A Reassessment of Mortality in North Korea, 1993-2008

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Introduction and Background

Little is known about mortality in North Korea (also known as the Democratic People's Republic of Korea). One analyst describes a statistical "blackout" resulting from the government's limited data-gathering capabilities as well as its desire to keep secret much of the information it did collect (Eberstadt, 2000). Moreover, even for the data that have been released, questions have sometimes been raised about their reliability (Eberstadt and Banister, 1992). To assemble a coherent picture of North Korea's demographic and health situation requires one to piece together scattered and sometimes inconsistent clues.

Yet a variety of data on mortality and health has been available. A key source is the 1993 census, the first modern national census ever taken in North Korea. In addition to the census, vital statistics from North Korea's Central Bureau of Statistics (e.g., crude death rates[1]) have occasionally been released, although the quality and areal coverage of these statistics is uncertain. North Korea also conducted a series of surveys in collaboration with the United Nations that focused on child malnutrition and reproductive health (Katona-Apte and Mokdad, 1998; World Food Programme, et al., 1999; Central Bureau of Statistics, 2002, 2004, 2005), although these surveys contained no questions about mortality. The first in the series of nutrition surveys was conducted in 1997, near the peak of a severe famine.

The famine has been a focal point for demographic research on North Korea (Robinson, et al., 1999; Goodkind and West, 2001 and 2002; Natsios, 2001; Haggard and Noland, 2007). This protracted event, which unfolded from the mid-1990s to about 2000, was caused in part by repeated natural disasters, such as floods and associated crop failures.[2] Compounding these natural disasters were man-made factors such as the end of subsidies from the former Soviet Union, the decline of incentives to produce, and the associated collapse of the food production and distribution system, upon which many people depended (Natsios, 2001; Haggard and Noland, 2007). The number of deaths caused by the famine has been the subject of great speculation. Over a decade ago, some quoted figures of up to 3

[1] The crude death rate is the number of deaths per 1,000 population.

[2] Given some ambiguity about the onset and end of famine conditions, researchers have proposed different ways of dating the famine and/or its demographic impact: 1995-2000 (Goodkind and West, 2001), 1994-2000 (Lee, 2005), 1995-1998 (Haggard and Noland, 2007). Since the 1993 census provides a clear statistical marker, the present study shows estimates of excess deaths from 1993 to 2000, a period wider than that used in other studies of the famine.

million (*Agence France Presse*, 1999). Such figures, if true, would constitute a catastrophic loss of about 15 percent of the entire population enumerated in the 1993 census.

Among the few early studies offering an empirical basis for their estimates, Robinson et al. (1999) surveyed North Korean refugees in China. The survey asked about deaths that occurred among their family members in North Korea, including the date of death. The authors calculated excess mortality during the famine era among these sampled respondents, most of whom came from North Hamgyong province. Natsios (2001) extrapolated these results to imply 2.5 million famine deaths nationwide, a figure matching that quoted from Hwang Jong Yap, a high ranking defector who left North Korea in 1997 (ibid.; p. 203). A key question about the reliability of such estimates is the extent to which refugees in China were representative of the general population. If those experiencing the greatest hardships were most likely to become refugees, extrapolations from refugee populations would overestimate the true extent of famine deaths in North Korean families.

Given the lack of direct empirical evidence at the time, Goodkind and West (2001) used indirect models to estimate a range of 600 thousand to 1 million excess deaths during the era 1995-2000 – considerably below estimates offered by other investigators. The upper bound was based on China's mortality experience during a famine following its Great Leap Forward in the late 1950s.[3] The lower bound was based on aforementioned child nutrition studies in North Korea, with child mortality inferred based on international regularities between morbidity and mortality.[4] For both the upper and lower bounds, excess deaths were estimated against the assumption that mortality would have improved in the absence of famine conditions (ibid.).

Recently, North Korea released a report on its 2008 census. These results enable more rigorous methods to reassess estimates of mortality trends before, during, and after the famine. The present study begins with direct estimates of mortality rates

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[3] Lee (2005) challenged the use of China's Great Leap Forward era as an appropriate model for North Korea yet offered the identical range of famine-related deaths as Goodkind and West (2001) based on a similar analysis of results from the child nutrition surveys.

[4] Although the DPRK Central Bureau of Statistics released official crude death rate estimates for certain years, child malnutrition studies provided the only official empirical data from which corresponding child mortality estimates might be made, albeit indirectly. Mortality among adults was then estimated based on model life tables (Goodkind and West, 2001).

based on deaths reported during the year preceding the 2008 census. At almost all ages, these mortality rates exceed those reported in the year preceding the 1993 census and imply that life expectancy declined by three years. Yet this implied decline might reflect more complete reporting of deaths in 2008 as opposed to an actual deterioration in health conditions between the two censuses. Analysis then turns to three methods which permit estimates of average mortality during the intercensal period 1993-2008: 1) the residual between reported population growth rates and natural growth rates, 2) the Hill General Growth Balance Method, and 3) intercensal cohort survival. These methods all imply that mortality during the intercensal period exceeded what was reported during each census year.

To estimate varying patterns of mortality *within* the intercensal period, this paper considers a variety of contextual and empirical evidence, such as the aforementioned surveys of child nutrition. Since these surveys did not measure child mortality, this study does so indirectly by exploiting international regularities between child morbidity and child mortality. Model life tables then allow adult mortality estimates to be derived from these child mortality estimates. In order to formalize estimates of excess deaths due to the famine, cohort-component population projections based on estimated patterns of mortality are compared to assumptions about mortality in the absence of famine. This exercise suggests a likely range of 500 to 600 thousand excess deaths between 1993 and 2000. This figure is close to the lower estimate of famine-related deaths proposed earlier by Goodkind and West (2001; for the narrower period 1995 to 2000) yet still enormous in its impact.

Death Rates Reported in the 1993 and 2008 Censuses

The 1993 and 2008 censuses of North Korea enumerated 21.0 and 24.1 million people, respectively. Tabulations of the population, as well as household deaths reported during the year prior to each census, were published by age, sex, and province. Death rates are thus readily calculated. Table 1 shows age- and sex-specific death rates reported in each census. Since only deaths for the civilian population were published, the death rates shown are for the civilian population only[5] – the number of civilian deaths reported by sex and age group are divided by the civilian population count for that sex and age group.[6]

[5] Based on residuals between total and civilian counts, the military population was likely 652,036 males and 38,991 females in 1993 and 662,349 males and 40,023 females in 2008, very similar in size. Thus, about 3 percent of the population is likely in the military (Adlakha and West, 1997). In any case, given

The results are plotted on a logarithmic scale on Figures 1 and 2 for males and females, respectively. With the exception of ages 1-4, reported age-specific death rates rose for each sex between the 1993 and 2008 censuses. Life tables constructed from the reported death rates suggest that life expectancy declined by three years between the census years – from 68 to 65 for males and from 76 to 73 for females.

A decline of this magnitude would be notable. In general, death rates throughout the world have tended to decline as technology advances and standards of living improve. Exceptions to this rule can occur in cases of natural disasters, military campaigns, or sudden social upheavals. There are also examples of prolonged worsening of health conditions. For instance, life expectancy in Russia declined by about five years between the late 1980s and the mid-1990s due to a deteriorating health care system, as well as other factors (Notzon et al., 1998). It is thus not implausible that life expectancy in North Korea might have declined by three years during the 15 years between the censuses.

