Fetal Exposure to the 1918 Influenza Pandemic in Colonial Korea and Human Capital Development

Sok Chul Hong and Yangkeun Yun

The influenza pandemic of 1918 drastically affected colonial Korea infecting approximately 7.4 million people (44.3% of the total population) and killing approximately 140,000. This study examines the effect of fetal exposure to the pandemic on educational attainment, specifically, years of schooling and literacy among the 1910 to 1929 birth cohort found in the 1960 Korean population census. Using the difference-in-differences approach, we found that fetal exposure substantially deteriorated educational attainment particularly among those born in provinces severely affected by influenza.

Keywords: 1918 influenza pandemic, Fetal exposure, Colonial Korea, Educational attainment

JEL Classification: I15, I25, N35

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I. Introduction

The influenza pandemic of 1918 was the deadliest disease disaster in 20^{th}-century human history; the pandemic infected 500 million people and killed approximately 50 million across the world. This traumatic event provides researchers with a quasi-experimental framework for testing fetal origins hypothesis, a widely known theory that the prenatal exposure to negative health shocks has persistent effects on later health and socioeconomic outcomes. Previous studies have analyzed the 1918 influenza pandemic experienced in various countries to identify the causal association between in utero conditions and later socioeconomic outcomes (Almond 2006; Lin, and Liu 2014; Neelsen, and Stratmann 2012; Nelson 2010). For effective identification, studies have used cohort studies that compare outcome variables across birth cohorts and regional variations in pandemic intensity. The studies have consistently found that cohorts significantly exposed to the pandemic in utero experienced lower educational attainment, low wages and income, and poor health conditions in later life.

This current study seeks similar evidence from the historical experience of colonial Korea. Korea, which was under Japanese rule from 1910 to 1945, experienced the influenza pandemic from October to December 1918. The pandemic in colonial Korea occurred over a short period and mortally infected approximately 44.3% of the Korean population. Thus, the experience of colonial Korea provides a useful historical framework for identifying the causal effect of in utero insults as do studies on other countries including Brazil, Switzerland, Taiwan, and the United States.

However, the merits of studying colonial Korea include other aspects. First, colonial Korea experienced various nationwide traumatic events during the years 1919 and 1920 including an independence movement, crop failure, another wave of influenza pandemic, a great flood, and a cholera outbreak. These events were as influential to the health and nutritional status of fetuses and infants as those of the 1918 influenza pandemic. Thus, such turbulent situations are useful in distinguishing the significance of influenza from other comparable events and the significance of fetal exposure to external shocks and exposure in infancy. Second, the educational environment in colonial Korea had distinct characteristics. The country's system and national support for modern education were inferior and highly inadequate throughout the early 20^{th} century. Household resources for education were heavily concentrated on primary education and sons. Thus, this study will advance the understanding as to whether the association between fetal health and lifetime development is distinctive under such inferior educational environments.

Similar to previous studies, we assume that the birth cohort born in 1919 was largely affected by the pandemic in utero (*i.e.*, the first difference) and utilize regional variations in pandemic intensity measured by the influenza death rate (*i.e.*, the second difference). To prove the validity of this approach, we discuss potential selection issues and provide quantitative evidence supporting that pregnant women and fetuses were at high obstetric risk during the pandemic period.

The key finding of this study is that, as people spent the fetal period in provinces severely affected by the pandemic, they achieved significantly lower educational attainment. The gap between the most and least-affected birth provinces amounts to approximately 10% for years of schooling and 8% for literacy rates as a percentage of each outcome variable's sample mean. It is intriguing that the estimated magnitude of the adverse effects is estimated to be more substantial for higher education than primary schooling, and for males than females in colonial Korea. This seems to be closely associated with the distinct educational environment in colonial Korea.

Although the burden of infectious diseases have been substantially reduced throughout the world, many developing countries are still at the high risk of various infections especially among pregnant women, infants and children. The findings in this study strongly suggest that the risk can impede those countries' economic development through deteriorating human capital accumulation. In addition, this can be worsen when educational infrastructure and resources are inferior and unbalanced. Accordingly, this study emphasizes that early-life disease controls and investment on education are necessary conditions for developing countries to achieve more human capital and economic development.

This paper is organized as follows. In Section II, we introduce related literature and the background of this research. In Section III, we discuss the experience of the 1918 influenza pandemic in colonial Korea and the validity of an empirical approach such as selection. Section IV explains the data, variables, and the identification strategy. In Section V, we present the results of baseline estimation, test whether the results are robust under alternative regression specifications, and examine the effects of exposure to other major events from the year 1919 to the year 1920. In the conclusion, we discuss the implications of this study from the perspective of development economics.

II. Background and Related Literature

The fetal origins hypothesis, which was first proposed in medical science, has gained prominence in economics suggesting that in utero insults can deteriorate later socioeconomic outcomes such as educational attainment and income (Almond, and Currie 2011; Barker 1998). The findings have been supported by scientific evidence that in utero insults or maternal stress can adversely affect cognitive development by altering fetal programming (Davis, and Sandman 2010). Some explain the mechanism of the findings with lifecycle interactions among health, human capital, and investment, which might be triggered by impaired fetal health (Heckman 2007).

However, when studies consider populations not randomly allocated to different fetal conditions, it has been empirically challenging to identify the causal link between fetal conditions and later socioeconomic outcomes. In most cases, we are unable to completely control for unobservable or unmeasurable characteristics, which are correlated with fetal conditions such as genetic factors and confounding covariates.

As the most effective solution to this difficulty, researchers have frequently sought traumatic events from the past that affected those in utero regardless of their characteristics. Such studies of natural experimental events have featured the Dutch famine from 1945 to 1946 (Scholte *et al.* 2015), the Chinese famine from 1959 to 1961 (Chen, and Zhou 2007), the Greek famine from 1941 to 1942 (Neelsen, and Stratmann 2011), the Chernobyl accident in 1986 (Almond *et al.* 2009), Islamic holy month Ramadan (Almond, and Mazumder 2011), and the Korean War from 1950 to 1953 (Lee 2014).

The influenza pandemic of 1918 is the historical event most frequently studied in literature. Because the pandemic was worldwide, its impact on fetal health and later outcomes have been studied for various countries. Using the 1960 to 1980 US population census records, Almond (2006) showed that cohorts born in 1919 achieved lower levels of educational attainment, income, and health status compared with the outcome of surrounding cohorts born from 1912 to

1922. Almond also exploited the regional differences in the estimated maternal influenza infection rate as a proxy for the severity of pandemics to identify the effect of the disease on maternal and fetal health.

Similarly, Nelson (2010) estimated the long-term socioeconomic impact of prenatal exposure to the 1918 influenza in Brazil. However, Nelson did not explore the effect of regional variations in the pandemic's intensity because individuals' birth place is not available in the dataset. Neelsen and Stratmann (2012) found a consistent effect of fetal exposure to the pandemic from Switzerland by exploiting regional variations measured by the death rate from influenza or other forms of acute respiratory diseases. Lin and Liu (2014) investigated the long-term effects of the influenza pandemic on Taiwan. Using regional variations in the maternal mortality rate related to the influenza pandemic, the authors found that the cohorts exposed to the influenza pandemic during the fetal period experienced low height, poor educational performance, and greater chronic health problems.

