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Age Structure and Population Momentum in South Korea

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The purpose of this research is to explain why the Korean population is still growing despite a very low fertility level and a changing age structure in Korea. To analyze the impact of age structure on the future population growth, population pyramids and estimations of population momentum are used. Population momentum then is further decomposed into stable and nonstable momentums. Decomposition allows the impact of low fertility on future population growth to be analyzed in two steps. We conclude that the history of high fertility has accumulated positive momentum and this momentum is still in effect for continuous population growth. In addition, this research provides a reason why population policy needs to be planned in a longer timeframe.

Keywords: *fertility, age structure, population momentum, stable momentum, nonstable nomentum, South Korea*

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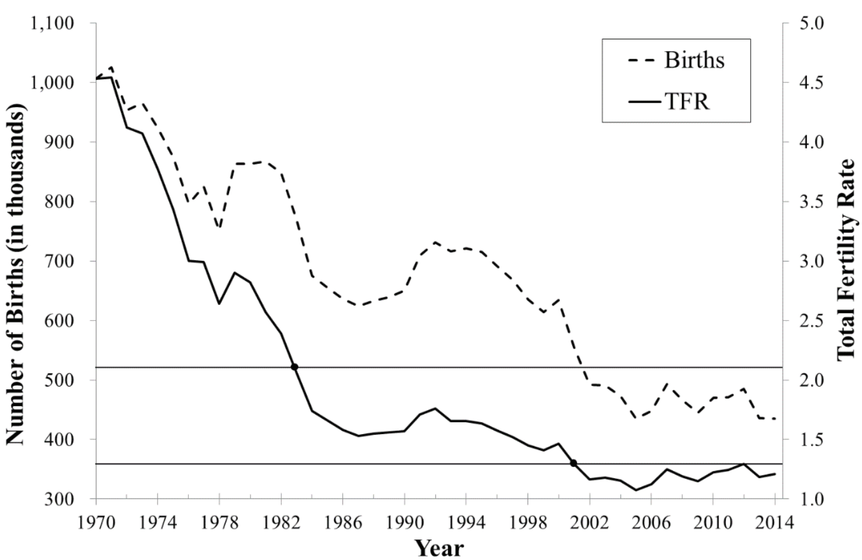
Introduction

This research paper aims to explain the reason why the Korean population continues to increase despite a low fertility rate. It involves in-depth discussion on changing age composition of the Korean population in the last thirty years. Population momentum quantifies impacts of compositional change on population growth. It can also be numerically decomposed into stable and nonstable momentums to express dynamics behind population growth.

Korea's total fertility rate has already dropped below the replacement rate of 2.1 in 1983, and lowest-low rate of 1.3 in 2001. (Kim 1996, See Figure 1) Reflecting back to 1970, the number of births was approximately one million. Thirty-two years later, the number halved. If Korea fails to restore total fertility rate above 1.3, it is considered that Korea will face population decline. Yet, population growth is expected to continue for another 15 years. (See Figure 2)

The balancing equation of population change gives an intuitive



Source.—Statistics Korea 2015.

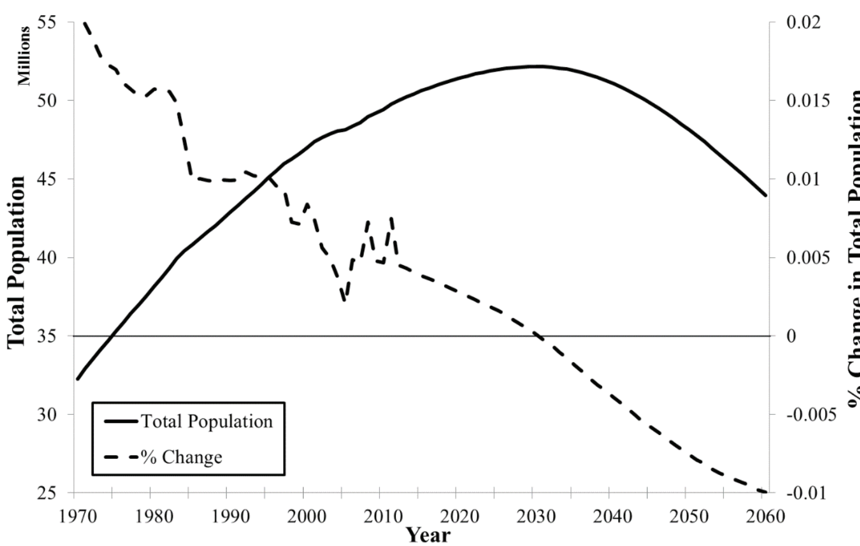
Fig. 1.—Number of births and total fertility rate, 1970-2014

summary why population increases while fertility rates decline. Assuming zero in-and-out-migration, for a given population during time interval t, marked by $[0, t]$,

$$\text{Population at time } t = \text{Population at time } 0 + \text{Births } [0,t] - \text{Deaths } [0,t] \quad (1)$$

