines over time, the mean generation size in each birth order declines more rapidly. As a result, the mean generation size was greater in all birth orders than the average for the age-specific female population in 2001 but lower than that of 2015 and afterward for first and second births, respectively. The mean generation size for third or higher births gradually approaches the average for the age-specific female population but remains above it in 2019.

In the meantime, the postponement of childbearing has continued in all birth orders for the observed period (not shown here). For example, women's mean age at first birth increased from 27.3 in 2001 to 31.4 in 2019. Women's mean age at second and third or higher birth also increased from 29.3 to 33.0 and from 32.3 to 34.5, respectively, though to a lesser degree than that of first birth.

The sustained rise in the mean childbearing age indicates that the tempo distortion caused by childbearing postponement remains considerable. Figure 5 illustrates the period TFR and tempo-and-parity adjusted TFRs (*adjTFRp*) based on Bongaarts and Sobotka's (2012) method. The gap between TFR and *adjTFRp* for first birth was somewhat reduced between the mid-2000s and mid-2010s, but it began to widen again from 2015 onward because of increased childbearing postponement. Between 2001 and 2019, the tempo distortion-free TFR for first birth declined from 0.910 to 0.811 (a 10.9 per cent fall), while the conventional TFR of first birth declined from 0.637 to 0.519 (an 18.5 per cent fall). For second and third or higher births, the tempo-distortion-free TFR followed a downward trend with minor fluctuations, in tandem with the conventional TFRs. For second birth, the tempo-adjusted TFR declined rapidly from 0.735 to 0.474

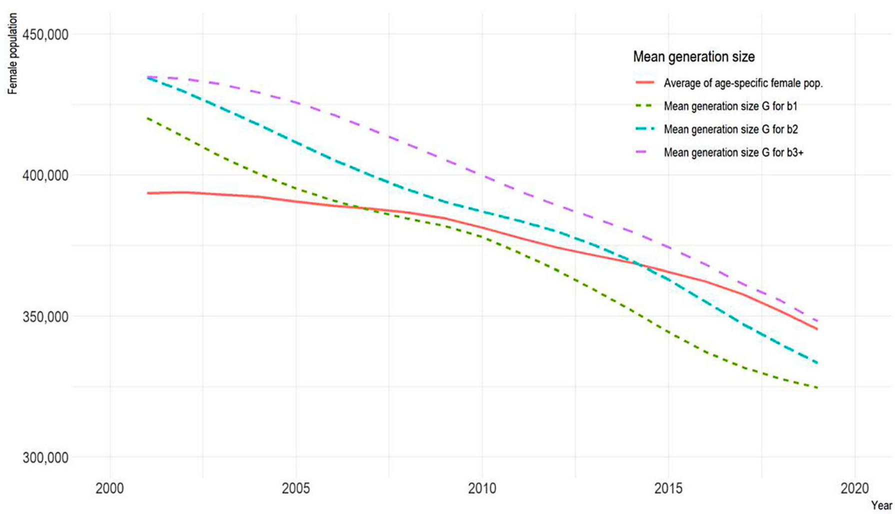


**Figure 4.** Average of the age-specific childbearing female population (aged 15–49) and mean generation size (*G*) by birth order, 2001–2019.