Finally, some studies revealed the effect of fetal exposure to influenza on later health outcomes. Brown *et al.* (2004) showed that the risk of schizophrenia may be increased if the fetus is exposed to influenza. Some documented that individuals born to mothers with influenza during pregnancy are at increased risk for future Parkinson's disease (Kwan *et al.* 2007) and childhood leukemia (Takahashi, and Yamada 2001).

III. The 1918 Influenza Pandemic in Colonial Korea

As Lim (2011) discussed in detail, the influenza pandemic of 1918 devastated colonial Korea over a brief period. Its pre-symptoms emerged in April 1918, but the Japanese Government-General of Korea did not pay attention to the symptoms at that time because the pattern was similar to typical seasonal influenza.[1] Without any preparation, influenza began to spread rapidly across colonial Korea from October 1918 and was rampant by December.[2] The toll on human lives among

[1] The pre-symptoms of the Spanish influenza in the spring with low fatality rates were also a worldwide feature of the pandemic.

[2] Dr. Frank Schofield, who was teaching at the Severance Medical School in colonial Korea, reported the wretched situation of the influenza pandemic in

the Korean population was tremendous. According to official records from the Japanese Government-General of Korea (1919), influenza infected approximately 7.4 million Koreans (44.3% of all Koreans) and caused approximately 140,000 deaths (8.3 deaths per 1,000) during the three months.[3]

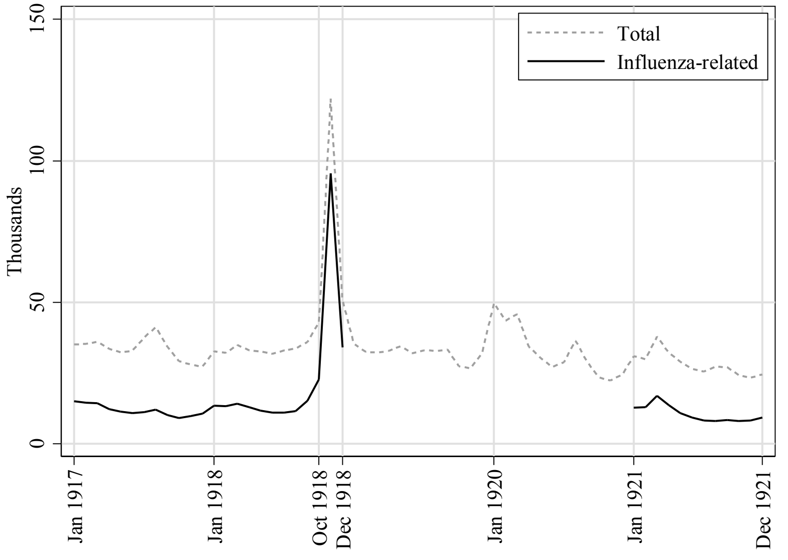
Figure 1 shows the monthly trend of total deaths from 1917 to 1921. Although the monthly average was around 32,000, the trend significantly deviated from the average from October to December 1918. The number of total deaths reached a peak of 121,941 in November. The monthly number of deaths from influenza is not available from historical vital statistics. Instead, using the statistics on the causes of deaths, we estimated the number of deaths from influenza-related diseases that include cold, otolaryngological diseases, respiratory diseases, and selected infectious disease.[4] The trend in Figure 1

colonial Korea in the Journal of the American Medical Association in 1919. The following is a part of the article's introduction.

"The great influenza pandemic made its appearance in Korea during the month of September, 1918. There seems to be no doubt that the infection came from Europe, via Siberia. The disease spread from north to south along the line of the Southern Manchurian Railway. The first cases seen by us in Seoul, the capital, were during the latter part of September. Before the middle of October the epidemic was at its height. The insanitary conditions of oriental life greatly enhanced the spread of the infection. At present, it is impossible to estimate either the number of cases or deaths, as accurate information has not been received from the Japanese authorities. From one quarter to one half of the population must have been affected." (Schofield, and Cynn 1919, p.981).

[3] According to the government report, approximately 3.9 per 1,000 died from influenza among Japanese who were living in colonial Korea. It is suggested that Koreans were more vulnerable to the influenza pandemic than Japanese in colonial Korea. This is probably because Koreans were typically living in poor sanitary conditions and had less access to supportive public health care than the Japanese. Regarding this issue, Patterson and Pyle (1991) showed that accessibility to health services after infection caused differences in mortality during the influenza pandemic of 1918 although there was no effective therapy.

[4] We selected deaths from infectious diseases excluding nine infections not related to influenza that were systematically reported in colonial Korea: cholera, typhoid fever, dysentery, diphtheria, typhus, smallpox, scarlet fever, paratyphoid, and epidemic cerebrospinal meningitis. For deaths from infections other than the nine causes above, the exact causes are unknown. Therefore, this way of calculating influenza-related deaths can slightly overestimate the actual number of deaths from influenza.



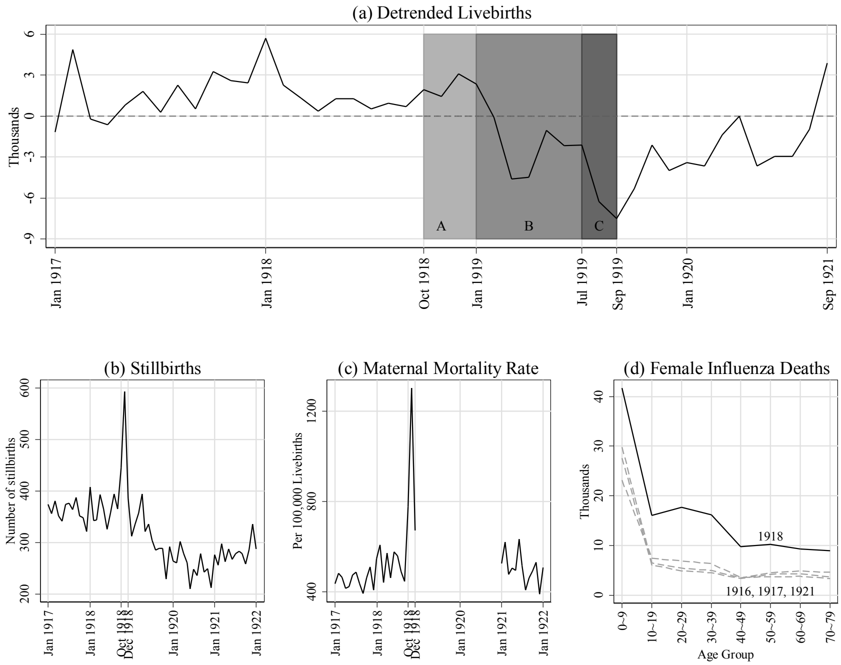
Sources: Statistical Yearbook of the Japanese Government-General of Korea
Notes: The definition of influenza-related deaths is discussed in the text. Its monthly information for 1919 and 1920 is not available.

Figure 1
Monthly Trend of Total and Influenza-Related Deaths, 1917-1921

suggests that the number of total deaths in 1918 primarily reflected influenza-related deaths. On the other hand, the trend of total deaths show another surge around January 1920. This resulted from the second wave of the Spanish influenza pandemic, which is known to have caused about 44,000 deaths. However, this number was comparable to that of seasonal influenza.

