Long-Term Health Consequences of Early-Life Exposure to the Korean War (1950-1953)

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Abstract

This paper investigates how in-utero exposure to the Korean War affected health outcomes at old age. The probabilities of suffering from a particular type of functional limitation as well as having any disability were significantly higher in 2010 among the individuals born in 1951, who were *in utero* during the worst time of the war. The results of difference-in-difference estimations suggest that the magnitude of the adverse 1951 cohort effect on health is significantly larger for individuals whose places of birth were more seriously devastated by the war. The adverse long-term effects of in-utero exposure to the Korean War found in this study are unlikely driven by selection bias: the subjects of the 1951 birth cohort were actually positively selected in terms of parental characteristics in 1960.

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1. Introduction

The Korean War (June 1950–July 1953) is the bloodiest incidence that Korea has ever experienced in the modern era. Despite its historical significance, the social and economic aspects of the conflict remain poorly understood. In particular, documents are inadequate on how wartime experiences influenced the subsequent health and socioeconomic performance of survivors over their life course.

The war likely damaged individual maternal and fetal health, especially in the first nine months of the war following the surprise invasion of North Korea. The frontline dramatically moved back and forth across the region, forcing civilians to suffer from severe war-related disruptions. Growing number of studies provide evidence that *in utero* exposure to negative health shocks has strong and persistent effects on health and socioeconomic outcomes at older ages (Barker 1992, 1994; Neugebauer, Hoek, and Susser 1999; Roseboom, Meulen, Ravelli et al. 2001; Almond and Mazumder 2005; Almond 2006; Neelson and Stratman 2011). However, how *prenatal* exposure to military conflict affects *adult* outcomes is considerably less known. How the effects of early-life conditions differ across periods and nations remain unclear, either, because existing evidence for this issue is drawn largely from the US and from Europe.[2]

A recent study suggests that prenatal exposure to the disruptions caused by the war negatively affected the educational attainment, labor market performance, and other socioeconomic outcomes (Lee 2014). However, the long-term health consequences of the traumatic event are less clearly understood. It has not been fully explored how old-age health outcomes of the Korean War cohorts were influenced by potential population selections caused by the war.

This paper contributes to these issues by investigating how in-utero exposure to the Korean War affected health outcomes at old age, namely, the probability of suffering from a particular type of functional limitation as well as any disability in 2010. We analyzed the 10% sample of the 2010 census that was recently made available only within the facility of the Korean Statistical Office. The 2006 Korea Longitudinal Study of Aging is also used as a supplemental source of evidence. This study also explores if differences in old-age health outcomes across birth cohorts are attributable to the population selections. For the purpose, the 1% sample of the 1960 census is utilized for comparing parental characteristics of different birth cohorts.

The present paper extends and improves the author's previous study on the topic (Lee 2014) in several respects. First, the strength of negative health shocks to fetal health was more accurately

[2] The effect of an adverse shock to health *in utero* depends on the patterns of postnatal investments in health and other types of human capital. Thus, the relationship between early-life conditions and later health outcomes is likely to differ across periods and countries. The differences depend on income, quality of medical care, and educational system, political and social structures, as well as cultural and social norms.

measured exploiting the variable on the place and additional information on the timing of birth drawn from a previously unavailable source, the 10% sample of the 2010 census. Second, particular types of functional limitations are considered as old-age health outcomes along with disability in general. Third, the present paper looks into the health outcomes of the Korean War cohorts at the ages 57 to 60, whereas the previous study concerned the probability of having a disability in the early 50s. Finally, the potential bias problems arising from population selections are more rigorously investigated using the newly-released 1% sample of the 1960 census.

The results suggest that the probabilities of suffering from a particular type of functional limitation as well as having any disability are significantly higher in 2010 among individuals born in 1951, who were *in utero* during the worst time of the war. The results of difference-in-difference estimations suggest that the magnitude of the adverse 1951 cohort effect on health is significantly larger for individuals whose places of birth were more seriously devastated by the war. The adverse long-term effects of in-utero exposure to the Korean War found in this study are unlikely driven by selection bias. There is no evidence that the subjects of the 1951 birth cohort were positively selected in terms of parental characteristics.

2. The Korean War (1950-1953)

The Korean War broke out in June 1950 with a sudden invasion of the North Korean army and lasted for three years. It is the bloodiest incidence that Korea has ever experienced in the modern era. Statistical data on wartime human losses are not highly reliable and substantially differ across sources. According to the official statistics of South Korea published in 1955, the number of civilian casualties during the three years of hostilities totaled 990,968, including 373,599 persons killed, 229,625 injured, 84,532 abducted, and 303,212 missing in South Korea alone (Chung 2010). It is likely that these estimates are understated. Military casualties were also heavy. An estimated 36,940 US servicemen and 245,000 to 415,000 South Korean soldiers were killed while in service during the war.

The Korean War forced civilians to suffer from severe war-related disruptions, because the frontline dramatically moved back and forth across the region, especially during the first nine months of the war (see Figure 1). The totally unprepared South Korean troops were repeatedly defeated and forced to retreat southward. The South Korean capital, Seoul, was captured by North Korean forces in only three days. By late August, only two months after the outbreak of the war, North Korea had occupied about 90% of the entire Korean Peninsula. The situation was reversed with the successful landing of the UN troops in Incheon in September. Within the following two months, the UN troops liberated Seoul, captured Pyongyang City, the North Korean capital, and eventually reached the

Amnok (Yalu) River, which divides North Korea and China. The tide of the war changed once again when Chinese communist forces secretly moved into North Korean territory and ambushed the UN troops in late November 1950, forcing the UN troops to fall back. Seoul was again lost to the enemy on 4 January 1951. Regrouped and reinforced, the UN forces fought back to the 38th parallel, the original borderline between South and North Koreas by the spring of 1951, and the war reached a stalemate that lasted until the armistice of July 1953.

Although quantitative evidence and systematic documentation are rare, visualizing the terrible ordeal suffered by the majority of the Koreans during the war is not difficult. With frontline troops dramatically moving back and forth across the region, practically the entire Korean Peninsula experienced the ravages of war. The chaotic situation in the early stages of the war directly exposed civilians to combat activities, which took a tremendous toll on human life. In addition to physical wounds and illnesses, a few survivors suffered from the mental damages that afflicted the soldiers, such as post-traumatic stress disorder.

Many of the people who remained in the areas occupied by North Korean forces suffered from atrocities such as massacres, tortures, imprisonment, and abduction. Civilians who remained under the communist control were also victimized by heavy bombings by the UN air forces that attempted to destroy North Korean military facilities and supply lines (Kim 2008). Refugee experience was no less arduous. Many refugees travelled on foot for days, carrying as many of their belongings as possible. People who were fortunate to get a train ride endured overly crowded cabins. Passengers who rode on the roof bore the suffocating smoke blowing out of the steam locomotive, especially when the train passed through tunnels. Away from home, the refugees endured chronic hunger and slept without proper shelter. The refugees joined the retreating troops pushed by the Chinese attack and suffered through the harsh winter cold.[3]

The small areas in the southeast that managed to avoid occupation, especially the two large cities of Busan and Daegu, were the main refugee destinations. Busan City, with a population of about 400,000, became home to more than 1 million people in only several months. Most refugees lived in shabby shelters made out of cardboard boxes, wooden planks, and makeshift tarp covering. Some people who had close relatives or friends living in Busan and Daegu fared slightly better, but they needed to cram themselves into small rooms. Emergency aid provided by the UN forces and ration distributions by the government prevented mass starvation, but these measure were still insufficient to solve the severe food shortage.

Despite its historical significance, the Korean War draws considerably less attention from people outside the country compared with World War II or the Vietnam War. Even the main participants (such as the US) who were directly involved in the campaign did not pay as much

[3] See memoirs by Korean writers including Kim (2006) and Chun (2006).

attention to the war. The "Forgotten War" is one of the best books written on the Korean War, which presents an account of the conflict that befits its current status. Relatively rich literature on political circumstances is devoted to the origin, progress, and aftermath of the war (Cumings 1981, 1990, 2010). Military actions are also reasonably well documented (Halberstam 2007). However, the social and economic aspects of the conflict remain poorly understood. In particular, documents are inadequate on how the war affected the everyday lives of civilians, and how wartime experiences influenced the subsequent health and socioeconomic performance of survivors over their life course. Studying the social history of the Korean War based on the narratives of survivors is a promising approach to fill this gap (Kim 2009; Pyo et al. 2003). However, the primary focus of such studies is the civil disputes and massacres caused by ideological conflicts.

3. Early Exposure to Negative Shocks and Later-Life Health

Prenatal exposure to war-related disruptions such as those described may negatively affect maternal and fetal health in different ways. First, food shortage during a war forces pregnant women to suffer from hunger. Malnutrition suffered while *in utero* can increase the risk of developing various degenerative diseases at older age (Barker 1992, 1994). A voluminous literature documents the negative health and socioeconomic consequences of early exposure to malnutrition caused by historical famines, such as the 1944-1945 Dutch Famine (Neugebauer, Hoek, and Susser 1999; Roseboom, Meulen, Ravelli et al. 2001; Bleker et al. 2005), the Chinese Famine from 1959 to 1961 (St. Clair et al. 2005; Luo, Mu, and Zhang 2006; Chen and Zhou 2007; Meng and Qian 2009; Almond et al. 2010), and Greek Famine in 1941-42 (Neelson and Stratman 2011).

Second, maternal stress from exposure to combat activities and from physical or emotional hardship can adversely affect fetal health. A few studies have found negative influences of maternal stress during pregnancy on offspring outcomes from various stressful events including the September 11, 2001 terrorist attacks (Lauderdale 2006; Eccleston 2011), hurricanes (Currie and Rossin-Slater 2012), and landmine explosion in Columbia (Camacho 2008). Excessive noise causes stillbirth, birth defects, and decreased birth weight as a result of changes in the uterine and placental blood flow (Geber 1970; Jones and Tauscher 1978; Knipschild et al. 1981). Among the Finnish population, Huttunen and Niskanen (1978) found that the prenatal loss of fathers increases the risks of suffering from schizophrenia and committing crimes. Rofe and Goldberg (2011) reported increases in the blood pressure of pregnant women who lived in an area in Israel that was a target of terrorist activities for a long period and suffered the effects of war.

A recent paper by Lee (2014) suggests that prenatal exposure to the disruptions caused by the Korean War negatively affected the individual socioeconomic and health outcomes at older ages.

According to the results of the study, the educational attainment, labor market performance, and other socioeconomic outcomes of the subjects of the 1951 birth cohort, who were *in utero* during the worst time of the war, were significantly lower in 1990 and in 2000. The results of difference-in-difference estimations suggest that the magnitude of the negative cohort effect is significantly larger for individuals who were more seriously traumatized by the war.

The results related to health outcomes given in Lee (2014) suggest that the 1950 male birth cohort is likely the major victim of the Korean War in terms of disability and mortality in middle or old age. Males born in 1951 were no more likely to be disabled and no similar negative 1950 cohort effect is observed among females. The differences between the two cohorts who were prenatally exposed to the war were attributed to the different timing of exposure. That is, it is conjectured, the education and labor market outcomes of the 1950 were less seriously affected by the war than the 1951 birth cohort because they were exposed to the war *in utero* after their brains were fully formed. It remains unclear why the health of the 1951 birth cohort was not negatively influenced by in-utero exposure to the war.

Compared to the results on the socioeconomic outcomes, it is less clear how prenatal exposure to the war influenced later-life health for the following reasons. First, since the place of birth is not reported in the data utilized for studying the health outcomes (micro data on the 2005 census and the vital statistics), the previous study was unable to investigate how the cohort effects on health differ by the severity of wartime experiences. Second, the subjects of the cohorts born during the Korean War were in their early 50s in 2005; it might be too early age to observe the long-term health consequences of prenatal exposure to negative health shocks.

4. Data and Methods

Identifying the Effect of War

Measuring the magnitude of war-related negative health shocks is central to examining the long-term health consequences of prenatal exposure to disruptions caused by the Korean War. Closely following the identification strategy used in previous studies of its kind (Lee 2014), we investigate how individual health outcomes at old age differ by the timing and the place of birth.

A comparison of two birth cohorts while keeping all other factors constant is infeasible. Given that most health outcomes only tend to change gradually across cohorts, identifying a cohort effect from other smooth effects is difficult. However, one feature of the Korean War helps disentangle the cohort effect. Although the war lasted more than three years, the major damage sustained by civilians happened in the first nine months following the invasion of North Korea (late June 1950 to late March 1951). During these months, the frontline troops rapidly and unexpectedly moved back and forth

across the region, and civilians were directly exposed to major war disruptions. After the war reached a stalemate around the 38th parallel after the spring of 1951, the civilian life in the south of the battlefield more or less stabilized. Thus, it would be reasonable to assume that the fetal health of individuals born in 1951 or late 1950 is more seriously damaged by war-related disruptions than other birth cohorts.

Two more assumptions are required to add credence to the cohort analyses performed in this study. First, following the fetal origins hypothesis, a particular wartime event is assumed to cause a stronger negative health shock while an individual is *in utero* than in the postnatal period. Second, all other experiences, except the war effect, are assumed to continuously or gradually change across the birth cohorts. In other words, no other major events (epidemics, short-term economic shocks, institutional changes, and so on) differentially affect the 1950 to 1951 birth cohorts and those adjacent to it.

Two types of evidence for the cohort effect are presented below. First, the raw data on old-age health outcomes for each birth cohort are graphically displayed to determine whether the 1950 or 1951 cohort reveals discontinuous cohort effects. The results for individuals born in the Central Region are highlighted because they experienced particularly severe hardships during the war, as explained later in the paper.

Second, the deviations of health outcomes from smooth cohort trends are systematically estimated for individuals born between 1945 and 1959. The estimation is carried out using the following regression equation:

$$(1)\quad h_i = \alpha + \sum_{t=1950}^{1951} \beta_t I_{it} + \gamma_1 YOB_i + \gamma_2 YOB_i^2 + \gamma_3 YOB_i^3 + \varepsilon_i$$

where h_i denotes the health outcome for individual i; I_t denotes the dummy variable with a value of 1 for individuals born in year t, and 0 otherwise; YOB denotes the last two digits of the birth year; and β_t measures the departure of outcomes for the birth cohorts *in utero* during the Korean War from the cubic cohort trend. In addition to simply including a cubic cohort trend, more non-parametric approaches to specifying cohort effects will be considered later on.

