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# A Study on the Population Structure and Aging of Reunified Korea*

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*The Republic of Korea is undergoing both unprecedented, rapid population aging and lowest-low fertility problems. These population trends eventually cause a population decline, manpower decrease, and other related socio-economic problems. Recently, reunification of the two Koreas has been discussed as a possible breakthrough to overcome population problems. This paper first conducts a population projection of the Democratic People's Republic of Korea, and then predicts the future population of a reunified Korea under possible scenarios of fertility and mortality. We further examine the population structure of reunified Korea using age-specific populations, aging indices and dependency ratios to investigate population aging and the socio-economic sustainability of the reunified Korea. Based on the projection results, reunification cannot drastically change the aging trend of the Republic of Korea, but can delay the decrease of the working- age population.*

**Keywords:** *population projection, LC model, scenario, population pyramid, aging index*

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## Introduction

The sustained low fertility and population aging rates in South Korea have appreciably changed the population structure. The proportion of the elderly population over 65 has increased to 13.1 in 2015, while the number of the working age population has been expected to decrease in a few years. In addition to labor shortages caused by low fertility, population aging has caused an imbalanced age-specific population distribution toward the elderly, affecting socio-economic and cultural environments (Park, Jang, and Kim 2013). For example, government expenditures for the elderly, such as medical expenses, health insurance, and the national pension, have drastically increased. In this respect, the problems of low fertility and population aging have been considered serious issues at the government level. Confronting these population problems, the South Korean government has implemented various pronatalistic policies, such as childbirth grants and maternity leave, in an effort to increase fertility, but the total fertility rate of South Korea still remained at a lowest-low level of 1.187 in 2013.

Park, Kim, and Kim (2013) have pointed out that fertility, rather than mortality, has a greater influence on changes in population structure, and it is the main cause of the decrease of the productive population. Park, Kim, and Kim (2013) have projected that the productive population in South Korea would rapidly decline in any fertility and mortality scenario, while the productive population is shown to maintain or increase on average in OECD nations that have an aging or aged society. In this respect, the population influx resulting from the reunification of the two Koreas, the Republic of Korea (hereafter, South Korea) and the Democratic People's Republic of Korea (hereafter, North Korea), has been discussed recently as a possible way to avoid a fall off the edge of the demographic cliff (Dent 2014).

As the German case shows, reunification involves both high costs and political, military, social, and cultural agreements between the divided nations. Division embodies not only a geographical separation, but also a socio-economic and cultural separation between South and North Korea. The economic gap between two Koreas is much larger than that of the German case. The per-capita GDP of South Korea is estimated to be more than 10 times that of North Korea, while the GDP of West Germany was less than twice that of East Germany ahead of their reunification. Socio-economic and cultural differences also led to different levels of fertility and mortality, because those factors reflect the quality of life, child nutrition, health care, medical services, and social welfare. Gjonca, Brockmann, and Maier (2000) pointed out that fertility and mortality rates change according to changes in society, and Jeon, Kim, and Park (2015) have shown that the mortality patterns and population structures of the two Koreas are totally different. Therefore, understanding the current and future population structure of North Korea is fundamental to accurately estimate the effect and cost of reunification.

Despite the need for timely information on the population of North Korea, research is limited due to limited sources of population data. In North Korea, only two national censuses have been conducted by the government of North Korea—in collaboration with the United Nations. The lack of reliable population data has been an obstacle to meaningful research on the North Korean population. On the North Korean population, there are three main research concerns. One is assessing the reliability of population data in North Korea (Eberstadt and Banister 1992a; Kim *et al*. 2011; Park 2012; Jeon *et al*. 2015). The second concern is identifying the population loss due to North Korea's famine (Eberstadt 2001; Goodkind and West 2001; Lee 2004; Park 2012). The last concern is generating population projections and prospects (Eberstadt and Banister 1992b; Adlakha and West 1997; Eberstadt 2001; Lee 2007; UNPD 2010; Kim *et al*. 2011; Stephan 2013).

Early studies on the population projection of North Korea have focused on total population and life expectancy. Adlakha and West (1997) projected gender-specific total populations of North Korea by utilizing indirect experiences of famine-related death rates in China during the Great Leap Forward 1958-1962. Goodkind and West (2001) offered population trends and life expectancies over 1994-2000 in North Korea, using information from famine refugees in China and the official crude birth and death rates released by the government of North Korea in 1999. Since the second census in 2008, more comprehensive analyses for the North Korean population were conducted. Park (2012) estimated the famine-related population losses for sex-and age-specific groups by reflecting the change of fertility and mortality. Spoorenberg and Schwekendiek (2012) demonstrated that official vital statistics, such as fertility and mortality rates for North Korea, can be considered as reliable, based on the consistency between reconstructed and observed populations in 2008. However, they assumed too high a life expectancy for the year 2000 in reconstructing their population, which was contrary to the official life expectancies released by the government of North Korea that show a clear increasing trend in the mortality rate from 2000 to 2008. In this regard, this paper firstly aims to project the future population of

North Korea, by properly reflecting fertility and mortality changes in North Korea.

There have been many discussions between the government and researchers about the necessity of reunification, and now a national consensus on this necessity has been formed. However, compared to the extensive discussions, quantitative studies on reunified Korea are scarce. Quantitative approaches to expect or estimate the effects and costs of reunification should be based on the population estimation and projection of reunified Korea. Therefore, this paper secondly aims to forecast the future population projection of reunified Korea, and examine population structure of reunified Korea using aging indices and dependency ratios.

This paper consists of four sections. Section 2 describes the population projection of North Korea, based on the cohort component method. Firstly, forecasts of fertility and mortality preceded the projection. We forecast mortality using the Lee and Carter model (LC model) by replacing their model with an exponentially weighted time effect model. We specify scenarios of fertility in North Korea due to the lack of official population data. Then, we project sex-age- specific future populations in North Korea in 2009-2060. Section 3 investigates the population structure and aging trend in reunified Korea based on the population projection of North Korea, using aging indices and dependency ratios. Then, we explore how the aging trend in reunified Korea would be changed. Section 4 contains concluding remarks and discussions.

## Population Projection of North Korea

Population projection is a postcensal forecast in the sense that it is implemented using projections of mortality, fertility, and migration based on the most recent census population. Declining fertility and mortality rates have been a primary determinant of population aging and of the age structure of future populations, including the pace of population aging. A good quality projection requires an accurate and reliable cohort time series of mortality, fertility, and migration. However, as discussed already, North Korea meets almost none of these requirements, due to the scarcity of official vital statistics such as fertility and mortality. Therefore, we consider scenarios for fertility and mortality as described below, assuming no migration in North Korea—except for a negligible number of North Korean refugees.

