Cohort Effects or Period Effects?

: Fertility Decline in South Korea in the 20th Century*

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Abstract

This study examines recent trends in fertility decline in South Korea. I attempt to answer a long-standing demographic question using a unique Korean experience: is fertility change driven by long-term cohort change or fluctuating period change? By using a classic age-period-cohort model, a moment decomposition method and a new summary fertility measure, 'cross-sectional average fertility (CAF)', I show that fertility change is primarily driven by period 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: 1) temporal variations that cut across cohorts (e.g., economic cycles) are more important than shared socializing experiences within cohorts and 2) the onset of the fertility transition is driven by delays in childbearing.

Cohort Change vs. Period Change in Demographic Behaviors

Korea transited from a high fertility country to a 'lowest-low fertility' country (Kohler et al. 2002) in less than a half century. The total fertility rate (TFR) in Korea was around 6.0 until the 1960s, but has rapidly declined since then. The TFR dropped below the replacement level (2.1) in 1983, and has continued declining. According to *World Health Statistics 2008* (World Health Organization 2008), the TFR in Korea was 1.2 in 2007, which is the lowest among the countries examined. This exceptionally rapid fertility decline in South Korea provides a good opportunity to examine a long-standing question in demography: is a demographic change a consequence of long-term cohort changes or an accumulation of fluctuating periodic changes? In other words, this study examines whether fertility decline in South Korea is driven by cohort changes or a set of period changes in fertility behaviors.

Because a birth cohort refers to a group of 'real' people born in the same year, changes in social and demographic behaviors across birth cohorts indicate that the given society experience social change (Ryder 1965). For example, 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 at time t (TFR(t)) 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 considerably change over time. Three weaknesses of such measures are routinely pointed out: (1) no reference to a real population, (2) contamination by period-specific events (e.g., fluctuation in economic conditions), and (3) just an average of cohort indices (Ryder 1965; Ní Brolchaín 1992). 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; Scheon 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 ($e_0^p(t)$) at time t and cohort life expectancy born in x years ago ($e_0^c(t-x)$) is almost constant for most part of the 20th century in the developed countries, suggesting that period life expectancy can be easily translated into cohort life expectancy with 'lag'. All these efforts are based on the notion that cohort changes in social and demographic behaviors appropriately represent social change (Ryder 1965).

Despite its theoretical primacy of cohort approach over period approach, empirical research does not always support this idea. Actually, cohort changes have been shown as more important than period changes in explaining increase in life expectancy over time (e.g., Mason and Smith 1985). However, period change has been more important than cohort change in explaining the 20th century's fertility change in developed countries. First, studies using age-period-cohort analysis (APC analysis) found insignificant cohort effects and significant period effects on fertility in the United States after controlling for one another (Pullman 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 cycle and adoption of new contraception methods) are more important than shared socializing experiences within cohorts in determining fertility (Pullum 1980: 241; Rinfuss et al. 1988).

Second, studies using moment decomposition methods showed that cohort fertility indices (e.g., level, timing and dispersion) are well-decomposed into period indices but not vice versa (Calot 1993; Foster 1990). This indicates that cohort fertility indices are just weighted averages of period fertility indices. In other words, cohort's 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. In short, cohort's primacy over period has been doubted at least in fertility studies. In this study, I examine this long-standing demographic question in the context of rapid fertility decline in South Korea.

Research Questions

This study examines if cohort's primacy over period holds for fertility decline in South Korea. As discussed above, two different ways have been proposed to examine cohort's primacy over period in demography. The first strategy is to separate cohort effects from period effects after controlling for each other along with age effects (APC model). We can see how strong cohort effects are net of period and age effects, or vice versa. Another way of examining this issue is to decompose period moments (e.g., level, timing, and dispersion) into cohort moments using non-linear equations or vice versa (Calot 1993; Foster 1990). If period moments are well-decomposed into cohort moments, this suggests cohort's primacy over period because period moments are just a function of cohort moments. In this study, I use both methods to see if fertility decline in South Korea is explained by cohort changes or period change. The following questions are examined.

1. How did the level of fertility change over time in South Korea?
2. After controlling for each other, are cohort effects and period effects on fertility significant? Which one is more important than the other?
3. Do cohort moments (level, timing and dispersion) of fertility account for period moments

or vice versa?

As I discussed above, studies of fertility changes in industrialized Western countries have shown that (1) we need to adjust period TFR to capture the change in the quantum of fertility due to the influences of period-specific events like 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 (Pullman 1980; Rindfuss et al. 1988), and (3) cohort indices are weighted sums of period indices but not vice versa (Foster 1990). In this study, I examine if these patterns hold for the Korean fertility transition. The Korean experience is different from those of Western countries in the 20th century at least in two regards. First of all, the pace of fertility change in South Korea is much faster than in Western countries. The difference in rate of change may make the difference. Second, the fertility in South Korea since the 1960s has been monotonically decreasing whereas Western countries experienced fluctuations in the 20th century (Foster 1990). The difference in direction of change may also make the difference. Hence, this study will illustrate the similarities and dissimilarities in fertility change between South Korea and Western countries.

Methods

Trends in fertility

The period total fertility is most widely used in fertility study partly because of its quick availability. This measure, however, may be badly influenced by idiosyncratic periodic fluctuations and would deviate from a cohort's experiences when fertility behaviors changed fast. To correct this problem, tempo-adjusted measures have been proposed (Bongaarts and Feeney 1998; Schoen 2004), which require more information than period TFR like 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 historical context and nature of data (e.g., Li and Wu 2003). In this study, I develop a new measure for fertility trend, ‘*cross-sectional average fertility* (CAF)’ complement the weaknesses of these two conventional measures.

This measure was originally developed to measure ‘cross-sectional’ average life expectancy (CAL(t), Guillot 2003). CAL(t) 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 present population than period life expectancy. In addition, the CAL(t) reflects cohorts’ real experiences rather than those of a ‘synthetic cohort’. Empirically, the CAL (t) is almost always lower than period life expectancy and the trend of CAL (t) is smoother than period or cohort life expectancy (Guillot 2003: 45). The lower value of CAL (t) than period life expectancy represents mortality improvement over time, and the smoother trend shows the robustness of CAL(t) to period- or cohort-specific mortality experience.

In this study, I develop ‘cross-sectional’ average fertility (CAF(t)) by revising CAL(t) to fertility. Whereas conventional TFR(t) is a sum of period age-specific fertility rates, CAF(t) is a sum of ‘cross-sectional average’ age-specific fertility rates of currently reproductive women.