The severity of wartime experiences differs by region of residence, which offers another opportunity to identify the effect of the war on maternal and fetal health. Because of the manners the frontline moved during the war, as explained in the preceding section, the extent of war-related disruptions experienced by a particular locality was strongly influenced by the distance to the border (the 38th parallel). For example, the residents of the Central Region, the northern provinces of South Korea, had had less time to respond to the surprise attack of the North Korean forces compared with

the residents of the southern regions because of their proximity to the 38th parallel. As a consequence, they likely suffered from the occupation of North Korean troops and the bombings by UN forces. Even if the residents of the Central Region managed to escape from the communist control, they would have had to travel a longer distance to reach the Busan perimeter. Moreover, since a large part of the Central Region was occupied by North Korea twice, many of the residents in the region were displaced twice.[4]

To study the magnitude of wartime stress experienced while *in utero*, a difference-in-difference method is employed in examining the variations across places of birth. The basic idea is that if the cohort effect captures the direct influences of war-related disruptions, then it should be stronger for those persons who underwent more traumatic wartime experiences. To verify this assumption, we use regression to estimate the following equation

$$(2)\quad h_i = \alpha + \beta_1 I_i + \beta_2 (I_i \times S_i) + \beta_3 S_i + \gamma_1 YOB_i + \gamma_2 YOB_i^2 + \gamma_3 YOB_i^3 + \delta X_i + \varepsilon_i$$

where I denotes the dummy variable that identifies an individual as *in utero* between the summer of 1950 and the spring of 1951, S is the dummy variable indicating that the person was born in the Central Region, and X represents other personal or location-specific factors of the health outcome.[5]

Data and Variables on Old-Age Health Outcomes

Measures of old-age health are obtained from the 2010 census, which indicates whether a person has particular disability or limitation for all respondents. The 2010 census is the only census that provides information on both the health (variables on functional limitations) and place of birth of the cohorts born during the Korean War. The 2000 census offers information on functional limitations only for individuals aged 65 and older; the cohorts born during the Korean War birth cohorts were 50 or younger when the census was taken. The 2005 census provides the health variables for all individuals, but does not indicate the place of birth. The publicly available 2% micro sample of the 2010 census does not offer the variables on the place of birth. By obtaining permission from the Korea Statistical Office, we analyzed the 10% sample of the census that provides a broader range of variables including the county (or district) and the exact year of birth.

The health variables available from the 2010 census include: (1) any disability or functional

[4] Since the establishment of the 38th parallel as the border between North and South Korea was an arbitrary decision of the United States based on military and political considerations, the geographic variations in war-caused damage sustained by civilians are perhaps exogenously determined (Lee 2014).

[5] A more accurate measure of the severity of wartime experiences is whether the mother of a person lived in the Central Region when the Korean War broke out. The place of birth of Korean War cohorts is a reasonably effective proxy of the mother's place of residence at the beginning of the war (Lee 2014).

limitation (Disability), (2) limitations in sight, hearing or speaking (Communication), (3) limitations in walking or ascending stairs (Moving), (4) mental impairments (Mental), (5) limitations in memory, learning, or concentration (Cognitive), (6) limitations in eating, bathing, or dressing (Basic activities), (7) limitations in shopping or going to hospital (Outing), and (8) restrictions in working (Working).

As a supplementary source of evidence, the Korea Longitudinal Study of Aging (KLoSA) is used. The KLoSA is perhaps not particularly appropriate for the purpose of this study because of its excessively small sample size (about 10,000 persons aged 45 and older in 2006). The number of single-year birth cohort by gender born during the Korean War ranges from 150 to 250. However, the KLoSA provides a larger sample of cohorts born around the war period than do other Korean micro data that contain additional detailed information on personal characteristics (e.g., the Korean Labor and Income Study). The KLoSA offers rich information on health outcomes. Furthermore, the month of birth is available from the source. Thus, the examination of how health outcomes changes by year and quarter of birth is possible. The following measures of health outcomes are obtained from this source and analyzed: (1) score of self-reported health (1 to 5, representing the best and worst health status); and (2) probability of having any disability.

Table 1 presents the sample means of the health outcomes of all male and female individuals and those who were born in the Central Region from 1945 to 1959. The fraction of the birth cohorts with any disability in the 2010 census is 12.4% for both males and females. The percentage of the individuals disabled in the 2006 KLoSA is lower, 7.5% and 3.6% for males and females. Individuals born in the Central Region were more likely to have any health problems than the entire sample. The percentage with a particular disability among males is higher than that of female for all but limitation in moving.

5. Long-Term Effect of the Korean War on Health Outcomes at Old Age

Identifying the effect of war: the year of birth

The percentage of persons born in the Central Region with any disability by birth cohort is presented in Figure 2. A strong downward trend in the rate of disability is shown by these cohorts, with the 1950 and 1951 birth cohorts veering from this steady trend. In particular, a deviation of the 1951 cohort from the tendency for long-term decrease in the disability rate is clearly revealed.[6]

The fraction of the Central Region natives with a particular type of disability is compared across birth cohorts, as shown in Figures 3 to 9. As with the trend of disability in general, the disadvantage of the 1951 birth cohort is graphically evident for six out of seven types of functional

[6] Although not presented here, digression of the 1951 birth cohort from the trend is also observed in the entire sample, albeit at a smaller magnitude.

limitations, namely, restrictions in moving (Figure 4), mental impairments for males (Figure 5), cognitive disability (Figure 6), limitations in basic activity for females, limitations in outing (Figure 7), and restrictions in working (Figure 9). In particular, the male subjects of the birth cohort born in 1951 were at much higher risks of suffering from mental condition, cognitive disability, and restriction in working.

Table 2 provides the estimates of β_t in Equation (1), indicating the magnitude of the health outcome deviation of male subjects born in 1950 and 1951 from the cubic cohort trend. Standard errors were adjusted in testing the statistical significance for the clustering of birth year.[7] The regression results confirm that the rates of overall disability and particular types of disability among the 1951 birth cohort are significantly high, especially among the subjects born in the Central Region.[8] Two exceptions are found in the results for "moving" and "mental" for females that show the statistically insignificant 1951 cohort effect.

The regression results for males and females, though largely similar with each other, are different in several respects. First, it appears that the health of the males was more strongly influenced by in-utero exposure to the Korean War than that of females. The estimated coefficients for the 1950 and 1951 birth dummy variables are larger and statistically more significant for males in general. Second, for females, the negative health consequences of early exposure to the war are found only for the 1951 birth cohort, whereas the male subjects of the 1950 birth cohort were significantly more likely to suffer from disability. Third, the particularly strong negative effect of the war sustained by the Central Region natives compared to the entire sample are more clearly revealed among females than among males.

Lee (2014) finds that in-utero exposure to the Korean War significantly affects adult socioeconomic outcomes, including educational attainment, occupation, and marital status. Since old-age health can be influenced by socioeconomic status, the regression results reported in Table 2 may in part capture the indirect effects of early exposure to the war through different socioeconomic outcomes. To examine if this is the case, Equation (1) is estimated with controlling for the years of schooling and dummy variable on marital status (=1 if married and =0 otherwise).

Columns 1 and 3 of Table 3 present the results for males and females born in the Central Region. In the case of males (Column 1), the coefficient for the 1951 birth cohort remains significantly positive for all categories of functional limitations if socioeconomic variables are added, except "communication" (panel B). However, the magnitude of the 1951 cohort effect modestly

[7] All the coefficients of interest are jointly significant at the 1% level for all the regressions reported in this paper.

[8] The negative effect of being born in 1951 on the quality of occupation is not fully explained by the disadvantage in educational attainment of the cohort. Although the education factor is controlled, the 1951 cohort effect remains statistically significant.

diminishes: as for the probability of having any disability (panel A), for instance, the magnitude of the regression coefficient for the 1951 birth decreases by 24%. For females (Column 3), the 1951 cohort effect is statistically significant for five out of eight measures of health. Overall, the results suggests that the long-term direct impact of early exposure to the Korean War is a more likely explanation for the negative 1951 cohort effect on health than possible indirect influences of the war via socioeconomic status.

A possible concern of the baseline regressions conducted above is that a cubic function of the year of birth may not accurately capture the actual smooth cohort trend. To address this concern, a more flexible cohort trend is applied to the cohort analysis, in which a quadratic cohort trend is allowed to change across the pre-war (1945 to 1949), wartime (1950 to 1954), and post-war (1955 to 1959) cohorts. The results reported in Columns 2 and 4 of Table 3 are similar to those based on the cubic specification, especially for males born in 1951. For females, the negative effects of birth in 1951 on mental and cognitive limitations are less strongly revealed if the new specification is applied.

Identifying the effect of war: the month of birth

The long-term effects of early exposure to war-related disruptions could differ by the timing and length of exposure. Previous studies suggest that the consequences of prenatal exposure depend on which trimester of pregnancy the shock is received (Torche 2011; Lee 2013). Since the Korea Statistical Office only provides the year of birth in the micro sample of the censuses, it is difficult to fully identify the timing and duration of exposure. However, utilizing the information on the age at the time of census enumeration (November 1) and the year of birth, it is possible to identify if a person was born prior to November 1 in a given year. Among the subjects of the 1951 birth cohort, for instance, if a person's age is reported 59 in the 2010 census, his or her birth month should be January to October; if the age is reported as 58, the person's birth month should be either November or December.

To investigate if there were differences in the old-age health outcomes by the timing of birth among the 1951 birth cohort, regressions based on Equation (1) are conducted where dummy variables on birth in January to October 1951 and birth in November to December 1951 are included instead of dummy variables for the 1950 and 1951 birth cohorts. Two specifications with cubic and more flexible cohort trends are employed. Standard errors are adjusted for clustering at the level of the two periods (January to October and November to December) of the birth year.

The results reported in Table 4 suggest that the adverse cohort effect is more strongly revealed for those born prior to November 1. Except for the case of male limitations in communication, the individuals born in January to October 1951 were more likely to suffer from functional limitations. In contrast, the estimated coefficient for the birth in November to December 1951 is either insignificant

or even significantly negative for 23 out of 32 regressions. For the nine regressions in which the coefficient for the birth cohort born in November or December is significantly positive, the magnitudes of the cohort effect on disability are generally similar between the two groups of individuals born in 1951.

With the information on the month of birth for the generations born during the Korean War, the KLoSA can supplement the results related to the differences by the timing of birth. Two health outcomes, the average score of self-reported health and the percentage of individuals having any disability, are plotted based on data from the 2006 KLoSA for each birth quarter from 1948 to 1955. Place of birth is not identified in the KLoSA, thus the results pertain to the entire sample. Figures 10 and 11 present the results for males and females.

Although the measures of health considered in the analysis considerably fluctuate across birth quarters (perhaps because of the small sample size), the male subjects born in the second quarter of 1951 clearly deviate from long-term patterns predicted in the two health outcomes. In the case of self-reported health, the males born in the first half of 1951 were more likely to report poorer health status than the neighboring birth cohorts (Figure 10-A). In contrast, the plotted variables for females do not reveal any clear cohort effects (Figures 10-B and 11-B).

Regression results for self-reported health and disability are consistent with the patterns of cohort effects displayed by the figures (not reported in the paper). The male subjects born in the first and second quarters of 1951 are significantly more likely to report poorer health; those born in the second quarter of 1951 are more likely to have disability. Females who were *in utero* for any length of time during the worst nine months of the war do not exhibit any significant disadvantages in self-reported health and disability.

It cannot be determined by the available evidence whether the timing or duration of exposure produces the worse health outcomes of the persons born in the earlier months of 1951 compared to those born at the end of the year. Given that the war-related disruptions experienced by civilians were largely concentrated in the nine months from late June 1950 to late March 1951, the subjects of the 1951 cohort born in November or December were exposed to the difficulties caused by the war only during the first trimester of pregnancy. In contrast, the persons born the spring of 1951 spent the entire prenatal period during the worst nine months of the war. The persons born in the first half of 1951 spent at least the first and second trimesters of pregnancy during the worst time of the war. The males born in the second quarter of 1951, the biggest victims of the war in terms of self-reported health and disability reported in the KLoSA, passed at least the first and second trimesters of pregnancy under the highly stressful nine months of the war. Thus, the evidence given here suggests: (1) the longer the duration of prenatal exposure to the war-caused disruptions the worse the old-age health outcomes; or (2) exposure during the second trimester of pregnancy is especially harmful for old-age health

outcomes.

Identifying the effect of war: difference-in-difference estimation

If the deviation of health outcomes of the 1951 birth cohort reflects the influences of war-related disruptions experienced while *in utero*, then its magnitude should be larger for individuals exposed to worse *in-utero* circumstances during the war. This hypothesis is consistent with the fact that the disadvantages of the 1951 birth cohort are particularly pronounced among individuals born in the Central Region. Figure 12 compares the percentage of each birth cohort with any disability between the natives of the Central and the South. The upward deviation of the disability rate of the 1951 birth cohort is observed only among those born in the Central Region.

Regressions are conducted based on a difference-in-difference model, as displayed in Equation (2). If the 1951 cohort effect increases with the magnitude of wartime stress, then the coefficient of interaction between the dummy variable for the birth in January to October 1951 and the dummy variable for the birth in the Central Region should be positive if the dependent variable is the probability of suffering from a disability. The cubic cohort trend (i.e., YOB, YOB^2, and YOB^3), dummy variable for the birth in January to October 1951, and the Central Region dummy are controlled.

The first column of Table 5 reports the summary results (the coefficient of the interaction term) of 16 difference-in-difference regressions conducted on eight measures of health outcomes of males and females. The results suggest that for all health outcomes except male "communication" the 1951 cohort effect is stronger for individuals who suffered more serious wartime stress while *in utero*. The coefficient of the interaction between the birth in 1951 and wartime stress is significantly positive in 11out of 16 regressions. The results among females are similar to those among males in terms of general disability and particular functional limitations such as those in moving, basic activity, and outing. However, prenatal exposure to war-related disruptions had considerably weaker effects on mental and cognitive limitations for females than for men.

The measures of the intensity of the war likely capture the exogenously-determined distance between the place of birth and the 38th parallel, but they might be correlated with selections of the treated group (i.e. the 1951 birth cohort born in the Central Region) as well.[9] Accordingly, a number of control variables pertaining to the characteristics of the person and the place of birth were added to the difference-in-difference regressions, including (a) personal characteristics including the years of schooling and marital status (Column 2), (b) the extent of urbanization of the place of birth (Column

[9] Variables on parental characteristics should be added to the regressions to address this concern. However, census reports the information on parents only if they reside in the same household. As the survival of and co-residence with parents are selective, conducting analyses based on a sample of people living with their parents would be problematic.

3), and (c) personal characteristics and urbanization combined (Column 4). To construct the variables for extent of urbanization, places of birth were classified as follows: (a) Seoul; (b) five metro cities, namely, Busan, Inchon, Daegu, Deajun, and Kwangju; (c) all other smaller cities; and (d) rural areas (omitted category).

Columns 2 to 4 of Table 4 present the regression results with additional controls. For males, the results of difference-in-difference estimations do not change much by applying different specifications. The notable difference is that the magnitude of the coefficient modestly diminishes if the variables on schooling and marital status are controlled. The regression results with additional controls for females are qualitatively similar to those of the baseline regressions, too. However, only the coefficients for "moving," "basic activity," and "outing" remain statically significant. These gender differences in the difference-in-difference regressions are consistent with the results of the cohort analyses (reported in Tables 2 and 3): the long-term health effects of early exposure to the war-related disruptions are weaker and less robust for females than for males, especially in mental and cognitive limitations.