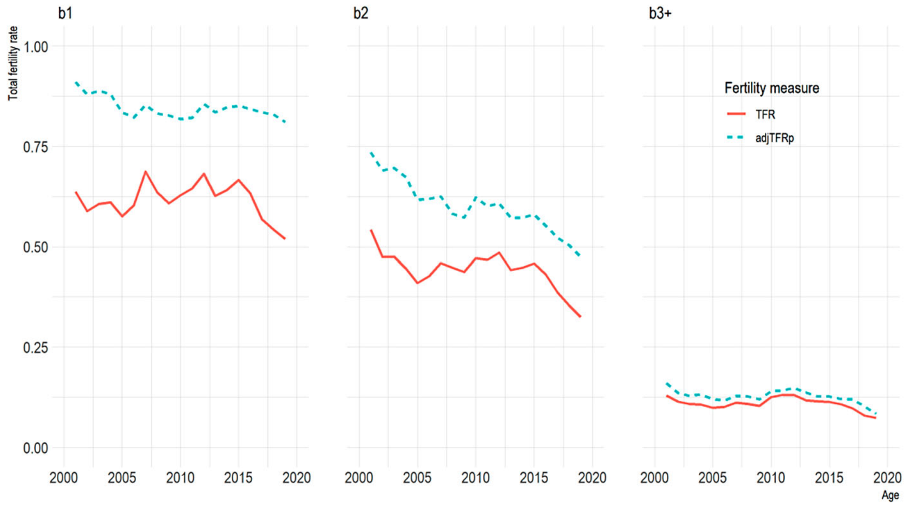


**Figure 5.** Order-specific total fertility rates (*TFR*) and tempo-adjusted total fertility rates (*adjTFRp*), South Korea, 2001–2019. *Note*. Tempo-adjusted total fertility rates (*adjT*FRp) were based on the Bongaarts-Sobotka method (Bongaarts & Sobotka, 2012).

(a 35.5 per cent drop), with the most significant decline occurring since the early 2010s. A similar trend is observed in third or higher births, which have declined by 47.4 per cent, from 0.161 to 0.084, primarily since the early 2010s. The relative change in fertility quantum was more pronounced among third or higher births, but its contribution to the overall decline of tempo-distortion-free TFR was the largest among second births.

## *Decomposition analysis*

Figure 6 illustrates the indexes of relative change in the total number of births and the three components in comparison with the reference year (2001). The decomposition result for the period 2001–2019 is presented in Table 1. The index of the total number of births (*IB*) reveals a considerable decline with periodic changes: specifically, a decline in the early 2000s, moderate fluctuations between the mid-2000s and mid-2010s, and a significant decline since the mid-2010s. As a result, the total number of births in 2019 declined by as much as 45.9 per cent in comparison with 2001.

In the same period, the index of mean generation size (*IG*) shows a gradual, monotone downward trend, recording a 22.7 per cent drop. The decline in mean generation size

**Table 1.** Indexes of relative change in the number of births, mean generation size, fertility quantum, tempo distortions, and interactions in 2019 compared to 2001.

| | | Birth order | | |
|---|---|---|---|---|
| Item | Total | 1st | 2nd | 3rd+ |
| Indexes of relative change | | | | |
| Number of births (IB) | −0.459 | −0.370 | −0.540 | −0.546 |
| Mean generation size (IG) | −0.227 | −0.228 | −0.233 | −0.199 |
| Fertility quantum (IQ) | −0.249 | −0.109 | −0.355 | −0.474 |
| Tempo distortions (IT) | −0.062 | −0.085 | −0.071 | 0.078 |
| Residuals | 0.079 | 0.051 | 0.118 | 0.049 |

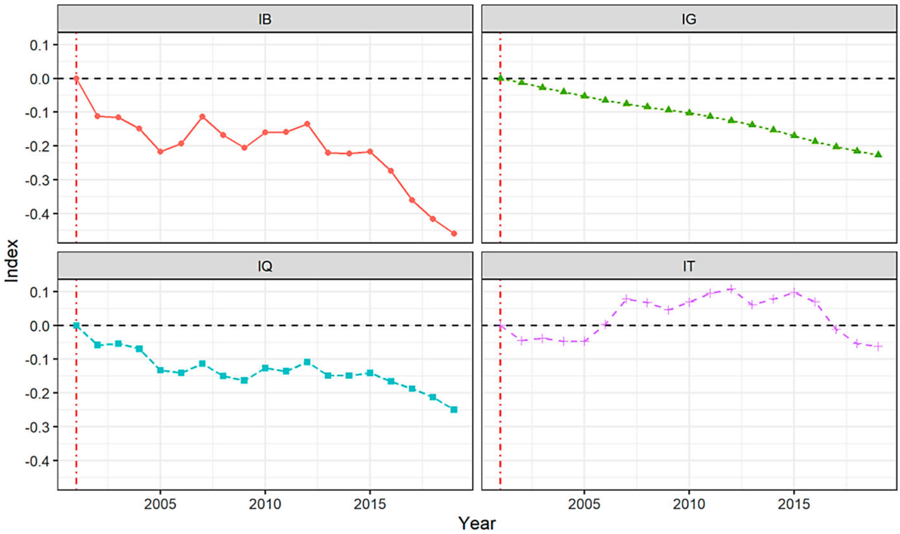


**Figure 6.** Indexes of relative change in the total number of births (*IB*), mean generation size (*IG*), fertility quantum (*IQ*), and tempo distortion (*IT*), 2001–2019. *Note*. Indexes are rates of change in each component in comparison with a base year, 2001.

accounts for nearly half of the total decline in the number of births between 2001 and 2019. Mean generation size shrinkage has been quite stable over the observed period, negatively affecting the total number of births.