Cross-sectional average age-specific fertility rate $\phi_{ca}(x,t) = \sum_{y=x}^{49} \phi_c(x,t-y)/(50-x)$ ---(1)
(where $\phi_c(x,t)$ is the fertility rate at age x of a cohort born at time t and x=15, 16, … 49).

For example, the cross-sectional average fertility rate for age 15 at time t ($\phi_{ca}(15,t)$) 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 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. Actually, $\phi_{ca}(15,t)$ reflects all currently reproductive cohorts' fertility experience at age 15 whereas $\phi_{ca}(49,t)$ reflects only one cohort's fertility experience that is exactly the same as the age-specific fertility rate at age 49 in time *t*.

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

CAF(t) is just a sum of cross-sectional average age specific fertility rates ($\phi_{ca}(x,t)$). Because the CAF(t) 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 the TFR(t). If there were no difference in the timing and quantum of fertility among currently reproductive women, the CAF(t) would be equal to the TFR(t) 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. First of all, the influence of tempo effects are smaller for the CAF(t) than the TFR(t). In this sense, the CAF(t) are more robust to period-specific fluctuation than the TFR(t). However, the impact of drastic change on the CAF(t) lasts longer than the TFR(t). For example, a drastic fertility drop in one year does not have any mathematical relationship with the TFR(t) in next year although people are likely to behave differently from the previous period, which may alter the TFR(t) next year. By contrast, the drastic fertility drop in one year should have impact on the CAF(t) in following years because the CAF(t) reflect past childbearing experiences. This is a shared property with cross-sectional average life expectancy

(CAL(t), Guillot 2003). Second, the influences of the change in tempo of fertility on the CAF(t) are dependent on age, which is different from the TFR(t). To examine this issue more concretely, let us consider two hypothetical situations: (1) young women (like age 25) forgo their births in a year vs. (2) old women (like age 40) did so. Let us further assume cohort quantum of fertility does not change in either case. The implications for the TFR(t) are dependent on the magnitudes of reduction in births in a given year. Actually, age may matter because the magnitude of reduction is usually dependent on the age. So, complete loss of births in fertility intensive age (e.g., around age 25) should have 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(t) are mathematically dependent on age. The change in young age has less impact on the CAF(t) than that in old age does: the cross-sectional average fertility at younger age is the average of more cohorts than that at older age. However, the influence of change in young age lasts longer because young women remain reproductive longer than their old counterparts and the influence of change in old age fade away soon.

Age-period-cohort (APC) analysis

Linear dependence among age, period and cohort makes it difficult to identify age, period and cohort effect separately after controlling for the other two (Fienberg and Mason 1979, 1985). In other words, after controlling for age, we cannot separate 'linear' cohort effect from period effect or vice versa. There are two ways to get around the identification issue. First, Fienberg and Mason (1979) proposed imposing constraints on at least one parameter based on 'substantive knowledge' to identify the estimates and this method has been used as a standard. Recent development of 'intrinsic estimators' eliminates the arbitrariness of old methods (Yang et al.

2004). Second, we may use our substantive knowledge about each element to avoid linear dependency. For example, period indicators in APC model may be replaced by substantive period measures (e.g., unemployment rates), which are not linear dependent on age and cohort indicators. Of course, cohort and age indicators can be replaced by substantive measures like level of schooling (cohort) and fecundity (age). There are several advantages of this 'proxy variable' approach over classic APC model. First, we can avoid somewhat arbitrarily imposing linear constraints on parameters. Second, this may provide substantive explanation why cohort or period effects are more important than the other. Finally, this approach may allow for examining interaction effects. In classic APC model, each effect is assumed to be constant. In other words, period effect is assumed to be independent of age and cohort, and this is also the case for age and cohort effect. However, some effects may be interactive, which should be tested empirically. 'Proxy variable' approach can provide us with a tool to test interaction effects.[1]

Coale and Trussell (1974)'s parametric martial fertility model is an example of 'proxy variable' approach. This model captures how the level of marital fertility and the degree of fertility control in a population differ from natural fertility. Coale and Trussell model is specified as follows (Coale and Trussell 1974: 187, Wachter 2007: 298):

$$r(x) = n(x)M \exp(m \cdot v(x)) \text{--} (3)$$

(where $r(x)$ is fertility rate at age x, $n(x)$ is 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,

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[1] In addition, 'proxy variable' approach can be used to estimate causal effect of age, period and cohort on outcomes of interest by specifying mechanisms that generate each effect. This is based on the idea of Judea Pearl (2000)'s 'front-door criterion' and Winship and Harding (2008) applied this method to estimate causal effect of age, period and cohort on political alienation.

which represent a fertility schedule under natural fertility. Xie and Pimentel (1992: 979) presented several sets of values in addition to Coale and Trussell (1974)'s original estimates. I estimated the models with different sets of $n(x)$ and $v(x)$. The results do not depend on varying estimates of $r(x)$ and $n(x)$, so I present the results using Coale and Trussell (1974)'s original estimates. The level parameter (*M*) and fertility limitation parameter (*m*) can differ by populations. *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 (Wacther 2007: 299).

The original Coale and Trussell model is suggested to account for cross-national variations in marital fertility. Johnson (1985) extended this approach to account for temporal variation in marital fertility in a society, distinguishing 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. Hence, 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 if the level and the fertility limitation vary upon cohorts or periods.

In this article, I estimate APC model with constraints (Fienberg and Mason 1979), 'intrinsic estimator' (Yang et al. 2004) and Johnson (1985)'s marital fertility model. This analysis shows which factor (cohort or period) is more important in accounting for fertility decline in South Korea.

Decomposition

The APC models discussed above try to separate cohort effects from period effects or the other way around. By using this approach, we can assess if cohort difference in fertility is explained by period difference or vice versa. An alternative way of assessing the relative importance of cohort change over period change is a moment decomposition method developed by Foster (1990). 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 non-linear function of cohort moment or vice versa although the mathematical derivation is quite complex. If period moments are well-decomposed into cohort moments but not vice versa, this strongly suggests that cohort change drove the changes in period indices. Because the derivation is quite long and need to take considerable space, I present an abridged version of derivation. Readers interested in the derivation should see Foster (1990).