Yet another possible explanation for the reported rise in mortality between the censuses is that deaths were more completely reported in the latter census. Such improved reporting would be consistent with the greater technical involvement of the United Nations in the latter census (Engracia, 2010). Table 1 provides potential evidence that death reporting was less complete in the earlier census. For instance, only at ages 1-4 were mortality rates in 1993 higher than those reported in 2008. Yet even at ages 1-4, where mortality seemed most completely reported in 1993, child mortality was only 3.2 per thousand, surprisingly low compared to other Asian societies.[7]

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the lack of military conflict, civilian mortality *rates* by age and sex should be close to those for the civilian and military populations combined.

[6] Given some uncertainty about growth rates of the civilian population by age and sex, central death rates (which are based on populations six months prior to each census) were not calculated. In a growing population, since an enumerated population will exceed that which existed six months before it, central death rates will slightly exceed the rates calculated based on a census population.

[7] Comparable rates for children 1-4 in Asia are as follows: 9.8 (males) and 8.6 (females) for China in 1981 (Coale, 1993); 9.2 (males) and 6.4 (females) for Thailand in 1969-71 (United Nations, 1982); and 17.8 (males) and 14.0 (females) for South Korea in 1971-75 (United Nations, 1982). A comparison of reported mortality at ages 0 and 1-4 in both the 1993 and 2008 censuses to a series of model life tables suggests that infant and child mortality were likely underreported in both censuses, particularly the 1993 census. In addition, infant mortality seems to have been relatively underreported compared to child mortality, again particularly in the 1993 census.

Single-census techniques to evaluate death reporting completeness in each census were attempted yet rejected as unreliable.[8] The next section presents evidence from two-census techniques, such as the Hill General Growth Balance Method, which indicates improved death reporting in 2008. These models also cast doubt on the hypothesis of a gradual deterioration in health during the 15 years between the censuses.

Assessments of Reporting Completeness Between the Censuses

Intercensal Residuals Estimated from Linear Trends Between Census Endpoints

The simplest approach to assess the quality of reporting between two censuses is to check for consistency using the demographic balancing equation, which can be expressed either in terms of numbers or rates, as follows:

Population (t_2) = Population (t_1) + Births – Deaths + Net Migration

Population Growth Rate = Crude Birth Rate – Crude Death Rate + Net Migration Rate

Based on the two census counts of 1993 and 2008, the average annual growth rate of the civilian population was 8.8 per thousand.[9] The 1993 and 2008 censuses also provided a crude birth rate (CBR) and crude death rate (CDR) for the civilian population during the years prior to each census. The reported CBR declined from 20.5 per 1,000 in 1993 to 14.8 per 1,000 in 2008, while the CDR increased from 5.6 per 1,000 in 1993 to 9.3 per 1,000 in 2008. The difference between the CBR

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[8] Single-census methods typically estimate death rates above age X as the residual of birth rates (at age X) and growth rates above age X. Such methods are appropriate for a population that is stable (Brass) or quasi-stable (Preston-Coale). The estimated rates can then be compared to reported rates to infer the completeness of death reporting. However, due to its tumultuous past, the North Korean population has been neither stable nor even quasi-stable – Banister and Hill (2004) noted that China’s population also violated this requirement of single-census methods. Moreover, estimates from both methods were sensitive to the data points selected to estimate the parameters, particularly in the case of the Brass method.

[9] We focus on growth of civilian population counts because we wish to compare overall growth to natural growth, and natural growth figures from the censuses are available only for civilians.

and the CDR is the rate of natural increase, which in 1993 was 14.9 people per 1,000 population, compared to only 5.5 per 1,000 in 2008.

Of course, the actual pattern of natural growth between the censuses is unclear.[10] Under the simplifying assumption that both birth and death rates changed by constant increments during the intercensal period, the average annual natural growth between the census dates is 9.9 per 1,000. The shortfall of actual growth (8.8 per thousand) versus natural growth would then be 1.1 per 1,000, which would amount to 369 thousand persons.[11] This figure is comparable to the 340 thousand estimated by Park Keong-suk of Seoul National University (*The Hankyoreh*, 2010).

The first factor that might explain the discrepancy between natural growth and actual growth is, of course, out migration. However, there is no evidence supporting this magnitude of net outmigration from North Korea between the two censuses. U.S. Census Bureau (2010) and Robinson (2010) conclude that net outmigration during this period was less than 40 thousand. Factors other than migration would have to explain the remaining 330 thousand person discrepancy between natural growth and actual growth. Such factors include the following:

1. The CDR rose above the assumed trend line during the intercensal period.
2. The CBR fell below the assumed trend line during the intercensal period.
3. Less complete reporting of deaths (or more complete reporting of births) in the 1993 census resulted in an estimated natural growth rate that was too high at the starting point for the trend.

The aforementioned study by Park assumed that the discrepancy was due entirely to the first explanation, which was presumed to reflect excess deaths due to the famine (The Hankyoreh, 2010). If the other two factors were involved, less of the discrepancy could be attributed to excess deaths.

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[10] There is evidence that the government has annual crude birth and death rate statistics but they are rarely published. For example, the report *Analysis of 1993 Population Census Data DPR of Korea* (DPRK Population Centre, 1996) contains historical crude birth rates for selected years from 1944 to 1991. More recent government crude death rate figures were quoted in Goodkind and West (2001). Luisa Engracia (UN Chief Technical Adviser for the 2008 Census) stated that she was provided crude birth and death rate figures for 1993 and 2008 which she found to be comparable to census results for those years.

[11] This figure is calculated by multiplying the average civilian population from the two censuses (21.9 million) by the excess in the annual natural growth rate (1.1 per 1,000) and then by the number of years between the censuses (14.75).

Conversely, the 330 thousand person shortfall in actual growth would be *underestimated* if the population counted in 1993 was less complete than in 2008.[12] If so, actual growth would be lower than reported growth, so the shortfall compared to natural growth would be larger. It should also be noted that if our assumed linear trend in intercensal natural growth is incorrect (e.g., if it was instead exponential), the disparity with population growth would be different than was estimated above. Given the many uncertainties about the reliability of assumptions underlying the above method, the following sections turn to other methods that allow further exploration of mortality conditions in North Korea.

Hill General Growth Balance Method

The Hill General Growth Balance method provides estimates of the completeness of death reporting between two censuses, as well as the completeness of population enumeration in one census relative to another (Hill, 1987; United Nations, 2002). It does so through algebraic representations of the relation between observed death rates and estimated death rates (birth rates minus growth rates) above a particular age. The Hill method requires population counts by 5-year age groups in both censuses, as well as estimates of all deaths at those ages occurring between the censuses. In contrast to single-census methods, the Hill method does not require the underlying population to be stable or even quasi-stable, although it does require other simplifying assumptions.[13]

Given the lack of death data between the two censuses, annual deaths are estimated by interpolating the deaths reported by age at each census endpoint. We further assumed, as Hill guidelines seem to suggest, that deaths within each age group change in a geometric, rather than a linear fashion. This application of the Hill method implies 82 percent completeness in death reporting over the intercensal period (relative to the second census), or 582 thousand deaths which cannot be accounted for during the intercensal period (not shown). Note that the Hill method

[12] Shortly before the 1993 census was conducted, Eberstadt and Banister (1992), based on analysis of a 1960 official total population for North Korea, a 1960 South Korea census, and 1986 administrative counts for North Korea, projected the 1993 population to be 22.6 million. At face value, that would suggest a 7 percent undercount in the 1993 census.