The index of fertility quantum (*IQ*) also follows a downward trend, which is similar to the trend in the *IB*, although to a lesser extent. Fertility quantum declined in the early 2000s, fluctuated moderately between the mid-2000s and mid-2010s, and declined further after the mid-2010s. Fertility quantum declined by as much as 24.9 per cent, accounting for 54.3 per cent of the birth deficit since the beginning of lowest-low fertility. The fertility quantum's contribution to the birth dearth is comparable to that of mean generation size, although the former's trend features more active fluctuations.

Unlike other indexes that display an overall coherent direction, the index of tempo distortions (*IT*) shows more dynamic changes. *IT* was negative until 2005; it became positive between 2006 and 2016, offsetting the negative effects of the other two factors, namely the *IG* and the *IQ*, on the total number of births. However, the *IT* also eventually turned negative again in 2017, contributing thereafter to the declining number of births. It should be noted that the *IT* is measured in comparison to the base year, 2001, which is a year when tempo distortions were already high. Therefore, the positive *IT* values between 2006 and 2016 are not positive tempo distortions, but rather a lesser extent of tempo distortion compared to 2001. Given the sustained delay in childbearing, tempo distortions, in absolute terms, remain strong throughout the observed period.

Figure 7 illustrates trends in the indexes of the total number of births and the three components by birth order. The order-specific index of the number of births generally shows a downward trend, with a considerable fall after the early 2010s in all birth orders. Compared to the base year, 2001, the number of first births declined by as

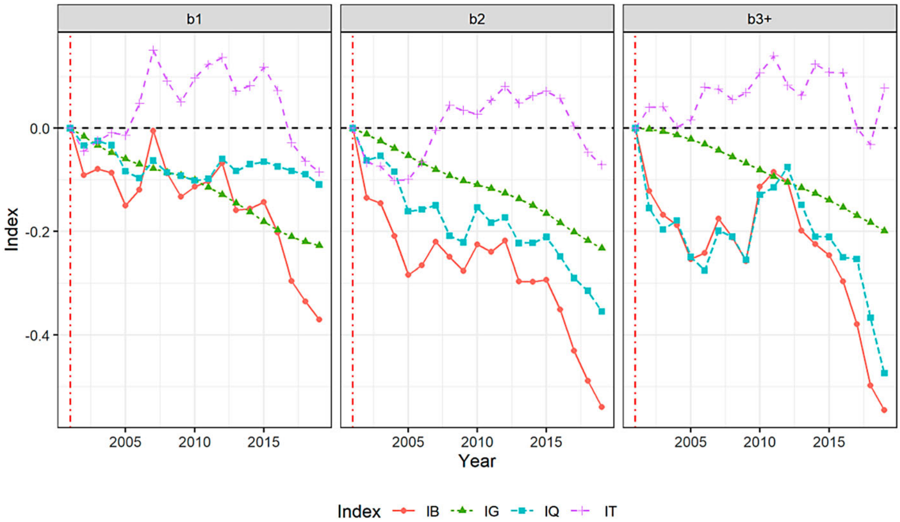


**Figure 7.** Birth-order specific indexes of the total number of births (*IB*), mean generation size (*IG*), fertility quantum (*IQ*), and tempo distortion (*IT*), 2001–2019.

much as 37.0 per cent in 2019, but the extent of the birth decline was more severe for second and third or higher births, which recorded drops of 54.0 per cent and 54.6 per cent, respectively.

All birth orders share a more or less monotone downward trend for the *IG*. The extent to which mean generation size declined is similar between birth orders, ranging from −23.3 per cent for second births to −19.9 per cent for third births or higher (see also Table 1). The trend in the *IT* is quite unstable over time, with variations over birth orders. The *IT*, which was positive until the mid-2010s, turned negative near the end of the observation period in all birth orders, except for third or higher births. Compared to the base year, 2001, the extent of tempo distortions was smaller by the mid-2010s, partly offsetting the reduced births in all orders between the late-2000s and mid-2010s. However, in the late 2010s, the magnitude of the tempo distortions in first and second births exceeded those in 2001 and contributed to the decline in births.