Following Foster (1990), I define the fertility rate for cohort *t* at age *x* ($\phi_c(x,t)$) in terms of a vector of parameters ($\theta_c(t)$), $\phi_c(x,t) = H(x,\theta_c(t))$ -------- (4). The parameter vector, $\theta_c(t)$, would be composed of cohort effects plus period effects in APC model, and this would be level parameter (*M*) and fertility control parameters (*m*) in Coale and Trussell (1974)'s parametric marital fertility model. Foster (1990: p.310) proposed three-parameter schedule (*g*, *a,* and *b*):

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

(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 $\phi_s(x)$ is a standard fertility schedule).

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

$$\phi_c(x,t) = H(x,\theta_c(t)) = \phi_s(x) + h(x)^T \theta_c(t) + e_c(x,t)$$
$$= \phi_s(x) + \phi_s(x)/G_s g_c(t) - \phi_s{}'(x)a_c(t) - [\phi_s(x) + -\phi_s{}'(x)(x-\mu_s)]/\sigma_s b_c(t) + e_c(x,t) \text{ -- (6)}$$
(where $h(x) = \partial H / \partial\theta_c(x,\theta_o)$).

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

$$F(t) = \int \phi_c(x,t-x)dx$$
$$= \int [\phi_s(x) + \phi_s(x)/G_s g_c(t-x) - \phi_s{}'(x)a_c(t-x) - [\phi_s(x) + -\phi_s{}'(x)(x-\mu_s)]/\sigma_s b_c(t-x) + e_c(x,t-x)]dx$$
$$= G_s + \int \phi_s(x)/G_s g_c(t-x)dx - \int \phi_s{}'(x)a_c(t-x)dx - \int [\phi_s(x) + -\phi_s{}'(x)(x-\mu_s)]/\sigma_s b_c(t-x)dx + u_p(t)$$
--- (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 easily 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 $\phi_c(x,t) - \phi_s(x)$ on $h(x)$ using equation (6), $h(x)^T \theta_c(t) + e_c(x,t)$.

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

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

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

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

If these decomposition formulae work perfect, 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.

Data

A long time-series of one-year age interval fertility rates and marital fertility rates would be ideal for the analysis for this study. In reality, such data are not available. To complement data limitations, I use three different data: (1) 5-year age interval fertility rates between 1925 and 2005 to compute TFR(t) and CAF(t) and to conduct APC analysis, (2) 5-year age interval martial fertility rates between 1960 and 2005 to estimate Coale and Trussell model (hereafter, CT model), and (3) 1-year age interval fertility rates to conduct moment the decomposition analysis. A few comments need to be made about data sources. First, Korean demographers reconstructed the first data set (5-year age interval fertility rate data 1925 – 2005) based on vital statistics, census data and imputation (Kwon 1977; Jun 2004). Birth registration data are known to be reliable since 1980, so vital statistics are used to compute age-specific fertility rate between 1980 and 2005. The census data are used to compute these rates between 1960 and 1980. Korean census has been done every 5 years, and this is a reason why this data set uses 5-year age interval. For the period between 1925 and 1960, no detailed age-specific fertility rates are available while the estimates for period total fertility and marriage rates are available. Kwon (1977) developed imputation method for age-specific fertility rates between 1925 and 1960. 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 total period fertility, Kwon (1977) estimated age-specific fertility rates during this period. It has been a standard way of imputing age-specific fertility rates before 1960 among Korean demographers, and I also follow this convention in this study. Although this data reconstruction may deviate from the actual age-specific fertility rates, the assumption (i.e., constant marital fertility pattern between 1925 and 1960) is not very strong given the stability in marital fertility patterns in pre-transition societies. It is also necessary to use this information to examine long-term fertility trends in Korea. The second data set (5-year age interval marital fertility rates between 1960 and 2005) is constructed using census, and the third data set (1-year age interval fertility rates) is based on vital statistics and Korean Statistical Office's population projection by age. See the appendices for each data set (Appendix 1 - 3).

I use the published rate data in which sample sizes are not provided. Some data are drawn from vital statistics and others are from census. The Korean Statistical Office does not report a sample size for each computation. Because of the lack of this information, I cannot perform formal statistical test for APC model and marital fertility model. So, model selection has been done based on two criteria. First, I check index of dissimilarity between observed and predicted rates. I exclude the models in which the index of dissimilarity is greater than .05, which means that there is more than 5 percent discrepancy between observed and predicted rates. Second, I check if estimated parameters behave reasonably. For example, some APC models yield a set of age parameters that suggest monotonic increase of fertility across ages. I excluded these models, too. In the following section, I discuss the results that pass these two criteria.

Results

Trends: TFR(t) and CAF(t), 1955 - 2005

<Figure 1> about here

Figure 1 shows a time-series of TFR(t) and CAF(t) between 1955 and 2005. First, we can see that CAF(t) is consistently higher than TFR(t), suggesting that currently reproductive women experienced higher level of fertility than the fertility level implied by fertility behaviors in current years.

Second, overall slopes of these two measure are quite similar (.117 decrease in TFR(t) per year vs. .115 decrease in CAF(t) per year). This suggests that 'tempo distortion' is not a main story in Korean fertility transition. '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, TFR(t) should decline much more rapidly than cohort total fertility and CAF(t). However, the analysis shows that the rates of decline in TFR(t) and CAF(t) are similar, suggesting that delay in childbearing does not fully explain fertility decline in South Korea.

Another noticeable feature in this graph is change in relative steepness between CAF (t) than TFR (t). While the slope of TFR (t) is much steeper than that of CAF (t) in the onset of fertility decline (e.g., in the 1960s), the pattern is reversed during the 1990s. Because CAF (t) represents multiple periods' fertility experiences, this is robust to period-specific fertility change. While a sudden reduction in fertility has a big impact on period fertility, the impact on CAF (t) is not as large. However, the impact on CAF (t) is prolonged. While TFR (t) became almost flat after 1990, CAF (t) still decline although the rate of change is not fast, reflecting rapid decline during the 1970s and 1980s. This shows that drastic fertility change has a smaller but longer impact on CAF (t) than on TFR (t), which is parallel to the relationship between CAL (t) and period life expectancy.

A steeper slope of TFR (t) than CAF (t) 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 TFR (t) because this reduces birth flow at time *t* controlling for age. When delays of childbearing become more prevalent, TFR (t) should decrease more rapidly than average fertility experiences of currently reproductive women. Hence, the slope difference between TFR (t) and CAF (t) 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 TFR (t) in recent period suggests that delays of childbearing may hit the peak and become less pronounced.