In the regression analyses, we compare later outcomes among the cohort exposed to the 1918 influenza pandemic in utero and its surrounding cohorts. Whether or not conception and childbirth were selective due to the threat of influenza would be a key condition for the validity of this empirical strategy. If mothers could predict the pandemic and thus avoid pregnancy in advance, the estimation can be biased.

To discuss the potential selection issue, we examine de-trended livebirths in Figure 2 (a). We use the regression residuals as de-trended values after controlling for month dummies. The trend of livebirths in the period of influenza pandemic, denoted by ‘A’ in the figure, looks



Sources: Statistical Yearbook of the Japanese Government-General of Korea
Notes: Figure (a) plots the regression residuals of livebirths after controlling for month dummies using the 1916-1922 dataset. Maternal mortality in Figure (c) is defined in the text. Its monthly variable is not available for 1919 and 1920. Figure (d) shows the number influenza-related deaths among Korean females by age group in 1916, 1917, 1918 and 1921. We defined deaths from influenza-related diseases in the text.

FIGURE 2
OBSTETRIC AND FETAL RISK DURING THE 1918 INFLUENZA PANDEMIC

normal. This suggests that the pandemic was unpredictable. However, the number of livebirths substantially declined from January to September in 1919, deviating from its seasonality. Those born in the shaded period B were conceived before the pandemic began. If the pandemic was unpredictable, this rapid decrease in livebirths seems to have resulted from sudden increase in miscarriage, stillbirths and maternal deaths driven by the pandemic. As supporting evidence, Figures 2 (b) and (c) provide the monthly trend of stillbirths and maternal deaths reported in Statistical Yearbook of the Japanese

Government-General of Korea. Both strongly suggest that fetuses and pregnant women were exposed to high obstetric and mortality risk during the pandemic period.[5] Moreover, Figure 2 (d) shows the number of influenza-related deaths among Korean females for four separate years. Young females of childbearing age more likely died from influenza-related diseases in 1918 compared to the surrounding years.[6] This indirectly supports the finding that influenza was particularly harmful to the fetal environment. Accordingly, those who survived risky fetal environment would be healthier than otherwise. This selection can underestimate the long-term effect of fetal exposure.[7]

The declining trend of livebirths looks accelerated in the shaded period C in Figure 2 (a). Those born in that period were conceived during the pandemic months. Mothers would want to avoid pregnancy. But it is hard to provide direct evidence saying about the direction of selection bias because of lack of reliable historical records. Alternatively, it might be useful to compare the Korean trend of livebirths with that of Japanese in colonial Korea who had higher socioeconomic conditions. Korean livebirths declined by 29% between July-September in 1918 and the same months in 1919, but Japanese livebirths experienced a mild decrease of 13%. This suggests that families with low socioeconomic status less likely tried to have babies during the pandemic months or they experienced more miscarriage and stillbirths due to poor nutrition and burden of diseases. This potential positive selection can

[5] The statistics on miscarriage in colonial Korea is not available. But Johnson (2006) showed that the 1918 influenza pandemic had significant impacts on birth with a rapid increase in miscarriage.

[6] This w-shaped pattern of influenza deaths by age is a distinct characteristic of the Spanish influenza pandemic. Similar patterns are found in the United States (Walters 1978; Almond 2006). Influenza pandemics typically have a U-shaped curve with peaks in the very young and old age groups (Taubenberger, and Morens 2006).

[7] This type of selection can be greater if weak newborns affected by influenza in utero died prior to 1960. We examined the population size by birth cohort from the 1925 colonial census records and the changes between 1925 and 1960. The 1919 birth cohort survived 78%, whereas the 1918 and 1920 cohorts survived 70% and 64%, respectively, during these 35 years. This suggests that those who survived the risky fetal environment might be enough stronger to more likely survive up to old ages than other cohorts.

underestimate the effect of fetal exposure.[8]

IV. Data and Identification Strategy

This study uses a sample from the 1960 Korean population census to compare educational attainment across cohorts born in early 20th century colonial Korea. The 1960 census is the first modern survey conducted in South Korea under the auspices of the United Nations. Statistics Korea provides a 2% micro sample of the 1960 census through Microdata Integrated Service (MDIS). From the sample, we select 100,361 individuals born during the period 1910 to 1929, who are thought to have completed their education by 1960.[9]

Because the influenza pandemic occurred from October to December 1918, those born from October 1918 to August 1919 are thought to have been exposed to the influenza in utero. We are unable to include these birth cohorts in a treatment group in regression analyses because birth month is not available from the 1960 Korean census.

Alternatively, we use those born in 1919 as a treatment group to include more individuals affected by the influenza pandemic in the group. This classification is also supported by the finding in previous studies that influenza more significantly affected later outcomes when exposure occurred in the first or second trimester rather than the third trimester (Almond 2006). Note that this set-up may underestimate the effect of influenza because the 1919 birth cohorts contain a considerable number of people who were born after August 1919 and were not affected by influenza in utero.

As we discuss later, the 1919 birth cohort was exposed to the 1918 influenza pandemic but also to other nationwide events in utero and during infancy such as crop failure, the great flood, and cholera outbreaks. Thus, it is undesirable to estimate the effect of fetal exposure to the influenza pandemic by simply comparing later outcomes between

[8] Brown and Thomas (2011) suggested that the 1919 birth cohort in the United States was negatively selected. Their parents had relatively lower socioeconomic status due to the systematic selection process of conscription during World War I than did those of other birth cohorts.

[9] Some key variables used in the analyses are not available before 1910. In addition, education among those born in the 1930s and 1940s was affected by educational reforms after independence from Japan in 1945.

1919 and non-1919 birth cohorts because it is impossible to effectively control for the effects of confounding events.

Considering such limitations on data availability, we use geographical variation in pandemic intensity across birth province to identify the effect of influenza. Figure 3 shows that the pandemic intensity measured by the influenza death rate varied across birth provinces.[10] The average death rate was slightly higher in South Korea regions (8.3 per 1000) than in North Korea regions (7.6 per 1,000).[11] The death rate was particularly severe in three provinces: South Chungcheong, North Gyeongsang, and South Gyeongsang. Although there is no perfect explanation for regional variation in influenza death rate, Chun and Yang (2007) suggested that the residents in coastal areas were more likely infected because they had more frequent contact with foreigners at ports than residents of other areas.[12]

For identification, we employ difference-in-differences type regression models. The first difference is to compare later outcomes between the 1919 and non-1919 birth cohorts. The second difference is to compare the first difference (*i.e.*, the disadvantage of 1919 birth cohorts) across the severity of the influenza pandemic at the birth province, which is measured by the influenza death rate. The identification framework is also useful to rule out other competing hypotheses. The patterns of geographic variation in other events differed from those of influenza pandemics. We test the validity of other hypotheses using such differences in regional variations.