This study also examined whether the effect of interaction between the 1951 birth and the measure of war-caused damage (birth in the Central Region) is sensitive to the functional form of cohort trend by including birth year dummies (1945 is the omitted category) interacting with each measure of wartime stress in the regressions, as represented by the following equation:

$$(3) \qquad h_i = \alpha + \sum_{t=1946}^{1959} \beta_{1,t} I_{i,t} + \sum_{t=1946}^{1959} \beta_{2,t} (I_{i,t} \times S_i) + \beta_3 S_i + \delta X_i + \varepsilon_i \,.$$

Figure 13 plots the coefficients for the interaction terms estimated from the regressions in which the probability of having any disability is used as the dependent variable. The coefficient for the 1951 dummy for males interacted with the Central Region dummy stands out as a clear upward outlier. It is the only statistically significant coefficient at the 5% level for males. A discontinuous drop in the magnitude of the coefficient between 1950 and 1951 is clearly observed in females, too. However, unlike males, the 1951 female birth cohort is less clearly distinguished from the neighboring wartime birth cohorts, and the coefficient is statistically insignificant.

6. Discussion

Potential Selection Bias

A natural concern in interpreting the results of this study is the pattern of selection of Korean War birth cohorts that survived six decades after the conflict. If individuals who were *in utero* during the worst time of the war were positively selected in terms of characteristics correlated with later life health, then maternal health can no longer be considered as explanation for the results given in the

preceding section.

Lee (2014) considers several types of population selections possibly influenced the composition of war-time birth cohorts, including (a) marriage and fertility behaviors; (b) deaths of pregnant women; (c) prenatal deaths; and (d) postnatal deaths. Based on various pieces of circumstantial evidence, the study maintains that the long-term influences of in-utero exposure to the Korean War on adult socioeconomic outcomes were unlikely driven by selection bias.[10]

A newly-released micro sample of the 1960 census can offer more direct evidence as to the direction and magnitude of selections in conception, live birth, and childhood death. In the censuses, parental characteristics can be observed only when the person co-resides with his or her parents. Any evidence from the censuses after 1960 cannot determine the direction of potential selections because parental survival and co-residence decisions are not random. But in 1960, the birth cohorts considered in this study (1945 to 1959) were under age 15, and thus the majority of them were expected to live with their parents.

The following parental characteristics are compared across the birth cohorts born from 1947 to 1957 to examine if there were any selections in the quality of family backgrounds among the individuals who were prenatally exposed to the disruptions caused by the war. Firstly, if the father or mother was absent in the household in 1960 is considered (parent absent). Five variables on parental socioeconomic status are constructed for individuals who resided with a parent: unable to read or write (illiterate), years of schooling, high school graduation (high school or higher), no formal education (no schooling), and currently working (working). The sample is further limited to the persons with a working parent for constructing variables on occupation: being employed as a wage worker (wage worker) and in a professional job (professional). Table 6 presents the sample means and standard deviations of these variables.

Figures 14 to 19 plot these variables on parental characteristics as of 1960 by the year of birth of children. Judging from graphical presentations, it appears that the subjects of the 1950 and 1954 birth cohorts were negatively selected in terms of parental characteristics, whereas the 1951 birth cohort does not deviate from smooth cohort trends. The children born in 1950 were more likely to live without their father (Figure 14), to have illiterate parents (Figure 16), and to have low-educated parents (Figures 15 and 17) than the adjacent birth cohorts. The fathers of the 1950 birth cohort were

[10] A possible source of selection in fertility behaviors is selective enlistment in the military (Brown 2011). Existing qualitative evidence suggests that men from particular socioeconomic backgrounds were unlikely to be recruited more than the others during the Korean War (Korean Military Manpower Administration 1985, pp. 264–286; Tucker 2002, pp. 354–359). Considering that the majority of civilians who died during the Korean War were victims of either combat activities or politically motivated murders (Chung 2010), survival during the Korean War should be more randomly determined compared with events such as famines or epidemics. The 2006 KLoSA provides weak but more direct evidence for positive selection of the 1951 birth cohort: the years of schooling for both the fathers and the mothers of children born in 1951 are longer than those predicted by long-term cohort trends.

less likely to be employed in a professional job (Figure 19). Similarly, the subjects of the 1954 birth cohort were more likely to have illiterate parents (Figure 15), and to have parents with lower educational attainment (Figures 16 to 18); the fathers of the cohort were less likely to be employed in a wage and salary job or to hold a professional occupation (Figure 19).

The deviations of the parental characteristics from smooth cohort trends are systematically estimated for individuals born between 1947 and 1957. The estimation is carried out using the following regression equation:

$$(3)\quad Z_i = \alpha + \sum_{i=1950}^{1954} \beta_i I_i + \gamma_1 YOB_i + \gamma_2 YOB_i^2 + \gamma_3 YOB_i^3 + \varepsilon_i$$

where Z_i denotes a given parental characteristic of the birth cohort *i*; I_i denotes the dummy variable with a value of 1 for the birth cohort *i*, and 0 otherwise; *YOB* denotes the last two digits of the birth year; and β_i measures the departure of the parental variable for the birth cohorts *in utero* during the Korean War from the cubic cohort trend. Regressions are also conducted in which a quadratic cohort trend employed instead of a cubic cohort trend.

The results of the regressions reported in Table 7 confirm that there is no evidence that the subjects of the 1951 birth cohort were positively selected in terms of parental characteristics. Although statistically insignificant, they were less likely to live without a parent, and were more likely to have parents with higher educational attainment. In contrast, the parental socioeconomic status of the 1950 and 1954 birth cohorts is significantly lower than predicted by smooth cohort trends. It is also notable that the subjects of the 1952 birth cohort show signs of positive selections: lower mother's illiteracy rate (Cols. 3 and 4 of panel A), higher parental years of schooling (panel C), and higher percentage of persons with professional father (panel H).

Year-by-year regressions are also conducted for four measures of paternal characteristics where the dummy variable for each birth cohort born from 1947 to 1957 is included one by one. The results of 44 regressions summarized in Table 8 confirm the baseline results reported in Table 7. The percentages of fatherless children and of those with illiterate fathers are significantly lower for the 1951 birth cohort, whereas the subjects of the 1950 and 1954 cohorts are negatively selected in terms of the absence, illiteracy, year of schooling, and occupation of their fathers. The fathers of the 1952 birth cohorts were more educated (Col. 3), less likely to be illiterate (Col. 2), and more likely to have a professional job (Col. 4).

In sum, the adverse long-term effects of in-utero exposure to the Korean War found in this study are unlikely driven by selection bias. Further studies are needed for a better understanding of why the direction of selections in birth and survival changed across the cohorts born from 1950 to

1954, but some conjectures can be offered. The positive selections of the 1951 and 1952 birth cohorts may be attributable to the severe wartime disruptions from the summer of 1950 to the spring of 1951. Under the highly unfavorable circumstance, the advantages of the individuals with higher socioeconomic status would be more strongly revealed in fertility behaviors and survival of children. By contrast, the negative selections of the 1950 and 1954 birth cohorts could result from the relatively favorable conditions of 1949 to early 1950 (following the establishment of the South Korean government in August 1948) and of late 1953 to early 1954 (following the end of the Korean War in July 1953).

Comparisons between Health Outcomes in 2005 and 2010

The patterns of the differences in disability rates across birth cohorts in the 2010 census are similar to the features of the variations in socioeconomic outcomes drawn from the 1990 and 2000 censuses (Lee 2014). When aged 40 to 50, measures of educational attainment, employment, and quality of occupation were significantly lower for the 1951 birth cohort, and the 1951 cohort effect is more strongly revealed for the individuals born in the places that were more seriously devastated by the war.[11] Similarly, the subjects of the 1951 birth cohort emerge as the biggest victims of the Korean War if old-age functional limitations are concerned.

However, the results of the present paper are a little different from the previous results related to disability obtained from the 2005 census (Lee 2014). In 2005, in general, the health consequences of early-life exposure to the Korean War were only weakly presented compared to the impacts on socioeconomic outcomes. Moreover, it was the males born in 1950, not the 1951 birth cohort, whose health was most seriously affected by prenatal exposure to wartime disruptions. No significant health effect of the Korean War is observed for females.

In the 2010 census, by comparison, adverse long-term effects of early-life exposure to the war are more apparently revealed than in 2005. Although the disadvantages of the 1950 birth cohort continue to be observed, the 1951 birth cohort turns out to be more seriously affected by in-utero experiences of the war. As in 2005, the effects of prenatal exposure to the war on health are weaker for females than for males in 2010; however, unlike 2005 census outcomes, the negative long-term impacts of the war on female health became statistically significant for a few health outcomes by 2010.

Although speculative at this point, several possible explanations for the differences in the

[11] The effects of in-utero exposure to the Korean War on educational attainment do not change between 1990 and 2010. Since wage and salary workers retire from their lifetime jobs in the early or mid 50s, it is difficult to investigate the impacts on labor-market outcomes using the census taken in 2010 when the Korean War birth cohorts were aged 57 to 60.

results drawn from the 2005 and 2010 censuses can be offered. First, in analyzing the 2010 census, the place of birth is considered for identifying the severity of wartime experiences, which is unavailable in the 2005 census. This might help more accurately identify the long-term effects of the war, as in the case of the results on socioeconomic outcomes based on the 1990 and 2000 censuses. Indeed, the 1951 cohort effect is more strongly observed for the natives of the Central Region (Tables 2 and 5).

Second, the long-term effects of in-utero exposure on old-age health might depend on the age of measuring health outcomes. As apparent from Figure 1, the disability rate begins to increase rapidly from the mid 50s (in Figure 1, from the 1954 birth cohort who were aged 56 in 2010). The rise in the disability rate after age 55 is particularly sharp for females, whose overall disability rate overtakes the males' at age 60 (Figure 1). The persons born in 1951 were aged 54 in 2005, and it is perhaps too early age to observe how early-life experiences eventually affected the risk of suffering from disability, especially for females. This hypothesis might explain why early-life exposure to the Korean War exerts increasingly strong effects on the health over time (e.g. why the 1951 cohort effect estimated from the entire sample is significant in 2010, not in 2005).

Finally, the differences in the features of population selections between the 1950 and 1951 birth cohorts could contribute to the earlier development of health problems among the persons born in 1950 compared to the 1951 birth cohort. The preceding section demonstrates that the parental socioeconomic status is significantly lower for the 1950 birth cohort than the neighboring cohorts. In contrast, the subjects of the 1951 birth cohort were generally privileged compared to other cohorts (except the 1952 birth cohort) in terms of family backgrounds (Tables 7 and 8). Furthermore, the 1951 birth cohort went through much more pronounced population selection between 1960 and 1990 compared to the 1950 birth cohort.[12] As noted by previous studies (Stanner et al. 1997; Bozzoli, Deaton, and Quintana-Domeque 2009), this stronger population selection should leave more robust persons alive within the 1951 cohort, thus postponing the onset of health conditions at older age. This hypothesis might answer the question of why the 1950 birth cohort began to experience the health consequences of the war-caused shocks earlier (e.g. from 2005) than the 1951 birth cohort.

7. Conclusion

This paper has investigated how in-utero exposure to the Korean War affected health outcomes at old age. The results suggest that the probabilities of suffering from a particular type of functional limitation as well as any disability were significantly higher among the individuals born in

[12] For comparing the relative mortality rates of the two cohorts, census survivorship method is applied to the age-specific population from 1960 to 1990. Between 1960 and 1990, the relative size of the male and female cohorts born in 1951 (among the cohorts born from 1945 to 1959) diminished by 0.15% and 0.50% respectively, whereas the relative size of the male and female subjects of the 1950 birth cohort increased by 3.10% and 2.95%.

1951, who were *in utero* during the worst time of the war. The results of difference-in-difference estimations suggest that the magnitude of the adverse 1951 cohort effect on health is significantly larger for individuals whose places of birth were more seriously devastated by the war.

The adverse long-term effects of in-utero exposure to the Korean War found in this study are unlikely driven by selection bias. There is no evidence that the subjects of the 1951 birth cohort were positively selected in terms of parental characteristics. Although statistically insignificant, they were actually less likely to live without a parent, and were more likely to have parents with higher educational attainment. In contrast, the parental socioeconomic status of the 1950 and 1954 birth cohorts is significantly lower than that of the neighboring cohorts.

The patterns of the variations in the disability rates across birth cohorts considerably differ between 2005 (Lee 2014) and 2010. First, early-life exposure to the Korean War exerts stronger effects on health outcomes in 2010 than in 2005. It is perhaps attributable to the facts that the rates of functional limitation sharply increase over the late 50s, and that the Korean War birth cohorts were a little too young in 2005 to pay the full prices for the harmful prenatal experiences. Second, it was the males born in 1950 in 2005 whose health was most seriously affected by prenatal exposure to wartime disruptions, whereas the subjects of the 1951 male birth cohort emerge as the major victim of the unfavorable in-utero circumstances caused by the war. Available evidence suggests that the differences in the features of population selections between the 1950 and 1951 birth cohorts might contribute to the earlier development of health problems among the persons born in 1950 compared to the 1951 birth cohort.

This paper provides new evidence pertaining to the fetal origins hypothesis. Along with Lee (2014) that focuses more on socioeconomic outcomes, a rare account of the long-run health consequences of direct exposure to a war *in utero* is offered. Thus far, previous studies have focused on how famines, infections, and exposure to toxic substances *in utero* affect adult outcomes. Several observed impacts of the Korean War may partly be explained by the effects of malnutrition and infection while *in utero*. However, the extent of malnutrition during the Korean War should be considerably milder than that experienced during the Dutch or Chinese famine. Despite the vivid memories of hunger among many survivors, finding a case of civilian death caused by starvation proved difficult. In addition, there were no records found on major epidemics of infectious diseases during the war. Although further research is required to determine the main mechanisms by which the war damaged fetal health, the following wartime experiences may have played important roles: suffering from atrocities under the North Korean occupation, physical and mental hardships faced while taking refuge, and direct exposure to bloody combats.

This study suggests that military conflict can lead to long-term negative health and economic consequences by adversely affecting maternal and fetal health. This finding is more evident in

civilians directly exposed to combat, as in the case of the Korean War, which implies that the conventionally estimated costs of historical wars may be understated. In general, only physical damages and direct human losses such as wartime deaths and wounds are counted in assessing the economic costs of a war (Goldin and Lewis 1975). Several studies consider the longer-term effects on the impaired health of individuals, especially those who fought in the war (Lee 2005, 2008; Edwards 2010). Lee (2014) suggests that lowered education resulting from the in-utero exposure to the Korean War incurs substantial earnings losses.[13] If the long-term adverse effect on the health outcomes of the next generation is also considered, the actual total costs of modern military conflict, which tend to expose civilians to various disruptions, should be substantially larger than suggested by conventional estimates.