APC analysis

<Figure 2> about here

Figure 2 shows parameter estimates in logarithm scale for APC analysis. The coefficients represent the deviation from reference points, age 15, year 1920, and cohort born in 1880. I present three different estimates: gross effects, net effects in 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 imposing period constraints are reasonable. In addition, these estimates are consistent with IE estimates, which provide more confidence in these estimates.[2] For gross period and cohort effects, I present the estimates from AP and AC model respectively because of primary importance of age in fertility. First, age effect shows an inverted U-shape, 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 more negative until the 1980s, indicating considerable contribution of period effects to fertility decline during this period. For example, an IE estimate for period effect in 1980 is -.8, implying that women in 1980 produced 55 percent [100*(1-exp(-.8)] fewer children than women in 1920 (or 1960) after controlling for age and cohort effects. The period effect did not drop as fast as before since 1980, but this still shows the downward trend. In addition, the negative gross effect is considerably greater than net effect since the 1960s, and the difference was quite large during the fast decline (e.g., until the 1980s).

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[2] As I discussed earlier, I am using rates data in which the exact sample sizes are not available. Most rates are computed based on big samples, so we can assume that point estimates are quite reliable and statistical test for model comparison is not necessary. Hence, I present the results based on the models that yield reasonable parameter estimates and misclassified the age-specific fertility rates less than 5 percent.

This means that fast fertility decline is partly explained by cohort effect. For example, gross period effect is -1 in 1980, which is -.2 more negative than the net effect. This means that about 20 percent of fertility difference between 1920 and 1980 after controlling for age effect is explained by cohort effect. The gap peaks in 1970, suggesting the biggest cohort effects in this period.[3]

Finally, we can see a downward trend of cohort effect, but the pattern is different from period effects. Net effect is indistinguishable from gross effect for cohorts born before 1940, suggesting that period change do not fully explain cohort change. However, there was no monotonic fertility decline across cohorts and the rate of change is quite slow. This pattern changed rapidly, starting from cohort born in 1940. First, negative gross effects became greater. For example, the difference in gross cohort effect between those who were born in 1940 and born in 1975 is -1.2, meaning 70 percent reduction in fertility between the two cohorts[4]. However, net cohort effects show quite different patterns. Net cohort effect actually became less negative, meaning higher fertility level of the later born after controlling for period and age effects. For example, the difference in net cohort effect between 1940 cohort and 1975 cohort is .5, meaning 40 percent 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 period effect? This indicates that period effects are primary causes of fertility decline in South Korea. Cohort difference is an accumulation of period effects rather than unique difference across cohorts. This is consistent with the pattern found in Western countries in which period effects have been more important than cohort effect

[3] 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.
[4] I do not interpret cohort coefficients for the youngest and oldest cohort, which the estimates in APC models are unreliable at the corners (Fienberg and Mason 1979).

(Pullum 1980; Rindfuss et al. 1988).

Coale and Trusse's parametric marital fertility model

As I discussed earlier, the APC analysis does not allow for estimating age-cohort and age-period interaction effects without making strong assumptions. Hence, age pattern of fertility is assumed to remain unchanged over time and across cohorts in the APC model, which is hardly defensible. To avoid this problem, I estimate Coale and Trussell (1974)'s parametric martial fertility model that allows for age-cohort and age-period interactions in the model. Even though martial 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 dominance of marital births over non-marital births (Jun 2004). Among 16 CT models estimated in which m and M parameters may or may not vary over time and across cohorts, the model in which fertility control (m) varies over time and level of fertility (M) depends upon cohorts yielded the most reasonable estimates. The results are presented in Figure 3.

<Figure 3> about here

Figure 3-(a) shows how fertility level varies upon cohorts. After controlling for age and age-period interaction, the level of marital fertility increased across cohorts until 1960 and then decreased. The pattern of fertility control varies over time (Figure 3-(c)). The m estimate peaked at 3 in 1985, suggesting 3 times stronger fertility control in 1985 than in 1960. Afterwards, m became smaller, but still remains greater than 2, which represents strong fertility control (Wacther 2007: 299). Cohorts indeed differ from each other in fertility level, but the patterns of fertility did not change across cohorts. This implies that fertility decline is actually driven by reduction in cohort fertility. Fertility control increased over time, indicating the increasing use of

contraception over time. Insignificant age-cohort interaction in fertility control implies that an innovative contraceptive method did not have a limited influence on a certain birth cohorts but universal effects on reproductive women.

Part (b) and (d) in Figure 3 show age patterns of fertility level (*M*) and fertility control (*m*) over periods and cohorts. Figure 3-(b) shows interesting patterns of fertility level after controlling for fertility control. We can see that *M* parameters in general became greater over time. This implies that fertility would increase over time if fertility control remains constant over time. However, as we can see in Figure 3-(c), fertility control became stronger over time until 1985 and stayed high afterwards, offsetting the increasing trend of *M*. Figure 3-(d) shows stronger fertility control for younger cohorts during their 20s and 30s. In their 40s, the trends are reversed: stronger fertility control for older cohorts. Given the concentration of childbearing in the 20s and the 30s, intensive practices of fertility controls among younger cohorts led to lower fertility for them.

Decomposition

<Figure 4> about here

Foster (1990) suggested to limit decomposition analysis to cohorts whose age-specific fertility rates are available at least for age 21 – 29 to ensure the precise parameter estimates. Hence, the decomposition includes women born between 1960 and 1977 for whom fertility rates in their 20s are available. Figure 4 shows how estimated period deviation parameters fit the data well. Whereas the level and the timing of childbearing are well predicted from this estimation, standard deviation is not predicted well particularly after 1995. The bad fit of standard deviation should influence the decomposition to some extent.

<Figure 5> about here

The graphs on the left in Figure 5 show the decomposition of period deviations into cohort deviations, and those on the right represent the decomposition of cohort deviations into period deviations. For the level decomposition, cohort decomposition works clearly better than period decomposition. Whereas only 12 percent of variance in estimated period indices is explained by cohort indices, this amounts to 60 percent in cohort decomposition. For the timing decomposition, the same pattern is found: better fit for cohort decomposition than period decomposition. In particular, cohort decomposition fit the data almost perfectly (r^2 = .96). For the decomposition of standard deviation, period decomposition works better than cohort decomposition (r^2: .61 vs. .45). By and large, the cohort decompositions work pretty 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 to 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 that period change is more important than cohort change in explaining fertility decline in South Korea.