Equation (1) suggests that natural population increase can only result from a number of births greater than the number of deaths. Thus the current low fertility rate still yields a higher absolute number of births than deaths. Such a phenomenon is a consequence of age structure, which is the result of high fertility in the past.

Age structure can be graphically described with a population pyramid. However it is limited to a snapshot of a single point in time. Overcoming its limitation, population momentum is a quantitative concept to analyze compositional change in age structure over time. Also decomposition of population momentum allows how change in vital rates influences future population growth. Stable momentum represents permanent component reflecting long-term levels of vital rates. In contrast, nonstable momentum is



Source.—Statistics Korea 2011.

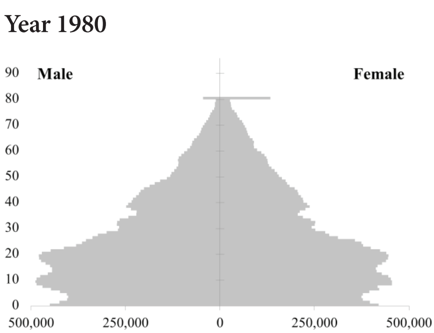
Fig. 2.—Total population and percentage change in total population, 1970-2010 (observed) and 2011-2060 (projected)

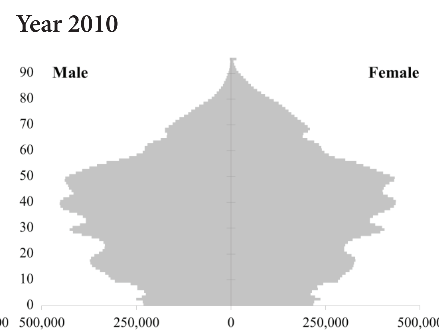
a transient part of momentum that is sensitive to changing vital rates. These two momentums together adjust the magnitude and timing of population growth. This paper will start with a brief introduction to age structure in Korea with population pyramids. Then total, stable and nonstable momentums are estimated from 1985 to 2040. Finally, estimated momentums are used to solve the puzzle of population growth under conditions of low fertility.

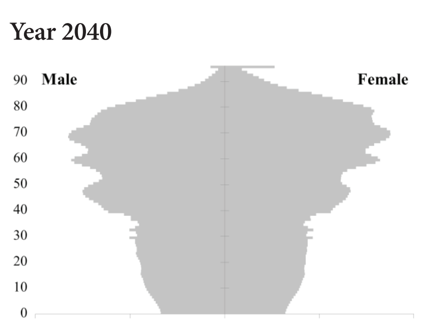
Age Structure in Korea

In the 60 year period between 1980 and 2040, Korea has showed and is expected to show dynamic changes in its age structure, as displayed in Figure 3. The median age was 21.8 in 1980, 37.9 in 2010, and is expected to rise to 52.6 in 2040. These numbers not only indicate that Korean population is getting older, but also show that Korea is losing its ability to have children to increase population, or at least to maintain the current population size.

In the late 1970s and early 1980s, the Korean government took strong







Source.—Statistics Korea 2011

Fig.—3. Age structure of Korean population in the years 1980, 2010 and 2040 (from top-left, clockwise) drive on family planning programs to reduce the number of births. So Korea showed a sharp drop in total fertility rates: from 3.0 in 1976 to 1.58 in 1986. However, this was offset by the generation of baby boomers (1955~1963 birth cohorts) entering childbearing stages. As a result, approximately one third of the Korean population was below 14 years of age in 1980, resulting in a pyramidal age structure in that year.

In 2010, age structure became a diamond shape, due to relatively smaller population size in the later generations after 1980. But the Korean population is still growing. First, longer life expectancy has increased the older population. Second, children of baby boomers (ages 18 to 31 in 2010) continue to enter reproductive ages. They are called the 'echo generation' and make up about 20% of the Korean population. (Statistics Korea 2012, p. 1) Therefore it is possible that the echo generation may result in another new sizable generation in the next decade, despite the low fertility trend, as their mothers did.