[13] Like single-census methods, the Hill method assumes a demographic system with zero net international migration. It also assumes that the completeness of death reporting is the same in each census and at each age group. Moreover, it assumes that relative completeness in population enumeration between the two censuses is the same at each age group.

cannot distinguish which portion of these 582 thousand deaths reflects underreporting during one (or both) census years, excess deaths occurring *between* them, or factors unrelated to mortality (e.g., net outmigration).

If there was no underreporting of deaths during either census, then all 582 thousand deaths might be due to excess mortality during the intercensal interval, which includes the famine years. Given the aforementioned likelihood of incomplete death reporting in the 1993 census, this would appear to be an upper limit of famine-related deaths.

In addition to providing estimates of death reporting completeness, a useful byproduct of the Hill General Growth Balance Method is that it provides an estimate of the relative completeness of population enumeration between the two censuses. The above application of the method implies that the census enumeration in 1993 was 2.3 percent less complete than in 2008.[14] This estimate seems plausible, given the greater involvement of UNFPA in the latter census (Engracia, 2010) and is used in the following cohort survival analysis.

Analysis of Cohort Survival Between the Censuses

Another method for assessing mortality is to compare the ratios of those counted in the 2008 census to those counted almost 15 years earlier in 1993 (e.g., ages 10-14 in 1993 versus ages 25-29 in 2008). An advantage of this cohort survival method compared to those just discussed is that *no direct measurement of deaths is required*. In fact, even an undercounting of the population would not adversely affect survival estimates either, as long as cohorts were undercounted to the same extent during each census. An additional advantage of the survival method is that mortality can be assessed for the entire North Korean population, not just the civilian population.

Figures 3 and 4 show cohort survival ratios for males and females, respectively, implied by population enumerations (civilian plus non-civilian) in the 1993 and 2008 censuses. Given the findings from the Hill method (previous section), the

[14] A post census evaluation survey indicated nearly 100 percent completeness for the 2008 census. Such a survey was apparently not taken following the 1993 census or its results were not published (Engracia, 2010). The lack of experience in conducting and processing a census may have contributed to undercounts in the 1993 census.

1993 census is assumed to be under-enumerated by 2.3 percent relative to the 2008 census. The 1993 counts were scaled up assuming the percent under-enumerated was the same at each age group. The x-axis shows the initial age of the cohort in 1993. The ratios shown at each age group depict the proportion of the cohort that survived until the next census 14.75 years later. The pattern of survival ratios is fairly smooth across successive ages, with the exception of the cohort of males at ages 20-24 in 1993. The angular decline, followed by an increase, in survival ratios among young males likely reflects either reporting problems or possible misallocation of military males by age.[15]

Figures 3 and 4 also show 15-year survival ratios calculated from period life tables derived from mortality reported before each census. Intercensal cohort survival ratios are lower than those implied at the census years for both males and females, but particularly for males. For instance, at ages 60-64, cohort survival suggests that the share of males surviving the next 14.75 years was less than 26 percent, compared to 37 percent based on life tables from the 1993 census and 33 percent based on life tables from the 2008 census. If the risk interval of cohort survival (14.75 years) was extended by an additional quarter year to match the comparable risk interval from the period life tables (15 years), the shortfall in cohort survival compared to the two census years would be even larger.

The level of mortality implied by these cohort survival ratios is estimated by comparing them to 15-year survival ratios from a variety of model life tables (not shown). The sum of residuals across all age groups (arithmetic and proportional), was minimized for males when compared to the Coale-Demeny North model life table with a life expectancy of 60 years. For females, the residuals were minimized when compared to the United Nations Far East model life table with a life expectancy of 70 years. These estimates for males and females are five and three years, respectively, below those reported in the 2008 census (65 years for males and 73 years for females). They are even further below the levels reported in the 1993 census (68 years for males and 76 years for females). Overall, male life expectancy appeared to fall more in between the census years than female life expectancy.

[15] In the 1993 and 2008 censuses, one can infer the military population of males and females by subtracting the number of civilian males and females shown on age-specific tables from the total enumeration of males and females (see footnote #5). The age distribution of military was also available for 2008. However, the age distribution of the 1993 military population had to be estimated indirectly via analysis of expected sex ratios and other comparative methods.

Likely Mortality Trends in Years within the Intercensal Interval

None of the intercensal methods described above suggest a gradual decline in health conditions to the 2008 level, as one might infer from the data reported prior to each census. Instead, they point to a greater deterioration in health conditions for at least some portion of the intercensal period. Among the methods described, cohort survival likely yields the most accurate estimates, yet this and other methods only allow us to estimate average mortality across the full intercensal interval. Other evidence is needed to apportion mortality elevation within this interval. The following exercise attempts to do so in a way that is consistent with other evidence, such as findings from child nutrition surveys.

To begin, assumptions are required about mortality in 1993 and 2008. Mortality is assumed to be fully reported in 2008 at all ages except 0 and 1-4. Comparative life table analysis provided evidence of modest underreporting of deaths at these ages (not shown), so death rates are adjusted accordingly. Given evidence of relatively less complete death reporting in 1993 vs. 2008, as well as evidence that mortality was higher during the intercensal interval than in the census years, in this section mortality in 1993 is assumed to be identical to that in 2008.

To estimate mortality around the famine years, Figure 5 compares child malnutrition to overall life expectancy in Asian countries for which data were available. The percent of children stunted at ages 0-72 months is derived from UNICEF data around 2000, while life expectancies for the corresponding year are drawn from the U.S. Census Bureau's International Data Base. There is a strong correlation between these two measures, with higher child morbidity associated with lower life expectancies.

As mentioned earlier, North Korea undertook a series of child nutrition surveys beginning around the time of the famine in the late 1990s. The share of children stunted was 38.8 percent in 2002 and 35.9 percent in 2004, which, given the linear trend line on Figure 5, corresponds to life expectancy (both sexes) of about 61 and 62 years, respectively. These malnutrition figures are well below those recorded around the peak of the famine in 1998, when 64 percent of children were reported to be stunted (World Food Programme et al., 1999; Katona-Apte and Mokdad, 1998), which implies life expectancy in the low 50s. However, such life expectancies during the peak famine era seem too low – if they were correct, life expectancy across the full intercensal interval would be below that implied by cohort survival, which provides a plausible anchor of intercensal mortality.[16] Life expectancies around 59 years during the peak famine years of 1997-1998 were more consistent with findings from cohort survival.[17]

Assumptions of annual life expectancy are shown in Table 2.[18] The average life expectancy from 1993 to 2008 is 59 for men and 69 for women, just a year below the intercensal life expectancy indicated by survival analysis. The series was designed to have somewhat lower average life expectancy, since survival analysis from the censuses does not include children born after the 1993 census who died prior to the 2008 census.