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[13] The aggregate earning losses from lowered education is estimated at about 2.0 trillion won in 2010 (about 1.8 billion US dollars in 2010 value), not much smaller than the entire physical cost of the Korean War, estimated at 11.8 trillion Won in 2010 (Lee 2001).

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Table 1
Sample Means of Health Outcomes of the 1945-1959 Birth Cohorts

	All		Born in the Central Region	
	Male	Female	Male	Female
2010 Census: % with Disability				
All types	12.4	12.4	13.6	13.1
Communication (sight, hearing, speaking)	3.1	2.2	3.4	2.4
Moving (walking, ascending stairs)	6.3	8.0	6.7	8.2
Mental	4.5	2.9	5.4	3.5
Cognitive (memory, learning)	4.7	3.1	5.6	3.8
Basic activities (eating, bathing, dressing)	1.9	1.3	2.6	1.5
Outing (shopping, going to hospital)	2.5	2.4	3.0	2.8
Working	2.4	1.8	2.7	1.9
2006 KLoSA				
Self-reported health score	2.5	2.8	N/A	N/A
% Disabled	7.5	3.6	N/A	N/A

Source: The 10% sample of the 2010 census; the 2006 Korea Longitudinal Study of Aging (KLoSA).
Note: See text for the definition of the variables.

Table 2
Deviation of the 1950 and 1951 Birth Cohorts' Health Outcomes from 1945-1959 Trend

Outcome	Males				Females			
	(1) South Korea		(2) Central Region		(3) South Korea		(4) Central Region	
	∂y/∂x	S.E.	∂y/∂x	S.E.	∂y/∂x	S.E.	∂y/∂x	S.E.
A. Disability								
Born in 1950	**0.0033**	0.0011	**0.0060**	0.0009	-0.0018	0.0017	-0.0005	0.0020
Born in 1951	**0.0076**	0.0010	**0.0136**	0.0009	**0.0042**	0.0016	**0.0087**	0.0018
B. Communication								
Born in 1950	**0.0016**	0.0006	**0.0021**	0.0004	-0.0003	0.0009	0.0011	0.0011
Born in 1951	**0.0017**	0.0005	**0.0009**	0.0004	**0.0017**	0.0007	**0.0030**	0.0009
C. Moving								
Born in 1950	0.0003	0.0011	-0.0004	0.0011	-0.0008	0.0013	0.0009	0.0011
Born in 1951	**0.0038**	0.0009	**0.0072**	0.0010	0.0016	0.0012	**0.0060**	0.0010
D. Mental								
Born in 1950	**0.0014**	0.0005	**0.0042**	0.0005	-0.0001	0.0005	0.0006	0.0008
Born in 1951	**0.0054**	0.0005	**0.0077**	0.0005	-0.0002	0.0005	**0.0014**	0.0008
E. Cognitive								
Born in 1950	0.0006	0.0007	**0.0032**	0.0011	-0.0002	0.0006	0.0009	0.0007
Born in 1951	**0.0063**	0.0006	**0.0085**	0.0010	**0.0026**	0.0007	**0.0040**	0.0006
F. Basic activity								
Born in 1950	**0.0019**	0.0004	**0.0029**	0.0006	-0.0008	0.0006	-0.0001	0.0010
Born in 1951	**0.0017**	0.0003	**0.0031**	0.0005	**0.0011**	0.0005	**0.0035**	0.0008
G. Outing								
Born in 1950	**0.0014**	0.0005	**0.0034**	0.0007	-0.0005	0.0004	0.0006	0.0006
Born in 1951	**0.0021**	0.0005	**0.0041**	0.0007	**0.0010**	0.0004	**0.0036**	0.0005
H. Working								
Born in 1950	0.0005	0.0005	0.0005	0.0008	0.0001	0.0004	0.0005	0.0007
Born in 1951	**0.0033**	0.0005	**0.0042**	0.0008	**0.0017**	0.0004	**0.0032**	0.0006

Source: The 10% micro sample of the 2010 population census.
Notes: (a) "South Korea" includes persons who were born in North Korea and those for whom the place of birth is not reported; (b) Polynomials of the year of birth (YOB, YOB^2 and YOB^3) are included in the regressions; (c) Standard errors are adjusted for clustering at the level of year of birth; and (d) The estimated coefficient in bold number is statistically significant at 10% level.

Table 3
Deviation of the 1950 and 1951 Birth Cohorts' Health Outcomes from 1945-1959 Trend: Robustness Tests

Outcome	Males born in the Central Region				Females born in the Central Region			
	(1) + Schooling and marital status		(2) More flexible cohort trend		(3) + Schooling and marital status		(4) More flexible cohort trend	
	∂y/∂x	S.E.	∂y/∂x	S.E.	∂y/∂x	S.E.	∂y/∂x	S.E.
A. Disability								
Born in 1950	**0.0029**	0.0011	0.0020	0.0029	-0.0025	0.0020	-0.0024	0.0043
Born in 1951	**0.0058**	0.0010	**0.0082**	0.0012	0.0031	0.0019	**0.0088**	0.0022
B. Communication								
Born in 1950	**0.0013**	0.0004	**0.0027**	0.0012	0.0006	0.0011	-0.0012	0.0023
Born in 1951	**-0.0013**	0.0004	**0.0013**	0.0007	0.0016	0.0009	**0.0026**	0.0090
C. Moving								
Born in 1950	-0.0017	0.0010	0.0001	0.0023	-0.0003	0.0011	0.0011	0.0027
Born in 1951	**0.0039**	0.0010	**0.0080**	0.0011	**0.0027**	0.0011	**0.0061**	0.0016
D. Mental								
Born in 1950	**0.0025**	0.0005	0.0030	0.0024	-0.0001	0.0009	-0.0045	0.0027
Born in 1951	**0.0034**	0.0006	**0.0068**	0.0015	-0.0008	0.0008	-0.0010	0.0016
E. Cognitive								
Born in 1950	0.0015	0.0014	-0.0045	0.0033	0.0002	0.0008	-0.0059	0.0023
Born in 1951	**0.0042**	0.0012	**0.0042**	0.0019	**0.0018**	0.0008	0.0000	0.0013
F. Basic activity								
Born in 1950	**0.0023**	0.0007	**0.0039**	0.0016	-0.0004	0.0010	-0.0003	0.0022
Born in 1951	**0.0016**	0.0006	**0.0039**	0.0007	**0.0026**	0.0008	**0.0039**	0.0011
G. Outing								
Born in 1950	**0.0025**	0.0007	**0.0072**	0.0020	0.0000	0.0006	0.0034	0.0009
Born in 1951	**0.0020**	0.0007	**0.0065**	0.0014	**0.0021**	0.0006	**0.0058**	0.0004
H. Working								
Born in 1950	-0.0002	0.0009	0.0004	0.0029	0.0002	0.0007	-0.0002	0.0021
Born in 1951	**0.0024**	0.0008	**0.0039**	0.0020	**0.0022**	0.0007	**0.0030**	0.0014

Source: The 10% micro sample of the 2010 population census.
Notes: (a) "South Korea" includes persons who were born in North Korea and those for whom the place of birth is not reported; (b) In Columns 1 and 3, years of schooling, dummy variable for marital status, and polynomials of the year of birth (YOB, YOB^2 and YOB^3) are included; (c) In Columns 2 and 4, a quadratic cohort trend is allowed to change across the pre-war (1945 to 1949), war-time (1950 to 1954), and post-war (1955 to 1959) cohorts; (d) Standard errors are adjusted for clustering at the level of year of birth; and (e) The estimated coefficient in bold number is statistically significant at 10% level.

Table 4
Deviation of the 1951 Birth Cohorts' Health Outcomes from 1945-1959 Trend by the Month of Birth

Outcome	Males born in the Central Region				Females born in the Central Region			
	(1) Cubic cohort trend		(2) More flexible cohort trend		(3) Cubic cohort trend		(4) More flexible cohort trend	
	∂y/∂x	S.E.	∂y/∂x	S.E.	∂y/∂x	S.E.	∂y/∂x	S.E.
A. Disability								
Born in Jan. to Oct. 1951	**0.0134**	0.0016	**0.0115**	0.0021	**0.0114**	0.0018	**0.0126**	0.0032
Born in Nov. to Dec. 1951	**0.0086**	0.0016	**0.0068**	0.0021	**-0.0033**	0.0018	-0.0021	0.0032
B. Communication								
Born in Jan. to Oct. 1951	0.0015	0.0009	0.0009	0.0018	**0.0028**	0.0006	**0.0032**	0.0005
Born in Nov. to Dec. 1951	**-0.0040**	0.0009	**-0.0045**	0.0018	**0.0028**	0.0006	**0.0033**	0.0005
C. Moving								
Born in Jan. to Oct. 1951	**0.0070**	0.0009	**0.0077**	0.0007	**0.0073**	0.0011	**0.0071**	0.0023
Born in Nov. to Dec. 1951	**0.0087**	0.0009	**0.0094**	0.0007	-0.0016	0.0011	-0.0018	0.0023
D. Mental								
Born in Jan. to Oct. 1951	**0.0082**	0.0010	**0.0066**	0.0014	**0.0027**	0.0008	**0.0027**	0.0010
Born in Nov. to Dec. 1951	0.0011	0.0010	-0.0005	0.0014	**-0.0056**	0.0008	**-0.0056**	0.0010
E. Cognitive								
Born in Jan. to Oct. 1951	**0.0095**	0.0012	**0.0081**	0.0013	**0.0057**	0.0009	**0.0049**	0.0014
Born in Nov. to Dec. 1951	0.0007	0.0012	-0.0008	0.0013	**-0.0050**	0.0009	**-0.0058**	0.0014
F. Basic activity								
Born in Jan. to Oct. 1951	**0.0028**	0.0007	**0.0022**	0.0010	**0.0042**	0.0006	**0.0049**	0.0009
Born in Nov. to Dec. 1951	**0.0013**	0.0007	0.0008	0.0010	-0.0002	0.0006	0.0005	0.0009
G. Outing								
Born in Jan. to Oct. 1951	**0.0042**	0.0009	**0.0036**	0.0015	**0.0046**	0.0008	**0.0052**	0.0013
Born in Nov. to Dec. 1951	0.0005	0.0009	-0.0001	0.0015	**-0.0018**	0.0008	-0.0013	0.0013
H. Working								
Born in Jan. to Oct. 1951	**0.0063**	0.0008	**0.0060**	0.0013	**0.0030**	0.0007	**0.0031**	0.0012
Born in Nov. to Dec. 1951	**-0.0059**	0.0008	**-0.0062**	0.0013	**0.0032**	0.0007	**0.0033**	0.0012

Source: The 10% micro sample of the 2010 population census.
Notes: (a) Polynomials of the year of birth (YOB, YOB^2 and YOB^3) are included in Columns 1 and 3; (b) A quadratic cohort trend is allowed to change across the pre-war (1945 to 1949), war-time (1950 to 1954), and post-war (1955 to 1959) cohorts; (c) Standard errors are adjusted for clustering at the level of two periods (January to October and November to December) of the year of birth; and (d) The estimated coefficient in bold number is statistically significant at 10% level.

Table 5
Summary of Regressions for Difference-in-Difference Model: Interaction between the Central Region dummy and deviation of the Health Outcomes of the birth cohort born in Jan. to Oct. 1951 from 1945 to 1959 Trend

	(1) Baseline Model		(2) + Schooling and marital status		(3) + Urbanization		(4) + Schooling, marital status, urbanization	
	∂y/∂x	S.E.	∂y/∂x	S.E.	∂y/∂x	S.E.	∂y/∂x	S.E.
1. Males								
A. Disability	**0.0099**	0.0038	**0.0062**	0.0032	**0.0086**	0.0038	**0.0061**	0.0033
B. Communication	-0.0019	0.0019	-0.0031	0.0019	-0.0021	0.0019	-0.0029	0.0019
C. Moving	**0.0064**	0.0032	0.0046	0.0033	**0.0059**	0.0032	0.0049	0.0033
D. Mental	**0.0051**	0.0026	**0.0037**	0.0019	**0.0044**	0.0025	**0.0032**	0.0019
E. Cognitive	**0.0057**	0.0025	**0.0042**	0.0023	**0.0049**	0.0025	**0.0040**	0.0022
F. Basic activity	**0.0038**	0.0013	**0.0032**	0.0014	**0.0036**	0.0013	**0.0031**	0.0013
G. Outing	**0.0041**	0.0011	**0.0032**	0.0013	**0.0038**	0.0011	**0.0031**	0.0013
H. Working	0.0025	0.0015	0.0017	0.0015	0.0024	0.0015	0.0019	0.0015
2. Females								
A. Disability	**0.0111**	0.0060	0.0076	0.0051	0.0099	0.0057	0.0075	0.0052
B. Communication	**0.0031**	0.0016	0.0022	0.0016	**0.0029**	0.0016	0.0023	0.0017
C. Moving	**0.0108**	0.0037	**0.0084**	0.0034	**0.0101**	0.0037	**0.0085**	0.0034
D. Mental	0.0036	0.0025	0.0027	0.0023	0.0031	0.0025	0.0026	0.0024
E. Cognitive	0.0040	0.0032	0.0030	0.0029	0.0034	0.0030	0.0028	0.0030
F. Basic activity	**0.0059**	0.0014	**0.0055**	0.0015	**0.0058**	0.0014	**0.0055**	0.0015
G. Outing	**0.0057**	0.0014	**0.0048**	0.0014	**0.0054**	0.0014	**0.0048**	0.0014
H. Working	0.0029	0.0019	0.0024	0.0018	0.0028	0.0020	0.0024	0.0019

Source: The 10% micro sample of the 2010 population census.
Notes: (a) Summary of 64 regressions; (b) A cubic cohort trend is included in each regression but omitted from the table; (c) Standard errors are adjusted for clustering at the levels of province of birth; and (d) The estimated coefficient in bold number is statistically significant at 10% level.

Table 6
Parental Socioeconomic Characteristics of the 1947-1957 Birth Cohorts in 1960

Variable	(1) Father		(2) Mother	
	Mean	S.D.	Mean	S.D.
A. Parent absent	0.0645	0.2457	0.0112	0.1052
B. Illiterate	0.2121	0.4088	0.4568	0.4982
C. Years of schooling	4.1333	4.3123	2.3130	3.2927
D. High school or higher	0.0681	0.2520	0.0156	0.1237
E. No schooling	0.4480	0.4973	0.6380	0.4806
F. Working	0.9636	0.1872	0.3003	0.4584
G. Wage workers	0.2267	0.4188	0.0250	0.1562
H. Professional	0.0975	0.2966	0.0140	0.1175

Source: The 1% samples of the 1960 census.
Note: See text for the definition of the variables. The sample consists of 66,251 children aged 3 to 13 in 1960. For panels B to F, the sample was restricted to the children whose father (column 1) or mother (column 2) was present in the household (the number of observations is 61,976 and 65,509, respectively). For panels G and H, children of working father (column 1: N = 59613) or mother (column 2: N = 19,641) were included in the sample.