Keyfitz (1971, p. 71) mentioned, "a history of high fertility has resulted in a high proportion of women in the reproductive ages, and these ensure high crude birth rates long after the age-specific rates have dropped." Korea indeed had a history of high fertility above 3.0 before 1975. Therefore, the number of females continued to increase until the year 2000. Table 1 shows

TABLE 1.
Number of women in childbearing age, 1985-2010 (observed) and 2015-2040 (projected)

Year	Female Population			
	15~49 YRO		25~40 YRO	
1985	11,072,131	82.5%	4,918,697	73.2%
1990	12,127,623	90.4%	5,843,341	87.0%
1995	12,858,436	95.8%	6,524,344	97.2%
2000	13,417,883	100.0%	6,715,546	100.0%
2005	13,097,021	97.6%	6,288,353	93.6%
2010	13,128,348	97.8%	6,244,192	93.0%
2015	12,602,404	93.9%	5,661,460	84.3%
2020	11,710,038	87.3%	5,423,833	80.8%
2025	10,709,856	79.8%	5,041,622	75.1%
2030	9,907,182	73.8%	4,685,624	69.8%
2035	9,150,114	68.2%	4,146,976	61.8%
2040	8,681,783	64.7%	3,680,145	54.8%

Source.—Statistics Korea 2011; Statistics Korea 2015.

how the number of women in childbearing ages has changed and is expected to change.

After 2000, the repercussions of the history of high fertility diminished and the trend of low fertility rates takes effect. By 2040, the Korean population will continue to decline due to a larger number of deaths and a smaller number of births. That means, referring to the balancing equation (1), net increase in population will be negative. The accumulated older population will face an unprecedented level of crude death rates. At the same time, the comparatively smaller younger population is expected to maintain the current level of low fertility. Borrowing the words of Keyfitz, a low level of fertility has resulted in a smaller proportion of females of reproductive age. Then, even at the replacement fertility rate, the number of newborns is likely to be lower than that of the years with a large number of mothers.

It is evident that changing age structure affects future population growth. Linking a series of population pyramids over time graphically expressed changes in the age structure. However, it is not enough to further analyze the dynamics of age structure change. To overcome such shortcomings, demographers developed the concept of population momentum.

Population Momentum

Literature Review

Population momentum quantifies impacts of the current age structure on future population growth under the assumption of immediate return to replacement level[1] fertility. It may be thought that if the fertility level suddenly reaches replacement level, the population growth or decline will stop instantly also. However, Keyfitz (1971, p. 71) found that abrupt return to replacement level age-specific birth rates would not translate immediately into zero- growth in population size.

Momentum came under the spotlight in the field of demography to describe the phenomenon where the population kept increasing while the fertility rate dropped below replacement level. Positive momentum – momentum above 1 – means that even if age-specific fertility rates reaches the replacement level, the population would continue to increase. It is often

[1] The replacement level of fertility implies age specific fertility rates that would exactly replace the current population. In many countries with low mortality, the replacement level is approximately 2.1.

found in developing countries where above-replacement fertility levels are prevalent. It is also found in countries whose fertility rates once were above replacement level.

In recent literature, momentum became a useful tool to analyze population decline in countries with below-replacement fertility. (Knodel 1999; Lutz, O'Neill, and Scherbov 2003) Negative momentum – momentum below 1 – translates into a population decrease even if fertility rates immediately achieved the replacement level. Knodel (1999, p. 6) noted that this is becoming widely spread for many developed countries, where momentum has already or is expected to change from positive to negative.

Population momentum can be described simply as the inverted ratio of current population size and its corresponding stationary[2] population. In other words, it shows how deviated current population is from its stationary population. Momentum can also be expressed in the complex mathematical form (Keyfitz 1985, pp. 155-6):