Summary and Discussion

In this paper, I examine recent trends in fertility decline in South Korea. I attempt to answer a long-standing demographic question using a unique Korean experience: is fertility change driven by long-term cohort change or fluctuating period change? By using a classic age-period-cohort model, a moment decomposition method and a new summary fertility measure, ‘cross-sectional average fertility (CAF)’, I show that fertility change is primarily driven by period 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: 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.

How can we explain period primacy over cohort in accounting for the Korean fertility decline in the 20th century? This implies that childbearing is heavily influenced by current social, economic and cultural conditions instead of 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 Korean population. This has an important implication for current population policies in Korea that attempt to boost ‘lowest-low’ fertility. If fertility change were largely driven by long-term change, it would be difficult to expect a certain fertility-enhancing policy (e.g., cash subsidies) may not be effective. However, primacy of period effects over cohort effects suggests that women (or families) respond to current socioeconomic conditions in making fertility decision. This in turn suggests that well-designed policy may provide incentives of childbearing to women or families. This policy should take into account complicated mechanisms that governs childbearing, which is beyond the scope of current study.

References

Bongaarts, John and Griffith Feeney. 1998. "On the Quantum and Tempo of Fertility". *Population and Development Review* 24 (2): 271 – 291.

Calot, Gérard. 1993. "Relationships between Cohort and Period Demographic Indicators: Translation Revisited". *Population* 5: 183 – 222.

Coale, Ansley J. and T. James Trussell. 1974. "Model Fertility Schedules: Variations in The Age Structure of Childbearing in Human Populations". *Population Index* 40 (2): 185 – 285.

Fienberg Stephen E. and William M. Mason. 1985. "Specification and Implementation of Age, Period and Cohort Models". pp.25 – 88. 227. William M. Mason and Stephen E. Fienberg. eds. *Cohort Analysis in Social Research*. New York: Springer-Verlag.

Fienberg Stephen E. and William M. Mason. 1979."Iedntification and Estimation of Age-Period-Cohort Models in the Analysis of Discrete Archival Data". *Sociological Methodology* 10: 1 – 67.

Foster, Andrew. 1990. "Cohort Analysis and Demographic Translation: A Comparative Study of Recent Trends in Age Specific Fertility Rates from Europe and North America". *Population Studies* 44(2): 287-315.

Goldstein, Joshua R. and Wachter, Kenneth W. 2006. "Relationships between Period and Cohort Life Expectancy: Gaps and Lags". *Population Studies*. 60 (3): 257–269

Guillot, Michel. 2003. "The Cross-sectional Average Length of Life (CAL): A Cross-Sectional Mortality Measure that Reflects the Experience of Cohorts". *Population Studies* 57 (1): 41 – 54.

Johnson, Robert A. "Analysis of Age, Period, and Cohort Effects in Marital Fertility". pp.229–257. 227. William M. Mason and Stephen E. Fienberg. eds. *Cohort Analysis in Social Research*. New York: Springer-Verlag.

Jun, Kwang-Hee. 2002. "Fertility". in Kim Doosup, Park Sangtae, and Eun Ki-Soo. eds. *Population in Korea*. Korea National Statistical Office. (in Korean)

Koher, Hans-Peter and Jose Antonio Ortega. 2002. "Tempo-adjusted period parity progression measures, fertility postponement and completed cohort fertility". *Demographic Research* 6 (6): 91-144 (available at http://www.demographic-research.org).

Kohler, Hans-Peter, Francesco C. Billari, and Jose Antonio Ortega. 2002. "The Emergence of Lowest-Low Fertility in Europe during the 1990s". *Population and Development Review* 28 (4): 641 – 680.

Kwon, Tae Hwan. 1993. "Exploring Socio-cultural Explanations of Fertility Transition in South Korea". in Richard Leete and Iqbal Alam. eds. *The Revolution in Asian Fertility*. Oxford: Clarendon Press.

Kwon, Tae Hwan. 1977. *Demography in Korea*. Seoul: Seoul National University Press.

Li, Nan and Zheng Wu. 2003. Forecasting cohort incomplete fertility: A method and an application', *Population Studies*,57(3): 303 - 320.

Mason, William M. and Herbert L. Smith. 1985. “Age-Period-Cohort Analysis and the Study of Deaths from Pulmonary Tuberculosis”. pp.151 – 227. William M. Mason and Stephen E. Fienberg. eds. *Cohort Analysis in Social Research*. New York: Springer-Verlag.

Ní Brolchaín, Maire. 1992. “Period Paramount? A Critique of the Cohort Approach to Fertility”. *Population and Development Review* 18 (4): 599 – 629.

Pearl, Judea. 2000. *Causality: Models, Reasoning, and Inference*. Cambridge, UK: Cambridge University Press

Pullman, Thoma W. 1980. “Separating Age, Period, and Cohort Effects in White U.S. Fertility, 1920 – 1970”. *Social Science Research* 9: 225 – 244.

Rindfuss, Ronald R., S. Philip Morgan, Gray Swicegood. 1988. *First Births in America: Changes in The Timing of Parenthood*. Berkeley : University of California Press

Ryder, Norman. 1965. “The cohort as a concept in the study of social change”. *American Sociological Review* 30: 843 – 861.

Ryder, Norman. 1964. “The Process of Demographic Translation”. *Demography* 1: 74 – 82.

Scheon, Robert. 2004. “Timing Effects and the Interpretation of Period Fertility”. *Demography* 41 (4): 810 – 819.

Wachter, Kenneth W. 2007. *Essential Demographic Methods*. Unpulished Manuscript.