Table 7
Deviation of the 1950-54 Birth Cohorts' Parental Characteristics in 1960 from 1947-1957 Trend

	Father				Mother			
	(1) Quadratic Trend		(2) Cubic Trend		(3) Quadratic Trend		(4) Cubic Trend	
	∂y/∂x	P-value	∂y/∂x	P-value	∂y/∂x	P-value	∂y/∂x	P-value
A. Absence of a parent								
Born in 1950	0.0061	0.1633	0.0071	0.2600	0.0005	0.6853	-0.0003	0.8461
Born in 1951	**-0.0086**	0.0704	-0.0079	0.1899	-0.0003	0.8289	-0.0009	0.5278
Born in 1952	-0.0027	0.5326	-0.0024	0.6278	**0.0024**	0.0858	0.0021	0.1043
Born in 1953	-0.0007	0.8629	-0.0007	0.8415	0.0005	0.6743	0.0005	0.5578
Born in 1954	**0.0062**	0.0803	**0.0058**	0.0601	0.0002	0.8525	0.0005	0.4656
B. Illiterate								
Born in 1950	**0.0199**	0.0037	**0.0123**	0.0763	**0.0404**	<.0001	**0.0365**	<.0001
Born in 1951	-0.0008	0.9048	-0.0069	0.2725	0.0049	0.2934	0.0018	0.5332
Born in 1952	-0.0044	0.5338	-0.0076	0.1742	**-0.0143**	0.0102	**-0.0158**	<.0001
Born in 1953	0.0076	0.2855	**0.0079**	0.0989	0.0067	0.1472	**0.0069**	0.0047
Born in 1954	**0.0135**	0.0496	**0.0164**	0.0012	**0.0210**	0.0002	**0.0227**	<.0001
C. Years of schooling								
Born in 1950	**-0.3106**	0.0002	**-0.2065**	0.0006	**-0.2743**	<.0001	**-0.2153**	<.0001
Born in 1951	-0.0450	0.4931	0.0383	0.3538	-0.0720	0.1368	**-0.0254**	0.0112
Born in 1952	**0.1695**	0.0326	**0.2125**	<.0001	**0.1457**	0.0120	**0.1687**	<.0001
Born in 1953	-0.0151	0.8246	-0.0177	0.4256	-0.0231	0.6268	**-0.0265**	0.0359
Born in 1954	**-0.1794**	0.0105	**-0.2186**	<.0001	**-0.1381**	0.0058	**-0.1625**	<.0001
D. High school or higher								
Born in 1950	**-0.0031**	0.0555	-0.0002	0.8154	**-0.0029**	0.0225	**-0.0013**	<.0001
Born in 1951	0.0005	0.7726	**0.0018**	0.0440	-0.0011	0.4157	0.0001	0.5755
Born in 1952	**0.0056**	0.0118	**0.0068**	<.0001	-0.0013	0.3761	**-0.0007**	0.0844
Born in 1953	0.0017	0.3586	**0.0016**	0.0119	0.0006	0.6738	0.0005	0.2846
Born in 1954	**-0.0069**	0.0009	**-0.0080**	<.0001	-0.0017	0.1753	**-0.0023**	0.0005
E. No schooling								
Born in 1950	**0.0327**	0.0002	**0.0225**	0.0170	**0.0427**	<.0001	**0.0331**	<.0001
Born in 1951	0.0035	0.6166	-0.0047	0.5410	0.0096	0.2202	0.0020	0.2898
Born in 1952	-0.0112	0.1559	**-0.0154**	0.0283	**-0.0234**	0.0141	**-0.0271**	<.0001
Born in 1953	0.0055	0.4568	0.0058	0.1965	0.0027	0.7267	0.0033	0.1562
Born in 1954	**0.0181**	0.0157	**0.0220**	<.0001	**0.0202**	0.0119	**0.0242**	<.0001
F. Work								
Born in 1950	**-0.0055**	0.0111	**-0.0081**	0.0433	**0.0213**	0.0038	**0.0096**	0.0769
Born in 1951	0.0028	0.1589	0.0007	0.8312	**-0.0173**	0.0273	**-0.0265**	0.0004
Born in 1952	-0.0010	0.6243	-0.0021	0.4526	**-0.0198**	0.0197	**-0.0244**	0.0011
Born in 1953	-0.0006	0.7585	-0.0005	0.7767	-0.0039	0.5833	-0.0032	0.5806
Born in 1954	-0.0009	0.5743	0.0001	0.9343	-0.0016	0.7857	0.0032	0.5844
G. Wage worker								
Born in 1950	**-0.0127**	0.0939	-0.0017	0.5335	0.0027	0.4671	0.0022	0.6854
Born in 1951	-0.0019	0.8163	**0.0070**	0.0501	-0.0002	0.9600	-0.0006	0.9006
Born in 1952	0.0004	0.9570	0.0051	0.2184	**-0.0070**	0.0959	-0.0072	0.1132
Born in 1953	0.0085	0.2797	**0.0083**	0.0972	-0.0023	0.5323	-0.0021	0.5117
Born in 1954	**-0.0134**	0.0547	**-0.0174**	0.0047	-0.0037	0.2299	-0.0034	0.1835
H. Professional job								
Born in 1950	**-0.0138**	<.0001	**-0.0103**	<.0001	-0.0008	0.6654	0.0002	0.9187
Born in 1951	-0.0025	0.2796	0.0004	0.4894	**-0.0050**	0.0340	**-0.0042**	0.0627
Born in 1952	**0.0109**	0.0007	**0.0124**	<.0001	0.0013	0.5348	0.0016	0.4140
Born in 1953	0.0031	0.1713	**0.0031**	0.0056	-0.0030	0.1481	-0.0032	0.1110
Born in 1954	**-0.0075**	0.0017	**-0.0088**	<.0001	-0.0013	0.4522	-0.0019	0.3137

Source: The one percent micro sample of the 1960 census.
Note: The polynomials of the year of birth were included in the regressions, but omitted from the table. For panels B to H, the sample was restricted to the children whose father (columns 1 and 2) or mother (columns 3 and 4) was present in the household. For panels G and H, children of working father (columns 1 and 2) or mother (columns 3 and 4) were included in the sample. Standard errors were adjusted for clustering at the level of year of birth.

Table 8
Deviation of the 1950-54 Birth Cohorts' Parental Characteristics in 1960 from 1947-1957 Trend: Year by Year

	(1) Absence of Father		(2) Father Illiterate		(3) Father's years of schooling		(4) Father with professional jobs	
	∂y/∂x	P-value	∂y/∂x	P-value	∂y/∂x	P-value	∂y/∂x	P-value
A. Born in 1947	**-0.0214**	0.0030	**-0.0248**	0.0213	0.2155	0.1356	0.0049	0.5232
B. Born in 1948	**0.0118**	0.0005	**0.0131**	0.0033	-0.0751	0.1647	0.0008	0.7518
C. Born in 1949	-0.0056	0.2298	-0.0058	0.3628	0.0447	0.5968	0.0002	0.9630
D. Born in 1950	**0.0111**	0.0044	**0.0166**	0.0021	**-0.2777**	0.0004	**-0.0140**	0.0009
E. Born in 1951	**-0.0098**	0.0090	**-0.0118**	0.0540	0.0684	0.4913	0.0003	0.9468
F. Born in 1952	-0.0026	0.4162	**-0.0134**	0.0145	**0.2916**	0.0005	**0.0154**	0.0002
G. Born in 1953	-0.0015	0.5671	0.0037	0.5220	0.0280	0.7495	0.0045	0.2904
H. Born in 1954	**0.0074**	0.0007	**0.0160**	0.0015	**-0.2588**	0.0001	**-0.0123**	0.0007
I. Born in 1955	**-0.0045**	0.0688	**-0.0118**	0.0143	0.0679	0.4104	-0.0000	0.9927
J. Born in 1956	**0.0035**	0.0891	0.0022	0.5902	0.0333	0.5240	0.0028	0.2365
K. Born in 1957	-0.0074	0.1502	-0.0024	0.7895	-0.0052	0.9704	-0.0002	0.9810

Source: 1 percent micro sample of the 1960 census.
Note: Presented is a summary of the 52 OLS regressions that provide the estimated coefficient for the dummy variable indicating a particular birth cohort. The polynomials of the year of birth (YOB, YOB^2, and YOB^3) were included in the regressions, but omitted from the table. Standard errors were adjusted for clustering at the level of year of birth.

Figure 1
Movements of the Frontline during the Korean War: 1950-1953

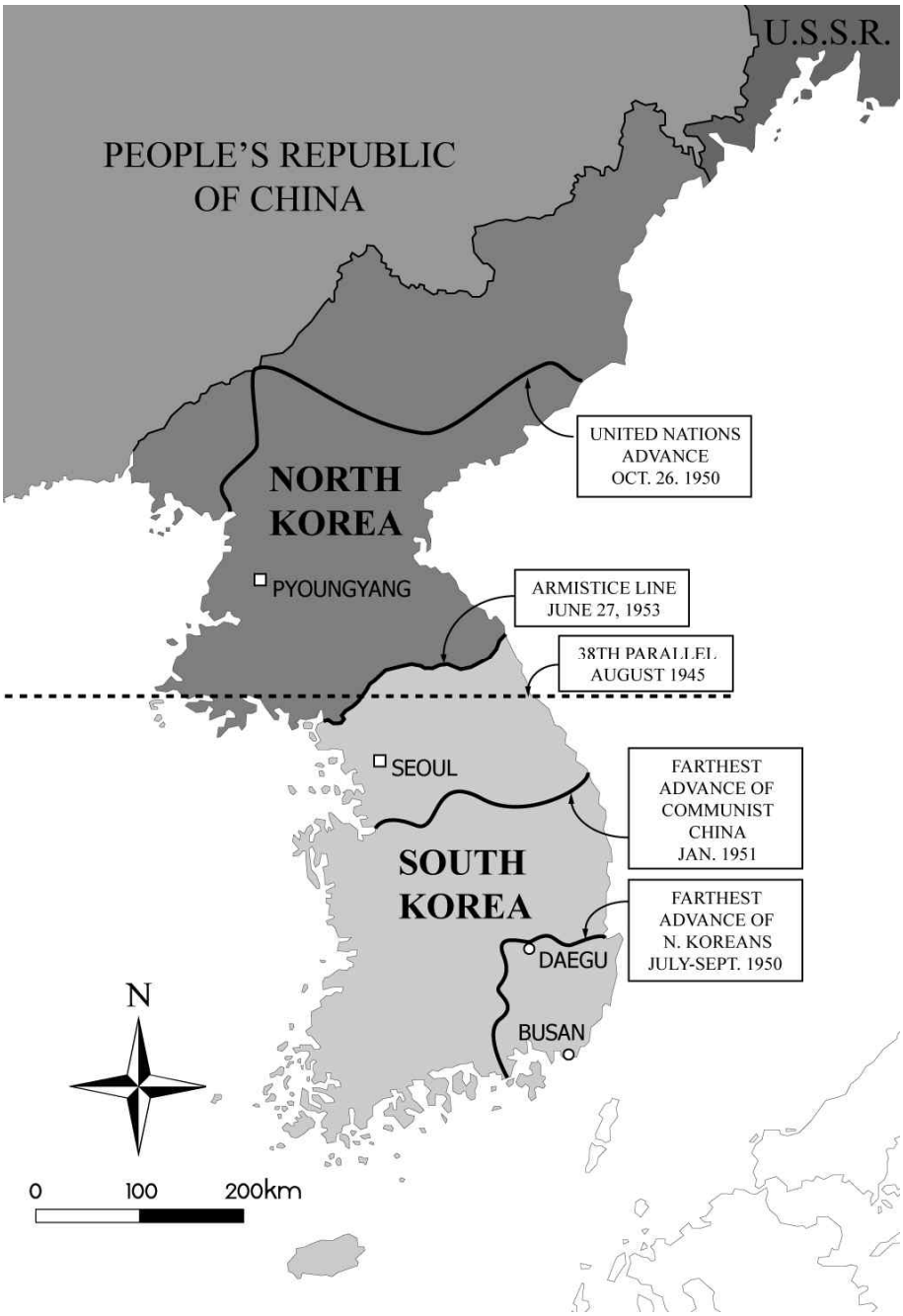
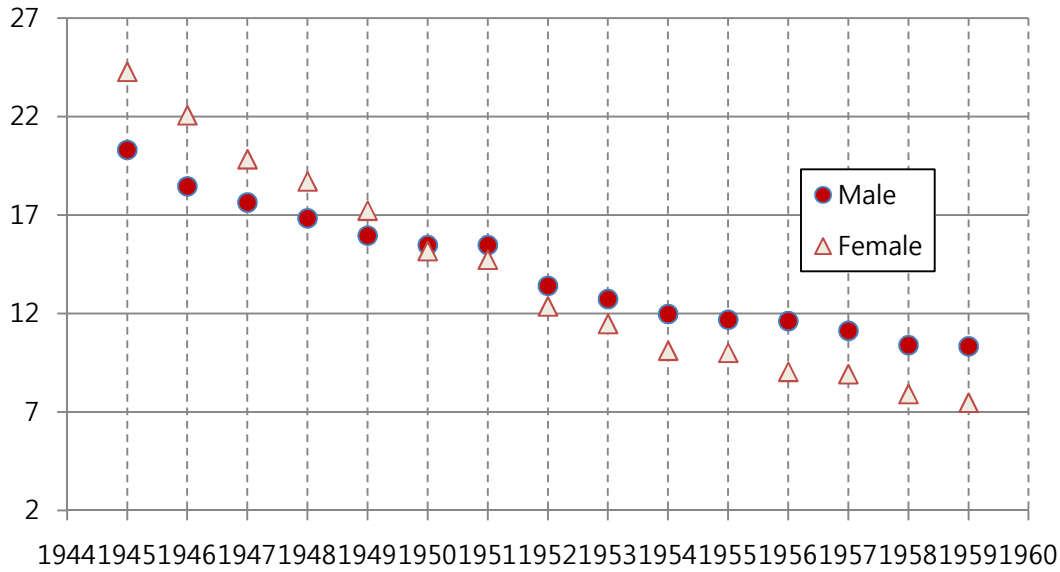
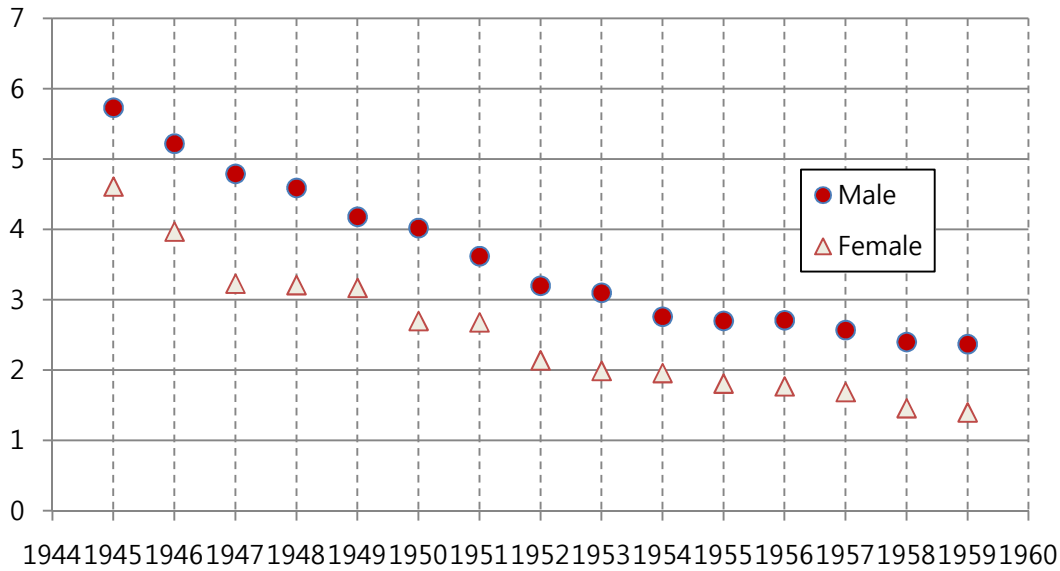