*Population Estimates between Censuses*

Jeon *et al*. (2015) assessed the reliability of the two national censuses in 1993 and 2008 of North Korea, and reconstructed the intercensal sex-age-specific populations between the censuses. Population losses related to North Korea's famine were estimated differently among researchers. For example, Lee (2000) estimated the population loss as approximately 300-800 thousand, but Eberstadt (2001) estimated ten times larger than that at approximately 3 million. Population losses were estimated by Goodkind and West (2001) as 600-1004, Lee (2004) as 580-690, Goodkind, West, and Johnson (2011) as 500-600, Park (2012) as 880, and Jeon *et al*. (2015) as 490-570 thousand. In addition to the population loss size, the period of influences due to famine has not been officially reported. Although the research methods are different, Goodkind and West (2001), Spoorenberg and Schwekendiek (2012), Park (2012), and Jeon *et al*. (2015) commonly stated that mortality peaks in 1998, three years after the onset of the famine in North Korea. Due to some ambiguity about the onset and end of the famine conditions, the reconstructed populations before 1998 may not be reliable (Goodkind and West 2001; Goodkind *et al*. 2011; Spoorenberg and Schwekendiek 2012). To avoid such an uncertainty and to minimize impact of the 1995 famine in future population projection, we reconstructed the sex-age-specific population estimates of North Korea from 1999 to 2007 and the 2008 census population.

*Fertility and Mortality Scenarios*

Future population projection based on the cohort component method requires the future fertility and mortality. To forecast the future mortality, we use LC model, which is the most widely used method of probabilistic forecasts of mortality (Lee and Carter 1992). The LC model of age- specific death rates is defined by

$$\ln m_{x,t} = a_x + b_x \cdot k_t + \varepsilon_{x,t}, \tag{1}$$

where $m_{x,t}$ is the death rate of people of age $x$ at time $t$. The parameters to be estimated are $a_x$, $b_x$, and $k_t$, where $a_x$ is the average death rate at age $x$, $k_t$ is the index of the general level of mortality varying with time $t$, and $b_x$ is an age-specific coefficient of adjustment on the change in $k_t$. We apply the LC model

TABLE 1
LEVEL OF MORTALITY OVER TIME, , IN NORTH KOREA

| Year | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|---|---|---|---|---|---|---|---|---|---|---|
| Male | 11.4 | 5.91 | 4.18 | 2.39 | 0.05 | -1.62 | -3.73 | -5.94 | -6.32 | -6.32 |
| Female | 23.0 | 17.5 | 12.5 | 6.20 | 0.63 | -5.03 | -10.6 | -14.7 | -14.7 | -14.7 |

to the population data between 1999 and 2008 to minimize the impact of the famine on the mortality forecasts. Table 1 shows the estimated $\hat{k}_t$ for each year for each age $x = 0, \ldots, 100$, and $\hat{k}_t$ for each year.

The estimated $\hat{k}_t$ for males decreases as time advances, and the decreasing trend is more obvious in females than in males. This implies that mortality has decreased for both sexes, and that female mortality has decreased faster than male. To forecast future mortality, we can use these time series values of $\hat{k}_t$ which were estimated from the constructed (or, estimated) populations except for the empirical population in 2008. It is more reasonable to weight the most recent data (i.e., the 2008 mortality data) than the past data. Therefore, we consider a double exponential smoothing model, giving more weight to the most recent terms in the time series and less weight to values in the early part of series (Brown 1962). The predicted model using the time series of $\hat{k}_t$ from 1999 to 2008 is

$$\tilde{k}_{T+t} = (2 + 0.118t)\, S_T - (1 + 0.118t)\, S_T^{(2)}, \tag{2}$$

where $S_T = 8.97$ and $S_T^{(2)} = 27.44$ for males and $S_T = 21.91$ and $S_T^{(2)} = 66.98$ for females, with $T = 2008$.

Then, we can forecast the future mortality $\tilde{m}_{x,t} = \exp(\hat{a}_x + \hat{b}_x \cdot \tilde{k}_t)$, for $t > 2008$ from equation (1), using the estimated $\hat{a}_x$ and $\hat{b}_x$, and the forecasted $\tilde{k}_t$ from the double exponential smoothing model in equation (2). The 95% upper and lower bounds of $\tilde{k}_t$, denoted by $\tilde{k}_t^U$ and $\tilde{k}_t^L$, produce the upper and lower forecasts of the mortality rate $\tilde{m}_{x,t}$, *i.e.*, $\tilde{m}_{x,t}^U = \exp(\hat{a}_x + \hat{b}_x \cdot \tilde{k}_t^U)$ and $\tilde{m}_{x,t}^L = \exp(\hat{a}_x + \hat{b}_x \cdot \tilde{k}_t^L)$. These two upper and lower forecasts of the mortality rate can be considered as two possible scenarios of mortality, high mortality and low mortality, respectively. Therefore, we consider three scenarios of the future mortality, low, medium and high mortality, using $\tilde{m}_{x,t}^L$, $\tilde{m}_{x,t}$, and $\tilde{m}_{x,t}^U$. The corresponding life expectancies at birth are summarized in Table 2.

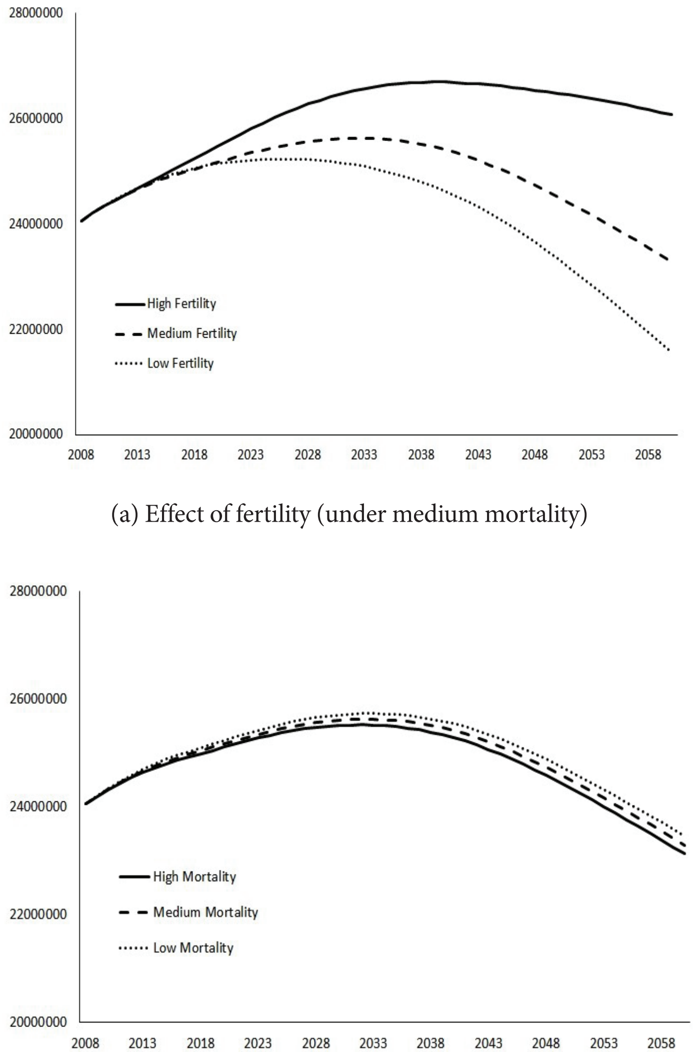
The future life expectancies for North Koreans in 2060 are predicted to be 74.18 years for males and 83.27 for females at birth, which are still less than the life expectancies of South Koreans in 2010, 77.2 years for males and

