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Abstract This study examines if the Korean fertility decline is driven by long-term cohort changes or by fluctuating period changes. By using a classic age–period–cohort model, a moment decomposition method, and a new summary fertility measure—'cross-sectional average fertility'—I show that the Korean fertility decline is primarily driven by period changes and that delayed childbearing has important consequences for the onset of fertility decline. These findings are in line with the existing literature in fertility changes such as theories of fertility transitions and sociological accounts of fertility changes in Western countries in the twentieth century. The policy implications of these findings are also discussed.

Keywords Fertility decline in South Korea · Cross-sectional average fertility (CAF) · APC analysis · Moment decomposition

Cohort, Period, and Fertility Transition

South Korea evolved from a high fertility country to a 'lowest-low fertility' country, defined as period total fertility below 1.2 (Kohler et al. 2002), in less than a half century. The period total fertility in South Korea was around 6.0 until the 1960s, but has rapidly declined since then. The period total fertility dropped below the replacement level (2.1) in 1983, and has continued declining ever since. According to *World Health Statistics 2010* (World Health Organization 2010), the period total fertility in South Korea was 1.2 in 2008, which is the lowest among the countries examined. This study examines this rapid fertility decline in South Korea by using a classic age–period–cohort (APC) analysis, a moment decomposition method, and a new summary fertility measure, 'cross-sectional average fertility' (CAF).

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The primary goal of the current study is to examine if fertility decline in South Korea is more associated with period effects than cohort effects. A birth cohort refers to a group of ‘real’ people born in the same year, and changes in social and demographic behaviors across birth cohorts indicate that the given society experiences social changes (Ryder 1965). For example, the reduction in completed cohort total fertility indicates that the level of fertility declines over time. By contrast, period measures in demography need to be interpreted with caution because these are constructed by resorting to a concept of ‘synthetic cohort’. For example, period total fertility is the average number of children ever born to women if they were exposed to the same risk of childbearing as in time t over their reproductive years. This condition is hardly met in contemporary populations in which vital rates change considerably over time. Three weaknesses of such period measures in demography are routinely pointed out: (1) The period measures reference no real population, (2) there is a contamination by period-specific events (e.g., fluctuation in economic conditions), and (3) the period measures are simply an average of cohort indices (Ní Brolchaín 1992; Ryder 1965). Since Ryder made these points, these criticisms have been widely accepted among demographers and substantial efforts have been made to translate period measures to cohort experiences. For fertility research, Ryder (1964) presented a seminal translation formula, and recent development of adjusted measures (e.g., Bongaarts and Feeney 1998; Kohler and Ortega 2002; Schoen 2004) is also an effort to correct the diversion of period measures from cohort experiences. For mortality research, Goldstein and Wachter (2006) showed that the difference between period life expectancy at time t ($e_0^p(t)$) and cohort life expectancy born in x years ago ($e_0^c(t-x)$) is almost constant for the majority of the twentieth century in Sweden and the US, suggesting that period life expectancy can be easily translated into cohort life expectancy with a ‘lag’. All these efforts, to some extent, are based on the notion that cohort differences capture social changes better than do period differences (Ryder 1965).

Despite the cohort-centered theoretical exposition of social changes in demography, it is an empirical task to see if social changes are more associated with cohort changes than period changes (Ní Brolchaín 1992). The APC analysis has been widely used to evaluate the relative importance of cohort and period changes, and empirical evidence suggests that this depends on outcomes of interest. In mortality research, Yang (2008) showed that all reduction in U.S. mortality in the second half of the twentieth century is explained by cohort effects. Cohort effects are dominant because cumulative effects of medical advancements and improvement of nutrition in early childhood are more pronounced through successive cohorts than periods. By contrast, the fertility changes in the twentieth century in the US and European countries were more associated with period change than cohort change. First, studies using the APC analysis found smaller cohort effects than period effects on the fertility in the US after controlling for one another (Pullum 1980; Rindfuss et al. 1988). This suggests that period change, instead of cohort change, drove fertility change. This is because temporal variations that cut across cohorts (e.g., economic cycles and adoption of new contraception methods) are more important than shared socializing experiences within cohorts in determining fertility (Pullum 1980). Second, studies using moment decomposition methods showed that cohort fertility indices (e.g., level, timing, and dispersion) are well-decomposed into period indices in the US and European countries but not vice versa (Calot 1993; Foster 1990). This indicates that cohort fertility indices are simply weighted averages of period fertility indices. In other words, cohorts' fertility behaviors differ from each other not because there is something unique in each cohort but because each cohort lived through different time periods over its life course. The current study examines if this pattern holds for the case of Korean fertility decline.

The comparison between cohort effects and period effects also has implications for the theories of fertility transition. These theories point to multiple causes of fertility decline such as mortality decline, economic development, rising cost of living, diffusion of permissive attitude toward birth control, and implementation of family planning program (Mason 1997; McDonald 1993). These factors have an affinity with period-centered explanations. For example, mortality decline, a precondition of the onset of fertility decline (Mason 1997), is better-conceived in terms of period change than cohort change. When couples observe or conceive a decreasing trend of infant mortality, then they may stop childbearing once they reach the desired number of surviving children. Such a trend is likely to affect the currently reproductive couples as a whole rather than a particular birth cohort although we cannot rule out the possibility that mortality decline may stimulate fertility transition by changing a cohort's expectation of survival chances. Other factors also are more likely to work through period than cohort while cohort-centered explanations are certainly possible in some instances. Hence, the theories of fertility transition suggest that fertility transition was more associated with period changes than cohort changes, and the current study will examine if this is the case in South Korea.

The discussion about cohort and period effects also has policy implications. Fertility decline is a driving force of population aging, and population policies in developed countries typically aim at boosting fertility. These policies include provision of financial incentives, support for parents to combine work and family, and stimuli to broad social changes conducive to childbearing and parenting (McDonald 2002). Provision of financial incentives may boost period effects, and broader social policies influencing childbearing and parenting may be related with cohort effects because these policies work in a longer time horizon. This suggests that trends of period effects and cohort effects also reflect the strengths of different types of population policies. In other words, period effects would be greater than cohort effects if fertility policies pursued the immediate fertility changes rather than broader socioeconomic changes. Gauthier (2007)'s review showed that policy effects on fertility depend on the type of policies: insignificant or small effects of cash benefit-type policies on fertility, positive effects of female labor force participation on fertility, and mixed evidence for the effects of work-related policies (e.g., maternity leave). Policies for gender equity in labor markets and work-family balance warrant a longer time horizon and broader perspective than cash benefit-type policies, and are likely to work through a cohort dimension instead of a period dimension. I also account for these policy implications when interpreting the APC results.

Fertility Decline in South Korea

In this section, I briefly describe the Korean fertility decline. Mortality decline, socioeconomic development, and spread of family planning programs, and reproductive health technology were important in the Korean fertility decline, which is well fit to the theories of fertility transition (Mason 1997; McDonald 1993). Based on primacy of each factor, we can roughly separate four stages of fertility decline in South Korea.

First, the onset of fertility decline in the 1960s followed improvements in mortality conditions after the Korean War (1950–1953); this is consistent with the *'classical demographic transition theory'* (Cohen and Montgomery 1998; Notestein 1945; Preston 1978). Improved mortality conditions, in conjunction with the post-war baby boom in the late 1950s and adverse economic conditions,[1] provided strong incentives for fertility controls. Under such socioeconomic conditions, induced abortions were widely used to avoid unwanted childbearing, and people delayed marriages (Kwon 1993). In this sense, the onset of fertility decline in South Korea was driven by both 'preventive checks' and 'positive checks' in Malthusian framework (Davis 1963).[2]

The period total fertility in the 1970s continued declining, but the causes for decline were somewhat different from the 1960s. Economic development and the implementation of family planning programs in South Korea drove the decline in the 1970s (Choe and Park 2006; Kwon 1993). For example, the Gross National Product (GNP) per capita grew 6.5 times (from $200 to $1,300) in the 1970s, and poverty rates declined substantially (Kwon 1993). Sterilization was introduced in the early 1970s and was widely adopted, and an intensive campaign was conducted to reduce ideal family size and lessen son preference. In addition, induced abortion was still an important means of avoiding unwanted birth because of strong son preference, which was reinforced by the advancement of fetus sex-detecting technology (Choe and Park 2006).[3] As a result, the period total fertility in South Korea kept declining in the 1970s.

In 1983, the period total fertility in South Korea reached the replacement level (2.1), but there was no indication of slowdown in the pace of decline in the 1980s. Population policies in South Korea continued to emphasize family planning in spite

[1] For example, about 43 % of all households lived under the absolute poverty line in the 1960 s (Kwon 1993).

[2] Population growth is determined by the difference between inflows (births and in-migrations) and outflows (deaths and out-migrations). In Malthusian framework, such flows are closely related to changing economic circumstances to maintain adequate population sizes. The 'preventive checks' indicate the mechanisms that control the rate of births to prevent too-rapid population growth, such as delayed marriages. The 'positive checks' indicate consequences of rapid population growth that have a negative feedback on population size, such as increasing mortality (Malthus 1953; Schofield 1989).