From the 1960 census, we use six variables as measures of educational attainment: years of schooling; a dummy for having ever enrolled in school; dummies of completing primary school, middle school, or high school, and a dummy of being able to read and write. Summary statistics of the educational variables and covariates are

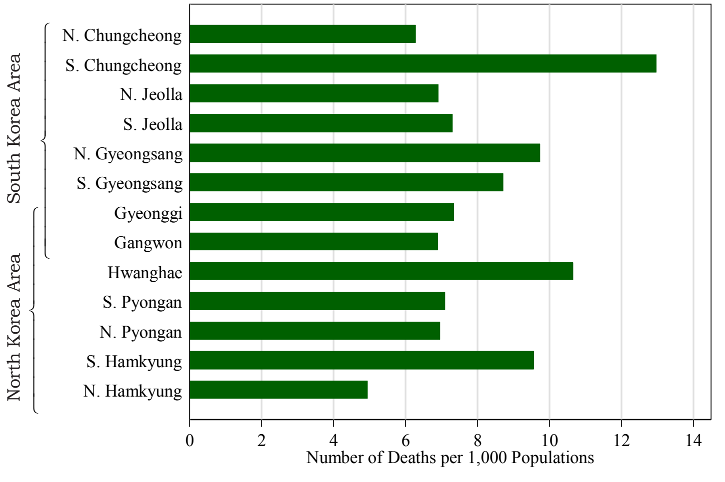
[10] Death toll from 1918 influenza pandemic was officially investigated by the Japanese Government General of Korea and reported in the March 1919 issue of the Korea Bulletin. We use this as pandemic intensity measure in later estimation.

[11] Cross-province standard deviation is 2.2 for South Korea regions, and 1.9 for North Korea regions. See Appendix Table 3 for summary statistics.

[12] The influenza epidemic in 1918 caused the most serious damage in Hyogo prefecture in Japan. The port of Kobe, Japan's representative port city in Hyogo, might have facilitated the spread of influenza (Rice, and Palmer 1993).

(a) Map

(b) Severity



Source for vital statistics: Japanese Government-General of Korea (1919), "Influenza," *Korea Bulletin* 13 March, pp. 87-88.

Notes: Colonial Korea consisted of the current area of both South Korea (not shaded in the map) and North Korea (shaded). Two provinces in colonial Korea, Gyeonggi and Gangwon, were divided into South and North Korea after the Korean War. This study regards only cohorts born in the area of South Korea, who are found in the 1960 South Korea census records.

Figure 3

Administrative Map of Colonial Korea and Influenza Death Rate by Province provided in the Appendix Table 1. In the appendix table, we also compare sample means of the variables across birth cohorts and provinces.

The modern school system was introduced in the 1910s in colonial Korea. Compulsory education for primary school was not enacted until the 1950s. Accordingly, average years of schooling among the sample cohort born from 1910 to 1929 are only 2.9. While the average rate of completing primary-school education was 37.6%, the average rate of completing middle and high-school education was as low as 9.7% and 3.7%, respectively. As a result of poor educational investment, only 63% of the sample cohort could read and write by the age of 30 to 50.

Another characteristic found in colonial Korea is that education for females was much more inferior than education for males. The average years of schooling for males (4.2 years) was 2.5 times higher than that for females (1.7 years). In particular, the gap was more substantial for higher education: 2.2 times higher for the likelihood of completing primary school, 4.7 times higher for middle school, and 7.2 times higher for high school. Only 48% of the female sample was literate while the literacy rate was 80% for males. We estimate the effect of fetal exposure to influenza on educational attainment by gender and associate the estimated results with gender disparities in colonial Korea.

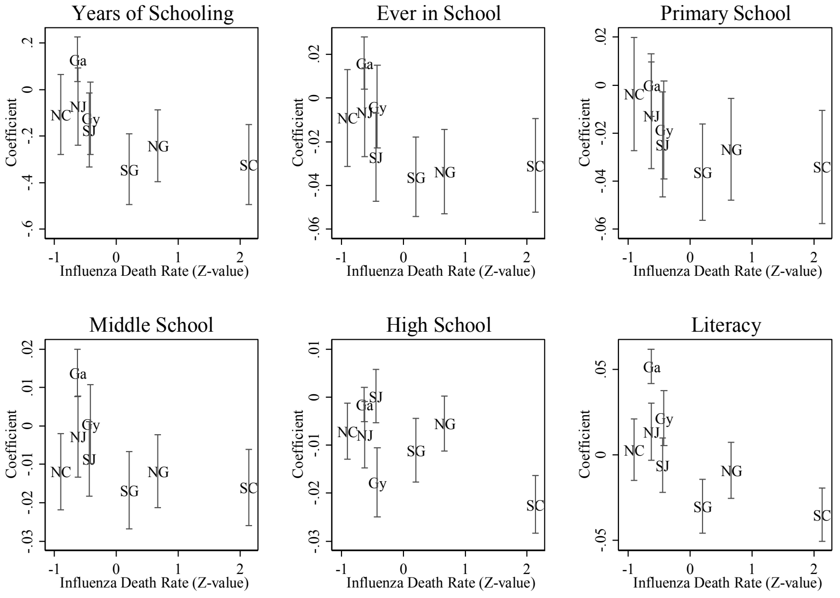
V. Fetal Exposure to the Pandemic and Human Capital Development

A. Estimation by Birth Province

We first estimate the difference in educational attainment between 1919 and non-1919 birth cohorts across birth provinces using the following equation.

$$y_i = \alpha + \beta BY(1919)_i + \textstyle\sum_j \beta_j \, BY(1919)_i \, BP(j)_i + \textstyle\sum_j \delta_j \, BP(j)_i + time + \varepsilon_i \quad (1)$$

In the equation above, y_i denotes the variable of educational attainment discussed in the previous section. $BY(1919)_i$ is the dummy variable that indicates whether individual i was born in 1919 or not. $BP(j)_i$ is the dummy of being born in province j. From eight provinces, we use Gangwon province as a reference group, which was the least affected province by influenza. '*time*' controls for linear time trends of



Notes: We conducted the regressions in equation (1) for six dependent variables, using Gangwon province as reference group. We depicted the estimated coefficient β for Gangwon province and $\beta + \beta_j$ for other provinces, which measures the gap in educational attainment between 1919 and non-1919 birth cohorts. The coefficients are indicated by the initials of birth provinces. We plotted them against standardized death rate (*i.e.,* z-value) from influenza at birth province. The initial (and full name) of birth province is as follows: SC (South Chungcheong), NG (North Gyeongsang), SG (South Gyeongsang), Gy (Gyeonggi), SJ (South Jeolla), NJ (North Jeolla), NC (North Chungcheong) and Ga (Gangwon)

FIGURE 4

ESTIMATED EFFECT ON LATER OUTCOMES BY INFLUENZA MORTALITY OF BIRTH PROVINCE

outcome variables. Therefore, the coefficient β estimates the extent to which the gap in educational attainment of those born at the reference province in 1919 differed from the gap in education attainment of those born in the same province in the years other than 1919. The sum of β and β_j measures the differential of the 1919 birth cohort among those born in province *j*.

To see how much the gap was associated with pandemic intensity in the birth province, we plot the estimated β and $\beta + \beta_j$ against the influenza death rate at each associated province in Figure 4. We separately conducted this analysis for six outcome variables, and used the standardized death rate for efficient interpretation.

The scatter plots in Figure 4 show that the estimated coefficients are negatively correlated with the influenza death rate at the birth province. This implies that the gap in educational attainment between 1919 and non-1919 cohorts is more substantial among those born in provinces more severely affected by influenza. In general, the pattern is estimated to be significant for those born in three provinces: South Chungcheong (denoted by SC in the figures), North Gyeongsang (NG), and South Gyeongsang (SG).