**TABLE 2**
**Projection of Life Expectancies at Birth in North Korea**

| Gender | Level | 2010 | 2020 | 2030 | 2040 | 2050 | 2060 |
|---|---|---|---|---|---|---|---|
| Male | Upper | 66.99 | 69.18 | 71.39 | 72.67 | 73.68 | 74.50 |
| | Medium | 66.35 | 69.14 | 71.00 | 72.33 | 73.35 | 74.18 |
| | Lower | 65.64 | 68.62 | 70.57 | 71.50 | 73.00 | 73.85 |
| Female | Upper | 75.24 | 78.04 | 79.90 | 81.35 | 82.57 | 83.67 |
| | Medium | 74.56 | 77.57 | 79.50 | 80.96 | 82.18 | 83.27 |
| | Lower | 73.79 | 77.06 | 79.08 | 80.57 | 81.78 | 82.85 |

84.07 for females at birth (Park *et al*. 2013a). This implies that the life expectancy of North Koreans is more than 50 years behind that of South Koreans. Also, under the medium mortality scenario, the life expectancy for a female in 2010 is 8.21 years longer than that for a male, and in 2060 the difference becomes 9.09 years. This implies that the speed with which mortality is decreasing for females is faster than that for males.

To forecast the future fertility, total fertility rate (TFR) or age-specific fertility rate (ASFR) are required. TFR is the average number of children a woman will bear between the ages of 15 and 49 years, and the ASFR is the average number of children a woman will bear at each age. Forecast based on fertility models have been suggested for TFR (for example, Hyndman and Booth 2008; Alkema *et al*. 2011) and ASFR (Peristera and Kostaki 2007; Park *et al*. 2013b), but neither TFR nor ASFR data is available in North Korea. The only fertility information available is the number of births in the 12 months preceding the 2008 census, from which the TFR is estimated to be 2.02 and the estimates of ASFR are 0.000667 for women aged 15-19, 0.0609 for 20-24, 0.216 for 25-29, 0.114 for 30-34, 0.019 for 35-39, 0.00327 for 40-44, and 0.000391 for those aged 45-49. More than 50% of births in 2008 were to women aged 25-29 years; by contrast, fertility is extremely low for those aged 15-19 and 40-49 years. This unusual fertility pattern might be the result of (1) the long military draft, explaining the concentration of fertility among women aged 25-29 years, (2) the lack of permission to marry early, explaining the extremely low fertility in those of a young age (15-19 years old), and (3) the high female labor force participation, explaining the low fertility in the older age group (40-49 years old). The age distribution of fertility collected in the 2003 2004, and 2006 Reproductive Health Surveys supports a similar pattern (Spoorenberg and Schwekendiek 2012). Thus, we assume that the distribution of the ASFR will remain constant in the future,




(a) Effect of fertility (under medium mortality)

(b) Effect of mortality (under medium fertility)

**FIG. 1.**—Effect of fertility and mortality on the future population

in line with the 2008 distribution, and that the TFR will decrease by 3.1% per year, reflecting the average decrease in the rate over the 2003, 2004, and 2005 crude birth rates.

Therefore, we consider three scenarios of the future fertility TFR, which the future ASFRs are obtained by multiplying these TFRs to the 2008 distribution of the ASFR. The first scenario is that the TFR decreases from 2.02 to 1.8, a lower limit for population replacement, until 2013 and then remains constant. The second scenario assumes that the TFR decreases to 1.5 until 2017 and then remains constant at 1.5, the lower limit for offsetting the aging problem through immigration. The third scenario is that it decreases to 1.3, a very low level of fertility, until 2022. Figure 1 presents the effects of fertility and mortality on the future population. Figure 1-(a) displays the trend in the total population for each fertility scenario under the medium mortality assumption, while Figure 1-(b) shows that for each mortality scenario under the medium fertility assumption. From Figure 1-(a) and Figure 1-(b), the projected total population seems more sensitive to a change in fertility than mortality.

*Future Population in North Korea*

Three levels of fertility scenarios and three levels of mortality scenarios produce nine scenarios for the future population of North Korea. For example, the low+low scenario indicates low mortality and low fertility, while the high+high scenario indicates high mortality and high fertility. Among these nine possible scenarios, we present here the three most likely scenarios for the North Korean population: high fertility+medium mortality (High+Med), medium fertility+medium mortality (Med+Med), and low mortality+low fertility (Low+Low). The first scenario, high fertility and medium mortality, indicates the future mortality rate at the predicted level and the fertility rate at 1.8, the most optimistic one among the nine scenarios. It assumes that the birth policies of the government will succeed and the mortality level will remain at the current time evolution given the current level of medical care. The second is the case of medium fertility and medium mortality, which is a moderate scenario. It assumes that the fertility and mortality rates will remain at the current time evolution. The last scenario is that of low fertility and low mortality, assuming that the low fertility phenomenon will last and the mortality rate will decrease with the development of medical technology. This can be thought of as the worst population scenario, but the most realistic scenario, because it would result in the fastest population decline due to the lowest number of births and the largest proportion of the elderly in the population. In projecting the population for each scenario, we assume a closed population for North Korea, with no international migration.

TABLE 3
FUTURE TOTAL POPULATION IN NORTH KOREA UNDER SCENARIOS

| Scenario | Sex | 2010 | 2020 | 2030 | 2040 | 2050 | 2060 |
|---|---|---|---|---|---|---|---|
| High Fertility | Male | 11,886 | 12,486 | 12,914 | 12,951 | 12,756 | 12,509 |
| + Medium Mortality | Female | 12,463 | 12,990 | 13,504 | 13,740 | 13,725 | 13,563 |
| (High + Med) | Total | 24,349 | 25,476 | 26,418 | 26,692 | 26,482 | 26,073 |
| Medium Fertility | Male | 11,843 | 12,334 | 12,508 | 12,307 | 11,760 | 11,099 |
| + Medium Mortality | Female | 12,419 | 12,840 | 13,107 | 13,110 | 12,753 | 12,191 |
| (Med + Med) | Total | 24,262 | 25,174 | 25,614 | 25,417 | 24,514 | 23,290 |
| Low Fertility | Male | 11,888 | 12,347 | 12,336 | 11,967 | 11,230 | 10,298 |
| + Low Mortality | Female | 12,465 | 12,859 | 12,944 | 12,785 | 12,249 | 11,424 |
| (Low + Low) | Total | 24,353 | 25,207 | 25,280 | 24,752 | 23,480 | 21,723 |

units: thousands

Table 3 provides the forecasts of the total population, every 10 years from 2010 to 2060, under the three possible scenarios, high fertility and medium mortality (High+Med), medium fertility+medium mortality (Med+Med), and low fertility and low mortality (Low+Low). The total population ranges from 25,280,000 to 26,418,000 in 2030 and from 21,723,000 to 26,073,000 in 2060. Under the most likely scenario, the medium fertility and mortality scenario, the maximum population forecast is 25,630,000 in 2032 and thereafter the total population decreases. The difference between the male and female populations widens as time advances, suggesting that the pace of aging of the female population in North Korea will be faster than that of the male population.