The *IQ* also exhibits an overall downward trend, but the extent to which fertility quantum contributed to the number of births varies with birth order and year. For first births, the fertility quantum declined until 2006 and has since fluctuated until the end of observation, recording a 10.9 per cent decline in 2019 compared to 2001. In contrast, the quantum indexes of second and third or higher births experienced long-term decline, with a bump in the early 2010s and drops of 35.5 per cent and 47.4 per cent in 2019, respectively. Of the three factors illustrated in Figure 7, the *IQ* is the closest to that of the *IB* in all birth orders.

Based on the indexes of relative change, we can compute estimates of the change in the number of births attributable to each component, as illustrated in Figure 8. Table 2 summarizes the results of the decomposition analysis regarding the number of births. It also provides estimates of the three components' relative importance. In the upper panel of Table 1, the change in the total number of births between 2001 and 2019 is

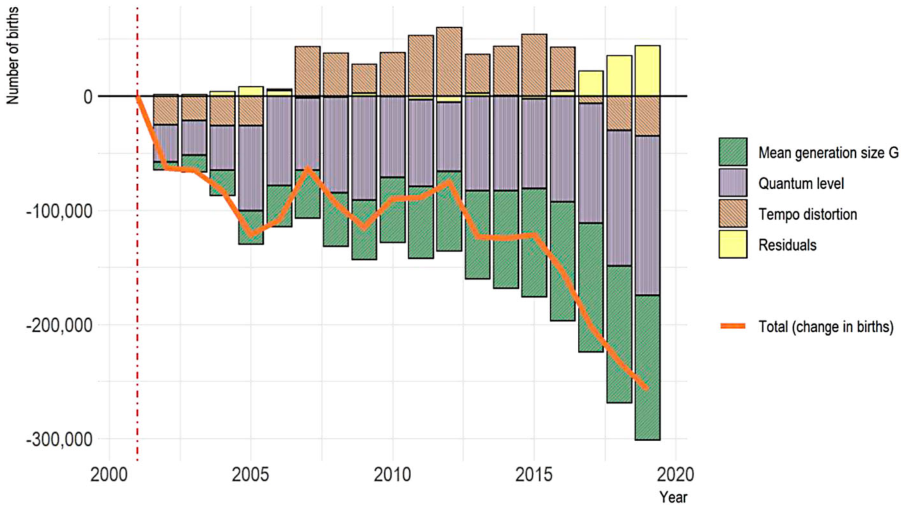


**Figure 8.** Total number of lost and gained births attributable to the three components and their interactions, 2001–2019.

decomposed into three components and their interactions (residuals), and then further disaggregated by birth order. Each of those components' relative contribution to the overall decline in the number of births is provided in the lower panel.

As mentioned above, the total number of births declined by as many as 257,205 (−45.9 per cent) between 2001 and 2019. Fertility quantum decline was the primary factor leading to the birth decline that has been persisting since 2001. More than half of the birth deficit is explained by the quantum decline (54.3 per cent). However, the shrinking mean generation size has also had comparable effects on the decline in the number of births, as it accounts for 49.4 per cent of the drop. Although its magnitude is smaller than that of other factors, tempo distortions caused by delays in childbearing and changes in parity composition also contributed to reduced births by 13.6 per cent. The

**Table 2.** Decomposition of the total number of births between 2001 and 2019.

| Item | Total | Birth order 1st | 2nd | 3rd+ |
|---|---|---|---|---|
| Total number of births | | | | |
| Births in 2019 | 302,616 | 168,565 | 108,391 | 25,660 |
| Births in 2001 | 559,821 | 267,664 | 235,671 | 56486 |
| Difference (2019–2001) | −257,205 | −99,099 | −127,280 | −30,826 |
| Difference in births attributable to | | | | |
| Mean generation size G | −127,038 | −60,924 | −54,864 | −11,250 |
| Fertility quantum | −139,620 | −29,218 | −83,629 | −26,773 |
| Tempo distortions | −34,935 | −22,683 | −16,680 | 4,427 |
| Residuals | 44,389 | 13,726 | 27,893 | 2,770 |
| Relative contribution to the difference | | | | |
| Total | 100.0% | 38.5% | 49.5% | 12.0% |
| Mean generation size G (IG) | 49.4% | 23.7% | 21.3% | 4.4% |
| Fertility quantum (IQ) | 54.3% | 11.4% | 32.5% | 10.4% |
| Tempo distortions (IT) | 13.6% | 8.8% | 6.5% | −1.7% |
| Residuals | −17.3% | −5.3% | −10.8% | −1.1% |

Note. Relative contributions were based on the absolute difference in the total number of births between 2001 and 2019. Components may not sum to totals because of rounding.

negative effects of these three factors on the total number of births are partly offset by possible interactions between them (17.3 per cent).