Estimation of Excess Deaths Based on Cohort-Component Projections

In the previous section, a likely pattern of mortality change was estimated for the years between the censuses, which include the famine years. But how many excess deaths occurred due to the famine? That is to say, in the absence of famine conditions, what would the trajectory of mortality have been? Two possibilities are considered below.

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[16] Surveys of child morbidity might not provide an accurate estimate of mortality for several reasons. The surveys might not be fully representative of North Korea. Alternatively, the relationship between child malnutrition and mortality (either for children or adults) may not always be linear.

[17] In addition to other evidence that 1997 and 1998 were peak famine years (Natsios, 2001; Haggard and Noland, 2007), further evidence is provided by the 2008 census. For instance, the sex ratio (males per females) in 2008 was slightly elevated among those at ages 10 and 11 – 105.7 at age 10 and 105.1 at age 11, compared to 104.8 for children born in adjacent cohorts. No such elevation in the sex ratio occurred at these ages in the 1993 census. The cohort showing this elevation in 2008 was born in 1997 and 1998, the presumed peak of the famine. This elevation in the sex ratio may be evidence of the human response to the famine. For hundreds of years, during bad economic times, many areas of East Asia have shown rising sex ratios, owing likely to parental favoring of sons over daughters during periods of extreme deprivation, or even female infanticide (Feeney and Kiyoshi, 1990). The numbers involved in this distortion are not huge – the sex ratio for this cohort would be "normal" (around 104.8) if there were just 2,300 additional females at ages 10 and 11. Nevertheless, excess female child deaths during the famine pale in comparison to the number of excess deaths to persons of both sexes, and, as noted earlier, male mortality appeared to increase more during the intercensal period than female mortality.

[18] In an earlier study, Goodkind and West (2001) used age- and sex-specific elevation in mortality during the Great Leap Forward in China to estimate elevation in mortality in North Korea during the peak years of 1997 and 1998. Interpolations between these indirect estimates of peak mortality and estimated mortality outside the famine era provided annual life tables. These same age patterns of mortality are used in the current study.

As in Goodkind and West (2001), excess deaths are estimated in Table 3 by comparing results from cohort-component population projections.[19] The base scenario projects the population using mortality estimated from the prior section (Table 2). Such projections incorporate annual changes to fertility and net migration, in addition to mortality. Then, two models project the population by specifying what mortality might have been like in the absence of famine conditions (Figure 6). The first of these assumes that mortality would have remained constant at the level estimated for 1993 shown in Table 2 (note that this Table assumed mortality in 1993 to be identical to that in 2008). A second alternate assumption is that mortality would have improved gradually after 1993 based on international historical patterns.[20] Other models besides these could also be considered.

Table 3 compares the differing estimates of deaths between the base scenario and the two without famine scenarios. During the period 1993 to 2000, no famine assumptions imply between 500 and 600 thousand excess deaths. [21]

In addition, these models imply between 100 and 400 thousand additional excess deaths from 2001 to 2008. Thus, these models imply a total of 600 thousand to 1 million excess deaths across the entire intercensal interval 1993 to 2008.

Summary and Remaining Questions

Cohort survival analysis between the 1993 and 2008 censuses imply that life expectancy during the intercensal period averaged about 65 years (both sexes combined). That is about 7 years below what was reported in 1993 (72) and 4 years below what was reported in 2008 (69). Thus, instead of a gradual decline

[19] The cohort-component projections begin with a population by sex and single years of age in 1993, based largely on the census. The population is projected to 1994 by subjecting each single-year cohort to the mortality and (net) migration estimated for that age group during 1994. The cohort at age zero is generated based on assumptions of fertility in 1994. The population is projected to 1995 and each subsequent year based on a similar procedure.

[20] This pattern is based on a model developed around 1999 at the U.S. Census Bureau. For simplicity, aside from incorporating different mortality assumptions, these two projections keep the same assumptions of fertility and migration as in our original estimated model.

[21] Estimates in a prior demographic study made different assumptions about mortality in 1993 and, as noted earlier, considered the famine era to have extended from 1995 to 2000 (Goodkind and West, 2001). The interval presented here from 1993 to 2000 is wider than that, due in part to some ambiguity about when to date the onset of the famine. Some studies suggest that deterioration in health likely began prior to 1995 (Lee, 2005).

in health from one census to the next, evidence seems to imply that health during the intercensal interval was worse than that in either census year. In addition, evidence suggests that the reported decline of three years in life expectancy between the census years may be due largely to more complete reporting of deaths in 2008 compared to 1993.

The annual series of mortality estimated was based on a variety of indirect evidence, such as child stunting reported in nutrition surveys. The annual series was anchored to be consistent with findings from cohort survival, perhaps the most reliable indicator of average intercensal mortality. These mortality estimates were then translated into estimates of excess deaths by comparing the resulting cohort-component projections to scenarios which assumed that no famine had occurred. In light of the shortfall in death reporting in 1993, these models all assume mortality levels in 1993 equal to those estimated for 2008.

The results suggest that excess deaths from 1993 to 2000 likely ranged from 500-600 thousand. These estimates imply that at least 2.3 percent of the North Korean population perished during this era, a staggering proportion by any standard – a comparable per capita loss in the United States would total over 7 million people. Moreover, when estimated across the entire intercensal era 1993-2008, the no famine scenarios imply 600 thousand to 1 million excess deaths. What seems even more notable about the North Korean famine goes beyond the numbers of excess deaths or the per capita impact. Compared to other historical famines (Sen, 1981, and see the list in Haggard and Noland, 2007; p. 7), the famine in North Korea is unique for having occurred in a society where fertility and mortality had fallen to very low levels. All other famines have occurred in societies that had yet to complete such demographic transitions.

We conclude by discussing some implications of our estimates in light of other findings regarding migration and fertility. Previously, the best-known estimates of famine mortality from direct evidence were derived from surveys of North Korea migrants in China (Robinson, et al., 1999; Natsios, 2001). The new estimates presented in this paper are one-quarter to one-fifth those based on the migrant-refugee survey. If the baseline for determining excess mortality within that survey was constructed correctly, then the extrapolated estimate was likely biased upwards due to migratory selection dynamics. A comparison of excess famine death estimates might provide a rough guide to these dynamics. For instance, if famine refugees were drawn only from the most disadvantaged pockets of the population that were most severely affected by the famine (with others showing little demographic change despite nutritional deprivation), the difference between the new estimates and that of the migration survey would imply that these disadvantaged pockets constituted one-fifth to one-fourth of North Korea's total population.

If this theory is correct, it might also explain what appears to be another anomalous finding. That is, in a separate analysis based on the 2008 census, fertility declined by no more than 5-10 percent during the peak of the famine era compared to that recorded in 1993 (see Table 2). Some observers might wonder why a famine of this estimated magnitude would not have had a greater depressive effect on fertility – due either to nutritional deprivation of mothers or migratory separation of spouses in search of food. In the wake of the Great Leap Forward, for instance, China's fertility fell by 30 and 42 percent, respectively, during the two peak famine years compared to pre-famine levels (Peng, 1987). One possible explanation for the mild fertility decline in North Korea could be that the majority of the population, while perhaps chronically malnourished due to food shortages, did not suffer starvation conditions or the demographic consequences that would have resulted. Thus, if 75 to 80 percent of the population did not experience much demographic change during the famine era, even a severe decline in fertility among the most disadvantaged minority would have been dampened.