[3] Strength of son preference may be positively related to fertility level, because son preference would promote births holding other factors constant. However, when fetus sex-detecting technology is available and induced abortion is socially acceptable, fertility could be reduced. According to Lee (2003), the number of abortions was almost equal to the number of births in 1990 and the sex ratio at birth in 1990 reached the highest level, 115 baby boys per 100 baby girls. This suggests that son preference in Korea would contribute to the fertility decline.

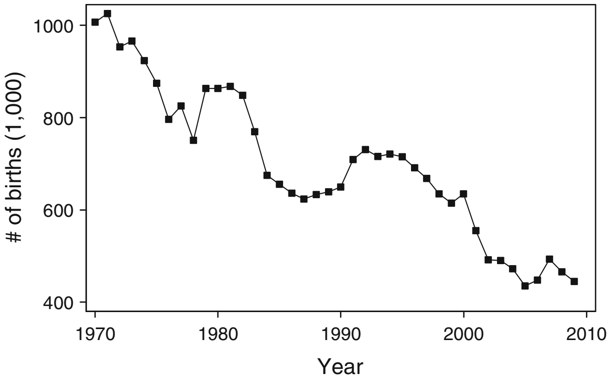

Fig. 1 Number of births in South Korea, 1970–2009

of the below-replacement level period total fertility. This was due to a lingering concern that population may increase fast once the post-war baby boom generation (born in the late 1950s and the early 1960s) entered primary childbearing age in the 1980s. Because of their large cohort size, even moderate levels of fertility would significantly increase the number of births. Figure 1 shows the change in the number of births in South Korea between 1970 and 2009. Although the overall trend suggests a decline in the number of births since the 1970s, there have been some fluctuations. In particular, there was an increase in births in the early 1980s. Because the period total fertility kept declining in this period, this increase in births reflects the large size of baby boomers.[4] The period total fertility continued declining in the 1980s in spite of fluctuation of birth streams. The advancement of medical technology such as ultrasound techniques facilitated detecting sex of the fetus, contributing to the overall downward trend and unbalancing sex ratio at birth (Choe and Park 2006). In addition, transition to parity three decreased substantially and contributed to the decline in the period total fertility during the 1980s (Han and Feeney 1993).

Fertility decline slowed to some extent in the 1990s. The steady decline, however, was still remarkable, given the extremely low level of period total fertility in this period. Patterns in fertility decline, however, differed from the previous period in several aspects. First, women's increasing economic participation contributed to fertility decline. More women participated in labor markets, and fertility differentials by employment status also increased (Choi 2004; Choe and Park 2006). There was also an increase in the proportion of childless women. While only 9 % of women would remain childless according to the parity progression schedule in 1990, 16 % of women would do so under the 2000 schedule (Choe and Park 2006). Economic crisis in 1997 also contributed to a further drop in fertility. Comparing two marriage cohorts—one married before economic crisis, and the other after the crisis—Lee (2006) found that women married after the economic

[4] Please see Lam and Marteleto (2008) for formal discussion about the relationship between changes in period fertility and cohort sizes.

crisis are less likely to give birth within 5 years of marriage. This additional delay in childbearing also led to the extremely low fertility in South Korea.

Research Questions

The current study aims at examining if fertility decline in South Korea is more associated with cohort changes than period changes. This is an application of formal demographic methods to the South Korean contexts, which will contribute to the literature in fertility change and bear implications for population policies. The following questions are examined:

1. How did the level of fertility change over time in South Korea?
2. After controlling for age effects, is Korean fertility transition more associated with period changes than cohort changes?
3. Do cohort moments (level, timing, and dispersion) of fertility account for period moments or do period moments account for cohort moments?

Regarding these questions, previous studies of fertility changes in industrialized Western countries have shown that (1) we need to adjust period total fertility to capture the change in the quantum of fertility due to the influences of period-specific events such as wars and economic shocks (Bongaarts and Feeney 1998; Kohler and Ortega 2002); (2) period effects are more dominant than cohort effects in explaining fertility changes (Pullum 1980; Rindfuss et al. 1988); and (3) cohort indices are weighted sums of period indices but not vice versa (Foster 1990). As discussed in the previous section, the Korean experience in the twentieth century is different from those of Western countries in two regards. First, the pace of fertility change in South Korea is much faster than in Western countries, suggesting the different patterns of period and cohort effects in South Korea than in Western countries. Second, fertility in South Korea has monotonically decreased since the 1960s, whereas Western countries experienced fluctuations in fertility in the twentieth century (Foster 1990). The difference in the direction of change may also matter. Nonetheless, the previous section suggests that the Korean fertility decline may be well explained by theories of fertility transition: mortality decline, socioeconomic development, and spread of family planning programs and reproductive health technology were important in the Korean fertility decline. These factors are more associated with period effects than cohort effects, suggesting that the Korean fertility decline is also more associated with period changes than cohort changes.

Methods

Trends in Fertility

The period total fertility is the most widely used in fertility studies. This information is readily available, and duly represents the current level of fertility after controlling for age structure. This measure, however, may be unduly influenced by idiosyncratic periodic fluctuations and would deviate from a cohort's experiences when fertility behaviors change rapidly. To correct this problem, tempo-adjusted measures have been proposed (Bongaarts and Feeney 1998; Schoen 2004), which require more information than period total fertility (e.g., parity progression). By contrast, completed cohort fertility reflects 'real' cohort experiences, but requires cohorts to have completed their reproduction. To have up-to-date completed cohort fertility, we are forced to make some assumptions about future fertility, which may or may not be correct depending on the historical context and nature of the data (e.g., Li and Wu 2003). In this study, I propose a new measure for fertility trend, the '*cross-sectional average fertility* (CAF).' This measure complements the weaknesses of the two conventional measures, and can be computed without assumptions about future fertility and additional information other than age-specific fertility rates.

This measure was originally developed to measure 'cross-sectional' average life expectancy (CAL) (Guillot 2003). CAL is a sum of cohort survival probability at time *t* and reflects past survival experience of cohorts alive at time *t*. Hence, it is arguably a better summary measure of mortality experience of the present population than period life expectancy. In addition, the CAL reflects cohorts' real experiences rather than those of a 'synthetic cohort'. Empirically, the CAL is almost always lower than period life expectancy and the trend of CAL is smoother compared to period or cohort life expectancy (Guillot 2003, p. 45). The lower value of CAL compared to period life expectancy represents mortality improvement over time, and the smoother trend shows the robustness of CAL to period- or cohort-specific mortality experiences.

In this study, I develop 'cross-sectional' average fertility (CAF) by revising CAL to summarize fertility experience. Whereas conventional period total fertility is a sum of period age-specific fertility rates (see the dotted box in Fig. 2), CAF is a sum of 'cross-sectional average' age-specific fertility rates of currently reproductive women. The cross-sectional average age-specific fertility rate is shown in the small trapezoids across ages in Fig. 2, and is defined in Eq. (1).

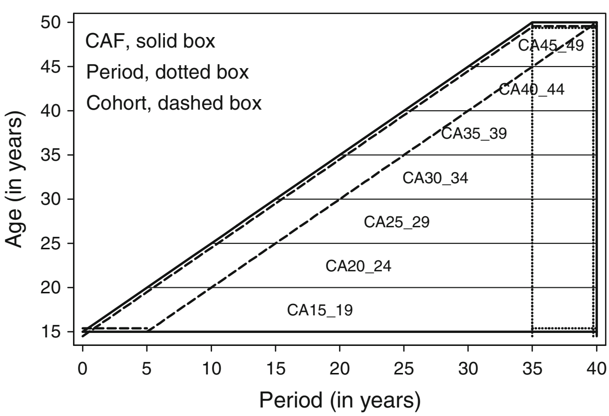

Fig. 2 Comparison of CAF, period total fertility, and completed cohort fertility

$$\text{Cross-sectional average age-specific fertility rate } \varphi_{ca}(x,t) = \sum_{y=x}^{49} \varphi_c(x, t-y)/(50-x) \quad (1)$$

(where $\varphi_c(x,t)$ is the fertility rate at age x of a cohort born at time t and $x = 15, 16,\ldots,49$).