Although the projection of sex-specific population and total population is of concern in preparation for reunification, the distribution of the age structure is more informative. The age composition of a population demonstrates the magnitude of the labor force, school enrollment, and the voting population, as well as important information that can be used to determine policies regarding health care, housing, and the public pension system. Based on the age-specific population projections for North Korea under the three scenarios, we can project the future population structure of North Korea. Table 4 presents the population projections for North Korea under the most possible scenario, the medium mortality and medium fertility scenario, which shows mortality at predicted level and that fertility would remain at 1.5.

Table 4 shows the future population in North Korea under the medium

TABLE 4
Future Population in North Korea under med+med Scenario

| Year | Total | 65+ years | -14 years | 6-21 years | 15-64 years | 25-49 years |
|---|---|---|---|---|---|---|
| 2010 | 24,262 | 2,233 | 5,412 | 6,256 | 16,690 | 9,310 |
| 2020 | 25,174 | 2,518 | 4,689 | 5,440 | 17,967 | 9,300 |
| 2030 | 25,614 | 3,364 | 4,401 | 4,865 | 17,849 | 9,317 |
| 2040 | 25,417 | 4,685 | 4,052 | 4,604 | 16,680 | 8,855 |
| 2050 | 24,514 | 4,801 | 3,617 | 4,136 | 16,096 | 7,845 |
| 2060 | 23,290 | 5,228 | 3,371 | 3,752 | 14,691 | 7,219 |

units: thousands

fertility and mortality assumptions, in terms of total population, aged population (over 65), child population (under 14), school-aged population (between 6 and 21), working age population (between 15 and 64), and power-at-work population (those between 25 and 49, assumed to hold the most power at work). The population trend of North Korea can be characterized by clearly decreasing trends in the population under 65 years old but an increasing trend in the number of older people (i.e., 65 years old or more). In other words, North Korea will also be faced with a decrease in the size of the young generation but an increase in the number of elderly, which is a typical pattern of population aging. In particular, the power-at-work population in North Korea will fall much faster than the general working age population during the 50 years from 2010 to 2060, implying a fast reduction in the working population in an economic sense. This would be likely to impose a heavier economic burden of dependency on the working population, and the living conditions in North Korea would be more likely to deteriorate seriously in the future if the current economic situation were not improved.

## Future Population in Reunified Korea

With the population projections for North Korea having been made, we can predict the future population structure of reunified Korea. In fact, population projection of a reunified Korea and the sum of the population projection of two Koreas are different concepts. However, there's no known demographic information of reunified Korea, as yet a virtual country, and we project the population structure in reunified Korea by summing up the population

TABLE 5
FUTURE POPULATION IN REUNIFIED KOREA UNDER MED+MED SCENARIO

| Year | Total | 65+ years | -14 years | 6-21 years | 15-64 years | 25-49 years |
|---|---|---|---|---|---|---|
| 2010 | 72,253 | 7,658 | 13,199 | 16,111 | 51,470 | 28,848 |
| 2020 | 74,930 | 10,536 | 11,545 | 13,133 | 52,849 | 26,996 |
| 2030 | 76,842 | 15,910 | 11,581 | 12,253 | 49,352 | 24,785 |
| 2040 | 76,722 | 21,296 | 10,639 | 12,209 | 44,787 | 22,308 |
| 2050 | 74,634 | 23,683 | 9,164 | 10,667 | 41,787 | 19,433 |
| 2060 | 71,549 | 24,847 | 8,989 | 9,627 | 37,712 | 18,901 |

units: thousands

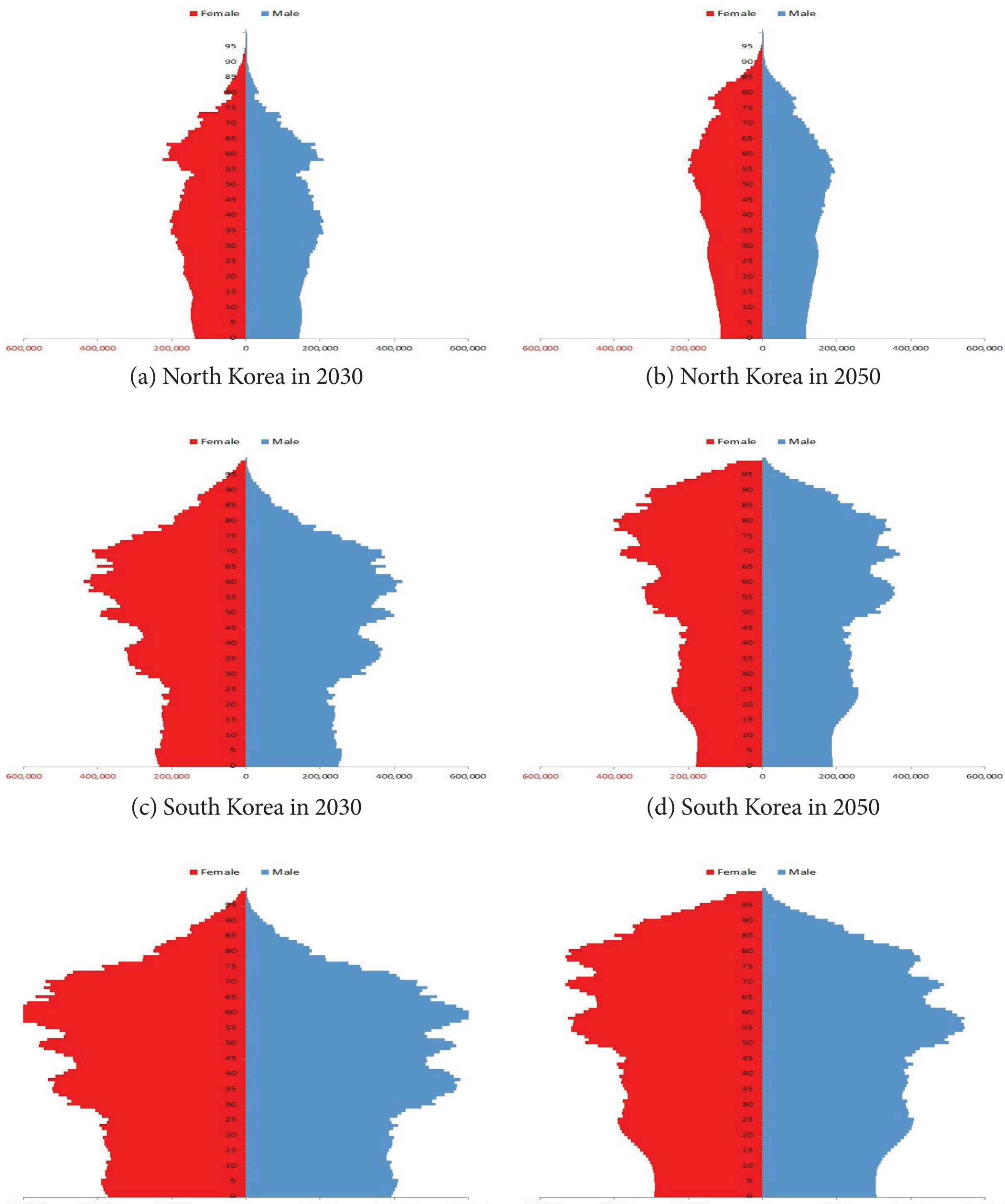
projection results of North and South Korea and by utilizing their demographic figures such as the fertility and mortality of each Korea. In this section, we present the population projections and aging indices of reunified Korea under the three most likely scenarios of fertility and mortality.