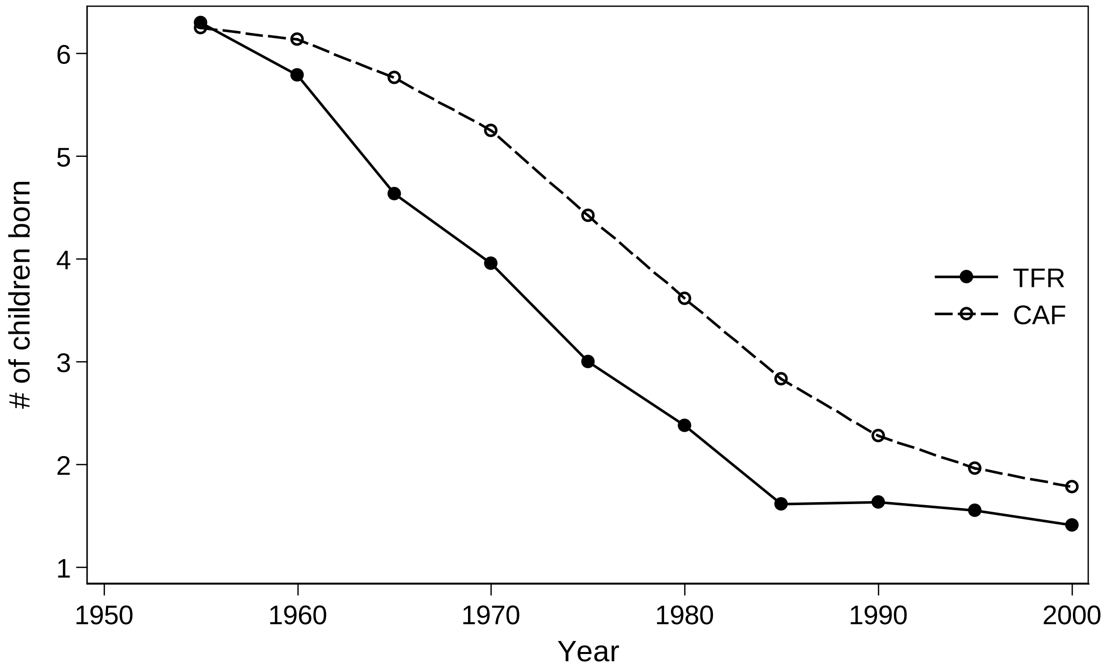
Winship, Christopher and David Harding. 2008. “A Mechanism-Based Approach to the Identification of Age Period Cohort Models”. *Sociological Methods and Research* 36(3) 362 – 401.

World Health Organization 2008. *World Health Statistics 2008.* France.

Xie, Yu and Ellen Efron Pimentel. 1992. “Age Patterns of Marital Fertility: Revising the Coale-Trussell Method”. *Journal of the American Statistical Association* 87: 977 – 984.

Yang, Yang, Wenjiang J. Fu, and Kenneth C. Land. 2004. “A Methodological Comparison of Age-Period-Cohort Models: Intrinsic Estimator and Conventional Generalized Linear Models.” *Sociological Methodology* 34: 75-110

Figure 1 TFR and CAF in Korea, 1955 - 2000



Sources: Jun 2002

Figure 2 Age, period and cohort effects (APC analysis)