Yet other possible explanations for the mild fertility decline in North Korea deserve consideration. For instance, although some investigators have used China's demographic experience following the Great Leap Forward as a model for North Korea (Goodkind and West, 2001; Eberstadt, 2010), the model is not fully applicable. For example, fertility fell sharply in China due in part to the social dislocation specifically engineered under the Great Leap Forward as an attempted spur to rapid industrialization – in contrast, North Korea did not have any such program in the 1990s. In addition, as noted earlier, North Korea's level of fertility in the 1990s was far below that of China in the 1950s. Since a higher proportion of women used contraception in North Korea, nutritional deprivation would have affected a smaller portion of women trying to get pregnant. Lastly, given the present findings that the per capita impact of excess famine deaths was lower in North Korea (2.3 percent) than in China (5 percent; Peng, 1987), the fertility-reducing impact of the famine should have been lower in North Korea as well.

In sum, there is not necessarily any inconsistency between the estimates of mortality and fertility in Table 2, nor evidence of massive irregularities in population counts. Once reporting anomalies are corrected for, North Korea's censuses suggest a consistent and plausible picture of demographic change.

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Table 1. Civilian Age-Specific Death Rates by Sex in North Korea: 1993 and 2008 Censuses

Year/ Age group	Deaths Male	Deaths Female	Population Male	Population Female	Age-Specific Death Rates (per 1,000) Male	Age-Specific Death Rates (per 1,000) Female
1993						
0	3,261	2,661	213,149	202,939	15.3	13.1
1-4	2,717	2,563	858,805	813,615	3.2	3.2
5-9	636	429	957,583	909,000	0.7	0.5
10-14	322	210	904,764	862,348	0.4	0.2
15-19	399	331	708,790	819,508	0.6	0.4
20-24	596	649	765,479	1,097,510	0.8	0.6
25-29	1,084	692	987,095	1,032,430	1.1	0.7
30-34	1,048	578	791,117	816,812	1.3	0.7
35-39	1,057	507	682,990	703,464	1.5	0.7
40-44	1,316	550	482,309	508,478	2.7	1.1
45-49	2,428	1,024	603,230	639,847	4.0	1.6
50-54	3,963	1,612	582,990	625,812	6.8	2.6
55-59	7,027	2,758	487,276	576,381	14.4	4.8
60-64	9,369	4,531	301,764	446,830	31.0	10.1
65-69	8,547	5,979	174,925	331,136	48.9	18.1
70-74	7,955	8,194	102,975	236,558	77.3	34.6
75-79	5,769	9,208	49,324	137,936	117.0	66.8
80+	4,552	11,087	23,098	84,084	197.1	131.9
Total	62,046	53,563	9,677,663	10,844,688	6.4	4.9
2008						
0	3,593	3,093	174,268	167,193	20.6	18.5
1-4	1,372	1,180	697,905	670,673	2.0	1.8
5-9	960	720	943,048	903,737	1.0	0.8
10-14	869	745	1,035,282	986,068	0.8	0.8
15-19	1,348	1,078	883,962	979,034	1.5	1.1
20-24	1,922	1,249	555,939	885,409	3.5	1.4
25-29	2,160	1,368	801,191	848,655	2.7	1.6
30-34	2,424	1,483	845,920	826,639	2.9	1.8
35-39	3,655	2,137	1,110,831	1,096,273	3.3	1.9
40-44	3,907	2,405	1,000,048	1,010,206	3.9	2.4
45-49	3,915	2,553	762,940	793,399	5.1	3.2
50-54	4,715	2,915	636,756	677,332	7.4	4.3
55-59	7,113	4,182	423,158	479,250	16.8	8.7
60-64	16,815	9,545	476,605	581,536	35.3	16.4
65-69	22,281	11,787	379,426	533,848	58.7	22.1
70-74	18,886	15,207	228,276	434,341	82.7	35.0
75-79	10,991	17,699	79,226	256,236	138.7	69.1
80+	5,901	24,443	24,708	160,541	238.8	152.3
Total	112,827	103,789	11,059,489	12,290,370	10.2	8.4

Note: Includes total deaths in private households and institutional living quarters (excludes military).

Sources: Central Bureau of Statistics DPRK, 1995, Tabulation on the Population Census of the Democratic People's Republic of Korea (31 December 1993), pp. 5-11, 297-303 and Central Bureau of Statistics, 2009, DPR Korea 2008 Population Census, Pyongyang, pp. 27, 92.

Table 2. Demographic Estimates and Projections for North Korea: 1993 to 2040

Year	Expectation of Life at Birth: Both sexes	Expectation of Life at Birth: Male	Expectation of Life at Birth: Female	Infant Mortality Rate: Both sexes	Infant Mortality Rate: Male	Infant Mortality Rate: Female	Total Fertility Rate	Net International Migration: Migrants	Net International Migration: Rate*
1993	67.9	64.1	72.0	29.9	33.1	26.5	2.28	-103	0.00
1994	66.0	61.9	70.4	36.2	41.1	30.9	2.22	-647	-0.03
1995	64.0	59.5	68.8	43.8	51.0	36.1	2.17	-636	-0.03
1996	61.8	56.9	67.0	52.9	63.2	42.0	2.11	-651	-0.03
1997	59.3	54.0	65.0	64.0	78.2	49.0	2.05	-98,180	-4.37
1998	59.3	54.0	65.0	63.9	78.1	49.0	2.05	-100,166	-4.45
1999	60.3	55.2	65.8	59.3	71.7	46.1	2.10	37,256	1.65
2000	61.3	56.3	66.6	54.9	65.9	43.3	2.10	37,092	1.63
2001	62.2	57.4	67.3	50.9	60.5	40.8	2.09	36,672	1.60
2002	63.1	58.5	68.1	47.2	55.5	38.3	2.09	36,116	1.56
2003	64.0	59.5	68.8	43.7	51.0	36.1	2.08	3,474	0.15
2004	64.8	60.5	69.5	40.5	46.8	33.9	2.08	2,862	0.12
2005	65.6	61.4	70.1	37.6	42.9	31.9	2.07	3,368	0.14
2006	66.4	62.3	70.8	34.8	39.4	30.0	2.07	3,178	0.13
2007	67.2	63.2	71.4	32.3	36.1	28.2	2.06	3,178	0.13
2008	67.9	64.1	72.0	29.9	33.1	26.5	2.06	1,786	0.07
2009	68.2	64.4	72.3	28.9	32.1	25.6	2.05	392	0.02
2010	68.6	64.7	72.6	28.0	31.0	24.7	2.03	-1,000	-0.04
2011	68.9	65.0	72.9	27.0	30.0	23.9	2.02	-1,000	-0.04
2020	71.6	67.7	75.6	19.9	22.2	17.5	1.92	-1,000	-0.04
2040	76.4	72.7	80.3	10.6	11.9	9.2	1.75	-1,000	-0.04

Note: Expectation of life in years, infant mortality rate per 1,000 live births, total fertility rate per woman, net international migration rate per 1,000 population.