*Population Structure of Reunified Korea*

In addition to the population projections for North Korea, we can also project the population trends for a reunified Korea for each of the three scenarios. Using population projections for South Korea (Park *et al.* 2013b), we can predict the population of the reunified Korea by adding the populations of the two Koreas.

Table 5 shows the total population in reunified Korea under medium mortality and medium fertility for both Koreas. Future total populations are projected to be more than 72 million by 2060. However, even if unification happens, it seems that it will be hard to avoid a total population decline, given the current levels of death and births. More specifically, even in reunified Korea, the only increasing population will be the aged population (65+ years), while the other populations decrease over time, including the child population (-14 years), the school-age population (6-21 years), the working age population (15-64 years) and the prime age-work population (5-49 years). In other words, reunification does not seem to solve the population aging of South Korea, at least in terms of population size.

To investigate a more detailed single-age population, a population pyramid is a very effective and widely used method of graphically depicting




(a) North Korea in 2030

(b) North Korea in 2050

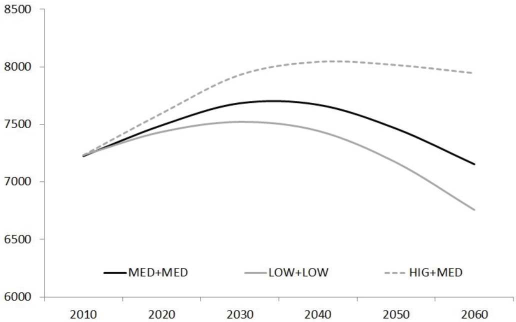
(c) South Korea in 2030

(d) South Korea in 2050

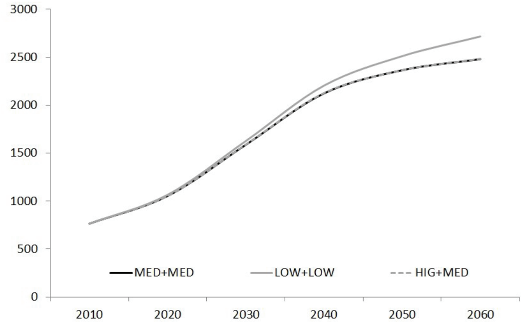
(e) Reunified Korea in 2030

(f) South Korea in 2050

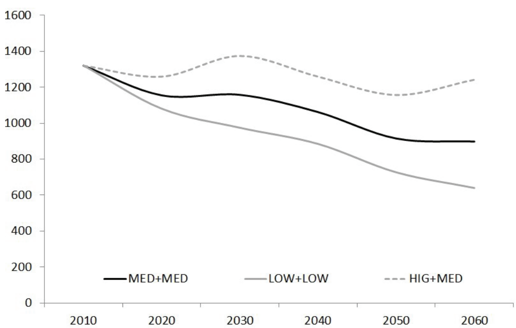
**FIG. 2.**—Population pyramids for two Koreas and reunified Korea



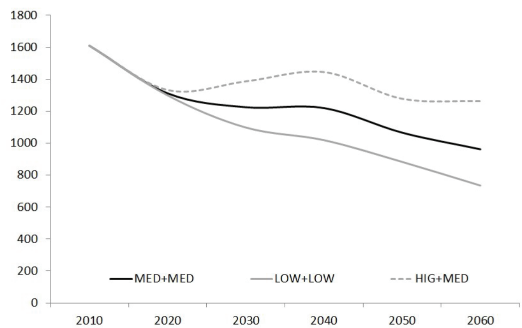

(a) total population



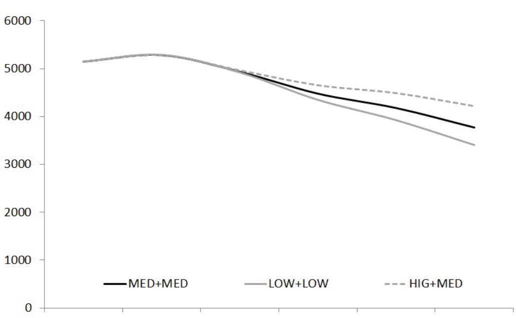

(b) aged population (over 65)



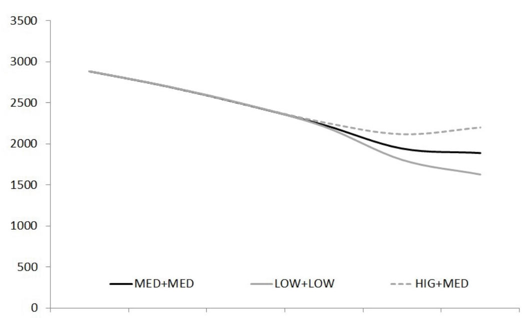

(c) child population (under 14)




(d) school-aged population (6-21)




(e) working age population (15-64)




(f) prime age worker (25-49)

**Fig. 3.**—Population projection of reunified Korea for scenarios

the age-gender composition of a population. As shown in Figure 2, the basic form of the pyramid consists of bars, representing the sizes of single-age populations in ascending order from lowest to highest. The bars for males are on the right of the central vertical axis, and those for females on the left.

The population pyramids in Figure 2 for both Koreas can be summarized as inverted triangle shapes with long bars for the old-aged population and short bars for the young-aged population, with a much more obvious distinction in South Korea than in North Korea. The pyramids for the unified Korea have the same shapes as those for South Korea, mainly because of the population size and the serious aging problem of South Korea. Therefore, it seems that reunification will not be enough to overcome population aging, because South Korea's aging problem is too serious and population aging is happening too quickly.

Figure 3 illustrates the population projection according to each scenario of fertility and mortality. In each of Figures 3(a)-(f), the solid black line indicates the population of the reunified Korea under the moderate scenario, at the current level, of medium fertility and medium mortality for both South and North Korea. The solid gray line indicates the population of the reunified Korea under the worst but most realistic scenario, as learned from German reunification, of low fertility and low mortality for both Koreas. The dotted gray line shows the optimistic scenario of high fertility and medium mortality for both Koreas.

From Figure 3(a), it seems hard to avoid a decrease in total population except under a high fertility rate of 1.8. While the total population is highly dependent on the fertility assumption, the projections for the aged population in Figure 3(b), the working age population in Figure 3(e), and the power-at-work population in Figure 3(f) show little difference across the scenarios. This means that the aging phenomenon and the labor shortage are likely to last for decades regardless of the fertility assumption, unless the fertility rate increases up to replacement rate. As expected, the child population in Figure 3(c) and the school-aged population in Figure 3(d) differ greatly between scenarios.