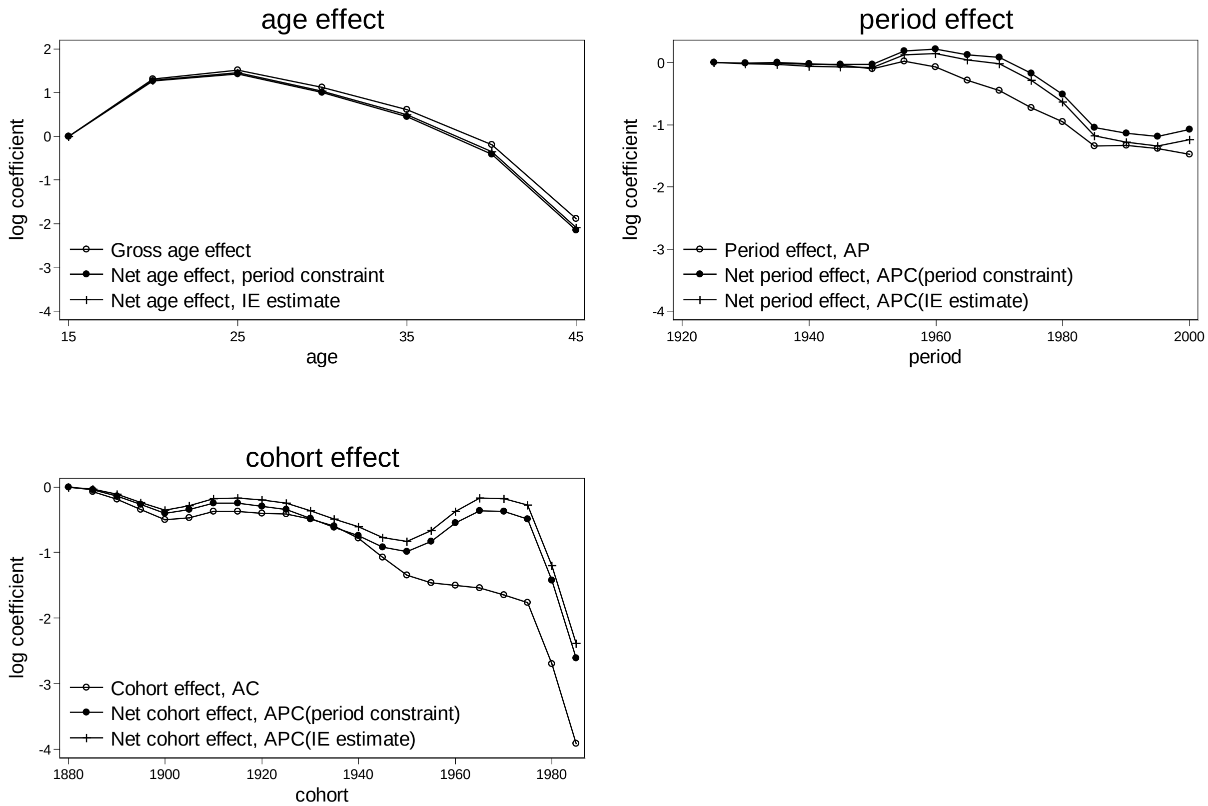


Figure 3 *M* (level) and *m* (fertility control) indices

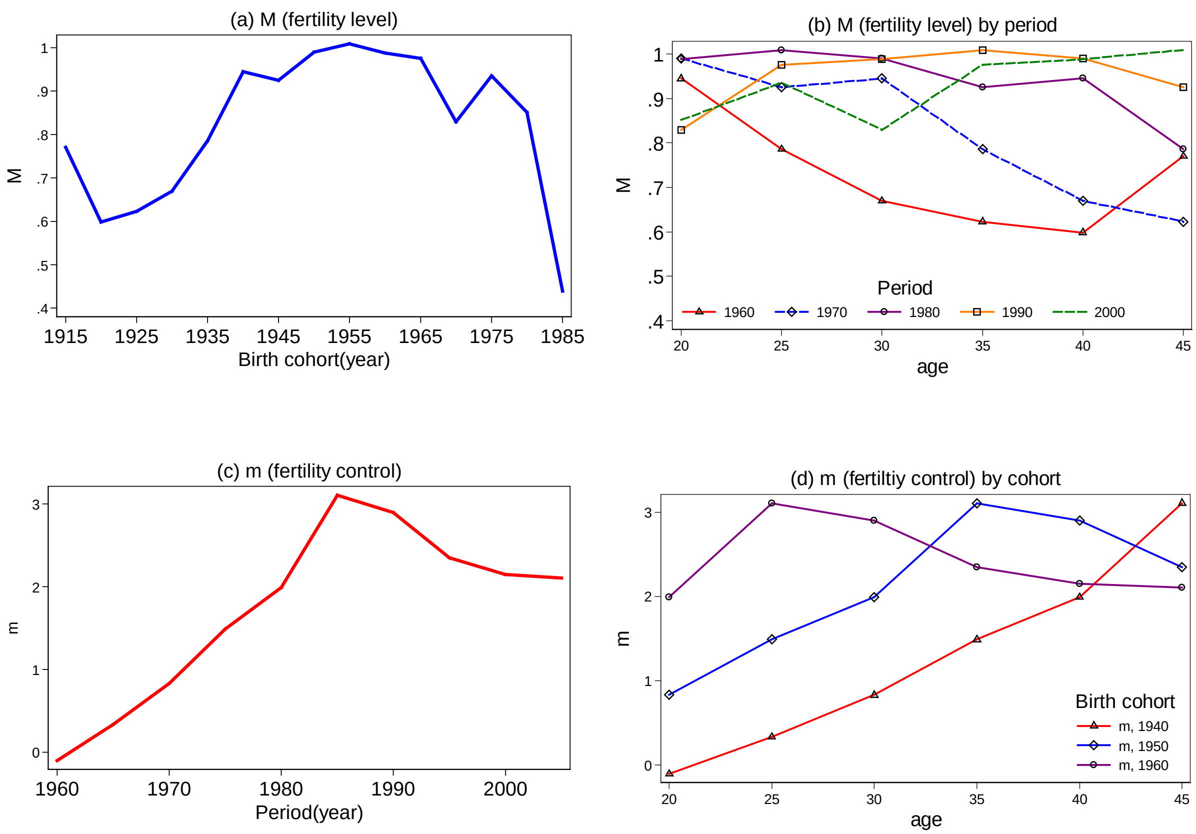


Figure 4 Total fertility, mean age of childbearing, and dispersion (1980 – 2007)

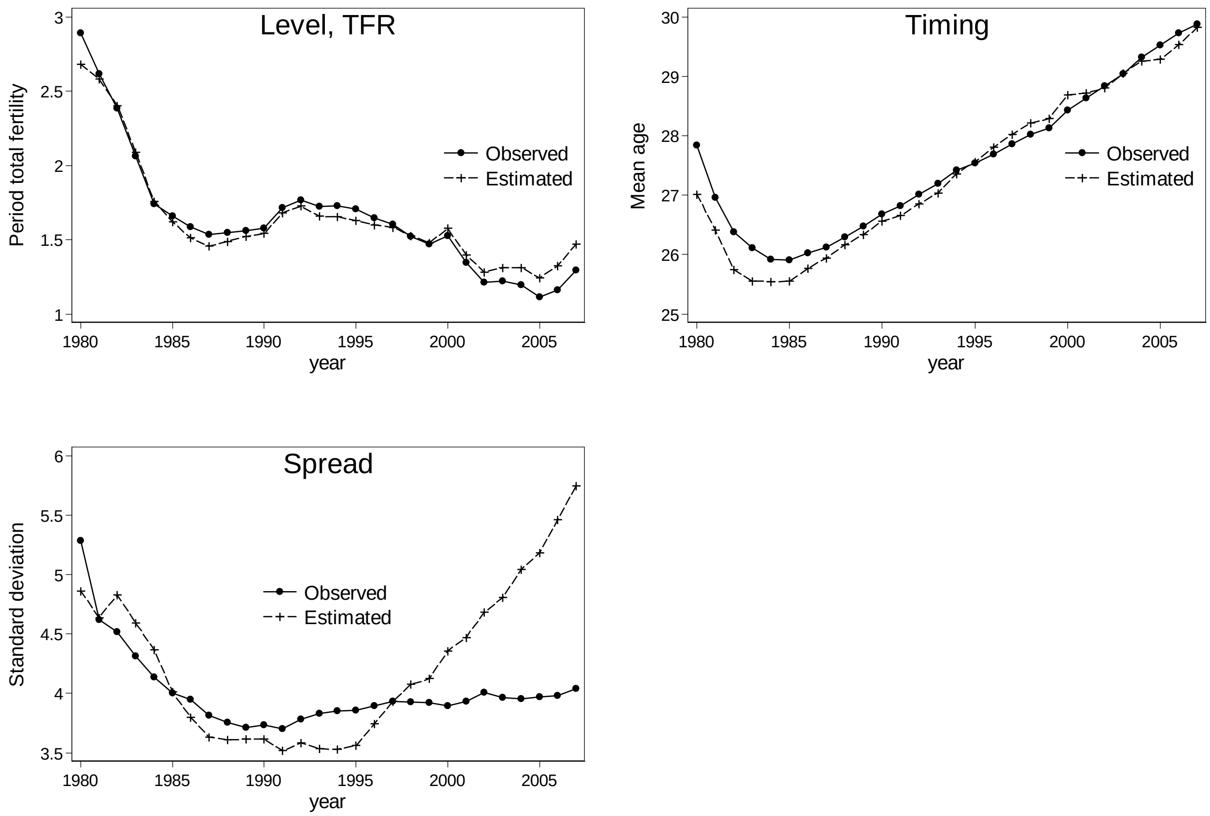
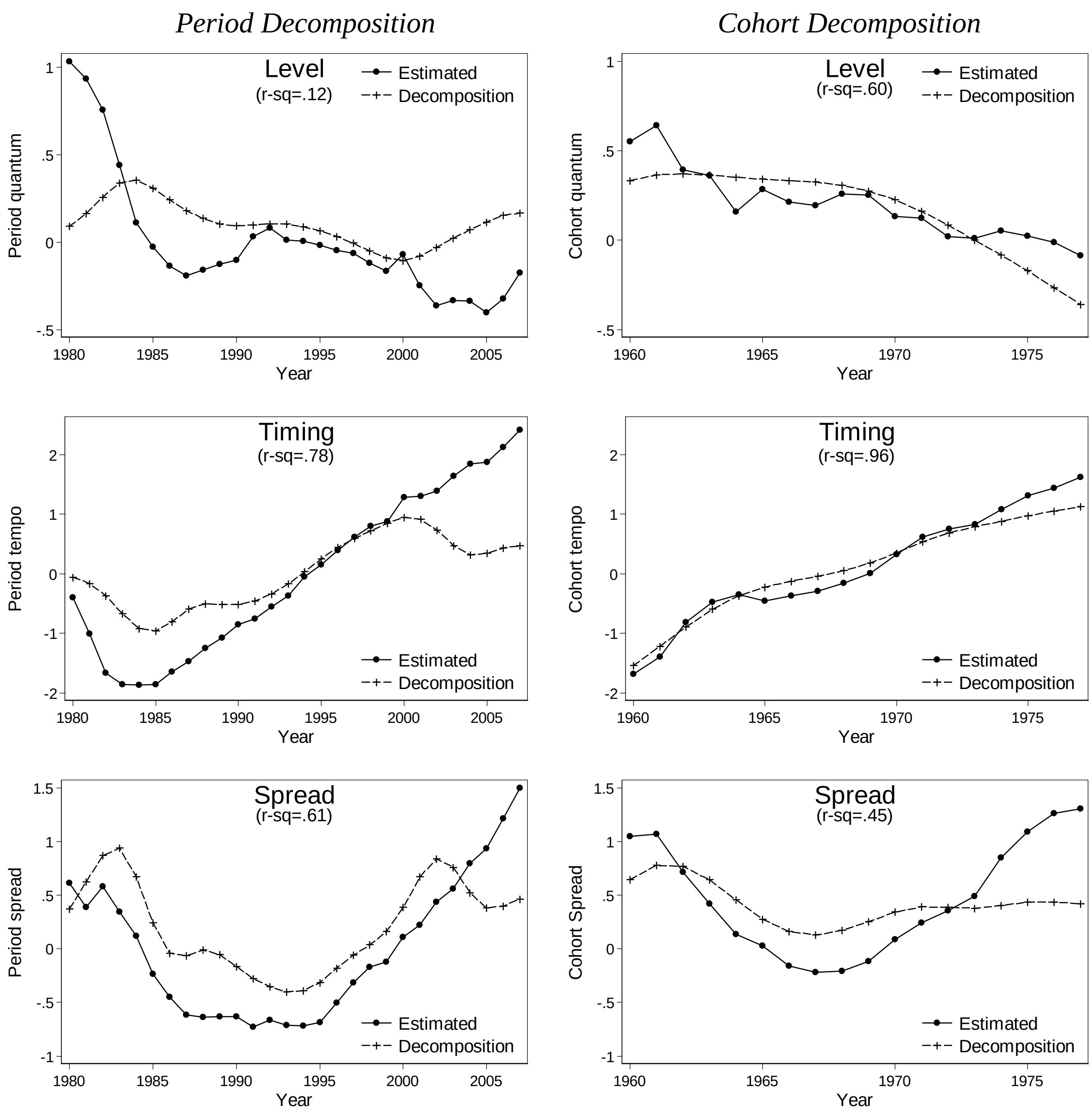