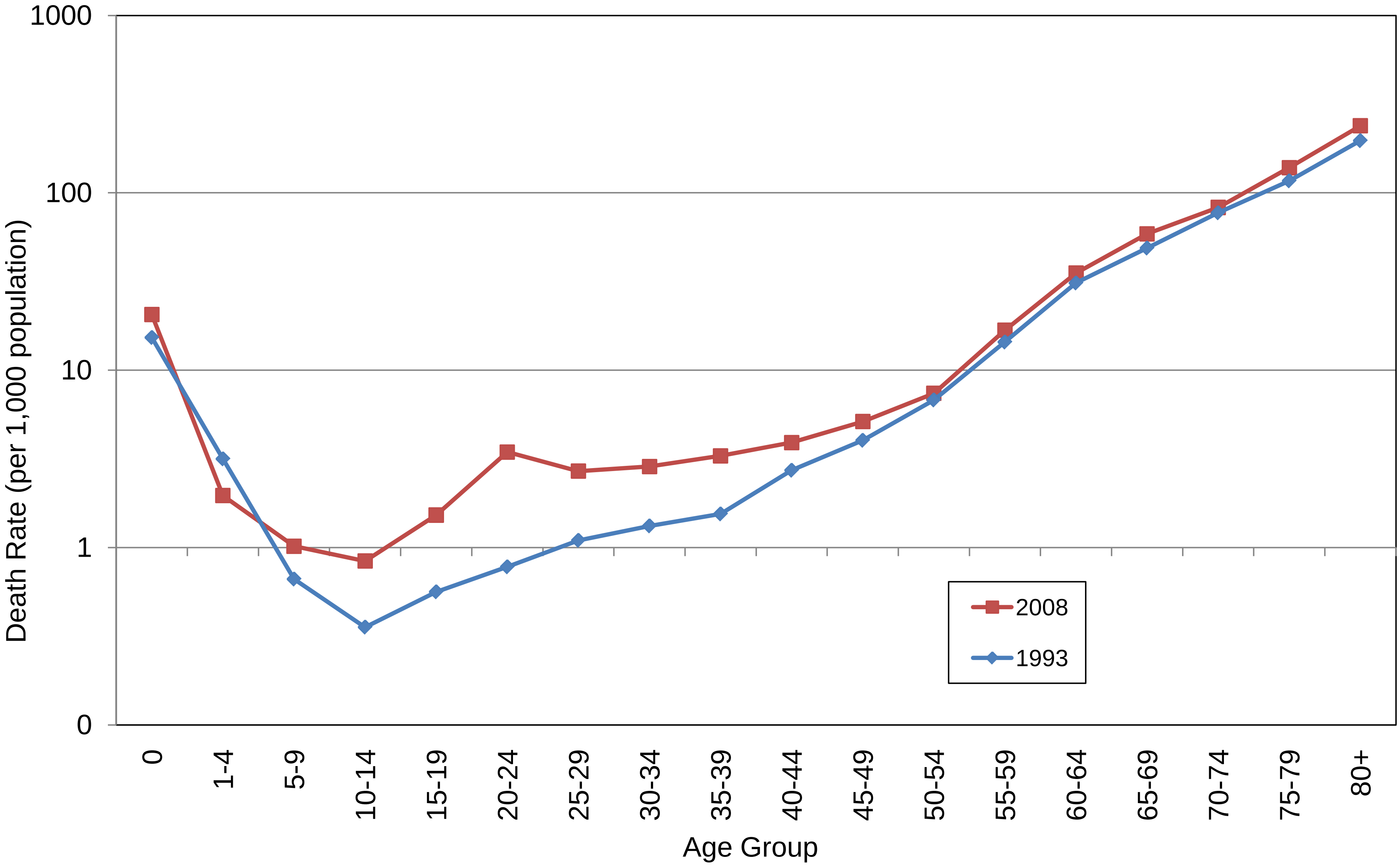
Source: U.S. Census Bureau. International DataBase. http://www.census.gov/ipc/www/idb/

Table 3. Estimates of Excess North Korean Deaths Based on Models Assuming No Famine: 1993-2008

		Mortality Constant at 1993 Adjusted Level		*Gradual Improvement in Mortality Since 1993*	
Interval	Estimated Deaths With Famine	Estimated Deaths Without Famine	Implied Excess Deaths	Estimated Deaths Without Famine	Implied Excess Deaths
1993-2000	1,883,381	1,394,841	488,540	1,294,079	589,302
2001-2008	1,864,642	1,770,929	93,713	1,464,188	400,454
1993-2008	3,748,023	3,165,770	582,253	2,758,267	989,756

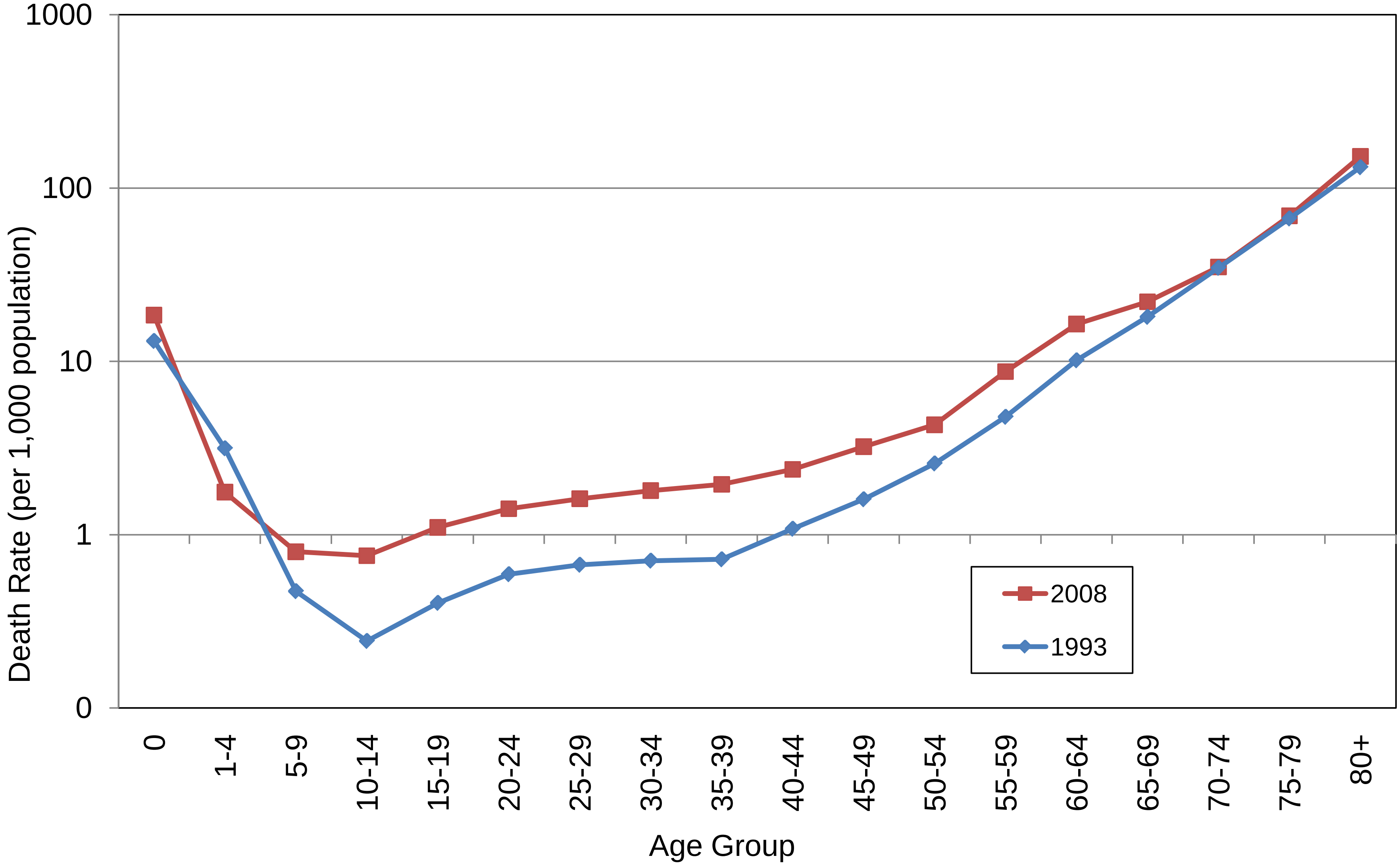
Notes: Estimated deaths are all derived from cohort-component projections forward from a 1993 census population, adjusted up for a presumed 2.3 percent undercount at each age and moved to mid-year. The first column assumes annual demographic change parameters as in Table 2. Without famine deaths are derived from cohort-component projections which assume that mortality remained constant or declined gradually following the 1993 censuses (fertility and migration assumptions are otherwise identical). Implied excess deaths represent the difference between estimated deaths with famine and estimated deaths without famine. See Table 2 and Figure 6 for further details.