### *Aging Indices of Reunified Korea*

Population aging can be measured by several indices, such as the proportion of the aged population, the burden of dependency that the working age population must bear, the proportion of the labor force population, and that of the powerful labor force. The most commonly used aging index is the

**TABLE 6**
**Aging Indices of North Korea and Reunified Korea (under med+med Scenario)**

| Korea | Year | PAP | ACR | CDR | TDR | WPR | PAWR |
|---|---|---|---|---|---|---|---|
| North Korea | 2010 | 0.0920 | 0.4126 | 0.3243 | 0.4581 | 0.6879 | 0.3837 |
| | 2020 | 0.1000 | 0.5371 | 0.2610 | 0.4011 | 0.7137 | 0.3694 |
| | 2030 | 0.1313 | 0.7644 | 0.2466 | 0.4351 | 0.6968 | 0.3637 |
| | 2040 | 0.1843 | 1.1563 | 0.2429 | 0.5238 | 0.6563 | 0.3484 |
| | 2050 | 0.1958 | 1.3273 | 0.2247 | 0.5230 | 0.6566 | 0.3200 |
| | 2060 | 0.2245 | 1.5508 | 0.2295 | 0.5853 | 0.6308 | 0.3100 |
| reunified Korea | 2010 | 0.1060 | 0.5802 | 0.2565 | 0.4052 | 0.7124 | 0.3993 |
| | 2020 | 0.1406 | 0.9126 | 0.2185 | 0.4178 | 0.7053 | 0.3603 |
| | 2030 | 0.2070 | 1.3738 | 0.2347 | 0.5570 | 0.6422 | 0.3225 |
| | 2040 | 0.2776 | 2.0016 | 0.2375 | 0.7130 | 0.5838 | 0.2908 |
| | 2050 | 0.3173 | 2.5842 | 0.2193 | 0.7861 | 0.5599 | 0.2604 |
| | 2060 | 0.3473 | 2.7642 | 0.2384 | 0.8972 | 0.5271 | 0.2642 |

proportion of aged persons (PAP), which is the widely accepted criterion for the degree of aging of a society. The PAP is the proportion of persons aged 65 years or more, and a population with a PAP of 7% is said to be 'aging', that of 14% to be 'aged', and that of 20% to be 'post-aged'. Other aging indices representing the level of population aging include the aged-child ratio (ACR), the total dependency ratio (TDR), and the child dependency ratio (CDR). The ACR is the ratio of persons aged 65 years or more to those under 15 years old. The CDR is the proportion of persons aged under 15 years, and the TDR is the ratio of persons under 15 years old or 65 years or more to the labor force population. A society with a low ACR (≤15%) or a high CDR (≥35%) is considered 'young', while a society is considered 'old' if the ACR is more than 35% or the CDR is less than 25% (Hobbs 2004). Besides the aging indices, the proportion of the population that is of working age (WPR) or of an age such that they have power at work (PWPR) can also represent the speed or degree of population aging as well as imply the nation's future growth potential.

Table 6 presents aging indices and burden of dependency ratios for the future North Korea under the medium fertility and mortality assumption. The table shows that in 2010 North Korea has already become an old and aging society in terms of the PAP and the ACR, and would be an aged society in 2030 with respect to the PAP and the CDR under this assumption. The TDR would increase from 45.8% in 2010 to 58.5% in 2060, due to the

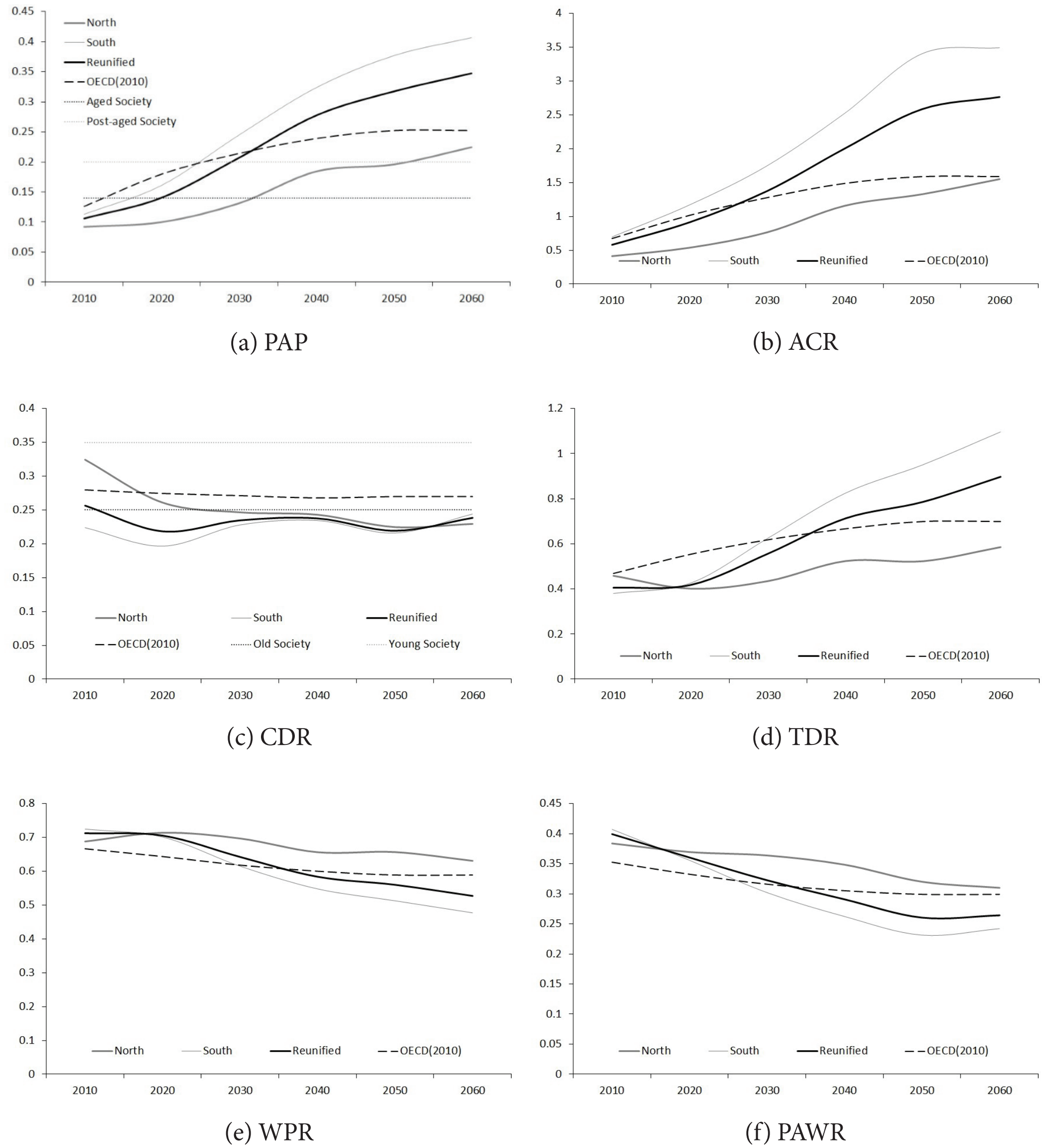



**Fig. 4.**—Aging indices for two Koreas and reunified Korea (under med+med scenario)

increasing proportion of elderly persons. The proportion of people in the labor force and with power in the labor force, WPR and PWPR, would decrease continually from 2010 onward, and the pace of decrease of the PWPR would be faster than that of the WPR over that period.