For example, the cross-sectional average fertility rate for age 15 at time t ($\varphi_{ca}(15,t)$) is an average of currently reproductive women's fertility rates at age 15. So, the cross-sectional average age-specific fertility rates reflect the past childbearing experience of currently reproductive women, whereas period age-specific fertility rates only measure childbearing patterns at time t. The cross-sectional average age-specific fertility rates at younger ages reflect more cohorts' fertility experiences than those at older ages. In fact, $\varphi_{ca}(15,t)$ reflects all currently reproductive cohorts' fertility experience at age 15 whereas $\varphi_{ca}(49,t)$ reflects only one cohort's fertility experience that is exactly the same as the age-specific fertility rate at age 49 in time t. The CAF is shown as a big trapezoid in Fig. 2, and is defined in Eq. (2).

$$\text{Cross-sectional average fertility (CAF) at time } t = \sum_{x=15}^{49} \varphi_{ca}(x,t) \quad (2)$$

Cross-sectional average fertility is simply a sum of cross-sectional average age-specific fertility rates ($\varphi_{ca}(x,t)$). Figure 2 graphically compares three summary fertility measures: CAF, period total fertility, and completed cohort fertility. The vertical axis represents age, and the horizontal is for period. The dotted box in the right represents period total fertility in the last five-year period (35–40). The dashed parallelogram shown diagonally represents completed cohort fertility for those who finish their reproductive period in the same time interval. The large solid trapezoid represents CAF in the same period, which uses all information on age-specific fertility rates of currently reproductive women at time t. Both CAF and period total fertility are sums of age-specific fertility rates in which an equal weight is given to each age group. Hence, these are age-standardized summary fertility measures that can capture the levels of fertility after controlling for age structure of population. Because the CAF captures the 'real' past childbearing experience of currently reproductive women, this is arguably a better summary measure of childbearing experience of currently reproductive women than is the period total fertility. CAF also has an advantage over completed cohort fertility because we do not need to wait until a birth cohort completes childbearing nor must we make assumptions about future fertility.

Comparison between period total fertility and CAF tells us how strong tempo effects are on fertility measures. If there were no differences in the timing and quantum of fertility among currently reproductive women, the CAF would be equal to the period total fertility as well as completed cohort total fertility. Change in timing or quantum of childbearing should yield discrepancy among these three measures. Two things are worth mentioning regarding such tempo effects. First, the influence of tempo effects is smaller for the CAF than the period total fertility. In this sense, the CAF is more robust to period-specific fluctuations than the period total fertility. However, the impact of any drastic changes on the CAF lasts longer than that on the period total fertility. For example, a drastic fertility drop in 1 year does not have any mathematical relationship with the period total fertility in the next year although people are likely to behave differently from the previous period, and this may alter the period total fertility in the following year. By contrast, the drastic fertility drop in 1 year should have an impact on the CAF in following years because the CAF reflects past childbearing experiences. This is a shared property with CAL (Guillot 2003). Second, the influences of the change in tempo of fertility on the CAF are dependent on age, which is different from the period total fertility. To examine this issue more concretely, let us consider two hypothetical situations: (1) young women (e.g., age 25) forgo their births in a year versus (2) older women (e.g., age 40) forgo their births in a year. Let us further assume that cohort quantum of fertility does not change in either case. The implications for the period total fertility are dependent on the magnitude of reduction in births in a given year. In fact, age may matter because the magnitude of reduction is usually dependent on the age. In this way, a complete loss of births in a fertility-intensive age (e.g., around age 25) should have a larger impact on period fertility than that in older ages. However, there is no other reason that the age of forgone childbearing matters for period fertility. By contrast, the implications for the CAF are mathematically dependent on age. The change in young age has less impact on the CAF than that in old age: the cross-sectional average fertility at younger ages is the average of more cohorts than that at older ages. However, the influence of change in younger ages lasts longer because young women remain reproductive longer than their older counterparts and the influence of change in older ages soon fades away.

Age–Period–Cohort Analysis

Linear dependence among age, period, and cohort makes it difficult to identify age, period, and cohort effects separately after controlling for the other two (Fienberg and Mason 1979, 1985). In other words, after controlling for age, we cannot separate the linear cohort effect from the period effect or vice versa. As Glenn (2005) pointed out, the perfect solution to the identification problem cannot be obtained. Nonetheless, there are two ways to circumvent the identification issue. First, Fienberg and Mason (1979) proposed imposing constraints on at least one parameter based on 'prior knowledge' to identify the estimates. Usually, a pair of adjacent ages, periods or cohorts are assumed to have the same effects on the outcome. While this 'equality constraint' approach has been used as a disciplinary standard, the estimates are sensitive to the choice of indentifying constraint. The recent development of 'intrinsic estimators' (IE) advanced the conventional APC model in several ways. The IE imposes a constraint on the geometric orientation of the parameter vector instead of equality constraints on coefficients. The IE depends less on the prior knowledge and also provides more precise estimates than does the conventional APC model (Yang 2008; Yang et al. 2004). Another recent development to resolve the identification problem is Hierarchical Age–Period–Cohort (HAPC) models (Yang and Land 2006). Instead of assuming fixed linear effects of age, period, and cohort, the HAPC allows for estimating random period or cohort effects using repeated cross-sectional individual data. This multi-level model allows for controlling for other covariates as well as avoiding linear dependence among age, period, and cohort. Although the HAPC may be useful in understanding the Korean fertility decline, the current study uses the classic APC model and IE method because the data necessary to estimate the HAPC (e.g., repeated cross-sectional data) are not available.

Second, we may use our substantive knowledge about each element to avoid linear dependency. For example, period indicators in the APC model may be replaced by substantive period measures (e.g., unemployment rates), which are not linearly dependent on age and cohort indicators. Of course, cohort and age indicators can also be replaced by substantive measures like level of schooling (cohort) and fecundity (age). This approach is called the APC characteristic model and has several advantages. First, we can avoid arbitrarily imposing linear constraints on parameters. Second, this may provide substantive explanations as to why cohort or period effects are more important than the other. Finally, this approach may allow for examining interaction effects. In the classic APC model, each effect is assumed to be constant. In other words, the period effect is assumed not to be dependent on age and cohort, and this is also the case for age and cohort effects. Age patterns of fertility, however, may change across periods and cohorts when fertility declines, suggesting age-period and age-cohort interaction. Given the rapid fertility decline in South Korea, this possibility should be taken into account. The classic APC model cannot address this issue because of an identification problem. Using the APC characteristic approach can provide us with a tool to test such interaction effects. Despite the usefulness of the APC characteristic model, replacing cohort or period by measured characteristics is also imperfect because measured proxies may not fully account for cohort or period (Yang 2011). Please see O'Brien (2000) and O'Brien et al. (2008) for more detailed discussion about this approach.[5]

Coale and Trussell's (1974) parametric marital fertility model is an example of such an APC characteristic model. This model uses the fact that marital fertility follows predictable age patterns. This model captures how the level of marital fertility and the degree of marital fertility control in a population differ from natural fertility. This model is initially developed to capture the degree of parity-specific control when the information about parity progression is not available, and can be extended to compare cohort and period effects on marital fertility. The Coale and Trussell model is specified as follows (Coale and Trussell 1974, p. 187; Wachter 2007):

$$\ln \frac{r(x)}{n(x)} = \ln(M) + m \cdot v(x) \tag{3}$$

[5] The APC characteristic model also can be used to estimate causal effects of age, period, and cohort on outcomes of interest by specifying mechanisms that generate each effect. This is based on the idea of Pearl's (2000) 'front-door criterion'. Winship and Harding (2008) applied this method to estimate causal effects of age, period and cohort on political alienation. The current study does not apply the APC characteristic model in analyzing fertility data because data are not available.

(where $r(x)$ is fertility rate at age x, $n(x)$ represents age-specific marital fertility rates under natural fertility, $v(x)$ is the weight for impact of fertility limitation on fertility rates for age x, M is background level of natural fertility, and m is the extent of fertility limitation).

In this specification, we need to have a set of values for $n(x)$ and $v(x)$ in advance. The $n(x)$ values represent marital fertility rates under natural fertility, which show an inverted U-shape with much higher rates than most contemporary societies. The $v(x)$ values become more negative in older ages, representing fertility reduction in older ages. This reduction captures parity-specific marital fertility control when parity-specific information is not available. The bigger the M, the higher are marital fertility rates. This is why M is called a level parameter. The bigger the m, the stronger is the impact of $v(x)$. Because $v(x)$ represents the degree of fertility reduction due to fertility control, m represents how strong fertility control is. M is typically less than 1, and m is between 0 and 2. If M is close to 1, this means maximum level of natural fertility. If m is close to zero, this means no fertility control (Wachter 2007, pp. 299–300).[6]

Johnson (1985) extended this approach to account for the temporal variation in marital fertility in a society, distinguishing between cohort and period effects. In Johnson's model, the level parameter (M) and fertility limitation parameter (m) are allowed to vary across cohorts and/or periods. In empirical application, each cohort and period can have different intercepts ($\ln(M)$) and interaction term with age (m) in Eq. (3). In other words, this model allows for capturing age-period and age-cohort interaction in fertility control. There are 16 possible models to estimate: from a model with no variation in level and limitation across periods and cohorts to a model with varying level and limitation parameters across periods and cohorts. By comparing these 16 models, we can examine whether the level and the fertility limitation vary upon cohorts or periods.

Moment Decomposition

An alternative way of assessing the relative importance of cohort change over period change is a moment decomposition method. Foster (1990) developed a set of translation formulae that decompose period fertility moments (e.g., level, timing, and dispersion of timing) into cohort moments or vice versa. Simply put, the aim of this exercise is to see if period moments are a non-linear function of cohort moments or vice versa. If period moments are well-decomposed into cohort moments but not vice versa, this strongly suggests that cohort change drives the changes in period indices. I present an abridged version of the derivation of moment decomposition in Appendix 1.