Figure 2
% Persons with Any Disability in 2010 by Birth Cohort:
Born in the Central Region



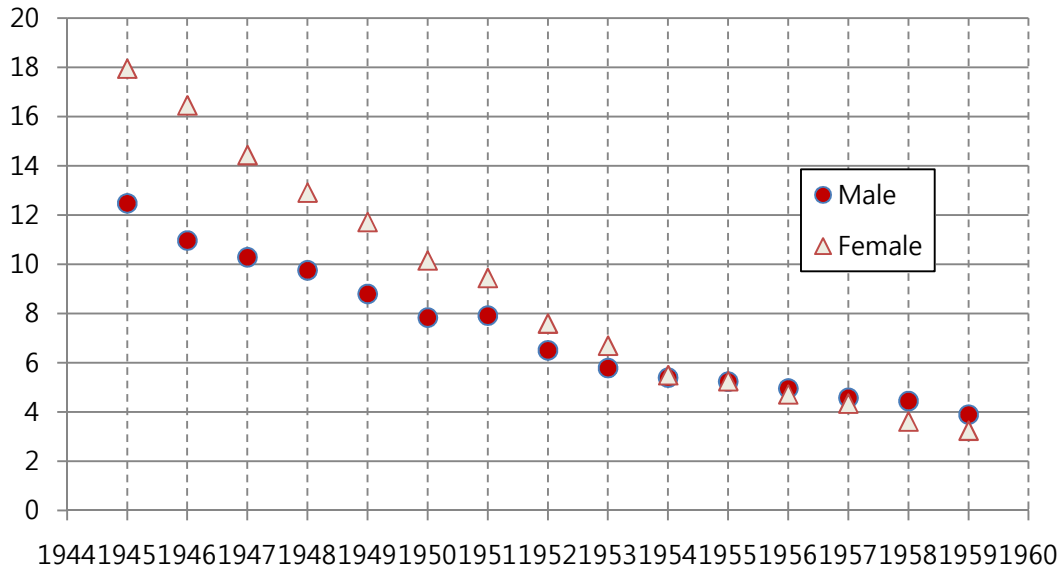
Source: The 10% sample of the 2010 census

Figure 3
% Persons with Limitations in "Communication" in 2010 Birth
Cohort: Born in the Central Region



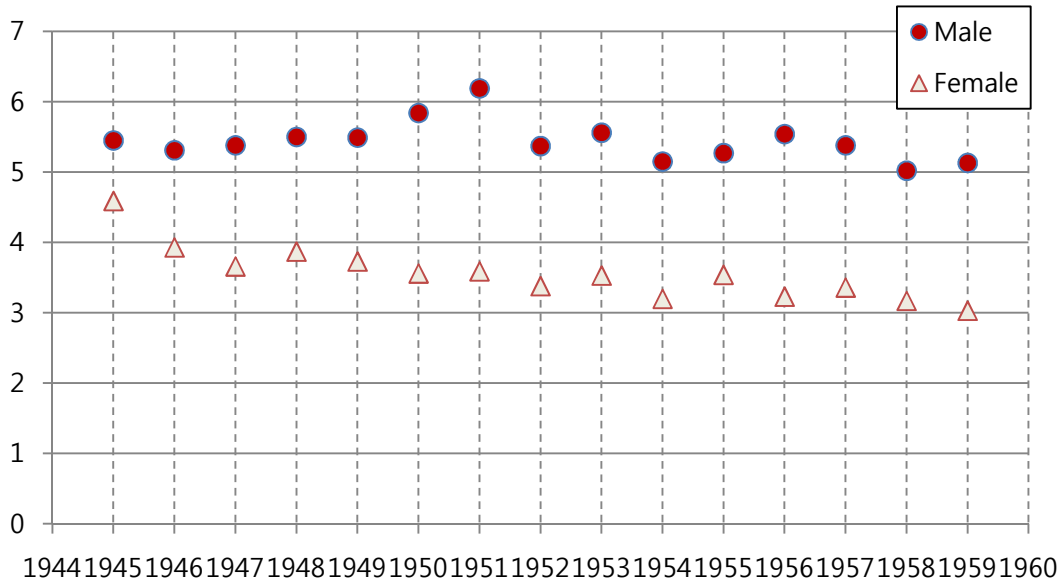
Source: The 10% sample of the 2010 census

Figure 4
% Persons with Limitations in "Moving" in 2010 Birth Cohort:
Born in the Central Region



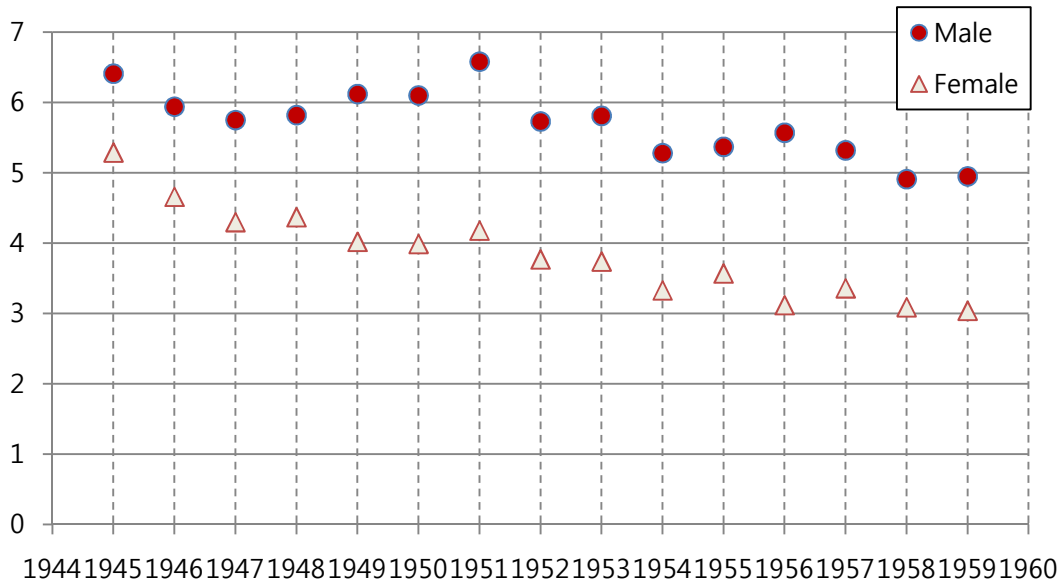
Source: The 10% sample of the 2010 census

Figure 5
% Persons with Mental Impairments in 2010 Birth Cohort:
Born in the Central Region



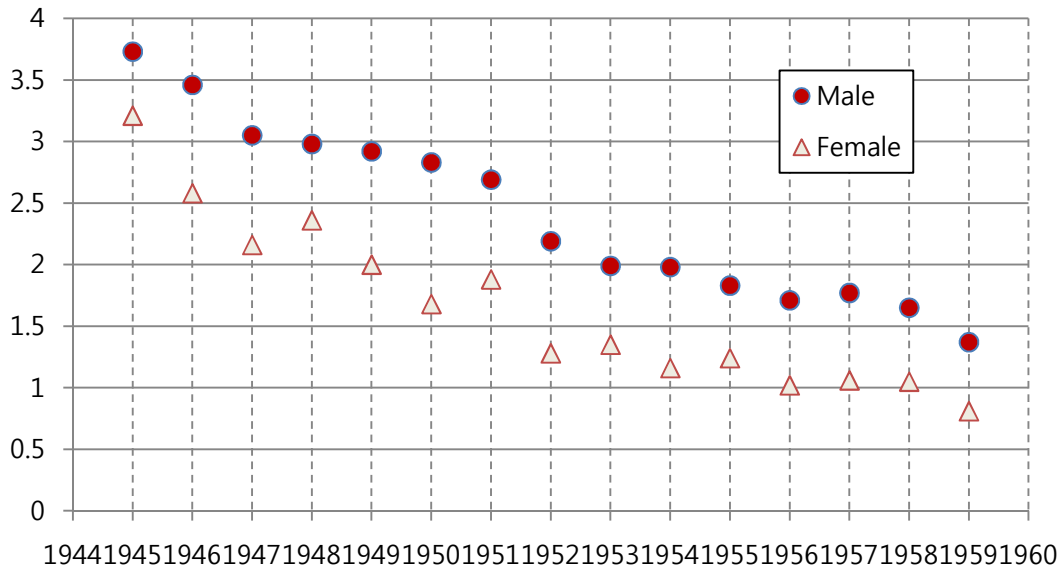
Source: The 10% sample of the 2010 census

Figure 6
% Persons with "Cognitive" Limitations in 2010 by Birth Cohort:
Born in the Central Region



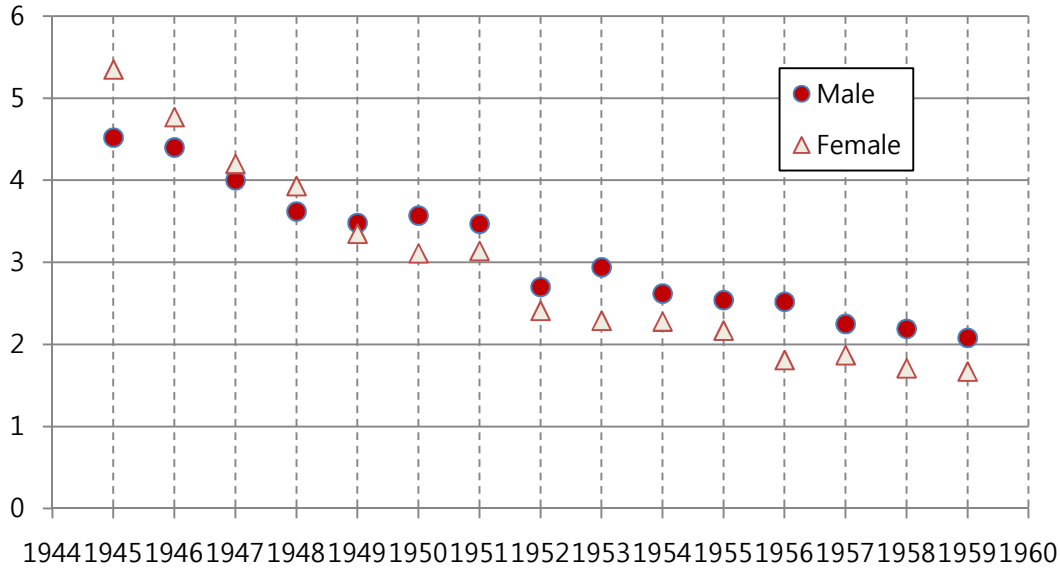
Source: The 10% sample of the 2010 census

Figure 7
% Persons with Limitations in Basic Activities in 2010
by Birth Cohort: Born in the Central Region



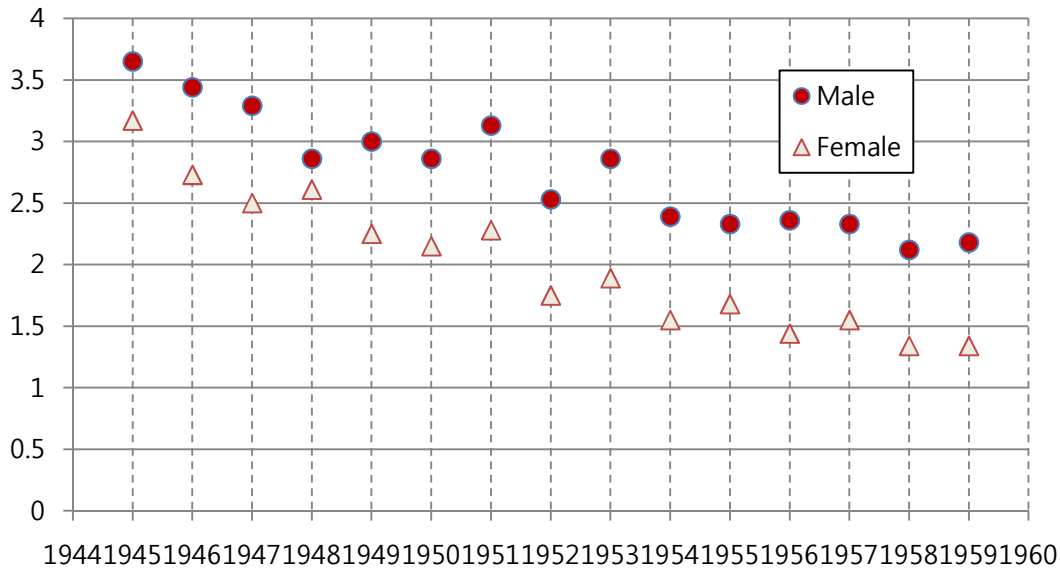
Source: The 10% sample of the 2010 census

Figure 8
% Persons with Limitations in Outing in 2010
by Birth Cohort: Born in the Central Region