In the three birth provinces, the difference between 1919 and non-1919 birth cohorts was estimated to be significantly negative for all outcome variables. However, the difference was estimated to be statistically insignificant for other provinces. This may be because they experienced a relatively milder pandemic in 1918 compared with seasonal influenza in other years. For example, the provinces of Gangwon (Ga), North Chungcheong (NC), and Gyeonggi (Gy) experienced relatively mild increases in the influenza-related death rate from surrounding years (1916 to 1917 and 1919 to 1920) to 1918: 33%, 38%, and 45% respectively. Three provinces, for which coefficients are estimated to be significantly negative, experienced severe pandemics: 173% for South Chungcheong, 126% for North Gyeongsang, and 124% for South Gyeongsang.

B. Baseline Estimation

In Figure 4, the level of association between the coefficient and the influenza death rate in the birth province depends on the slope of the scatter plots. As a negative slope is steeper, fetal exposure to the influenza pandemic more substantially deteriorated human capital development. We estimate this slope by replacing the dummies of birth province in equation (1) with standardized influenza death rate at birth province (S_i) as follows.

$$y_i = \alpha + \beta BY(1919)_i + \gamma BY(1919)_i\, S_i + \delta S_i + X_i\, H + time + \varepsilon_i \qquad (2)$$

The variable X_i includes the gender dummy and two variables as determinants of later educational outcomes measured at birth province:

TABLE 1

ESTIMATED EFFECT OF FETAL EXPOSURE TO THE 1918 INFLUENZA PANDEMIC ON LATER OUTCOMES

Control variable:						Sample mean	Magnitude of baseline coefficient (% of sample mean)
Gender	x	x	x	x	x		
Early-life conditions		x	x	x	x		
Birth province FEs			x	x	x		
Province-specific time trend							
Linear	x	x	x				
Quadratic				x			
Birth year FEs					x		
Dependent variable:	(1)	(2)	(3) Baseline	(4)	(5)	(6)	(7)
Years of schooling	-0.0822** (0.0243)	-0.0881** (0.0254)	-0.0949** (0.0280)	-0.0870** (0.0320)	-0.0894*** (0.0236)	2.90	9.82
Ever enrolled in school	-0.0090* (0.0042)	-0.0097* (0.0043)	-0.0105* (0.0048)	-0.0097* (0.0051)	-0.0098** (0.0037)	0.41	7.60
Primary school completion	-0.0071** (0.0028)	-0.0079** (0.0028)	-0.0087** (0.0030)	-0.0066 (0.0041)	-0.0079** (0.0024)	0.38	6.94
Middle school completion	-0.0046** (0.0015)	-0.0048** (0.0016)	-0.0052** (0.0018)	-0.0057** (0.0017)	-0.0047** (0.0018)	0.10	16.14
High school completion	-0.0039* (0.0018)	-0.0042** (0.0016)	-0.0043** (0.0015)	-0.0040** (0.0015)	-0.0044** (0.0015)	0.04	35.46
Literacy	-0.0157*** (0.0035)	-0.0154*** (0.0034)	-0.0165*** (0.0038)	-0.0177*** (0.0036)	-0.0159*** (0.0035)	0.63	7.83

Notes: We conducted the regressions in equation (2) for specified outcome variables. In the table, we reported only the coefficient for the dummy variable of 1919 birth cohort interacted with standardized influenza mortality rate at birth province (*i.e.*, γ) and its standard error clustered on birth province in parenthesis. We additively contained control variables from column (1) to (3) as specified in each column headings. To control for the trend of outcome variables, we use province-specific linear time trend in columns (1)-(3), province-specific quadratic trend in column (4), and year-of-birth fixed effects in column (5). A single asterisk denotes statistical significance at the 90% level of confidence, double 95%, and triple 99%. Column (6) reports the sample mean of each dependent variable. Each coefficient in the table measures how much the adverse effect on the 1919 birth cohort increases as influenza death rate at birth province becomes higher by one standard deviation (SD). For column (7), we first calculated the marginal effect for three-SDs increase in influenza death using baseline result in column (3), and then reported its magnitude as % of sample mean.

average number of doctors per capita in the years from birth to age five, and the average number of students enrolled in primary schools per capita from age six to ten. X_i also includes province-of-birth fixed effects to control for time-invariant regional conditions in early life considering potential omitted variables. We control for outcome variables' time trends in three ways: the province-specific linear trend as a baseline and the province-specific quadratic trend and year-of-birth fixed effects as a robustness check.

In equation (2), the coefficient γ estimates the 1919 cohort difference in educational attainment by influenza death rate in the birth province. Table 1 reports the coefficient and its standard error, which is clustered on birth province, for six dependent variables and different model specifications. The result for all controls is available in Appendix Table 2.

The estimation result strongly suggests that the 1919 birth cohort born in a province more severely affected by an influenza pandemic achieved a significantly lower level of educational outcome. Overall, the estimated result is robust for all the dependent variables considered and across different regression specifications.

Because the influenza death rate is controlled by its z-value, each coefficient measures how much the adverse effect on the 1919 birth cohort increases as the influenza death rate at the birth province rises by one standard deviation. For example, the baseline coefficient in column (3) suggests that the average years of schooling among those born in 1919 was lower by approximately 0.1 year because they were born in provinces with an influenza death rate that is one-standard deviation higher from the average province. Figure 4 shows that the influenza death rate at the birth province ranges over three standard deviations. Thus, the gap in years of schooling caused by the influenza pandemic in colonial Korea is estimated to be 0.3 years. This amounts to approximately 10% of the sample average.

Column (7) provides the gap explained by three standard deviations relative to the sample average in column (6). Although the change in higher education was small on average, it is intriguing that the magnitude of the adverse effect becomes greater when the completion of higher-level education is used as a dependent variable. Higher cognitive ability was required to enter and complete higher education in colonial Korea compared to today because access to higher education was limited. Thus, the result suggests that fetal exposure to an influenza pandemic might significantly deteriorate cognitive ability.

The magnitude reported in column (7) is greater than magnitudes reported in other studies. For example, according to Almond's (2006) estimates, the impact of fetal exposure to an influenza pandemic is calculated as a 2.4% decline in years of schooling and a 6.6% decline in high school completion among influenza-affected US cohorts.[13] Higher estimates for colonial Korea can be explained in several ways. First, this may be related to the country-specific educational environment. For example, compared with Americans, Koreans in the colonial period experienced fierce competition even for primary school access mainly due to limited supply. This environment required greater cognitive ability at an early age to pass entrance exams.[14] This could increase the marginal effect of fetal exposure to influenza on educational attainment. Second, prenatal care and medical benefits for infants and children were poor in colonial Korea compared with the conditions in the United States during similar periods.[15] Thus, initial health endowments damaged by influenza in utero could not be restored enough to obtain higher education.[16]

[13] Note that the magnitude in the two studies cited was approximately compared because both studies used different identification methods. Almond (2006) utilized estimated maternal infection rates as the severity of an influenza pandemic at the state level. The estimated marginal effect for years of education is -0.756 (Table 5). Using the coefficient and average maternal infection rate (=1/3), the author suggested that the impact of influenza on years of education was approximately 0.25 year (= 0.756 × 1/3) on page 705, 2.4% of average school years (= 10.7 years). The same method was applied when calculating the magnitude for high school completion.