Figure 1. Age-Specific Death Rates (log scale) for Civilian Males in North Korea: 1993 and 2008 Censuses



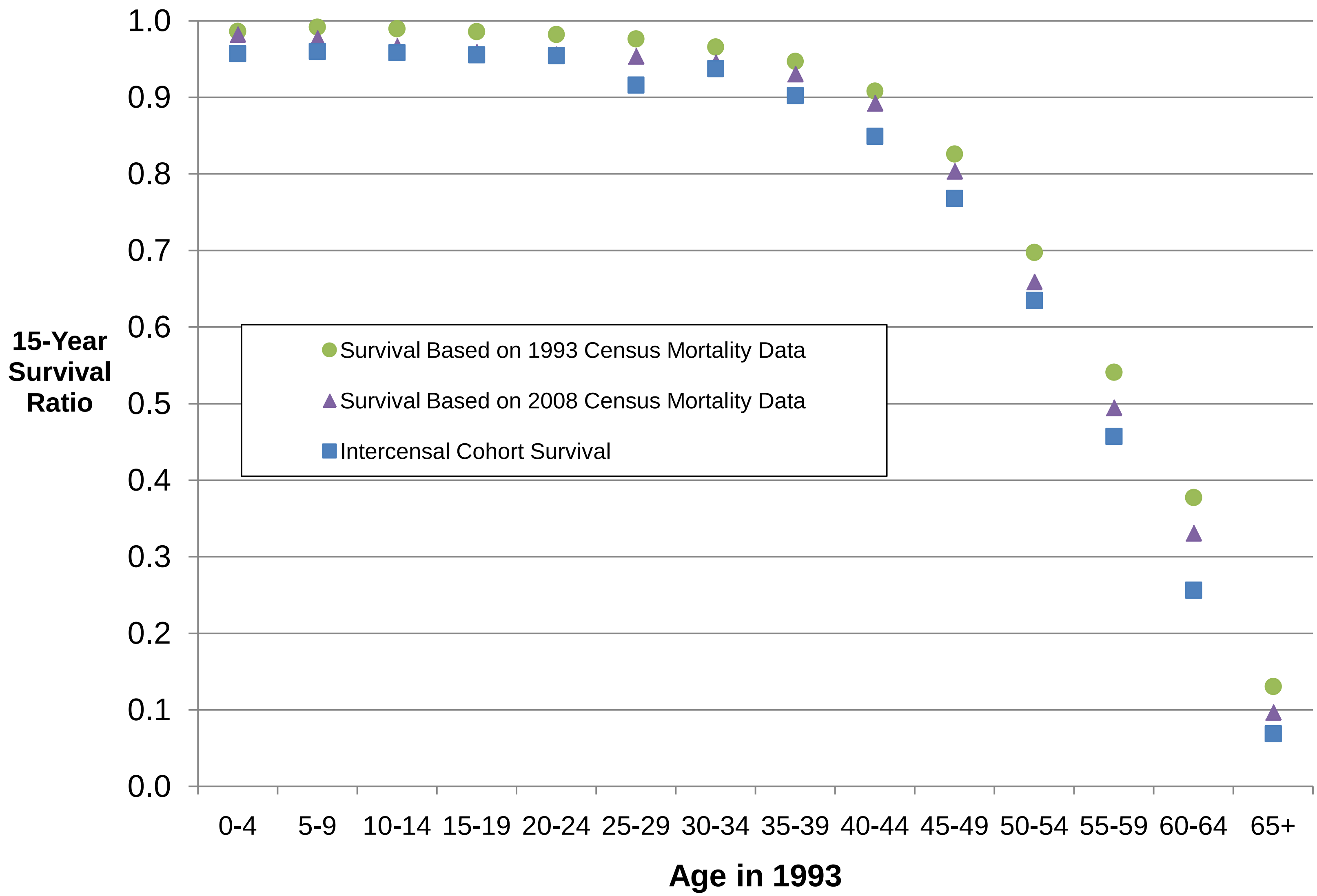
Source: Central Bureau of Statistics (1995 and 2009).

Figure 2. Age-Specific Death Rates (log scale) for Civilian Females in North Korea: 1993 and 2008 Censuses