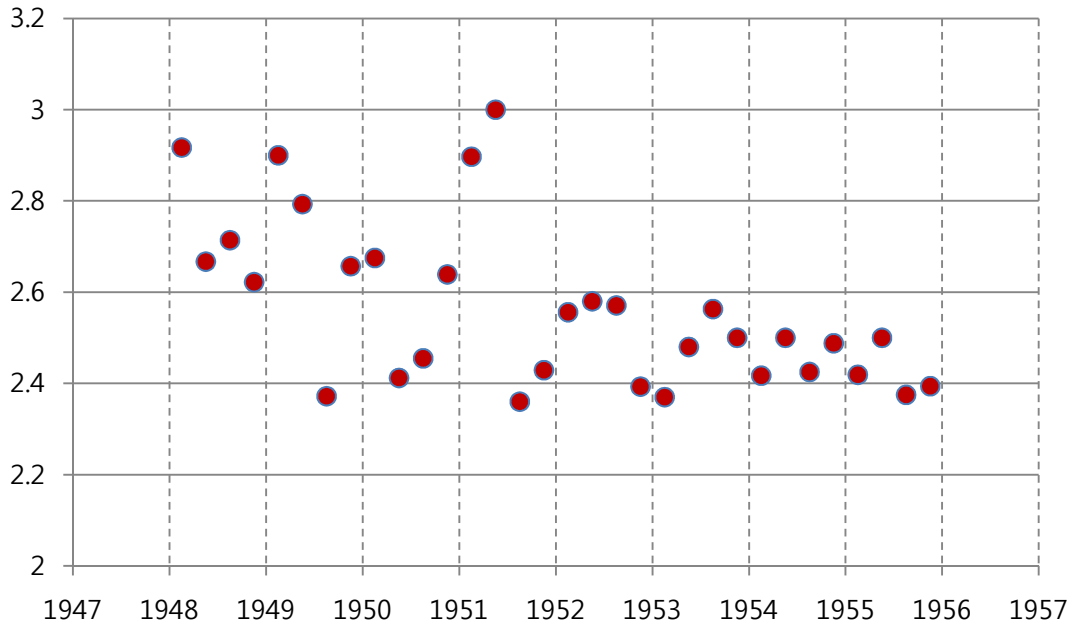
Source: The 10% sample of the 2010 census

Figure 9
% Persons with Limitations in Working in 2010
by Birth Cohort: Born in the Central Region



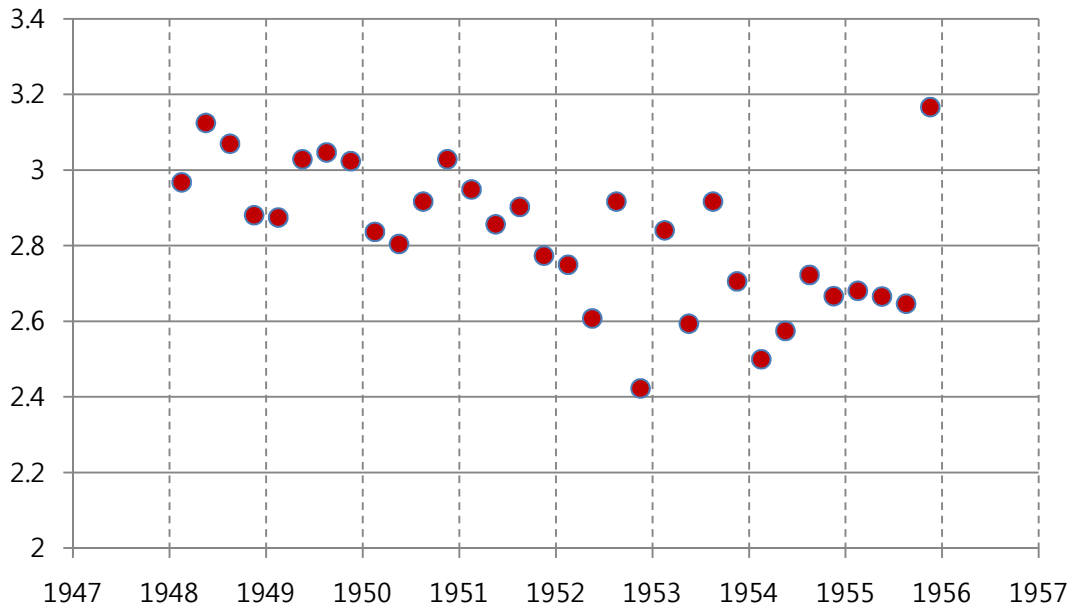
Source: The 10% sample of the 2010 census

Figure 10-A
Score of Male Self-Reported Health in 2006



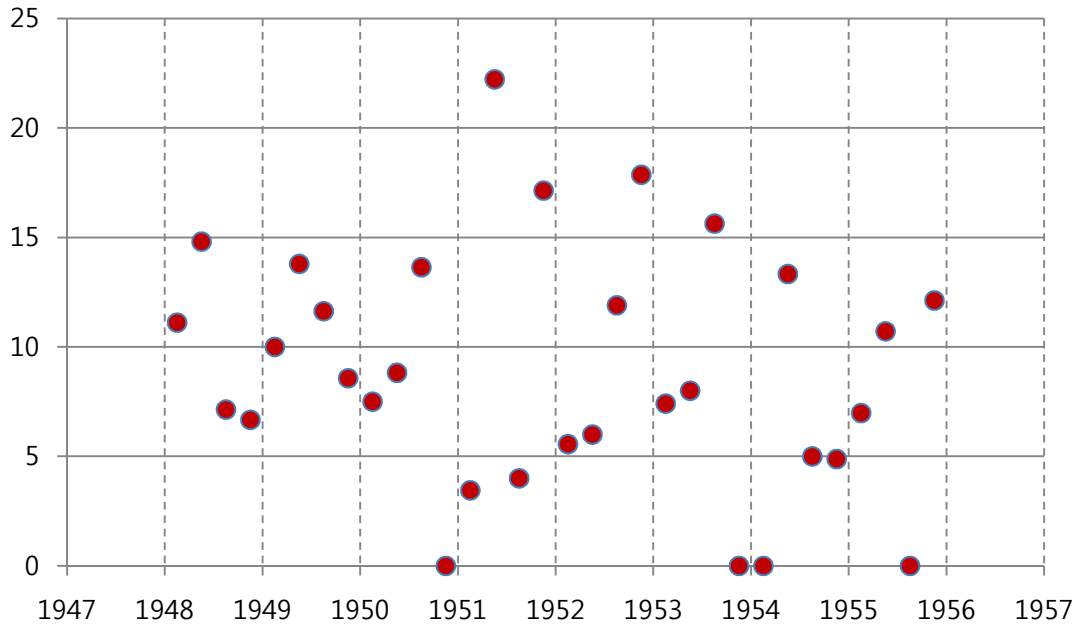
Source: 2006 Korea Longitudinal Study of Aging

Figure 10-B
Score of Female Self-Reported Health in 2006



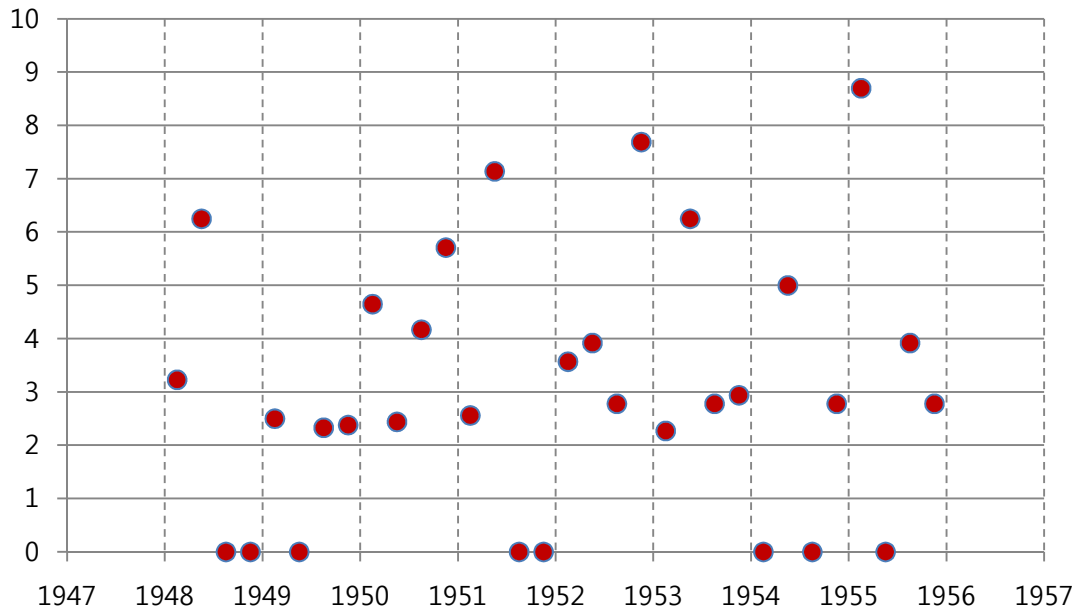
2006 Korea Longitudinal Study of Aging

Figure 11-A
% Males with Disability in 2006



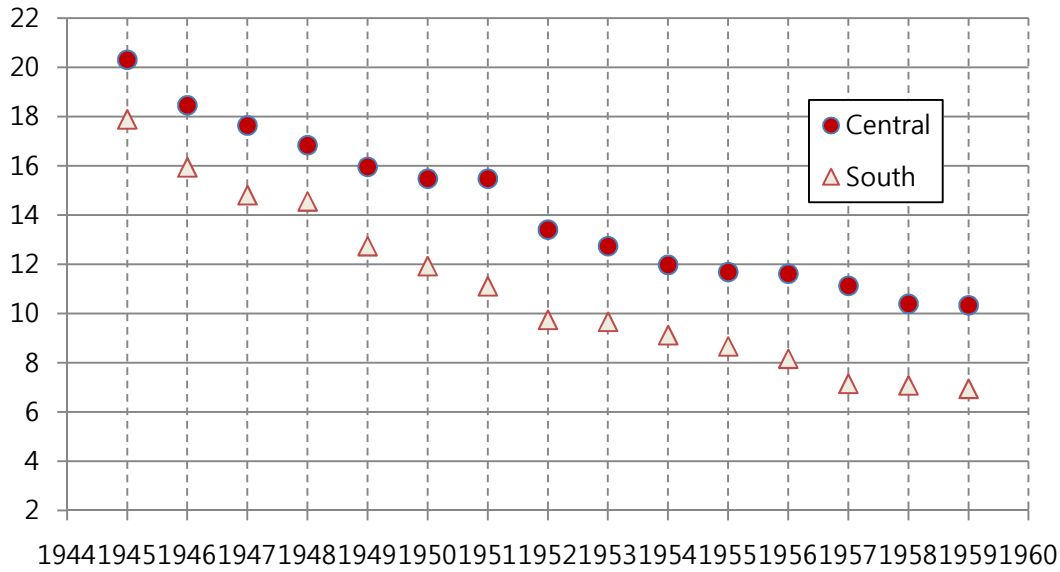
Source: 2006 Korea Longitudinal Study of Aging

Figure 11-B
% Females with Disability in 2006



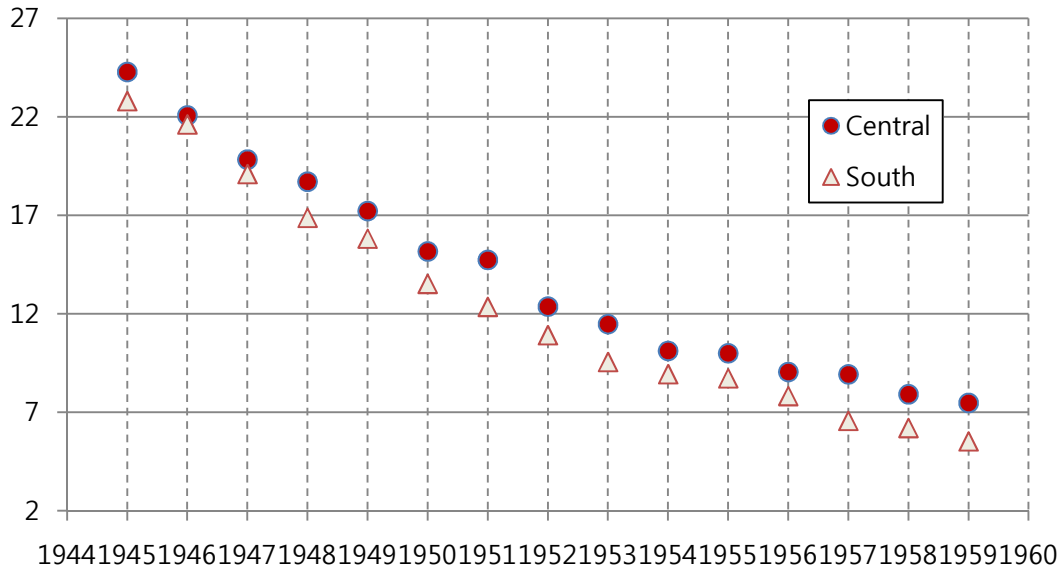
Source: 2006 Korea Longitudinal Study of Aging

Figure 12-A
% Males with Disability in 2010 by Birth Cohort:
Comparison between the Central and the South



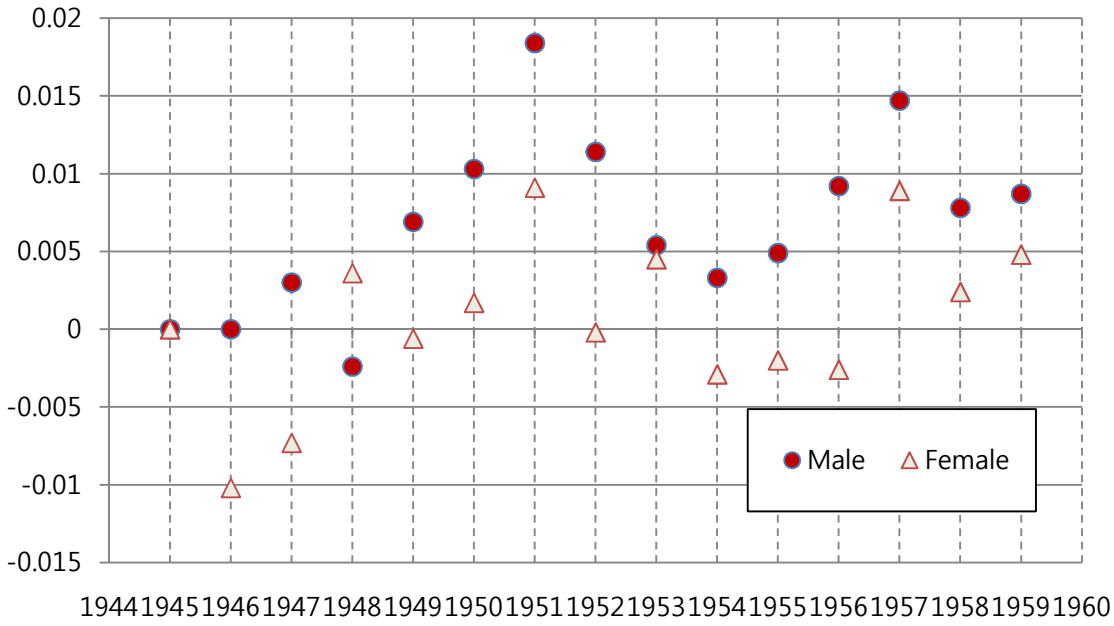
Source: The 10% sample of the 2010 census