Meanwhile, the reunified Korea would be an aged society in 2020 and a post-aged society in 2030 with respect to the PAP. This fast rate of population aging is due to the unprecedented pace of aging of South Korea. It implies that reunification in the near future (around 2020 or 2030) could be helpful for delaying the speed of aging for about 5-6 years, but reunification in 2050-2060 may be unable to delay the speed of population aging. In this time period, the elderly population would increase to about a third of the total population in reunified Korea.

Figure 4 illustrates the trends in the aging indices based on the projected population age distributions of North, South, and reunified Korea, and the OECD. Here, the indices for the OECD are calculated using five-year populations obtained from OECD statistics (http://stats.oecd.org). According to the PAP, South Korea, whose population is aging much faster than North Korea's, will become an aged society in about 2017. However, reunified Korea is expected to reach the status of an aged society about 5-6 years later than South Korea, and then become a post-aged society around the 2030s, which indicates a slower rate of aging than the average for the OECD. However, the PAP of the unified Korea is to be much larger and faster than that of OECD after the 2030s. Looking at the PAP, unification within a few decades would be expected to slightly slow down the speed with which one third of the population becomes aged.

North Korea is also not a 'young' society according to the ACR criterion. However, although the ACR of North Korea is already higher than 35% in 2010, the ACR of reunified Korea would increase more slowly than that of South Korea, which implies that reunification could slow the aging of South Korea's population. South Korea has already become an 'old' society in 2010, with a CDR of less than 25%. In terms of the TDR, it seems that reunification would have positive effects in mitigating the speed with which the total dependency rate is increasing compared to the labor force, and in delaying by about 10 years the time at which the reunified Korea would reach the average level across the OECD.

The WPR and PWPR projections show that reunification would lessen the drastic decrease in the proportion of the population of working age in South Korea, and delay by about 10 years the time at which South Korea would reach the OECD average, meaning that unification would play a

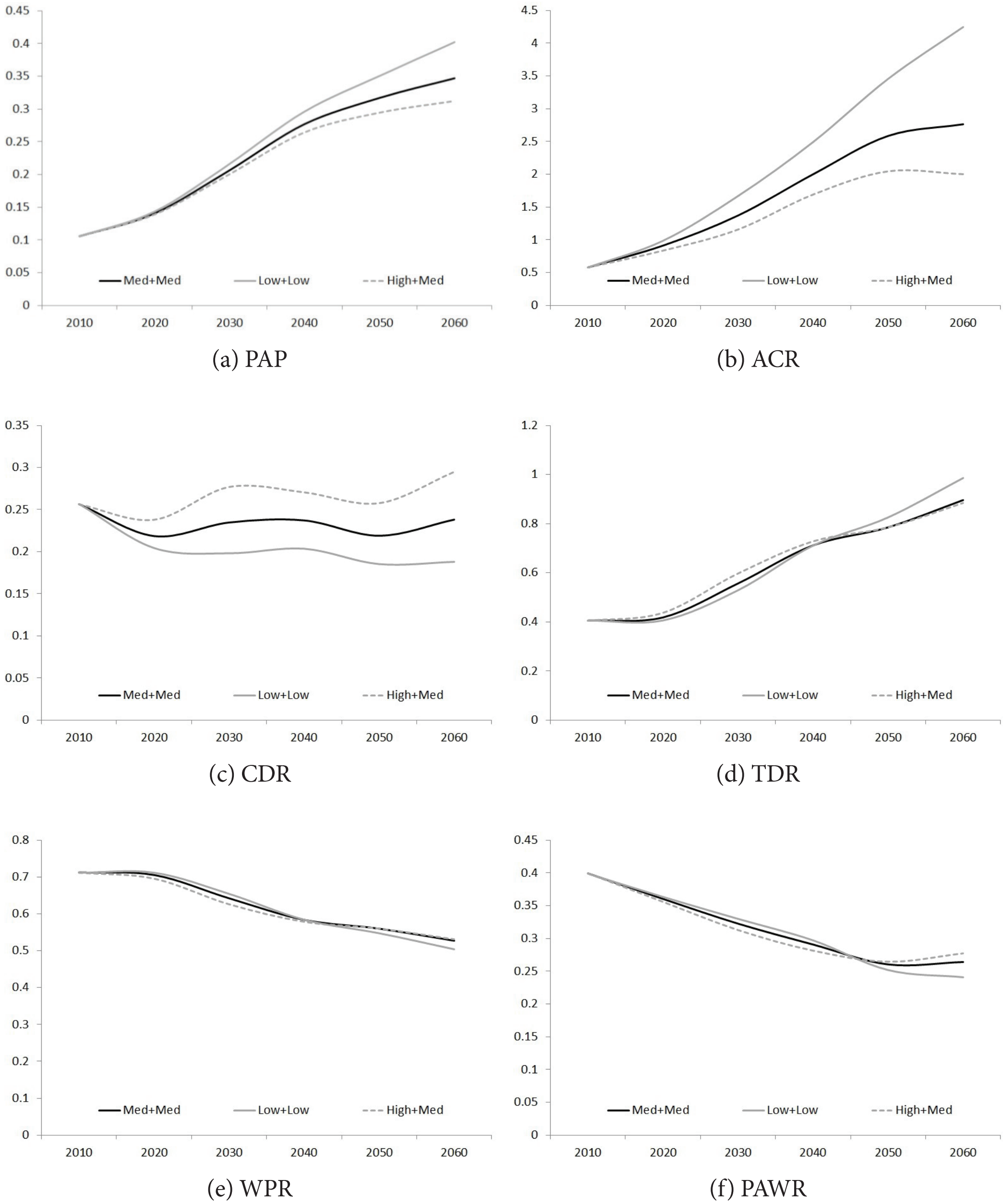



**Fig. 5.**—Aging indices of reunified Korea for scenarios

positive role in terms of the working population. However, reunification will not be enough to stop the phenomenon of a decreasing labor force due to the rapid pace of aging and the very low birth rate of South Korea. Although the PWPR of the reunified Korea is predicted to decrease more slowly than that of South Korea, it is expected to fall below the OECD average in the late 2030s. When assumed with a different scenario such as lower fertility and lower mortality, such expectations would be worse, and the future growth capability of Korea seems endangered.

Figure 5 shows the population indices of reunified Korea under the three scenarios. The fertility and mortality scenarios affect the youth rather than the elderly, in that the CDR and the ACR show notable differences between the scenarios while the other indices do not. The figure also shows that the fertility rate affects the population more than the mortality rate. Finally, in terms of population aging, reunification seems not to be a permanent solution without a considerable increase of the fertility rate.