$$\text{Momentum} = \frac{e_0}{\mu} \int_0^{\infty} c_n(x) v(x) dx \qquad (2)$$

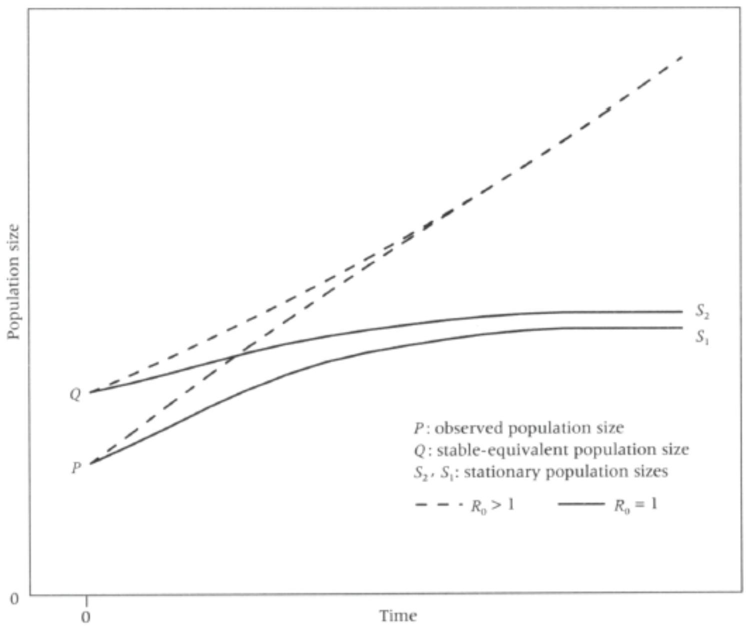
where e_0 is the expectation of life at birth in the stationary population, μ is the mean age at childbearing in the stationary population, $c_n(x)$ is the proportion of people between ages x and $x+dx$ in the current population, $v(x)$ is the decreasing, positive function of x and becomes nearly zero when x is bigger than the last reproductive age; $v(x)$ is called the reproductive value at age x under replacement fertility.[3]

If the current population is already stationary, momentum becomes 1. If the current younger population is larger than the stationary population, then momentum is above 1 since $v(x)$ is large when x is small. However, the current size of the older population does not affect momentum much, because $v(x)$ generally vanishes after the age of 50. In other words, momentum explains the influence of the young, especially reproductive, female population on future population growth.

Espenshade, Olgiati, and Levin (2011) went further to explain the dynamics of population momentum by decomposing it into stable and

[2] Achieving stationary population requires conditions of constant age-specific death rates, constant number of births, and zero net migration over a long period of time. When a population reaches stationarity, population size is stabilized at a certain level.

[3] For further explanation on this equation, refer to Keyfitz (1985, pp. 155-6).



SOURCE.—Espenshade, Olgiati, and Levin 2011, p. 1583.

FIG. 4.—Total, stable and nonstable population momentum

nonstable components. Stable momentum is the deviation between stable-equivalent[4] population implied from the current population and stationary population projected from the stable-equivalent population. It is the measure of how deviated the current fertility rate is from the replacement level fertility, taking mortality changes into account. Nonstable momentum is the deviation between the current population and its implied stable-equivalent population. It measures the deviation between actual age distribution and its corresponding stable age distribution.

Decomposition of total momentum is shown as a multiplication of three ratios:

[4] Stable-equivalent population of current population is the hypothetical population size that satisfies certain conditions and will converge to the same population size in the future as the current population. The conditions are current levels of age-specific death rates and age-specific birth rates applied over many years, under zero net migration. Thus the rate of population size change is constant, showing an exponential change.

$$\text{Momentum} = \frac{S_1}{P} = \frac{S_2}{Q} \times \frac{Q}{P} \times \frac{S_1}{S_2} \quad (3)$$

where P is the observed population size at time 0, Q is the corresponding stable-equivalent population size of the observed population size at time 0, S_1 is the stationary population size projected from P, and S_2 is the stationary population size projected from Q. (See Figure 4).

Stable momentum is the ratio of S_2 to Q, and nonstable momentum is the ratio of Q to P. The final term S_1/S_2, the offset factor, is known to be approximately equal to 1.[5] Blue and Espenshade (2011) used this equation to calculate the total, stable and nonstable momentums of 16 countries in various stages of demographic transitions, including Haiti, Brazil and Sweden.

Decomposition of momentum allows detailed analysis of why an instant drop in fertility does not simultaneously accompany a drop in total momentum. A drop in fertility level influences total momentum in three steps: decrease in stable momentum, increase in nonstable momentum, then adjustment of total momentum depending on the magnitude of changes in stable and nonstable momentum.

A drop in fertility decreases stable momentum. When fertility falls, given the same age-specific death rates, the population decreases at a faster rate. This increases the stable-equivalent population (Q), which is found by extrapolating the future exponential decrease of the current population backward in time. An increase in the denominator (Q) of stable momentum results in a decrease in stable momentum.

At the same time, a drop in fertility level increases nonstable momentum. It is also a result of an increase in the stable-equivalent population (Q). The stable-equivalent population, this time, is the numerator of nonstable momentum. Since the denominator (P) does not change except for the number of newborns, nonstable momentum increases.