[14] All schools in colonial periods, even primary schools, conducted entrance exams to admit new students. Average competition rates of primary schools and secondary schools are 2~3:1 and 10:1, respectively. [Sources: "Entrance examination for primary school," *Dong-A Ilbo*, April 9, 1920, p. 3; "What should be done to the difficulty in school entrance? Authority's responsibility," *Dong-A Ilbo*, March 26, 1922, p. 1; "Difficulty in elementary school admission. Does the authority perceive the responsibility?" *Dong-A Ilbo*, March 14, 1929, p. 1.]

[15] In the 1920s, there were approximately 1.3 physicians per 1,000 in the United States (Carter *et al.* 2006). However, the corresponding number for colonial Korea in the 1920s was approximately 0.08 (Japanese Government-General of Korea 1910 to 1942).

[16] Using the estimated coefficients in Lin and Liu (2014), we calculated that the Taiwanese experienced a 12% reduction in years of schooling and a 35% reduction in high school completion due to the 1918 influenza pandemic. The calculation is much similar to that of this study. This can be explained by the

C. Robustness Check

In Table 2, we examine whether the results of the baseline estimation are robust under various changes in regression specifications. First, the results of testing of different cohorts as the treatment group instead of the 1919 cohort are presented in columns (2) through (4). We assume that the main cohort affected by the 1918 influenza is that born in 1918 rather than in 1919 in column (2). We conduct the baseline estimation for six dependent variables, replacing the dummy of 1919 birth cohort with that of 1918 in equation (2) and reporting the key coefficients. Most are estimated to be statistically insignificant. This suggests that fetal exposure to external shock in the first or second trimester was more important for human capital development. Column (3) conducts a placebo test assuming the 1920 cohort as the treatment group. The result shows that the 1920 cohort was not affected by the influenza pandemic. In column (4) that sets the 1910 to 1919 cohorts as the treatment group, we assume that people would have been substantially affected by the influenza pandemic at various ages in utero, infancy, and childhood. The result strongly supports the significance of fetal exposure.

Second, we repeat the baseline estimation for the male and female sample. The results in columns (5) and (6) suggest that the adverse effect of influenza on educational attainment is more substantial among males than females. This disparity is related to Confucian culture and son preference in colonial Korea whereby parents typically invest in modern education only for sons. Therefore, girls who received modern education during this time period were not from the same types of families that educated their boys. Educated girls were on average in relatively well-off families, which indicates that the mothers from these families would have been less affected by the pandemic. This would presumably attenuate the coefficient of interest towards zero for female.[17] Although more significant coefficients are estimated for

fact that the level of educational and public-health conditions were similar in both countries during the colonial periods.

[17] There is an alternative biological hypothesis that female fetuses are more resilient to external shocks during the prenatal period than male fetuses. Mazumder *et al.* (2010) support this hypothesis showing that prenatal influenza exposure increases the risk of cardiovascular disease in men than women. In addition, the stillbirth and infant mortality rates in colonial Korea are typically

TABLE 2
ESTIMATION BY ALTERNATIVE SPECIFICATION

	Alternative treatment group				By gender		Alternative time windows		Alternative severity measure of influenza pandemic		
	1919 cohort (baseline)	1918 cohort	1920 cohort	1910-1919 cohorts	Male	Female	1914-1924	1917-1921	Detrended influenza-related death rate	Non-influenza death rate	Death rate among Japanese in Colonial Korea
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Years of schooling	-0.0949**	-0.0299	-0.0156	-0.0699*	-0.1382***	-0.0497	-0.0974***	-0.1175**	-0.1283***	0.0408	-0.0911***
	(0.0280)	(0.0314)	(0.0582)	(0.0366)	(0.0328)	(0.0687)	(0.0261)	(0.0400)	(0.0140)	(0.0397)	(0.0226)
Ever enrolled in school	-0.0105*	-0.0054	0.0009	-0.0114*	-0.0157***	-0.0052	-0.0113**	-0.0123*	-0.0169***	0.0094*	-0.0138***
	(0.0048)	(0.0044)	(0.0071)	(0.0053)	(0.0017)	(0.0088)	(0.0044)	(0.0059)	(0.0024)	(0.0047)	(0.0025)
Primary school completion	-0.0087**	-0.0053	-0.0022	-0.0079	-0.0161***	-0.0012	-0.0088**	-0.0070	-0.0124***	0.0053	-0.0083***
	(0.0030)	(0.0046)	(0.0075)	(0.0052)	(0.0037)	(0.0087)	(0.0029)	(0.0064)	(0.0013)	(0.0034)	(0.0016)
Middle school completion	-0.0052**	0.0008	-0.0004	-0.0018	-0.0024	-0.0077*	-0.0055**	-0.0077**	-0.0075***	0.0034	-0.0066***
	(0.0018)	(0.0024)	(0.0030)	(0.0023)	(0.0039)	(0.0035)	(0.0018)	(0.0023)	(0.0019)	(0.0025)	(0.0015)
High school completion	-0.0043**	-0.0005	-0.0018	-0.0026	-0.0068*	-0.0017***	-0.0037*	-0.0058**	-0.0018	-0.0023	0.0022
	(0.0015)	(0.0012)	(0.0017)	(0.0015)	(0.0035)	(0.0004)	(0.0017)	(0.0023)	(0.0022)	(0.0014)	(0.0019)
Literacy	-0.0165***	0.0009	-0.0005	-0.0076	-0.0184***	-0.0142	-0.0183***	-0.0185**	-0.0213***	0.0055	-0.0144**
	(0.0038)	(0.0055)	(0.0062)	(0.0044)	(0.0040)	(0.0084)	(0.0038)	(0.0060)	(0.0038)	(0.0070)	(0.0048)

Notes: We conducted the baseline regressions with full controls, using alternative specification. Column (2) supposes that the birth cohort mainly exposed to the 1918 influenza pandemic is those born in 1918 rather than in 1919. Column (3) sets the 1920 cohort as the treatment group, who was not exposed to the 1918 influenza pandemic. Column (4) uses the 1910-1919 cohorts as treatment group. Columns (5) and (6) present the results of regressions conducted, respectively, for male and female sample. In columns (7) and (8), we used alternative sample years: 1914-1924 and 1917-1921 rather than 1910-1929 used in the baseline regression. In columns (9)-(11), we applied alternative measure of influenza-pandemic severity at birth province to the baseline regressions as listed in each column's heading. Each measure of severity was used as standardized value. Each cell reports only the coefficient of the key variable γ in equation (2) and its standard error clustered on birth province in parenthesis. A single asterisk denotes statistical significance at the 90% level of confidence, double 95%, and triple 99%.

the completion of higher education among females, their meaning is less significant because a limited number of females were educated in middle or high schools at that time.

Third, we narrow the sample years of birth cohort from 1910 to 1929 to 1914 to 1924 in column (7) or 1917 to 1921 in column (8) to identify whether any big events or shocks other than the influenza pandemic in the sample period can cause biases to the baseline estimation. In addition, there is a concern that policy changes and cultural shifts during the 20-year sample period may bias estimates. The estimated coefficients in columns (7) and (8), which are similar to those of the baseline estimation, can rule out those concerns.