Order-specific results demonstrate that the extent to which each factor contributed to the overall decline in the number of births differs greatly by birth order. The decline in second births (127,280) was larger than that of first births (99,099), accounting for 49.5 per cent of the total decline in births between 2001 and 2019. In particular, a decline of 83,629 births, 32.5 per cent of the total reduction in births, is entirely attributable to the decline of the second-birth fertility quantum, which is the largest order-specific component contributing to the decrease in the total number of births between 2001 and 2019. This reflects the fact that the second-birth fertility quantum has plummeted by 32.5 per cent over the past 18 years. Third or higher births also showed a remarkable fertility quantum drop, exceeding that of second births, but because of the former's smaller share, its contribution to the decline in the total number of births is limited to 12.0 per cent of the overall birth decline.

## *Extended decomposition of the mean generation size (G)*

The strong effects of the change in mean generation size do not necessarily indicate that the change in female population size contribute to the birth deficit to a similar extent. This section is to evaluate the contribution of the change in female population to the change in mean generation size. Table 3 illustrates additional results that decompose the effects of mean generation size ($G$) shown in Table 1 & 2 into two components, one attributable to the shifts in fertility schedule ($G_S$) and another attributable to the change in female population size ($G_N$).

The decomposition analysis of $IG$ suggests that the decline in the mean generation size was mainly determined by the decline in female population (Table 3). The index of mean generation size ($IG$) declined 22.7 per cent for the period between 2001 and 2019, but the change in female population size accounts for 100.6 per cent of the drop (−0.241 out of −0.227). The contribution of the shift in fertility schedule is limited to −9.8 per cent of the $IG$ drop (0.022 out of −0.227), but rather operate in the opposite direction. The residuals remain marginal, 3.3 per cent of the $IG$ drop (−0.008 out of −0.227). The importance of the decline in female population is also confirmed in order-specific analyses, though its relative contribution to the change in mean generation size differ slightly by birth order.

**Table 3.** Extended decompositions of the mean generation size G.

| Item | Total | Birth order 1st | 2nd | 3rd+ |
|---|---|---|---|---|
| Based on the index of mean generation size | | | | |
| Index of mean generation size (IG) | −0.227 | −0.228 | −0.233 | −0.199 |
| Fertility schedule ($G_S$) | 0.022 | 0.005 | 0.036 | 0.046 |
| Female population size ($G_N$) | −0.241 | −0.263 | −0.229 | −0.186 |
| Residuals (ε) | −0.008 | 0.031 | −0.040 | −0.058 |
| Difference in births between 2001 and 2019 attributable to | | | | |
| Mean generation size (G) | −127,038 | −60,924 | −54,864 | −11,250 |
| Fertility schedule (Gs) | 12,409 | 1,293 | 8,547 | 2,569 |
| Female population size ($G_N$) | −134,920 | −70,416 | −53,978 | −10,527 |
| Residuals (ε) | −4,527 | 8,199 | −9,434 | −3,292 |

Note. This is the result from the extended decompositions of mean generation size ($G$). The values for total are based on birth-order specific results. Components may not sum to totals because of rounding.

The change in female population explains 116.0 per cent, 98.4 per cent, and 93.6 per cent of the change in the mean generation size for first, second, and third or higher order births, respectively.

In sum, for the period between 2001 and 2019, the decline in mean generation size *G* was overwhelmingly determined by the decline in female population, rather than shifts in fertility schedule. As a result, the results clearly suggest that nearly half of the birth deficit for the period is attributable to the change in age structure and size of childbearing female population.