As Glenn (2005) pointed out, solving the identification problem in the APC model is technically possible but warrants cautious interpretation. Without guidance of appropriate knowledge about the phenomenon of interest, mechanical application

[6] Xie and Pimentel (1992) presented several sets of values of $n(x)$ and $v(x)$ in addition to Coale and Trussell's (1974) original estimates. Because the results do not depend on varying estimates of $n(x)$ and $v(x)$, I present the results using Coale and Trussell's (1974) original estimates.

of a statistical solution may yield a misleading conclusion. In addition, the results are often dependent upon non-testable assumptions (e.g., equality constraint). The current study applies multiple methods that separate APC effects on fertility: the classic APC model, the IE APC model, the Coale and Trussell martial fertility model, and the moment decomposition method. As I will discuss later, these different methods yield fairly consistent results, suggesting that the results are not merely statistical artifacts.

Data

A long time-series of one-year interval age-specific fertility rates and marital fertility rates would be ideal for the analysis for this study. In reality, such data are not available. To compensate for such data limitations, I use three different data sources: (1) Five-year interval age-specific fertility rates between 1925 and 2005 to compute period total fertility and CAF and to conduct the APC analysis, (2) five-year interval age-specific marital fertility rates between 1960 and 2005 to estimate the Coale and Trussell model (hereafter, the CT model), and (3) one-year interval age-specific fertility rates between 1980 and 2007 to conduct the moment decomposition analysis.

The following comments are relevant when considering these data sources. First, Korean demographers reconstructed the first data set (five-year interval age-specific fertility rate data 1925–2005) based on vital statistics, census data, and imputation (Kwon 1977; Jun 2004). Vital statistics and census data are used to compute age-specific fertility rates between 1980 and 2005. Because the Korean vital statistics are known to be unreliable prior to 1980 (Kwon 1993) and the census had fertility modules between 1960 and 1980, the census data are used to estimate age-specific fertility rates during this period. For the period between 1925 and 1960, no detailed age-specific fertility rates are available. Kwon (1977) developed an imputation method for age-specific fertility rates between 1925 and 1960 using the estimates of the number of children ever born to women aged 15–49 in 1960, age-specific marital fertility rates, and marriage rates. Imputation is based on the assumption that the shape of age-specific marital fertility rates do not change between 1925 and 1960. Using this assumption along with available information about marriage rates and the number of children ever born to women who were reproductive in this period, Kwon (1977) estimated age-specific fertility rates during this period (Kwon 1977, pp. 125–131). Among Korean demographers it has been a standard way of imputing age-specific fertility rates before 1960, and I also follow this convention in this study. Although this data reconstruction may deviate from the real age-specific fertility rates, the assumption of constant marital fertility pattern between 1925 and 1960 is fairly reasonable given the stability in marital fertility patterns in pre-transition societies.[7] The second data set (five-year interval age-specific marital fertility rates between 1960 and 2005) is constructed using census data, and the third data set (one-year interval

[7] Kwon (1977, pp. 132–133) showed that age-specific martial fertility rates are fairly constant across several birth cohorts relevant for this period, using the data of a middle town in South Korea, Ichon. This suggests that the assumption of constant age-specific martial fertility is fairly good.

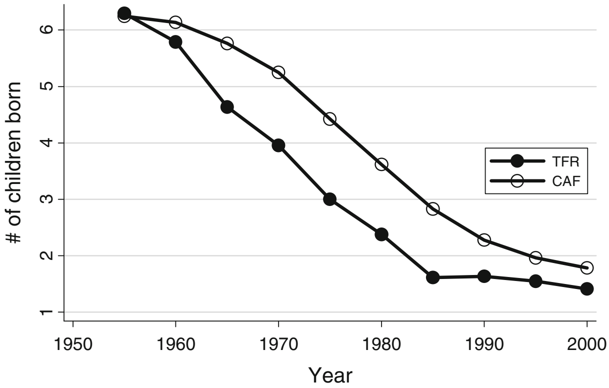

Fig. 3 Period total fertility and CAF in South Korea, 1955–2000

age-specific fertility rates) is based on vital statistics and the Korean Statistical Office's population projection by age between 1980 and 2007. Appendix Tables 1, 2 and 3 presents these three sets of data.

The analyses conducted in the current study use population data rather than sample data. This means that a statistical test is inappropriate (Pullum 1980). Hence, model selection is done based on two criteria. First, I check the index of dissimilarity between observed and predicted rates. I exclude the models in which the index of dissimilarity is >0.05, which means that there is >5 % discrepancy between observed and predicted rates. Second, I check to see if estimated parameters behave reasonably. For example, some APC models yield a set of age parameters that suggest a monotonic increase of fertility across ages. I exclude these models, too.[8] In the following section, I discuss the results that pass these two criteria.

Results

Trends: Period Total Fertility and CAF, 1955–2005

Figure 3 shows a time-series of period total fertility and CAF between 1955 and 2005. First, we can see that CAF is consistently higher than period total fertility, suggesting that currently reproductive women (aged 15–49) experienced higher levels of fertility in the past than the fertility levels observed between 1955 and 2005.

Second, overall slopes of these two measures are quite similar: on average, period total fertility decreased 0.117 per year, and CAF decreased 0.115 per year.

[8] Alternatively, we might view these data as a sample of a longer time series, which allows for a statistical test if we know the sample sizes. The exact sample sizes, however, are not available from the published data, making a formal statistical test unavailable: a statistical test depends on how I choose the size of denominators while the point estimates are independent of such a choice. Following Pullum (1980), I assume that all the denominators are equal to 1,000 to estimate the models. The statistical tests in terms of likelihood ratios and Bayesian Information Criterion (BIC) suggest that my preferred models, based on the conditions mentioned above, are also best-fitting models.

This suggests that a tempo distortion may not be a main story in the Korean fertility decline. Tempo distortion would be great if delayed childbearing is a primary source of period fertility decline (Bongaarts and Feeney 1998). If large tempo distortion persists over time or the change in level is slower than the change in the timing, period total fertility should decline much more rapidly than cohort total fertility and CAF. The analysis shows that the rates of decline in period total fertility and CAF are similar. This suggests that a delay in childbearing does not fully explain fertility decline in South Korea while there could be compensating factors that result in the parallel patterns of CAF and the period total fertility together with tempo changes.

Another noticeable feature in this Fig. 3 is the change in relative steepness between CAF and period total fertility. While the slope of period total fertility is much steeper than that of CAF in the onset of fertility decline (e.g., in the 1960s), the pattern is reversed during the 1990s. A steeper slope of period total fertility than CAF in the 1960s also suggests that delay of childbearing has important implications for the onset of fertility decline in Korea. The delay of childbearing has an immediate effect on period total fertility because this reduces birth flow at time t controlling for age. When delays of childbearing become more prevalent, period total fertility should decrease more rapidly than average fertility experiences of currently reproductive women. Hence, the slope difference between period total fertility and CAF in the 1960s suggests that the tempo effects were great on the onset of fertility decline in Korea, consistent with the previous research in Korea (Kwon 1993) and Western countries. By contrast, a flatter slope of period total fertility in recent periods suggests that delays of childbearing may hit the peak and become less pronounced.

APC Analysis

Figure 4 shows parameter estimates in logarithmic scale for the APC analysis. The coefficients represent the deviation from respective reference points such as age 15, year 1920, and cohort born in 1880. To estimate the classic APC model, I imposed the following equality constraints: no difference between the earliest two periods, 1925–1929 and 1930–1934 (period constraint); no difference between the earliest two cohorts, 1880–1884 and 1885–1889 (cohort constraint); or no difference between the oldest age groups, 40–44 and 45–49 (age constraint). I present three different estimates: gross effects, net effects in the APC model with period constraint, and intrinsic estimates (IE estimates). APC models with age constraints and cohort constraints yielded unreasonable estimates for age, period, and cohort effects, suggesting that imposing period constraints are appropriate. The estimates with period constraints are also consistent with IE estimates, which provide more confidence in these estimates. For gross period and cohort effects, I present the estimates from the AP and AC model respectively because of the primary importance of age in fertility. The following patterns are observed. First, age effects show an inverted U-shape pattern, which is hardly surprising: the risk of childbearing peaks around age 25, and then decreases.