Fourth, we use three alternative measures of influenza intensity in birth province: the detrended influenza-related death rate in column (9), non-influenza death rate in column (10), and the influenza death rate among Japanese who were living in colonial Korea in column (11). Column (9) examines a possible concern that the influenza mortality rate, which was used in the baseline estimation, may reflect regional variations in non-influenza conditions and not capture time variations in influenza risk. We employ the deviation of the influenza-related death rate in 1918 from its 1915 to 1930 trend.[18] However, the results in column (9) dispel such worries. The result in column (10) of using non-influenza death rate as an alternative risk measure well supports that the adverse effect on human capital accumulation was driven by influenza rather than other diseases. Finally, the result in column (11) of using death rates among Japanese in colonial Korea, which are thought to have been closely examined by the Japanese Government, is much similar to that of baseline estimation. This suggests that the report on Korean deaths from influenza is reliable, and well reflects the regional variation in the severity of the pandemic.

lower among females than males, suggesting that females are more resistant to external adverse environments in their early life (Japanese Government-General of Korea 1910 to 1942).

[18] Influenza-related death is defined and used in the text related to Figure 1 above. We removed the trend using the Hodrick-Prescott filter. Accordingly, this alternative measure reflects regional variations and time variations in influenza intensity.

D. Competing Hypothesis

Some may argue that low educational attainment among the 1919 birth cohort could be caused by other nationwide events that substantially affected development in utero or infancy. Such events include the 1919 Independence Movement (from March to April 1919), crop failure (from June to December 1919), the second wave of the Spanish influenza pandemic (from November 1919 to April 1920), the great flood (in July 1920), and a cholera outbreak (from July to October 1920). According to previous studies, exposure to these events could affect educational outcomes by causing maternal stress and lowering nutritional status through famine and infections (Almond, and Currie 2011).

We test the significance of these competing hypotheses with the same approach with that of the baseline estimation using the geographical variation in the intensity of each event presented in panel B of Appendix Table 3. We use equation (2) but replace the variable S_i with other intensity measures at the birth province as listed in Table 3. We report the coefficients for the dummy variable of 1919 birth cohort interacted with intensity measures and their standard errors in Table 3. The result does not provide any noticeable evidence that the educational attainment of the 1919 birth cohort was significantly impaired by other competing events.

VI. Concluding Remarks

The study has shown that fetal exposure to the influenza pandemic of 1918 had a detrimental impact on educational attainment using the historical experience of colonial Korea. The magnitude of the adverse effects is estimated to be larger for higher education than primary schooling and more substantial for males than females. This is closely related with educational environments in colonial Korea. In addition, we did not find any considerable effects when the exposure to other nationwide major events in 1919 to 1920 was analyzed. Consequently, we conclude that the influenza pandemic of 1918 substantially limited human capital development in colonial Korea.

After the Korean War, Korea experienced miraculous growth throughout the 1960s and 1970s. Working generations who led the successful industrialization in that period were the cohorts born in

TABLE 3
EFFECTS OF EXPOSURE TO SUBSTANTIAL EARLY-LIFE NATIONAL EVENTS AMONG THE 1919 BIRTH COHORT ON LATER OUTCOMES

Event	1919 Independence Movement	Crop failure	2^{nd} wave of Spanish influenza pandemic	Great flood	Cholera outbreak
Periods	1919. 3~ 1919.4	1919. 6~ 1919. 12	1919.11~ 1920. 4	1920. 7	1920.7~ 1920. 10
Measure of severity	Number of participants per capita	Production of rice	Death rate from influenza	Monetary value of damage	Death rate from cholera
	(1)	(2)	(3)	(4)	(5)
Years of schooling	0.0749*** (0.0173)	-0.0611 (0.0350)	0.1051*** (0.0235)	-0.0574 (0.0335)	-0.0154 (0.0304)
Ever enrolled in school	0.0127*** (0.0020)	-0.0119** (0.0039)	0.0159*** (0.0025)	-0.0086* (0.0044)	-0.0039 (0.0034)
Primary school completion	0.0071*** (0.0020)	-0.0069* (0.0030)	0.0104*** (0.0023)	-0.0063* (0.0033)	-0.0026 (0.0030)
Middle school completion	0.0058*** (0.0008)	-0.0043 (0.0023)	0.0068*** (0.0017)	-0.0029 (0.0022)	-0.0008 (0.0015)
High school completion	-0.0022* (0.0010)	0.0042* (0.0018)	-0.0012 (0.0023)	0.0005 (0.0023)	0.0028 (0.0017)
Literacy	0.0122*** (0.0030)	-0.0083 (0.0072)	0.0168*** (0.0040)	-0.0047 (0.0063)	-0.0046 (0.0048)

Notes: In the table, we estimate the effect of exposure to other substantial national events, which occurred in 1919-1920, in utero or infancy among the 1919 birth cohort on later outcomes. The regression model used is the same with that of baseline, but we used alternative severity variables that measure how differently each birth province experienced those events, as described in the table. Each cell reports only the coefficient of the key variable γ in equation (2) and its standard error clustered on birth province in parenthesis. A single asterisk denotes statistical significance at the 90% level of confidence, double 95%, and triple 99%.

the 1910s and 1920s. They had experienced various traumatic events such as frequent outbreak of infectious diseases, famine, and disaster in their early lives. Various theories—not only the fetal origins model examined in this study but also life course and pathway models—strongly support the theory that such harsh environments in early life would have limited their human capital development.[19] Without those early-life experiences, populations could accumulate higher levels of human capital and economic productivity. Thus, the contribution of the generations is astonishing.

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[19] Both life course and pathway models suggest that fetal conditions and childhood circumstances can be influential in health and human capital accumulation over the course of a lifetime. The life course model proposes that health status in childhood has direct impacts on adult health (Kuh, and Wadsworth 1993). The pathway model emphasizes the causal relationship between early-life circumstances, and adult health status would be indirect rather than direct (Marmot *et al.* 2001). The model predicts that early adulthood socioeconomic status influenced by childhood circumstances plays an intermediate role in determining later adulthood health status (Brunner *et al.* 1999).

Appendix

Appendix Table 1
Summary Statistics of Educational Attainment and Covariates by Birth Cohorts and Provinces

Birth cohort	Born in 1910-29		Born in 1919			Born in other years		
1918 pandemic intensity	All		Severe	Mild		Severe	Mild	
Statistics	Mean	SD	Mean	Mean	(3)-(4)	Mean	Mean	(6)-(7)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Educational attainment								
Years of schooling	2.900	3.847	2.240	2.698	-0.459	2.789	3.029	-0.240
Ever enrolled in school	0.414	0.493	0.332	0.392	-0.060	0.398	0.432	-0.034
Primary school completion	0.376	0.484	0.302	0.343	-0.042	0.366	0.389	-0.023
Middle school completion	0.097	0.296	0.066	0.090	-0.024	0.091	0.103	-0.011
High school completion	0.036	0.187	0.018	0.027	-0.009	0.035	0.039	-0.004
Literacy	0.632	0.482	0.575	0.637	-0.062	0.620	0.645	-0.025
Panel B: Covariates								
Male	0.482	0.500	0.498	0.496	0.001	0.484	0.479	0.005
Doctors per 100,000	6.935	5.375	5.194	7.029	-1.836	5.709	8.003	-2.294
Enrollments per 1,000	7.765	2.623	7.293	7.570	-0.278	7.711	7.838	-0.127
Sample size	100,361		2,202	2,766		42,866	52,527	

Notes: We classify South Chungcheong, North Gyeongsang, and South Gyeongsang as birth provinces severely affected by the influenza pandemic of 1918, and other provinces into mild group.