Figure 5 Decomposition of cohort and period moments



Appendices

Table A1 Annual age-specific fertility rates (1925 – 2005)

	Age						
Year	15-19	20-24	25-29	30-34	35-39	40-44	45-49
1925 – 30	0.189	0.324	0.269	0.213	0.153	0.075	0.014
1930 – 35	0.173	0.321	0.270	0.216	0.155	0.077	0.014
1935 – 40	0.158	0.323	0.281	0.226	0.161	0.080	0.015
1940 – 45	0.128	0.313	0.286	0.228	0.164	0.081	0.015
1945 – 50	0.096	0.305	0.292	0.234	0.167	0.083	0.015
1950 – 55	0.045	0.289	0.287	0.233	0.168	0.083	0.015
1955 – 60	0.038	0.308	0.335	0.270	0.194	0.096	0.018
1960 – 65	0.020	0.255	0.351	0.274	0.189	0.059	0.010
1965 – 70	0.012	0.180	0.309	0.223	0.134	0.059	0.010
1970 – 75	0.010	0.146	0.301	0.220	0.088	0.019	0.007
1975 – 80	0.013	0.152	0.253	0.122	0.038	0.017	0.005
1980 – 85	0.011	0.160	0.216	0.072	0.015	0.002	0.000
1985 – 90	0.004	0.103	0.168	0.039	0.006	0.003	0.000
1990 – 95	0.004	0.074	0.177	0.058	0.012	0.002	0.000
1995 - 00	0.003	0.056	0.159	0.072	0.015	0.005	0.000
2000 - 05	0.003	0.041	0.149	0.068	0.018	0.003	0.000

Sources: Jun 2002; Kwon 1993; Kwon 1977

Table A2 Annual age-specific marital fertility rates (1960 – 2000)

	Age					
Year	20-24	25-29	30-34	35-39	40-44	45-49
1960 – 65	0.443	0.383	0.295	0.212	0.111	0.022
1965 – 70	0.394	0.346	0.237	0.148	0.071	0.013
1970 – 75	0.431	0.342	0.231	0.096	0.022	0.009
1975 – 80	0.439	0.309	0.148	0.064	0.002	0.003
1980 – 85	0.458	0.292	0.103	0.028	0.007	0.001
1985 – 90	0.423	0.194	0.044	0.010	0.002	0.001
1990 – 95	0.306	0.234	0.053	0.007	0.001	0.000
1995 - 00	0.377	0.253	0.076	0.016	0.003	0.000
2000 - 05	0.364	0.255	0.097	0.019	0.003	0.000

Sources: Jun 2002

Table A3 Annual age-specific fertility rates, 1980 – 2007 (per 1,000)

	Year													
Age	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
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

(Continued)

(Continued)

Age	94	95	96	97	98	99	00	01	02	03	04	05	06	07
	Year													
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
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
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

Sources: Korean Statistical Office (www.kosis.kr)