Second, period effects became negative since 1960, indicating the onset of fertility transition in the 1960s. Period effects became increasingly negative until the

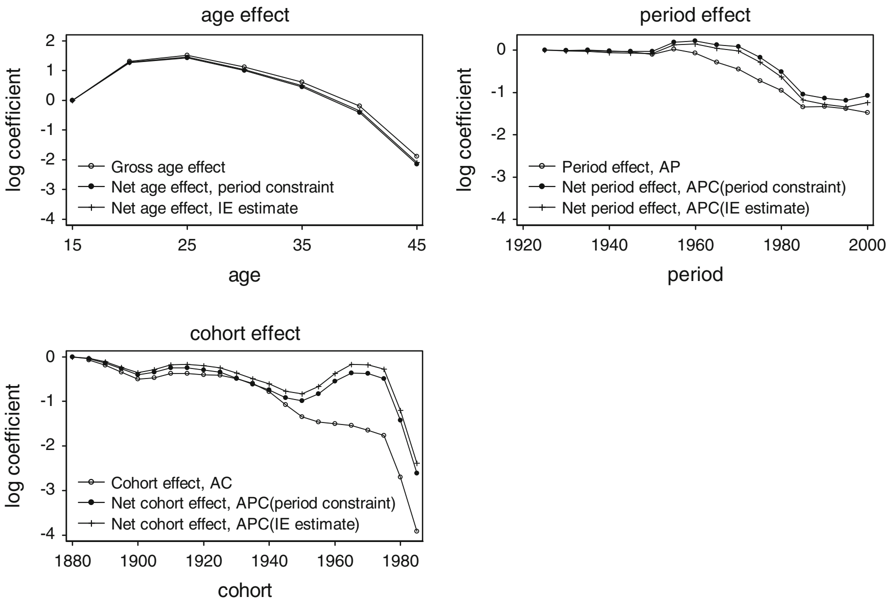

Fig. 4 Age, period, and cohort effects (APC analysis)

1980s, indicating a considerable contribution of period effects to fertility decline during this period. For example, an IE estimate for period effect in 1980 is −0.8, implying that women in 1980 produced 55 % [100*(1 − $e^{-0.8}$)] fewer children than women in 1920 (or 1960) after controlling for age and cohort effects. The rates of decrease in period effects became slower since 1980. In addition, the negative gross effect is considerably greater than the net effect since the 1960s, and the difference between net and gross effects was quite large during the fast decline (e.g., until the 1980s). This means that fast fertility decline is partly explained by a cohort effect. For example, gross period effect is −1 in 1980, which is −0.2 more negative than the net effect. This means that about 20 % of fertility difference between 1920 and 1980 after controlling for age effects is explained by cohort effect.[9] The gap peaks in 1970, suggesting the biggest cohort effects in this period.

Finally, we can also see an overall downward trend of cohort effects, but the pattern is different from period effects. The net effect is indistinguishable from the gross effect for cohorts born before 1940, suggesting that period changes do not explain cohort change during this period. In addition, there was no monotonic fertility decline across cohorts and the change was not substantial until the 1940 cohort. The pattern, however, changed rapidly, starting from the cohort born in 1940. First, negative gross effects became greater. For example, the difference in gross cohort effects between those who were born in 1940 and those born in 1975 is

[9] Because the deviation of fertility in 1960 from that in 1920 is almost negligible, we may interpret this result, referring to 1960 instead of 1920.

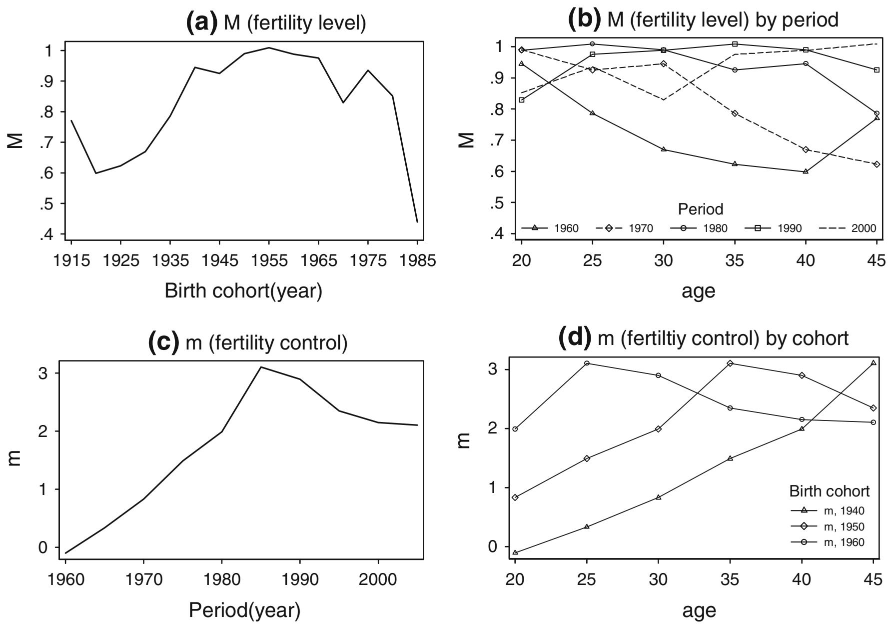

Fig. 5 *M* (level) and *m* (fertility control) indices

−1.2, implying a 70 % reduction in fertility between the two cohorts.[10] However, net cohort effects show quite different patterns. The net cohort effect actually became less negative, meaning higher fertility levels of the later born after controlling for period and age effects. For example, the difference in net cohort effects between the 1940 cohort and the 1975 cohort is 0.5, meaning a 40 % increase in fertility between the two cohorts after controlling for the period and age effects. How can we interpret this counter-intuitive pattern, given the rapid reduction in fertility without controlling for period effects? This indicates that the Korean fertility decline is more associated with period change than cohort change. Gross cohort difference can be seen as a mere accumulation of period effects rather than a unique difference across cohorts. This is consistent with the pattern found in Western countries in which period effects have been more important than cohort effects (Pullum 1980; Rindfuss et al. 1988).

Coale and Trussell's Parametric Marital Fertility Model

In this section, I present the results from the CT models. Although marital fertility is certainly different from fertility itself, this approach helps us understand how cohort and period change contributed to fertility decline in South Korea given the

[10] I do not interpret cohort coefficients for the youngest and oldest cohort because the estimates in APC models are unreliable at the corners (Fienberg and Mason 1979).

dominance of marital births over non-marital births (Jun 2004). Among the 16 CT models estimated in which m and M parameters may or may not vary over periods and across cohorts, the model in which fertility control (m) varies over periods and level of fertility (M) depends upon cohorts yielded the most reasonable estimates. In other words, intercepts vary across cohorts and significant interactions between period and age exist. The key findings are presented in Fig. 5.

Figure 5a shows how the level of marital fertility varies by cohorts. After controlling for age effects and age-period interactions in marital fertility control, the level of marital fertility peaked for those born in 1955–1959 and then somewhat decreased with considerable fluctuation.[11] Cohorts differ from each other in their levels of marital fertility, but the patterns of marital fertility control did not change across cohorts. The pattern of marital fertility control varies over periods (Fig. 5c). The m estimates peaked at three in 1985, suggesting three times stronger marital fertility control in 1985 than in 1960. Afterwards, m became smaller, but still remains greater than two, which represents strong marital fertility control (Wachter 2007, p. 299). Marital fertility control increased over time, indicating the growing use of contraception over time. Insignificant age-cohort interaction in marital fertility control implies that an innovative contraceptive method did not have a limited influence on a certain birth cohort but it did have universal effects on marital fertility.

Part (b) and (d) in Fig. 5 show age patterns of level of marital fertility (M) and marital fertility control (m) over periods and cohorts. Figure 5b illustrates how fertility levels vary upon ages in each period. Because each cohort has the same level of fertility (M), the level of age x in time t is equal to that of age $x + n$ in time $t + n$. We can see that there is no particular trend in M parameters over time. For example, M values in 1970 are greater than M values in 1960 except for age 45. However, M values became smaller between 1990 and 2000. Given the remarkable decrease in marital fertility in South Korea, such a fluctuating pattern is somewhat counterintuitive. This implies that marital fertility would not decrease so rapidly if marital fertility control remains constant over time.[12] However, as we can see in Fig. 5c, marital fertility control became stronger over time until 1985 and stayed high afterwards, offsetting the fluctuating trend of M. Figure 5d illustrates how marital fertility control varies upon ages in a cohort. Because each period has the same level of fertility control (m), the fertility control of age x of cohort born in time t is equal to that of age $x + n$ of cohort born in time $t - n$. Figure 5d shows stronger marital fertility control for younger cohorts during their 20s and 30s. In their 40s, the trends are reversed, with stronger fertility control for older cohorts. Given the concentration of childbearing in the 20s and the 30s, intensive practices of marital fertility controls in the 20s and 30s among younger cohorts led to lower fertility for them.

[11] The sharp decline is observed for those who were born in 1985. However, data for them are too limited to reach a solid conclusion.

[12] In addition to increasing fertility control over time, delays in marriage also contribute to declining fertility because this lowers the population ‘at risk’ of giving births substantially (Kwon 1993).

The trend of level parameter (M) across birth cohorts is counterintuitive given the monotonic decline in marital fertility in South Korea (See Appendix Table 2). This trend, combined with increasing marital fertility control over time, suggests that cohort marital fertility would have not decreased without increasing fertility control over periods. This confirms the conclusion of the APC analysis of fertility shown in the previous section, primacy of period effect over cohort effect. In sum, period changes are driving forces of overall and marital fertility decline in South Korea.

Decomposition

Following Foster (1990), I limit decomposition analysis to cohorts whose age-specific fertility rates are available for ages 21–29 to ensure precise parameter estimates. Hence, the decomposition includes women born between 1960 and 1977 for whom fertility rates in their 20s are available. Figure 6 shows how estimated period deviation parameters fit the data. Whereas the level and the timing of childbearing are well predicted from this estimation, standard deviation is not predicted well, particularly after 1995.