As a result, total momentum changes. Total momentum is roughly a multiplied value of stable and nonstable momentum. Recalling that stable and nonstable momentum move in different directions, all the impacts of fertility level decrease are not fully reflected on total momentum.

If the fertility level does not change after the sudden drop, stable

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[5] Observing 176 United Nations member nations in 2005, the absolute deviation is found to be less than 1.2% (Espenshade, Olgiati, and Levin 2011, pp. 1591-1592). It was also the case for this paper.

momentum would stay at the same level while nonstable momentum gradually decreases. It is because the difference between the current population (P) and the stable-equivalent population (Q) – under constant fertility level over time – lessens as time progresses. As a result, a decrease in total momentum from a sudden decline in fertility will occur over a period of time.

Population momentum provides guidelines for many population policies. First, momentum could be a good indicator of an aging population. Kim and Schoen (1997, pp. 422-3) found that momentum and aging of population are linearly related. An increase in the mean age of a population and the decreasing proportion of population under age 30 are the two phenomena leading to lowering momentum and aging population. Second, momentum illuminates the seriousness of low fertility rates issue hindered by ongoing population growth. Goldstein (2002, p. 72) noted that a population with low momentum loses its ability to return to its previous population growth trend even after fertility rates rebound to replacement. Another finding was by Frejka (1968, pp.386-92) who simulated various fertility rate increase schedules on the United States population. It was found that a gradual increase in the fertility rate, from a low fertility rate to the replacement rate, gives smaller population growth than that from an immediate increase to the replacement rate. This implies that not only the magnitude of fertility level change needs to be considered, but also the duration in which the change is planned to take place.

Data and Methodology for Estimating Population Momentums

Total, stable and nonstable momentums for Korea were estimated using the method employed by Blue and Espenshade (2011, pp. 728-31). Starting time points are every five years from 1985 to 2040.

Before estimation, replacement-level, age-specific fertility rates for each time point were estimated by proportionally increasing actual (or predicted) age-specific fertility rates until current age structure achieved stationary state in the long term. Survivorship proportions by sex and age, age-specific fertility rates and population by sex and age are also required information for population projection. Before 2010, this information was obtained from actual values reported by Statistics Korea. For the time points after 2015, information came from population projection published by Statistics Korea (2011).

Five-year interval projection was used for the year 1985 due to incomplete information on survivorship proportions by one-year interval.

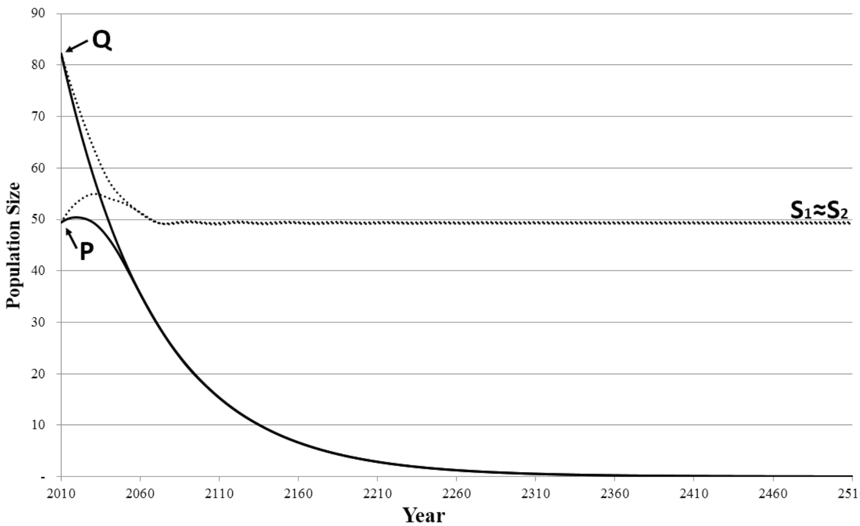

Fig. 5.—Four estimated population sizes (P, Q, S_1, S_2) of the year 2010

For other years, one-year interval projection was used. For all estimations, it was assumed that there is zero net migration and fixed sex ratio at birth of 1.05, which is at natural level.

After necessary information is collected, population at each time point is projected for the next 500 years until the population becomes stationary. Stationary population sizes S_1 and S_2 are found by projecting from observed population size (P) and stable-equivalent population size (Q) respectively, assuming both current survivorship proportions by sex and age and current replacement-level age-specific fertility rates fixed during the years of estimation. Since complete stationarity is not achieved within 500 years, S_1 and S_2 are taken as the values that future population sizes oscillate about. Stable-equivalent population size (Q) was found by extrapolating backward future population projected from observed population size (P) with current survivorship proportions by age and sex and current age-specific fertility rate. Figure 5 illustrates where these population sizes locate for the year 2010. A dotted line indicates the scenario under replacement fertility level and a solid line indicates the scenario under current age-specific fertility rates.