## Concluding Remarks

Information available on North Korea's population is rare despite its importance. We projected the future population in North Korea under population scenarios, composed of three scenarios of fertility level and three mortality levels of mortality. Based on the projection results, under the medium fertility and mortality scenario, the total population of North Korea reaches its peak in 2030 and then decreases. Aging indices for North Korea reveal a typical pattern of population aging with clear decreasing trends in the populations of children, persons of school age, and the labor force (those of working age), accompanied by an increasing trend in the number of aged persons more than 65 years old. According to these predictions, North Korea would be an 'old' society in 2030 in terms of the CDR, and an 'aged' one in 2030 and a 'post-aged' one in 2050 in terms of the PAP. In other words, population aging will be unavoidable in North Korea also, unless immediate and active pronatalistic and immigration policies are enforced. Therefore, reunification of the two Koreas does not seem to change drastically the aging trend in South Korea, but somewhat slows down the pace of aging. With regard to labor, reunification seems to delay the decrease of the working age population about 10 years.

Due to limited data sources, we could not directly obtain the population projection for reunified Korea, but instead added the separate population projections of South and North Korea under fertility and mortality scenarios in order to consider the effect of reunification. Therefore, these results can be changed if different levels of fertility and mortality scenarios are assumed. According to a study on the changes in fertility and mortality arising from Germany's unification, a fertility shock and an incremental increase in life expectancy after unification were more apparent in East than West Germany, mainly because of the different welfare regimes and health care systems in the two countries. In this respect, the population aging in the reunified Korea could be even speedier than we predict.

Meanwhile, the influx of labor resulting from reunification does have a negative side as well as a positive side. North Korea generally has very high labor force participation, especially for women, and thus the reunification cost in terms of social security, such as health insurance and public pension, would be expected to surge. Also, when considering the health problems of North Koreans, especially those who suffered the famine in the early 1990s, the social cost of health care would be expected to be substantial. As such, reunification would create a significant economic burden, which requires a sufficient discussion. This is beyond the scope of this paper, and therefore left for further study. However, this paper establishes a foundation for such a study in that it laid the basis for a discussion of the various issues of reunification by predicting the population distribution and population structure of a reunified Korea. The results assist in the prediction of some future reunification costs such as welfare and public pensions that may occur in the near future, and help plan policies for it.

Finally, we conclude that reunification can be helpful to delay the decrease of productive population, but in order to ensure the future growth of Korea, reunification should be considered with other provisions for population aging and low fertility, such as a long-term proactive policies to encourage childbirth in both Koreas and improve the overall health quality of North Koreans.

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## References

Adlakha, Arjun, and Loraine A. West. 1997. *Analysis of Democratic People's Republic of Korea 1993 Population Census Data and Population Projections*. US Bureau of the Census, International Programs Center.

Alkema, Leontine, Adrian E. Raftery, Patrick Gerland, Samuel J. Clark, François Pelletier, Thomas Buettner, and Gerhard K. Heilig. 2011. “Probabilistic Projections of the Total Fertility Rate for All Countries.” *Demography* 48(3): 815-839.

Brown, Robert Goodell. 2004. *Smoothing, Forecasting and Prediction of Discrete Time Series*. Courier Corporation.

Dent, Harry S. 2014. *The Demographic Cliff: How to Survive and Prosper During the Great Deflation of 2014-2019*. New York: Penguin Publishing.

Eberstadt, Nicholas, and Judith Banister. 1992a. *The Population of North Korea*. Berkely: Institute of East Asian Studies, University of California, Center for Korean Studies.

Eberstadt, Nicholas, and Judith Banister. 1992b. “Divided Korea: Demographic and Socioeconomic Issues for Reunification.” *The Population and Development Review* 18(3): 505-531.

Eberstadt, Nicholas. 2001. *Development, Structure and Performance of the DPRK Economy: Empirical Hints*. North Korea in Transition. Prospects for Economic and Social Reform 35.

Gjonca, Arjan, Hilke Brockmann, and Heiner Maier. 2000. “Old-Age Mortality in Germany prior to and after Reunification.” *Demographic Research* 3(1).

Goodkind, Daniel, and Loraine West. 2001. “The North Korean Famine and Its Demographic Impact.” *Population and Development Review* 27(2): 219-238.

Goodkind, Daniel, Loraine West, and Peter Johnson. 2011. *A Reassessment of Mortality in North Korea, 1993-2008*. Annual Meeting of the Population Association of America 31.

Hobbs, Frank B. 2004. *Age and Sex Composition*. The Methods and Materials of Demography, Elsevier.

Hyndman, Rob J., and Heather Booth. 2008. “Stochastic Population Forecasts Using Functional Data Models for Mortality, Fertility and Migration.” *International Journal of Forecasting* 24(3): 323-342.

Jeon, Saebom, Seongeun Kim, and Yousung Park. 2015. “A Study on the Population Structure of Democratic People’s Republic of Korea.” *Communications for Statistical Applications and Methods* 22(1): 1-10.

Kim, Du-Sup, Min-Ja Choe, Kwang-Hee Chun, Sam-Sik Lee, and Hyung-Seok Kim. 2011. *Bukhan ingu census bunsuk yeongu [Demography in North, Korea and Censuses],* Tongyechung [Statistics Korea].

Lee, Ronald D., and Lawrence R. Carter. 1992. “Modeling and Forecasting US Mortality.” *Journal of the American Statistical Association* 87(419): 659-671.

Lee, Suk. 2004. “1994-2000nyun bukhan gigun: balsaeng, chungkyuk, krigo tukjing [1994-2000 North Korean Famine: Excess Death and Regional Population Dynamics].” *Tongil yunkuwon [National Strategy]* 10(1): 117-144.

Lee, Sam-Sik. 2007. “Bukhan ingu byundongkwa bogunbokji jungchaekjuk hamui [Change in Population of North Korea and Policy Implications for Health and

Welfare].” *Bogun bokji forum [Health and Welfare Forum]* 132(10): 35-45.

Park, Keong-Suk. 2012. “Bukhanui sikryangna mit gigunkwa ingu byundong [The Economic Hardship and Famine since the 1990s in North Korea and Its Impact on the Population Dynamics].” *Tongil jungchaek yeonku [Unification Policy Research]* 21(1): 127-156.

Park, Yousung, Sunhwa Jang, and Seongyong Kim. 2013a. “Samang chugyerl yuihan ochasujung LC mohyung [VECM-LC model for forecasting mortality in Korea].” *Josa yeonku [The Korean Association for Survey Research]* 14(7): 19-47.

Park, Yousung, Miri Kim, and Seongyong Kim. 2013b. “Hwakryuljeok chulsanyul mohyungkwa hankukui mirae ingu gujo [Probabilistic Fertility Models and the Future Population Structure of Korea].” *Josa yeonku [The Korean Association for Survey Research]* 14(3): 49-78.

Peristera, Paraskevi, and Anastasia Kostaki. 2007. “Modeling Fertility in Modern Populations.” *Demographic Research* 16(6): 141-194.

Spoorenberg, Thomas, and Daniel Schwekendiek. 2012. “Demographic Changes in North Korea: 1993–2008.” *Population and Development Review* 38(1): 133-158.

Stephan, Elizabeth Hervey. 2013. *Demography of a Reunified Korea*. Center for Strategic and International Studies.

United Nations Population Division. 2010. *World Population Prospects: The 2008 Revision.* New York: United Nations.

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