The graphs on the left in Fig. 7 show the decomposition of period moments into cohort moments, and those on the right represent the decomposition of cohort moments into period moments. For the level decomposition, cohort decomposition clearly works better than period decomposition. Whereas only 12 % of variance in estimated period level index is explained by cohort indices, this amounts to 60 % in cohort decomposition. For the timing decomposition, the same pattern is observed:

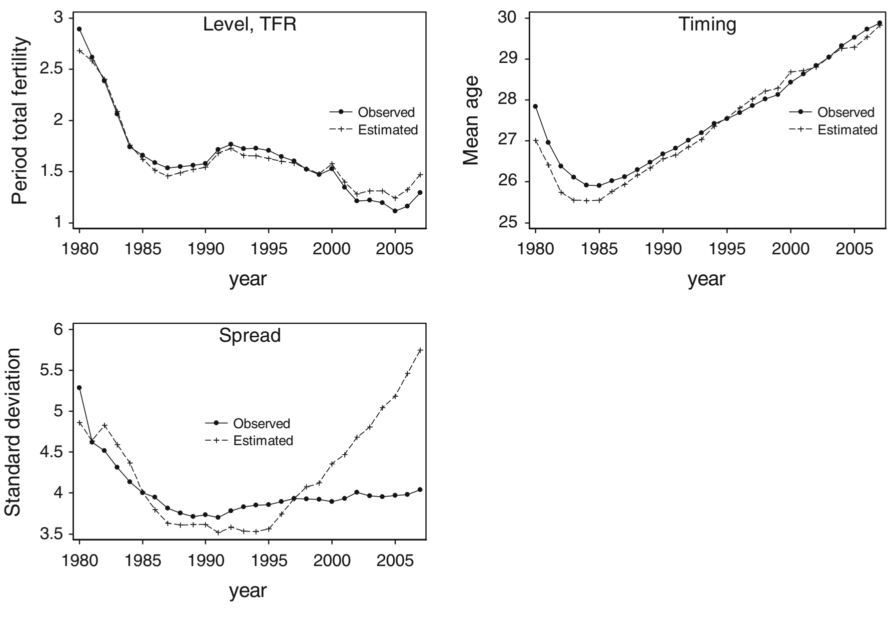

Fig. 6 Total fertility, mean age of childbearing, and dispersion (1980–2007)

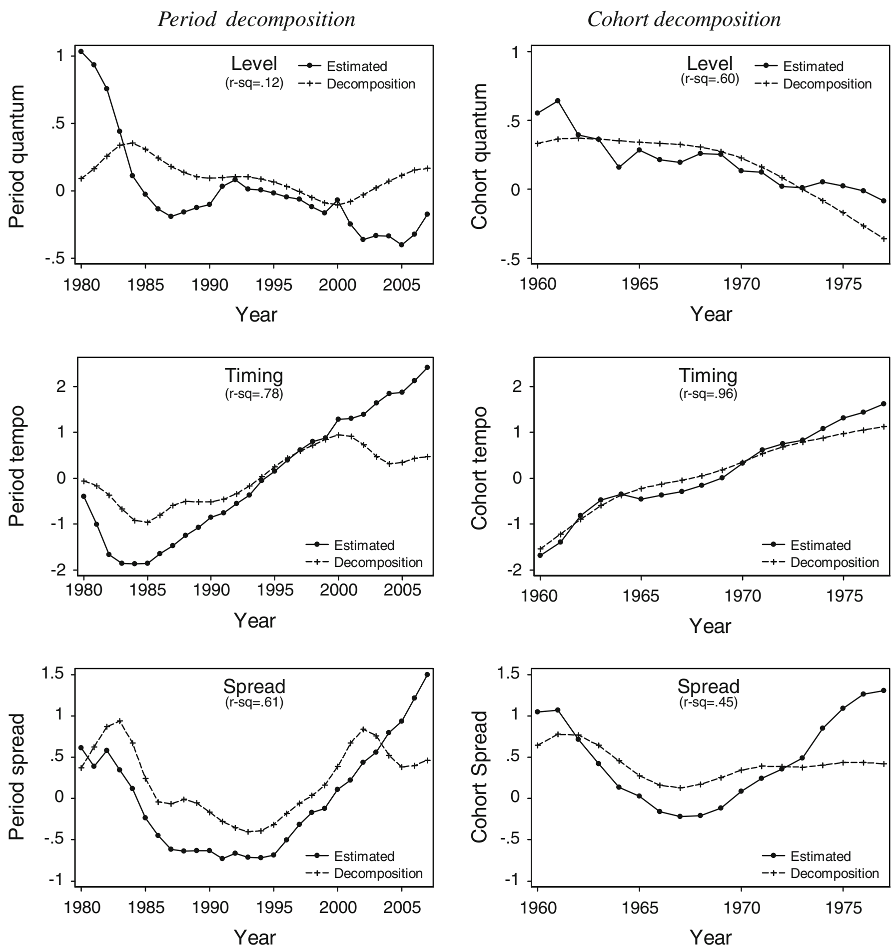

Fig. 7 Decomposition of cohort and period moments

there is a better fit for cohort decomposition than period decomposition. In particular, the cohort decomposition fits the data almost perfectly ($r^2 = 0.96$). For the decomposition of standard deviation, period decomposition works better than cohort decomposition (r^2: 0.61 vs. 0.45). By and large, the cohort decompositions work fairly well but the period decompositions do not. This means that cohort change in the level and the timing of fertility is well explained by period change but not vice versa. This is consistent with the pattern found in Western countries (Foster 1990), suggesting the primacy of period effects on fertility change over cohort effects. This is also consistent with the APC analysis reported in this study. All these results support the idea that period change is more important than cohort change in explaining fertility decline in South Korea.

Summary and Discussion

In this paper, I examine fertility decline in South Korea. By using a classic APC model, a moment decomposition method, and a new summary fertility measure—'cross-sectional average fertility (CAF)—, I show that the Korean fertility decline is more associated with period change than cohort change and that delayed childbearing has important consequences for the onset of fertility decline. These findings are consistent with sociological accounts of fertility changes in Western countries which show that: (1) temporal variations that cut across cohorts (e.g., economic cycles and spread of contraceptive methods) are more important than shared socializing experiences within cohorts, and (2) the onset of the fertility transition is driven by delays in childbearing. This similarity is found in spite of seemingly different patterns of fertility change in South Korea compared to Western countries—specifically, South Korea's faster rate of change and monotonic decrease. This suggests that period change is much more important than cohort change in explaining fertility change beyond Western contexts.

We can identify several factors that are in line with period-driven fertility change in South Korea. First, the strong implementation of family planning programs may explain why the Korean fertility transition is more associated with period change than cohort change. As discussed above, the Korean government rigorously implemented the family planning program since the 1960s. Even after reaching the replacement period total fertility in the 1980s, the Korean government still emphasized birth control due to the lingering concern of rapid population growth. No change in family policies in the 1980s may be associated with continuing negative trends of period effects. Women's increasing economic participation along with economic development and rising cost of living are also related with period-driven fertility change in South Korea. These changes increase direct and indirect costs of raising children (Becker 1974), and are likely to affect reproductive couples as a whole rather than a specific birth cohort. Of course, factors associated with cohort change also may affect the fertility transition. For example, the effect of improvement in educational attainment across birth cohorts on fertility may be realized through cohort effects. The patterns shown in Fig. 4, however, suggest that this is not always the case. In particular, the cohort effects became less negative between 1940 and 1970 after controlling for age and period effects, suggesting that the younger cohort would have given more births if they had lived the same periods as the older cohort. Hence, the empirical evidence presented in the current study suggests that fertility change in South Korea is more associated with period-related factors (e.g., family policies and economic development) than with cohort-related ones (e.g., improvement in education). In addition, the trend of period effects since 1960 is also in line with theories of fertility transition that attribute fertility transition to mortality decline, economic development, rising cost of living, diffusion of permissive attitude toward birth control, and implementation of family planning programs (Mason 1997; McDonald 1993). These factors are more related with period changes than cohort changes. Hence, the Korean fertility transition, which is more associated with period changes than cohort changes, is well fit into the theories of fertility transition.

The findings also have some policy implications. The analyses suggest that childbearing is heavily influenced by current social, economic and cultural conditions instead of a shared cohort experience. Strong and efficient execution of family planning programs and rapid economic development should contribute to this process. Apparent differences across cohorts are largely explained by this drastic socioeconomic change that encompassed all cohorts in the Korean population. This has an important implication for current population policies in South Korea that attempt to boost 'lowest-low' fertility. Period-driven fertility change in South Korea apparently suggests the importance of immediate policy implementation (e.g., cash subsidies), because women (or families) respond to current socioeconomic conditions in making fertility decisions. Gauthier's (2007) review, however, suggests that policies with longer time horizon (e.g., policies regarding labor market and work-family balance) are more effective than immediate policies. Taken together, effective fertility policies should affect the current conditions relevant to fertility decision but should not be confined to a myopic perspective. It is challenging to develop policies that satisfy these requirements. Population aging, however, is an emerging policy concern in South Korea, warranting the development of such well-designed family and fertility policies.