Obtained four projected population sizes (P, Q, S_1, S_2) are then entered into Equation (3) to estimate total, stable and nonstable momentums.

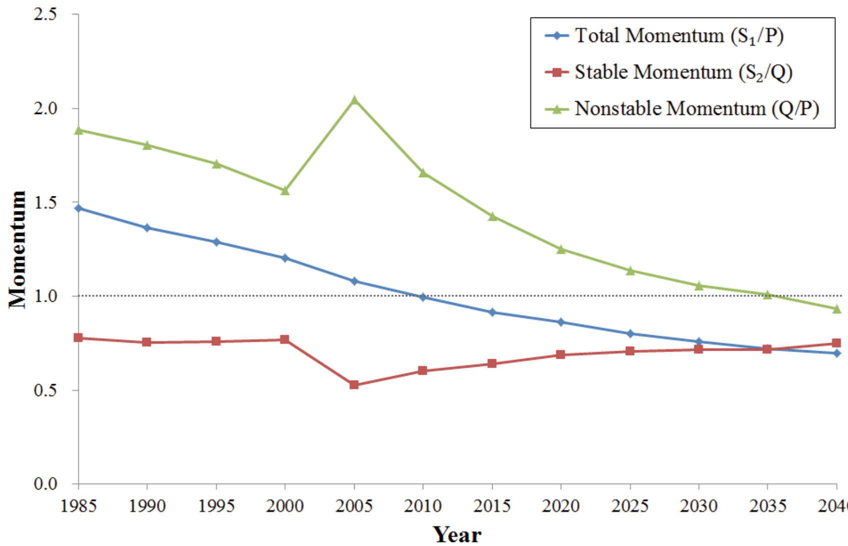

FIG. 6.—Trends of estimated total, stable and nonstable momentums, 1985-2040

Results

Figure 6 shows trends of estimated total, stable and nonstable momentums from 1985 to 2040, in five-year intervals. Although the three momentums essentially converge to support the same conclusion, they represent different concepts.

Total momentum decreases monotonically throughout this period. Declining momentum is a consequence of the decreased proportion of females of reproductive age in the Korean population. Around 2010, the total momentum changed from positive to negative. Before 2010, when the momentum was positive, the Korean population showed an increasing trend even under low fertility rates. After 2010, even if the fertility rate rebounded to replacement level, the Korean population would decrease for some time before total momentum turns positive.

Stable momentum, other than experiencing a sudden drop in 2005, remains below one throughout the given period. Stable momentum measures how much the current fertility rate is apart from the replacement level fertility rate. Since 1985, total fertility rates have stayed below the replacement fertility level. Therefore stable momentum has been the diminishing factor in total momentum in Korea.

Nonstable momentum generally shows a decreasing trend, except for the

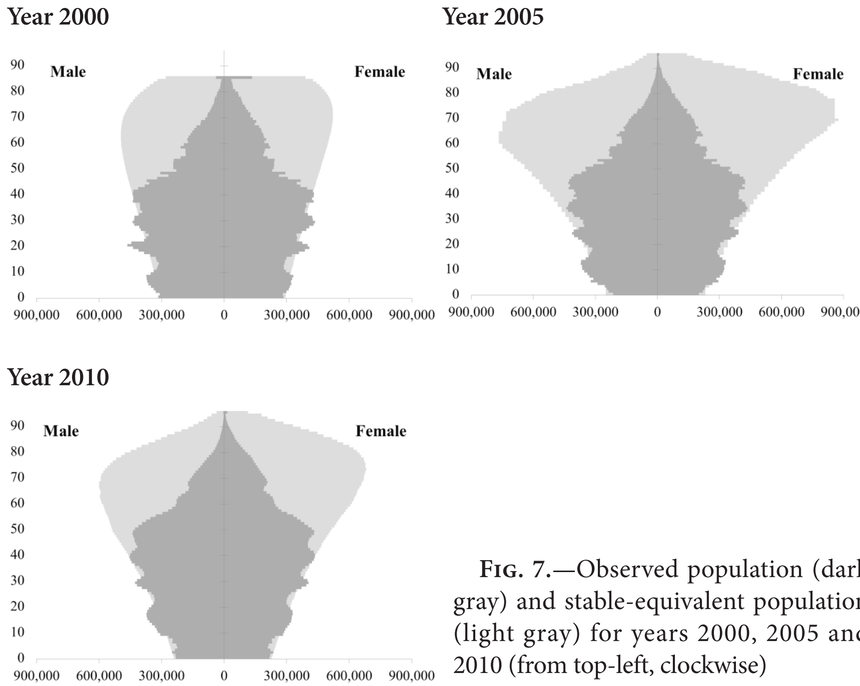

FIG. 7.—Observed population (dark gray) and stable-equivalent population (light gray) for years 2000, 2005 and 2010 (from top-left, clockwise)