Figure 12-B
% Females with Disability in 2010 by Birth Cohort:
Comparison between the Central and the South



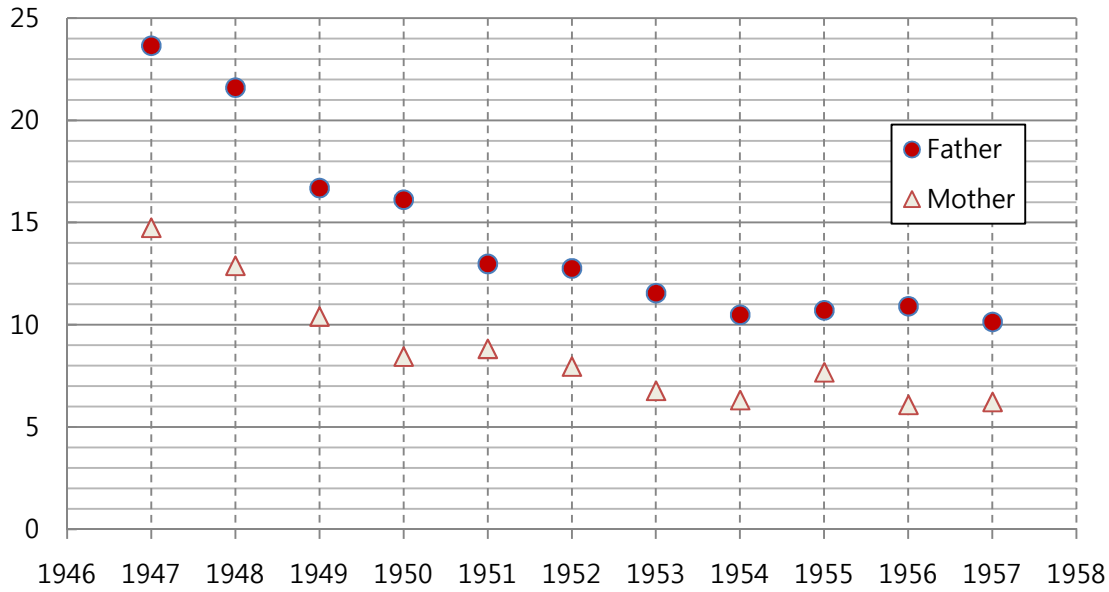
Source: The 10% sample of the 2010 census

Figure 13
Estimated Coefficients for Birth Year Dummies Interacted with
Measure of Wartime Stress: Probability of Disability



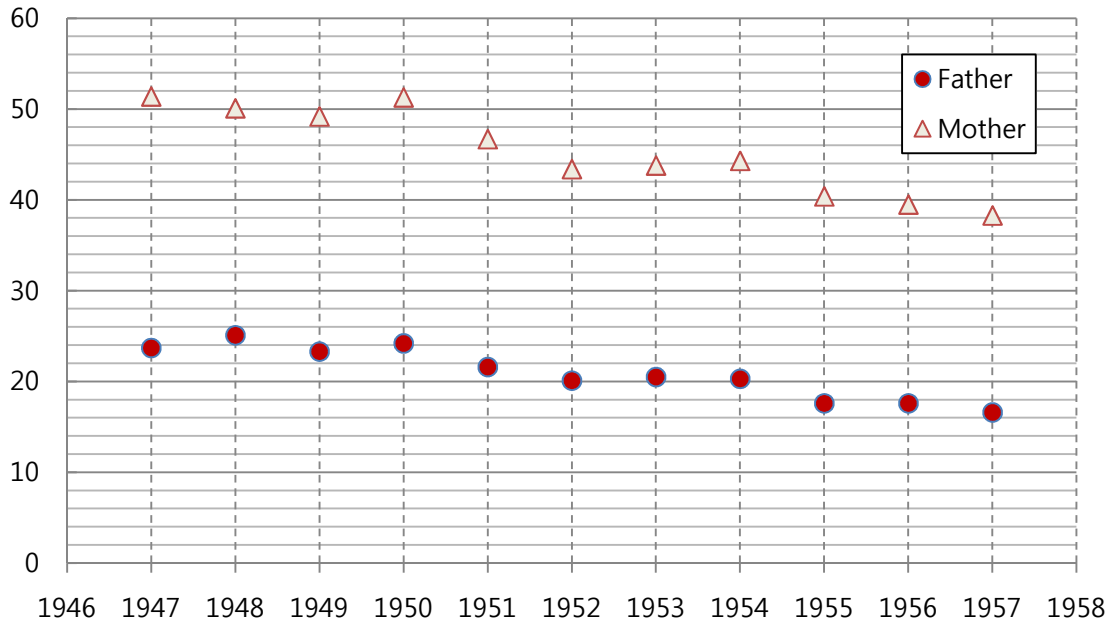
Source: Regression results from the 10% sample of the 2010 censuses.

Figure 14
% Absence a Parent in 1960
by Year of Birth of Children



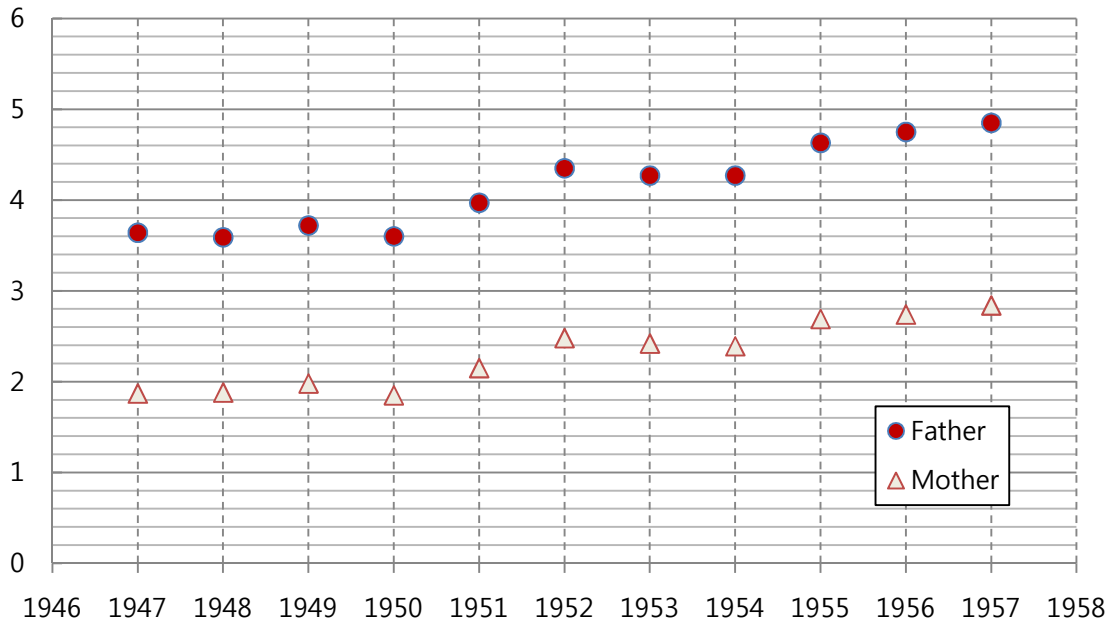
Source: The 1% sample of the 1960 censuses

Figure 15
% Illiterate Parents in 1960 by Year of Birth of Children



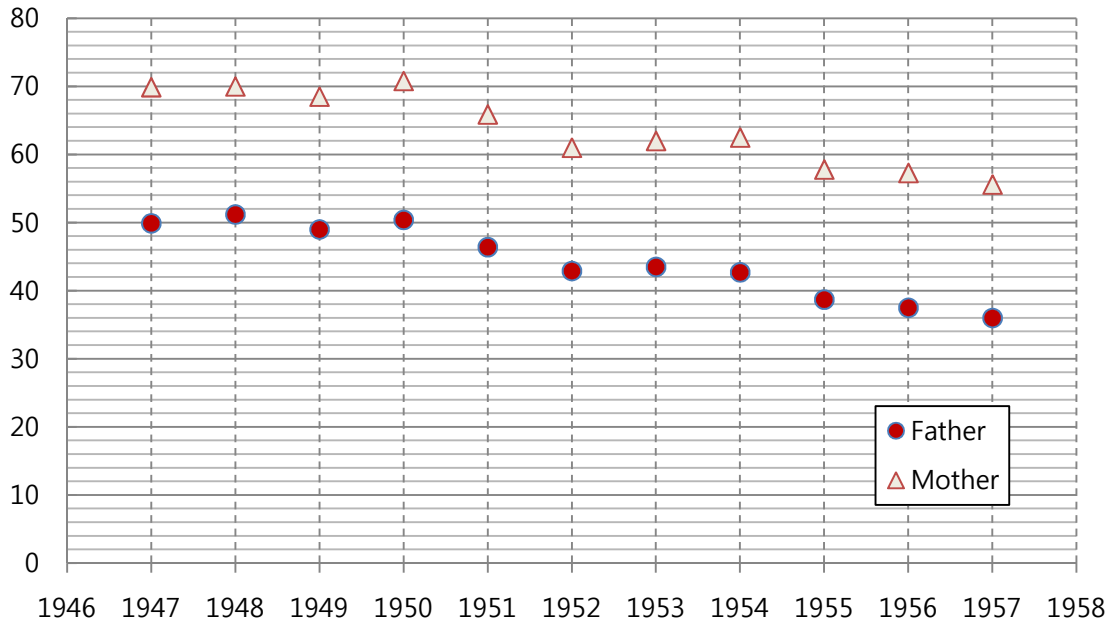
Source: The 1% sample of the 1960 censuses

Figure 16
Parent's Years of Schooling in 1960 by Year of Birth of Children



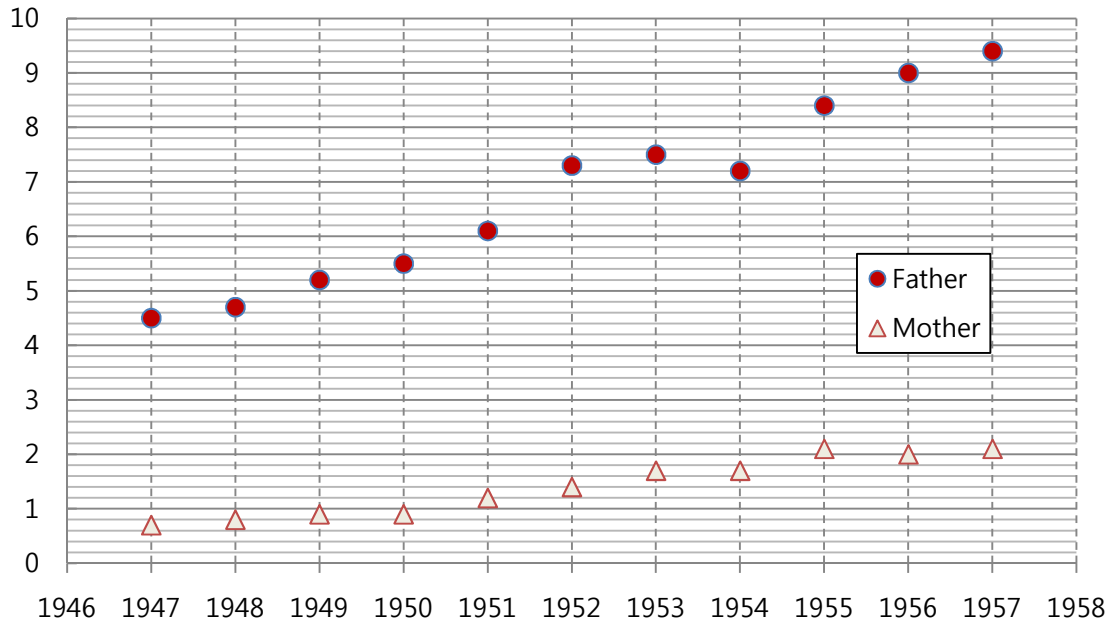
Source: The 1% sample of the 1960 censuses

Figure 17
% Parent with No Schooling in 1960 by Year of Birth of Children



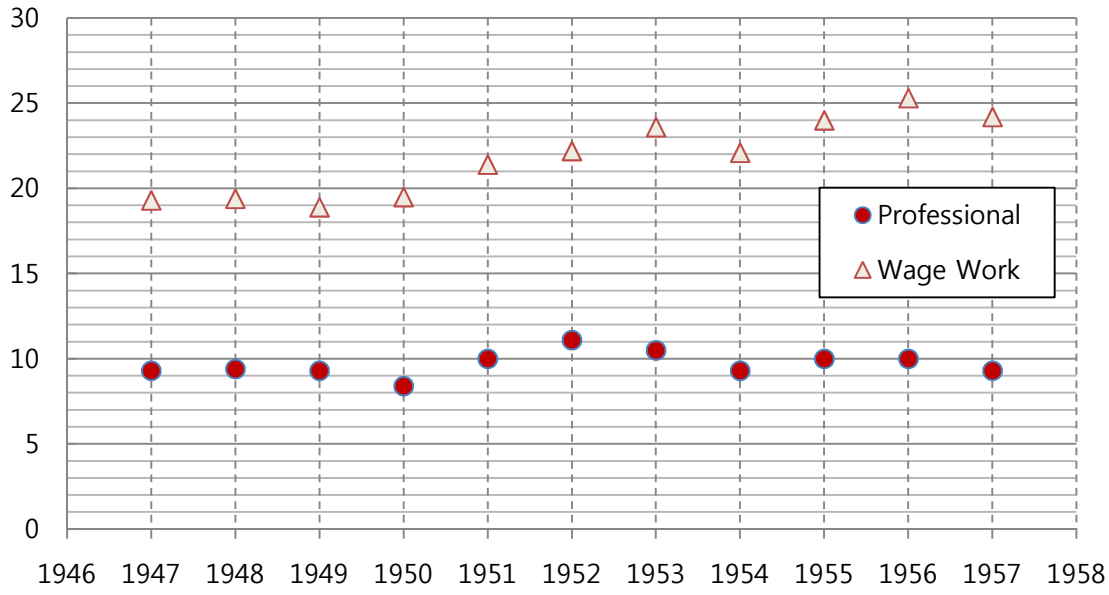
Source: The 1% sample of the 1960 censuses

Figure 18
% Parent with Highschool Diploma by Year of Birth of Children



Source: The 1% sample of the 1960 censuses

Figure 19
% Fathers with Professional Jobs and % Fathers with Wage and Salary Jobs in 1960 by Year of Birth of Children



Source: The 1% sample of the 1960 censuses