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Appendix 1: Derivation of Moment Decomposition Formulae

Readers interested in the full derivation should see Foster (1990). Following Foster (1990), I define the fertility rate for cohort t at age x ($\varphi_c(x,t)$) in terms of a vector of parameters ($\theta_c(t)$).

$$\varphi_c(x,t) = H(x, \theta_c(t)) \quad (4)$$

The parameter vector, $\theta_c(t)$, would be composed of cohort effects plus period effects in the APC model, and this would be level parameter (M) and fertility control parameters (m) in Coale and Trussell's (1974) parametric marital fertility model. Foster (1990, p. 310) proposed a three-parameter schedule (g, a, and b):

$$H(x; g, a, b) = \frac{G_s + g}{G_s} \frac{\sigma_s}{\sigma_s + b} \varphi_s \left(\frac{\sigma_s}{\sigma_s + b} (x - \mu_s - a) + \mu_s \right) \quad (5)$$

(G_s, μ_s and σ_s are the standard total fertility, mean age at childbearing and standard deviation of age at childbearing, respectively; G, μ, and σ are respective cohort moments; $g = G - G_s$, $a = \mu - \mu_s$, $b = \sigma - \sigma_s$; and $\varphi_s(x)$ is a standard fertility schedule).

Using a first-order Taylor's expansion around some θ_0 and setting $\theta_0 = [0,0,0]^T$ and Eq. (5), we can re-write $\varphi_c(x,t)$ as following:

$$\begin{aligned}\varphi_c(x,t) &= H(x,\theta_c(t)) = \varphi_s(x) + h(x)^T\theta_c(t) + e_c(x,t)\\ &= \varphi_s(x) + \varphi_s(x)/G_s g_c(t) - \varphi_s'(x)a_c(t) - [\varphi_s(x) + -\varphi_s'(x)(x-\mu_s)]/\sigma_s b_c(t)\\ &\quad + e_c(x,t)\end{aligned} \tag{6}$$

(where $h(x) = \partial H/\partial\theta_c(x,\theta_o)$).

Because the fertility rate for period t at age x ($\varphi_p(x,t)$) is equal to the fertility rate for cohort born at $t - x$ at age x ($\varphi_c(x,t - x)$) and period total fertility is sum of period age-specific fertility rates, we can decompose period total fertility as follows:

$$\begin{aligned}F(t) &= \int \varphi_c(x,t-x)dx = \int \big[\varphi_s(x) + \varphi_s(x)/G_s g_c(t-x) - \varphi_s'(x)a_c(t-x)\\ &\quad - [\varphi_s(x) + -\varphi_s'(x)(x-\mu_s)]/\sigma_s b_c(t-x) + e_c(x,t-x)\big]dx = G_s\\ &\quad + \int \varphi_s(x)/G_s g_c(t-x)dx - \int \varphi_s'(x)a_c(t-x)dx\\ &\quad - \int [\varphi_s(x) + -\varphi_s'(x)(x-\mu_s)]/\sigma_s b_c(t-x)dx + u_p(t)\end{aligned} \tag{7}$$

In other words, period total fertility can be decomposed into five additive terms: standard total fertility, three non-linear transformations of cohort deviations, and an error term. Hence, if we know the cohort deviation parameters, we can decompose period total fertility into cohort deviation parameters. However, these parameter estimates are not available for all cohorts because many cohorts did not complete their childbearing. To find cohort moments for these cohorts, I regress $\varphi_c(x,t)$ – $\varphi_s(x)$ on $h(x)$ using Eq. (8), $h(x)^T\theta_c(t) + e_c(x,t)$.

$$\hat{\theta}_c(t) = \left[\sum_w h(w)h(w)^T\right]^{-1} \sum_x h(x)(\varphi_c(x,t) - \varphi_s(x)) \tag{8}$$

Using these estimates, we can decompose period total fertility into deviations from cohort moments. The next step is to decompose cohort moments into period moments and vice versa. We can convert Eq. (6) into the period version by substituting $\varphi_p(x,t)(= \varphi_c(x,t-x))$ for $\varphi_c(x,t)$ and combining this with Eq. (4), which yields the following decomposition formula:

$$\begin{aligned}\hat{\theta}_p(t) &= \left[\sum_w h(w)h(w)^T\right]^{-1} \sum_x h(x)(\varphi_p(x,t) - \varphi_s(x))\\ &= \left[\sum_w h(w)h(w)^T\right]^{-1} \sum_x h(x)(\varphi_c(x,t-x) - \varphi_s(x))\\ &= \left[\sum_w h(w)h(w)^T\right]^{-1} \sum_x h(x)\left[h(x)^T\theta_c(t-x) + e_c(x,t-x)\right]\\ &= \sum_w \left[h(w)h(w)^T\right]^{-1} h(x)h(x)^T\theta_c(t-x) + u_p(t)\end{aligned} \tag{9}$$

This formula shows that the period deviation parameters (or equivalently period moments) are the function of cohort moments plus a residual vector ($u_p(t)$). A corresponding cohort formula is

Table 1 Annual age-specific fertility rates (1925–2005)

Year	Age						
	15–19	20–24	25–29	30–34	35–39	40–44	45–49
1925–1930	0.189	0.324	0.269	0.213	0.153	0.075	0.014
1930–1935	0.173	0.321	0.270	0.216	0.155	0.077	0.014
1935–1940	0.158	0.323	0.281	0.226	0.161	0.080	0.015
1940–1945	0.128	0.313	0.286	0.228	0.164	0.081	0.015
1945–1950	0.096	0.305	0.292	0.234	0.167	0.083	0.015
1950–1955	0.045	0.289	0.287	0.233	0.168	0.083	0.015
1955–1960	0.038	0.308	0.335	0.270	0.194	0.096	0.018
1960–1965	0.020	0.255	0.351	0.274	0.189	0.059	0.010
1965–1970	0.012	0.180	0.309	0.223	0.134	0.059	0.010
1970–1975	0.010	0.146	0.301	0.220	0.088	0.019	0.007
1975–1980	0.013	0.152	0.253	0.122	0.038	0.017	0.005
1980–1985	0.011	0.160	0.216	0.072	0.015	0.002	0.000
1985–1990	0.004	0.103	0.168	0.039	0.006	0.003	0.000
1990–1995	0.004	0.074	0.177	0.058	0.012	0.002	0.000
1995–2000	0.003	0.056	0.159	0.072	0.015	0.005	0.000
2000–2005	0.003	0.041	0.149	0.068	0.018	0.003	0.000

Source Jun (2004) and Kwon (1993, 1977)

Table 2 Annual age-specific marital fertility rates (1960–2000)

Year	Age					
	20–24	25–29	30–34	35–39	40–44	45–49
1960–1965	0.443	0.383	0.295	0.212	0.111	0.022
1965–1970	0.394	0.346	0.237	0.148	0.071	0.013
1970–1975	0.431	0.342	0.231	0.096	0.022	0.009
1975–1980	0.439	0.309	0.148	0.064	0.002	0.003
1980–1985	0.458	0.292	0.103	0.028	0.007	0.001
1985–1990	0.423	0.194	0.044	0.010	0.002	0.001
1990–1995	0.306	0.234	0.053	0.007	0.001	0.000
1995–2000	0.377	0.253	0.076	0.016	0.003	0.000
2000–2005	0.364	0.255	0.097	0.019	0.003	0.000

Source Jun (2004)

Table 3 Annual age-specific fertility rates, 1980–2007 (per 1,000)