sudden spike in 2005. Nonstable momentum reacts to the change in fertility and mortality rates. Because there was not a great change in fertility and mortality level, excluding the year 2005, nonstable momentum approaches one.

The year 2005 caused disruption in the general trends of stable and nonstable momentums. This is when total fertility rate reached an extremely low level of 1.076, which was a dramatic decrease from 1.467 in the year 2000. A Sudden drop in total fertility rate, while mortality rate remains similar, is translated into immediate adjustment of stable and nonstable momentums.

An even lower fertility rate deviates stable momentum further away from one. Also nonstable momentum increases sharply to capture larger deviation between stable-equivalent and current age structure due to fertility rate changes. Figure 7 illustrates how large the deviation was between stable-equivalent and current age structures in the years 2000 (before the drop), 2005 (the time the drop occurred) and 2010 (after the drop).

High nonstable momentum implies that the stable-equivalent population has a much larger population than the current population. Sudden shrinkage in the younger population occurred due to a drop in fertility rates in 2005. Stable population is characterized by a constant rate of change in the population size. Therefore, lower age-specific fertility rates are also reflected in the older population. Because lower fertility rates also applied to a relatively large middle-age group, the number of parents of the large middle-age group needed to be much bigger than the large middle-age group itself. This created a much larger portion of older population of stable-equivalent age structure, so it yields a greater difference between stable-equivalent and current age structures.

Decreasing nonstable momentum with already-low stable momentum hints at a Korean population decrease in the future. Between 2030 and 2035, projected nonstable momentum falls below one and stable momentum is below one. Nonstable momentum below one indicates that stable-equivalent population is less than the observed population. It implies that the observed population between 2030 and 2035 has a much higher share of older population than the stable-equivalent population. This implies a higher crude death rate in the observed population. Few babies born and many deaths from the older population jointly work to reduce population size. In fact, Statistics Korea (2011) projected the Korean population to peak in 2030. Nonstable momentum below one, therefore, may provide a sign of population decline after 2030.

A continuous decrease in nonstable momentum to one and constant stable momentum in the later years is the result of assuming very similar levels of low fertility rates for some period. Statistics Korea (2011) set the total fertility rate to stabilize close to 1.40 beyond 2025. When the fertility rate stays constant for a long time, nonstable momentum becomes redundant. So this is when the impact of low fertility rates in the past is fully reflected upon total momentum, through stable momentum.

Readers need to be reminded that figures beyond 2015 are based on population sizes projected from assumed vital rates for Population Projection in 2011 by Statistics Korea. Therefore it cannot be certain that such patterns will follow in the coming decades. However, unless fertility rates undergo another big change, nonstable momentum approaching one and below one stable momentum would persist.

Discussion

Analysis on the number of women in childbearing ages provided a simple explanation as to why the Korean population continues to increase while total fertility rates have marked below 1.5 since late 1980s. It is because the female population in the childbearing ages had increased by 21% from 1985 to 2000. Considering those between 20 to 45 years of age, there was more than a 36% increase in the number of females. Holding the current level of fertility constant, the number of births is proportional to the number of females in the childbearing ages. Therefore, a large number of mothers canceled the negative effect of the low total fertility rate, and kept number of newborns to maintain the 600~700 thousands range. In turn, a large newborn population was able to support continue positive population growth.

However, at some point in time, the number of females in the childbearing ages would decline due to continual trend of low fertility. In addition, Korea's fertility rate is not showing any sign of exiting the "lowest-low"[6] level. Total fertility rates below the lowest-low level and decrease in the number of females in the childbearing ages have worked jointly to bring down the birth figure to less than 500 thousands from the early 2000s. Accumulation of such negative effects on population growth will eventually reduce population size.

Estimation of total momentum was able to quantify changes in age structure. Total momentum turning from positive to negative in the year 2010 indicates that population is expected to decrease though total fertility rates rebound to replacement level. As population gains more negative momentum, it would become more difficult to maintain the current population size.