## Discussion and conclusion

Korea's TFR, which has remained below 1.3 since 2001, declined further in recent years, hitting a record low of 0.92 in 2019, which is the lowest among the OECD countries. The decline in the total number of births was far more severe than the decline in fertility, plummeting by 45.9 per cent during the same period. This study decomposes the decline in the total number of births between 2001 and 2019 into three factors, namely the mean generation size, the fertility quantum, and tempo effects.

The remarkable decline in the total number of births since the onset of lowest-low fertility is mainly attributable to both quantum decline and shrinking generation size. First, fertility quantum decline was found to be the primary factor accounting for more than half of the decline in the total number of births between 2001 and 2019. Fertility free from tempo distortions declined in all birth orders, but its negative impact on the number of births was especially pronounced among second births. Fertility quantum free from tempo distortions for second births showed a clear downward trend over the period of lowest-low fertility. Second, the mean generation size, which is the mean of the female population weighted by fertility schedule, also had a profound negative impact on the number of births. The mean generation size gradually declined throughout the observation period. The decline in the mean generation size was largely led by the decline in the size of reproductive-age female population, which is distinct from European experience (Sobotka et al., 2005). Lastly, tempo distortions have remained strong in Korea (e.g., Yoo & Sobotka, 2018), but have contributed to birth decline only in recent years, as indicated by the finding that the relative change in this component in comparison to the base year, 2001, was marginal.

The findings suggest that the total number of births in Korea will continue to decline for a while. As Lutz et al. (2008) noted, a smaller number of potential mothers results in fewer births, implying negative spiral effects. Shrinkage in the young cohorts caused by sustained low fertility since the early 1980s and further subsequent declines has negatively affected the total number of births in Korea. According to Statistics Korea (2019), the population of women aged 15–49 will be about 9.3 million in 2035, which is 22 per cent less than the current (2020) population of 11.9 million. Therefore, a further decline in the total number of births may be unavoidable in the future, even if an immediate fertility rebound takes place. Such a consistent decline in cohort size would also accelerate population aging, which is already threatening Korean society's economic sustainability, education, defence, and finances.

One of the findings indicates that second-birth fertility has continued to decline in the era of lowest-low fertility. Tempo-adjusted fertility for second births in Korea rapidly declined from 0.727 in 2001 to 0.474 in 2019. In most developing countries, the fertility transition to near-replacement levels is accompanied by a fall in the progression to third or higher births, which is usually irreversible once it happens (e.g., Abbasi-Shavazi et al., 2009; Yoo, 2014). Falling second-birth fertility might signal the emergence of another order-specific transition in the era of lowest-low fertility, which contrasts the fertility pattern in Western countries. Consequently, there is no sign of fertility decline reversal or slowdown in Korea (c.f. Esping-Andersen & Billari, 2015; Frejka et al., 2018). This study does not provide reasons for the declining second births. However, one possible explanation might be intergenerational transmission of and socialization into low fertility. As low fertility lasts more than three decades, young generations may regard having one child as the new childbearing norm. Young people of childbearing age were primarily born in and after the 1980s, and most grew up with no more than one sibling and enjoyed economic prosperity and a tertiary education. Therefore, it might be onerous for them to have more than two children, if they already have difficulty balancing work and family. Further investigations are needed to determine whether the fall in the second-birth rate is persistent and whether other developing countries suffering rapid fertility decline are also experiencing declining second births.

The findings of this study imply that policies aimed at raising Korea's birth rates have not yet been effective. However, given the long-term trends in marriage, divorce, and childbearing, a turnaround in fertility was rather unlikely. The government has spearheaded extensive efforts aimed at raising the birth rate, such as implementing diverse policies ranging from financial incentives to parental leave, but these efforts usually focus on promoting marriage and procreation. In this sense, one may interpret this study's findings in a different way; that is, policy works to some extent, at least in mitigating a further drop in the number of first births. However, policies promoting second or higher-order births deserve more consideration.