Age	Year													
	80	81	82	83	84	85	86	87	88	89	90	91	92	93
15	0.8	1.3	1.6	1.2	0.8	0.6	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
16	3.5	4.4	4.4	3.7	2.9	2.4	1.4	1.1	0.8	0.8	0.8	0.8	0.9	0.9
17	6.1	7.8	10.9	9.3	7.6	6.3	5.3	3.4	2.6	2.2	2.4	2.2	2.4	2.4
18	15.4	15.5	18.5	19.6	16.6	14.3	12.8	10.3	7.1	5.5	5.0	5.4	5.9	5.5
19	36.3	33.4	37.5	30.6	31.3	28.1	25.3	20.7	17.9	13.1	11.6	11.4	12.4	12.4
20	66.4	69.8	67.3	55.3	44.1	48.4	43.3	37.4	34.1	29.3	23.6	23.5	22.6	22.5
21	102.0	106.4	122.8	92.3	75.3	64.6	69.6	61.5	56.4	51.2	47.0	42.6	41.8	36.3
22	135.7	147.4	169.1	159.5	118.7	105.4	89.6	95.4	88.0	82.8	78.3	79.9	70.3	62.4
23	186.6	186.5	201.7	202.3	187.3	152.8	136.4	119.6	130.6	122.1	115.1	121.6	118.1	99.0
24	221.6	238.2	233.1	216.6	211.9	211.1	174.4	166.3	150.3	166.8	155.6	161.9	163.9	155.0
25	273.6	251.2	250.0	228.4	201.5	216.4	214.8	189.5	188.0	176.6	187.9	198.6	198.6	196.4
26	276.4	284.9	241.1	217.9	187.8	188.0	198.6	204.9	194.9	197.5	186.2	217.6	215.3	208.7
27	246.8	244.8	228.9	186.4	160.2	157.7	155.5	172.3	186.0	178.7	189.3	192.5	208.3	202.8
28	244.5	206.5	171.1	164.5	126.6	123.7	124.8	126.7	143.9	156.2	152.3	179.5	168.4	176.5
29	183.8	195.2	145.0	111.1	101.3	90.4	91.6	92.8	99.6	113.2	124.5	135.3	146.9	135.0
30	172.9	129.6	113.8	88.5	65.7	68.9	64.6	66.9	72.9	76.1	88.6	104.3	108.5	113.6
31	132.9	118.1	81.7	66.1	50.0	42.7	50.1	45.6	50.8	55.3	59.1	72.3	83.7	80.3
32	106.4	84.1	69.7	47.4	37.6	33.5	31.1	34.6	34.8	39.2	43.7	48.4	58.6	63.4
33	94.8	66.5	49.4	38.7	26.5	24.6	24.2	21.8	26.0	26.5	30.6	35.0	40.0	44.7
34	71.6	55.8	39.3	28.1	21.3	21.6	17.4	17.1	17.2	19.9	21.4	24.9	29.1	30.5
35	57.9	37.8	31.5	22.4	15.2	13.8	15.1	12.4	12.9	13.4	16.8	17.4	21.3	22.5
36	48.2	31.1	21.2	17.9	12.7	10.4	10.0	9.9	9.6	11.0	10.4	13.7	14.7	16.9
37	38.1	24.6	18.4	11.5	9.9	7.9	7.0	7.3	7.3	7.4	8.0	8.8	11.5	11.7

Table 3 continued

Age	Year													
	80	81	82	83	84	85	86	87	88	89	90	91	92	93
38	35.7	18.9	14.4	10.5	6.6	6.6	5.8	4.8	5.1	5.2	5.8	6.3	7.1	8.7
39	28.1	16.3	12.0	7.9	5.8	4.2	4.4	3.6	3.5	3.7	3.8	4.3	5.0	5.4
40	22.6	11.6	8.8	6.9	4.4	3.7	2.8	2.9	2.5	2.5	2.8	2.5	3.5	3.9
41	17.8	9.2	6.3	5.0	3.6	2.6	2.5	1.9	1.9	2.0	1.9	2.1	2.2	2.5
42	14.9	6.3	4.8	3.5	2.7	2.1	2.0	1.4	1.3	1.2	1.3	1.4	1.6	1.4
43	11.7	4.6	3.5	2.5	1.9	1.6	1.3	1.1	1.0	0.7	1.0	0.8	0.9	1.0
44	9.9	3.2	2.5	1.8	1.2	1.1	1.1	0.8	0.7	0.6	0.6	0.6	0.6	0.6
45	7.7	2.3	1.9	1.1	0.9	0.8	0.7	0.5	0.5	0.4	0.4	0.3	0.4	0.4
46	6.4	2.1	1.5	1.0	0.7	0.5	0.6	0.4	0.4	0.3	0.3	0.3	0.2	0.3
47	5.4	1.5	1.1	0.9	0.5	0.6	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.1
48	4.5	1.1	0.9	0.6	0.5	0.4	0.3	0.2	0.2	0.1	0.2	0.2	0.2	0.1
49	4.1	0.9	0.7	0.5	0.3	0.3	0.3	0.2	0.1	0.1	0.2	0.2	0.1	0.1

Age	Year													
	94	95	96	97	98	99	00	01	02	03	04	05	06	07
15	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.3	0.2	0.2	0.2	0.0
16	0.9	0.6	0.6	0.5	0.6	0.5	0.5	0.5	0.6	0.9	0.6	0.5	0.4	0.3
17	2.3	2.2	2.0	1.9	1.7	1.5	1.6	1.2	1.3	1.8	1.4	1.2	1.3	1.0
18	5.2	4.7	4.9	4.2	4.0	3.1	3.0	2.6	3.4	3.2	3.1	2.8	2.9	2.6
19	10.9	10.8	9.9	9.3	8.0	7.4	6.2	5.7	6.6	5.4	5.6	5.5	6.1	7.9
20	21.8	19.7	18.2	16.9	14.9	13.6	12.0	9.3	8.7	8.0	6.6	6.5	7.5	9.6
21	34.9	34.9	31.1	29.0	25.0	23.2	18.8	16.0	13.5	12.1	11.3	9.7	10.3	12.9
22	56.1	55.3	52.6	46.4	41.0	36.6	32.5	25.3	22.1	18.4	16.9	14.9	14.6	16.4

Table 3 continued

Age	Year													
	94	95	96	97	98	99	00	01	02	03	04	05	06	07
23	90.5	81.8	79.6	74.3	63.1	58.9	51.3	41.3	32.3	29.9	25.9	23.0	21.5	22.7
24	131.1	122.9	110.2	104.9	94.9	88.0	88.1	73.1	61.5	52.4	41.0	33.2	32.0	33.6
25	187.4	165.9	151.4	136.1	129.6	121.5	111.5	93.5	74.4	67.8	58.4	52.0	45.7	49.1
26	214.8	211.8	184.9	176.6	156.5	153.0	148.9	122.2	101.2	96.0	87.4	72.1	72.0	71.6
27	205.5	213.0	208.3	188.3	179.4	168.4	172.9	150.0	127.3	125.5	116.4	101.9	95.9	106.5
28	182.9	184.8	189.8	188.4	172.9	172.9	172.7	156.4	138.3	142.2	132.2	123.1	121.4	127.3
29	150.2	152.2	150.2	159.2	157.2	147.2	165.3	142.8	130.5	140.4	137.5	125.4	131.3	141.4
30	111.6	118.3	119.2	119.9	127.5	125.3	136.7	126.6	116.9	123.3	129.1	120.5	129.2	140.5
31	91.9	86.4	93.0	92.5	93.5	96.0	111.9	100.2	99.9	103.1	108.6	107.4	116.4	128.8
32	65.4	69.6	65.8	70.6	69.6	70.3	85.1	79.9	76.1	84.2	86.7	86.9	99.0	112.1
33	49.4	48.5	49.9	50.3	52.4	51.8	60.4	59.0	57.8	60.5	67.5	66.9	74.2	90.5
34	35.3	37.4	35.6	38.7	36.8	38.9	44.1	41.4	41.5	44.8	47.9	50.6	56.0	66.8
35	24.5	26.5	27.9	27.5	27.8	27.1	31.7	30.7	29.8	31.6	34.7	35.3	41.4	49.0
36	18.1	18.3	19.6	21.5	20.1	20.6	22.2	22.2	21.9	22.1	24.6	25.0	28.2	36.1
37	13.1	13.3	13.2	15.1	15.5	14.4	16.8	15.4	15.2	16.3	16.6	17.7	19.9	23.9
38	8.7	9.3	9.8	10.1	10.6	10.7	11.3	11.4	10.4	11.3	12.0	11.4	13.5	16.4
39	6.5	6.5	6.9	7.3	6.7	6.8	8.1	7.7	7.5	7.6	8.2	8.1	8.6	10.4
40	4.2	4.5	4.5	5.0	4.8	4.5	5.3	5.2	4.9	5.3	5.2	5.3	5.9	6.7
41	2.6	2.9	3.1	3.0	3.1	3.1	3.1	3.3	3.3	3.1	3.4	3.4	3.5	4.5
42	1.7	1.6	1.8	2.0	1.9	2.0	2.1	1.8	2.0	2.2	2.2	2.2	2.1	2.5
43	0.9	1.1	1.1	1.2	1.2	1.1	1.2	1.2	1.2	1.2	1.3	1.2	1.3	1.3
44	0.6	0.5	0.7	0.7	0.8	0.6	0.7	0.6	0.7	0.7	0.8	0.8	0.6	0.8
45	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4

Table 3 continued

Age	Year													
	94	95	96	97	98	99	00	01	02	03	04	05	06	07
46	0.2	0.2	0.3	0.3	0.3	0.2	0.2	0.2	0.3	0.3	0.2	0.2	0.2	0.2
47	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.1	0.2	0.2	0.1	0.1	0.1	0.1
48	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
49	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1

Source Korean Statistical Office (www.kosis.kr)

$$\hat{\theta}_c(t) = \sum_w \left[h(w)h(w)^T\right]^{-1} h(x)h(x)^T \hat{\theta}_p(t+x) + \hat{u}_c(t) \quad (10)$$

If these decomposition formulae work perfectly, the residual vectors, $u_p(t)$ and $u_c(t)$, should be zero vectors. If $u_p(t)$ is great and $u_c(t)$ is small, this indicates that period change is not explained by cohort change but cohort change is well accounted for by period change. If this is the case, this should be understood as evidence that fertility decline has been driven by period change.

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