Decomposition of total momentum into two types of momentums allows in-depth analysis of changing age structure and how it impacts population size. Stable momentum is a ratio of current level of fertility over replacement level fertility corresponding to current age structure. Korea's stable momentum stayed below one during the time of analysis. Nonstable momentum, however, showed a large decline over time. This measure is sensitive to changes in the fertility rate. A drop in the fertility rate causes corresponding stable age structure to have a greater share of older population than the current age structure. With time, the share of older population would increase due to a history of high fertility rates. So, assuming no large scale change in fertility, the age structure would become similar to stable age structure. Where there is a larger older population, stable age structure under

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[6] For more explanation on the term "lowest-low" fertility, refer to Kohler, Billari, and Ortega (2002).

low fertility is a contractual shape,. It implies that the aged society is a natural consequence of a long trend of low fertility. In conclusion, Korea will face population decline in the coming future accompanied by a higher share of older population.

If population decline is expected, is there still a possibility to maintain current population size? It is clear that there is a more effective timing for campaigns to increase fertility levels: it is when there is a large number of young females for childbearing. Translating into the words of demography, it is when there is a positive total momentum. However, Korea's total momentum has already become negative since 2010. This means that although an immediate rebound to replacement-rate fertility is achieved, population would stabilize at a smaller size compared to the scenario when momentum is still positive. Therefore, population policy should not only aim at maintaining certain level of population, but also at preparing for expected size and age structure changes in the future population.

The Korean government should mainly prepare for two upcoming problems. One is the problem of an aged society, which includes the welfare of elderly population. Another is shrinking productive population due to a decreasing younger population. The aged society issue is relatively well addressed because Korea has already become an aging society. However, the latter problem poses a long-term threat to Korea's economy. A greater number of births may result from two approaches: increasing the number of mothers or increasing the number of births per woman.

In the absence of immigration, the only way to maximize the number of mothers in a given population is to help women who want to be mothers to become mothers. The number of females with problems of infecundity due to old age or other medical reasons has increased. One possible reason for such phenomenon is the increase in mean age for first marriage. The government should continue to provide more opportunities through the medical system for them to enjoy motherhood.

Extensive social welfare systems to reduce the burden of childcare may support parents' decisions to have children. As more females take active roles in the labor market, it may be difficult to raise children and have jobs at the same time. Due to the high cost and burden of raising children, working mothers often feel discouraged to have more than one child. Reliable childcare systems and increases in work condition flexibility for working mothers in workplaces may relieve the burden of childcare and support childbirth.

As a final note, this research alerts policymakers that they should keep in mind that family planning policies need to be planned for the long term and policymakers need to wait for their real influence to take place. As seen in the example of 2005, abrupt large-scale changes in the fertility level does not directly translate into a change in total momentum. The impact of such change would occur after many years through readjusted momentum over time. So policymakers should create a well-made, long-term plan that is not easily be swayed by external political influences.

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Appendix

Population at different reference years, total fertility rate and result of population momentum estimation, 1985-2040

Year (t)	Population at time t (P)	Total Fertility Rate	Total Momentum (S_1/P)	Nonstable Momentum (Q/P)	Stable Momentum (S_2/Q)	Offset Factor (S_1/S_2)
1985	40,805,744	1.660	1.47025	1.88750	0.77956	0.99921
1990	42,869,283	1.570	1.36232	1.80706	0.75332	1.00076
1995	45,092,991	1.634	1.29103	1.70433	0.75690	1.00079
2000	45,983,421	1.576	1.20255	1.56505	0.76664	1.00227
2005	47,041,434	1.145	1.08138	2.04849	0.52727	1.00118
2010	49,410,366	1.228	0.99548	1.66016	0.60046	0.99862
2015	50,617,045	1.280	0.91499	1.42799	0.64032	1.00067
2020	50,959,702	1.350	0.86204	1.25110	0.68750	1.00222
2025	51,972,363	1.380	0.80244	1.13855	0.70560	0.99886
2030	52,160,065	1.410	0.75622	1.05596	0.71630	0.99979
2035	51,888,486	1.420	0.72164	1.01024	0.71348	1.00118
2040	51,091,352	1.420	0.69824	0.93530	0.74719	0.99914

NOTE.—1985~1995 values were estimated based on 5 year interval projection due to unavailability of some required information. 2015~2040 values were estimated using predicted values of age-specific fertility rates and survival rates from population projection (Statistics Korea 2011).