The approaches and analyses in this study are not without caveats. First, the age and parity distribution of the female population, which is required to estimate *adjTFRp,* is not available, so this study employs the adjustment based on observation of the 2000 population census and order-specific births for each year. There are other ways to estimate the age and parity distribution. However, given that the adjustment in this study is already based on detailed data, any estimated distributions produced using the alternative methods would be similar. Second, focusing on the era of lowest-low fertility, this study uses 2001 as a reference year. Due to the nature of decomposition analysis, the relative contributions of generation size, fertility quantum, and tempo effects to the declining number of births can differ depending on the reference year. However, the relative contributions do not affect the overall trends the abovementioned factors follow, nor do they alter the study's findings. The *IT*, which was also measured relative to 2001, shows less variation than other factors. This does not mean that the tempo effects were negligible. Rather, the tempo effects, in absolute terms, remain strong throughout the observations, continuously depressing Korea's period TFR. Lastly, some of the birth deficit are attributed to the residuals in the decomposition. The sizable residuals reflect significant interactions between mean generation size, fertility quantum, and tempo distortions. Alternative decompositions might provide a better interpretation by eliminating the residual term, but are unlikely to change the findings of this study.

Despite these limitations, the present study sheds light on factors related to the declining number of births in Korea since the period TFR reached 1.3 or below. Rigorous analysis of fertility changes in this study have provided a better understanding of how such extremely low fertility has continued and declined further in Korea. The shrinking generation size, caused by sustained low fertility, has begun to contribute to a decline in new cohorts, which imposes significant demographic burdens on Korean society. The Korean case contributes to the literature by enriching the discussion about the process of post-transitional fertility in developed countries with low fertility and providing significant implications that might be helpful for most developing countries experiencing rapid fertility decline.

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## Disclosure statement

No potential conflict of interest was reported by the author(s).

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## Appendix: Adjustments of census parity distributions

The analytic procedure utilized in this study includes the reconstruction of female parity distribution by age between 2001 and 2019. Statistics Korea releases the number of births by mother's age and birth order, and the mid-year female population by age annually, and these data are available online (kosis.kr). Therefore, both order-specific TFRs and age-specific fertility rates (ASFRs) can be easily computed. However, tempo- and parity- adjusted TFRs (*adjTFRp*) require the age and parity distribution of the female population, which is not available.

Alternatively, we use the age and parity distribution of the female population obtained from the 2000 population census to estimate the age and parity distribution for the following years up to 2019. The approach used in this study is like that described in the Human Fertility Database method protocol (Jasilioniene et al., 2009, pp. 33-35).

We first obtain the female population exposure for age $x$ and time $t$, $E(x,\ t)$, from the mid-year female population, $P(x,\ t)$, as follows:

$$E(x,\ t) = \frac{P(x-1,\ t-1) + P(x,\ t)}{2}$$

If we define the population weight of women aged $x$ at parity $i$ as $w_i(x)$, the population weight of women aged $x$ at parity $i$ as of January 1, 2000 is computed as follows:

$$w_i(x,\ 2000) = (1-Z)\cdot w_i(x-1,\ T) + Z\cdot w_i(x,\ T)$$

$$\sum_{i=1}^{3+} w_i = 1$$

where $Z$ is a fraction representing the days elapsed since the beginning of the year to the date of the census. The year 2000 was a leap year, and the Korean census was taken on November 1. Therefore, in this case, we have $Z = 182/366$.

Once women's age- and parity-specific population weights for the base year are obtained, the population weights for the following years can be estimated, as follows:

$$w_0(x+1,\ t+1) = w_0(x,\ t) - f_1(x,\ t)$$

$$w_i(x+1,\ t+1) = w_i(x,\ t) - f_i(x,\ t) + f_{i-1}(x,\ t) \text{ for } i = 1,\ 2$$

$$w_{3+}(x+1,\ t+1) = w_{3+}(x,\ t) + f_3(x,\ t)$$

where $f_i(x,\ t)$ represents unconditional fertility rates at age $x$ and parity $i$ for year $t$. The unconditional fertility rates are based on the order-specific number of births and total population exposure $E(x,\ t)$. With the estimated population weights $w_i(x,\ t)$, we can also compute the order-specific population exposure $E_i(x,\ t)$, as follows:

$$E_i(x,\ t) = w_i(x,\ t)\cdot E(x,\ t)$$

The order-specific population exposure $E_i(x, t)$ can then be utilized to compute a set of table-based fertility measures. For example, *adjTFRp* in this study is based on $p_i(x, t)$, conditional fertility rates of birth order $i$, regarding births of each order as separate non-repeatable events. Therefore, the denominators of $p_i(x, t)$ can be obtained by summing all order-specific population exposures for all women who have not yet reached order $i$. Please refer to Bongaarts and Sobotka (2012) for details about how to compute *adjTFRp*.