Appendix Table 2

Baselines Estimation Result for All Control Variables

Control variables	Years of schooling	Ever enrolled in school	Primary school completion	Middle school completion	High school completion	Literacy
	(1)	(2)	(3)	(4)	(5)	(6)
Born 1919	-0.1564*** (0.0402)	-0.0171** (0.0062)	-0.0186*** (0.0043)	-0.0070** (0.0025)	-0.0077*** (0.0018)	-0.0048 (0.0059)
Born 1919 × Severity	-0.0949** (0.0280)	-0.0105* (0.0048)	-0.0087** (0.0030)	-0.0052** (0.0018)	-0.0043** (0.0015)	-0.0165*** (0.0038)
Male	2.5057*** (0.0931)	0.3001*** (0.0111)	0.2858*** (0.0100)	0.1293*** (0.0114)	0.0572*** (0.0067)	0.3275*** (0.0183)
Doctors per 100,000	0.1714*** (0.0342)	0.0190*** (0.0042)	0.0212*** (0.0044)	0.0077*** (0.0018)	0.0072*** (0.0012)	0.0058 (0.0046)
Enrollment per 1,000	0.0329 (0.0182)	0.0023 (0.0025)	0.0033 (0.0021)	0.0016 (0.0013)	0.0030*** (0.0008)	0.0008 (0.0015)
Dummy of birth province						
Gyeonggi	1.2429*** (0.0661)	0.2009*** (0.0080)	0.1681*** (0.0083)	0.0401*** (0.0030)	-0.0157*** (0.0029)	0.1299*** (0.0075)
North Chungcheong	-0.2096*** (0.0262)	-0.0467*** (0.0034)	-0.0387*** (0.0032)	0.0147*** (0.0013)	0.0043*** (0.0011)	0.0644*** (0.0024)
South Chungcheong	-0.2810*** (0.0456)	-0.0377*** (0.0056)	-0.0366*** (0.0049)	0.0011 (0.0038)	-0.0144*** (0.0024)	0.0173*** (0.0039)
North Jeolla	-0.4987*** (0.0345)	-0.0376*** (0.0044)	-0.0552*** (0.0038)	-0.0316*** (0.0032)	-0.0328*** (0.0011)	-0.0706*** (0.0028)
South Jeolla	0.1614** (0.0498)	0.0227*** (0.0061)	0.0159** (0.0062)	0.0047 (0.0025)	0.0044 (0.0024)	-0.0685*** (0.0064)
North Gyeongsang	-0.3213*** (0.0203)	-0.0403*** (0.0030)	-0.0322*** (0.0027)	-0.0183*** (0.0012)	-0.0040*** (0.0007)	-0.0309*** (0.0031)
South Gyeongsang	-0.2410*** (0.0378)	0.0022 (0.0046)	-0.0068 (0.0045)	-0.0308*** (0.0030)	-0.0301*** (0.0008)	-0.0953*** (0.0044)

Appendix Table 2
(Continued)

Control variables	Years of schooling	Ever enrolled in school	Primary school completion	Middle school completion	High school completion	Literacy
	(1)	(2)	(3)	(4)	(5)	(6)
Year (linear time trend)						
× Gyeonggi	0.0276 (0.0284)	0.0050 (0.0036)	0.0032 (0.0036)	0.0017 (0.0018)	-0.0019* (0.0008)	0.0094** (0.0039)
× Gangwon	0.1349*** (0.0071)	0.0192*** (0.0010)	0.0182*** (0.0008)	0.0050*** (0.0006)	0.0011*** (0.0003)	0.0151*** (0.0006)
× North Chungcheong	0.1499*** (0.0067)	0.0224*** (0.0009)	0.0209*** (0.0008)	0.0041*** (0.0005)	0.0008** (0.0003)	0.0144*** (0.0006)
× South Gyeongsang	0.1450*** (0.0064)	0.0209*** (0.0009)	0.0199*** (0.0008)	0.0043*** (0.0005)	0.0015*** (0.0002)	0.0147*** (0.0006)
× North Jeolla	0.1344*** (0.0065)	0.0181*** (0.0009)	0.0177*** (0.0008)	0.0052*** (0.0005)	0.0021*** (0.0002)	0.0145*** (0.0007)
× South Jeolla	0.1174*** (0.0067)	0.0168*** (0.0009)	0.0162*** (0.0008)	0.0043*** (0.0005)	0.0008*** (0.0002)	0.0139*** (0.0008)
× North Gyeongsang	0.1431*** (0.0076)	0.0201*** (0.0011)	0.0190*** (0.0009)	0.0056*** (0.0006)	0.0012*** (0.0003)	0.0150*** (0.0007)
× South Gyeongsang	0.1229*** (0.0092)	0.0161*** (0.0013)	0.0154*** (0.0011)	0.0059*** (0.0007)	0.0015*** (0.0003)	0.0148*** (0.0011)
Constant term	-2.1641*** (0.1241)	-0.2342*** (0.0160)	-0.2617*** (0.0158)	-0.1200*** (0.0073)	-0.0688*** (0.0065)	0.1605*** (0.0202)
R-squared	0.1911	0.1757	0.1691	0.0779	0.0407	0.1637
Sample size	99,927	99,927	99,927	99,927	99,927	100,361

Notes: The table provides the baseline estimation result per equation (2). In each regression, Gangwon province is used as reference group. The coefficients for the variable of “born 1919 × Severity” is reported in column (3) of Table 1. Standard errors in parentheses are clustered on birth province. A single asterisk denotes statistical significance at the 90% level of confidence, double 95%, and triple 99%.

Appendix Table 3

Major Nation-wide Events and Intensity Measures

Events	Period of occurrence	Measure of intensity across province	Mean	Std. dev	Source of data
Panel A: 1918 Influenza pandemic					
The 1st wave of Spanish influenza pandemic	1918.10~ 1918. 12	Death rate from influenza: the number of deaths due to the Spanish influenza per 1,000 populations	8.272	2.204	Japanese Government-General of Korea (1919)
Panel B: Major events that occurred in 1919-1920 (used for the analysis in Table 3)					
The 1919 Independence Movement	1919. 3~ 1919.4	Participant rate: the number of people who participated in the March 1st Independence Movement divided by province populations	0.116	0.121	Park (1920)
Crop failure	1919. 6~ 1919. 12	Production of rice: the rice yield (1 unit = 144 ton) in 1919 after removing the trend of 1914 to 1924 with the Hodrick-Prescott filter	8.573	2.804	Statistical Yearbook of the Japanese Government-General of Korea
The 2nd wave of Spanish influenza pandemic	1919.11~ 1920. 4	Death rate from influenza: the number of deaths due to the second wave of Spanish influenza per 1,000 populations	2.278	1.582	Japanese Ministry of Home Affairs (1922)
Great flood	1920. 7	Monetary value of damage: the amount of the damage (¥ 1,000,000) caused by floods in 1920 after removing trends from 1914 to 1924 with the Hodrick-Prescott filter	0.809	0.700	Statistical Yearbook of the Japanese Government-General of Korea
Cholera outbreak	1920.7~ 1920. 10	Death rate from cholera: the number of deaths due to the cholera in 1920 per 1,000 population	1.110	0.993	Statistical Yearbook of the Japanese Government-General of Korea

Notes: The values of mean and standard deviation were calculated as sample mean and standard deviation for eight provinces located in the current region of South Korea.

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