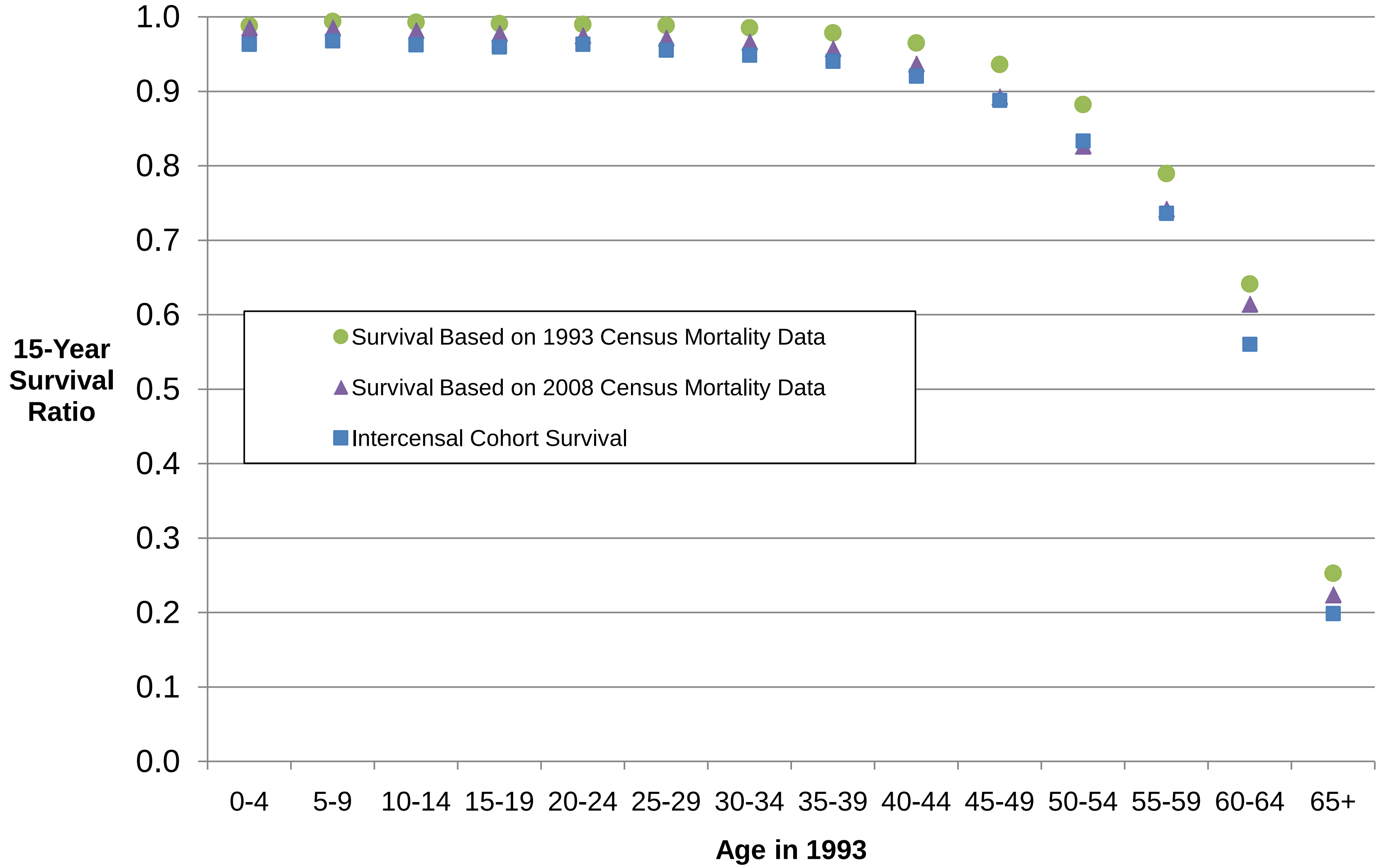
Source: Central Bureau of Statistics (1995 and 2009).

Figure 3. 15-Year Survival Ratios of Males in North Korea: Intercensal Cohort Survival vs. Reports in Years Prior to Each Census



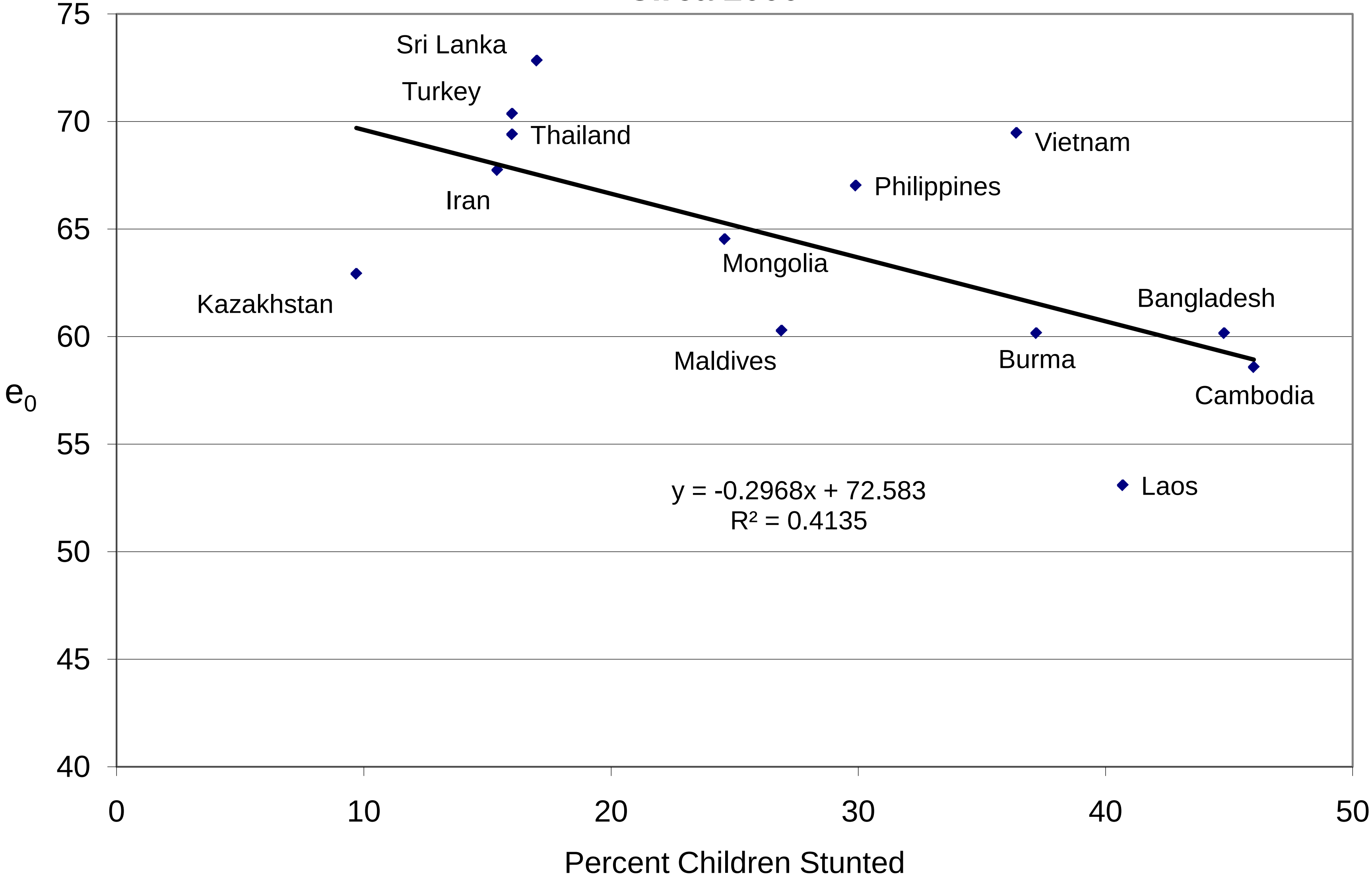
Source: Central Bureau of Statistics (1995 and 2009) and calculations by U.S. Census Bureau.

Figure 4. 15-Year Survival Ratios of Females in North Korea: Intercensal Cohort Survival vs. Reports in Years Prior to Each Census



Source: Central Bureau of Statistics (1995 and 2009) and calculations by U.S. Census Bureau.

Figure 5. International Comparison of Percent Children Stunted and Life Expectancy (e_0) for Both Sexes in Asian Countries - Circa 2000



Source: UNICEF (stunting) and U.S. Census Bureau, International DataBase (e_0) http://www.census.gov/ipc/www/idb/

Figure 6. Assumptions of Life Expectancy (e_0) for Both Sexes in the Absence of Famine to Calculate Excess Deaths