

**The Effect of In Utero Exposure to the 1918 Influenza Pandemic on
Life Expectancy in the United States**

Elaine M. Hernandez
Indiana University

Jonas Helgertz
Lund University and University of Minnesota

John Robert Warren
University of Minnesota

Florencia Torche
Stanford University

Claire Margerison
Michigan State University

Elizabeth Anderson
Indiana University

Extended abstract prepared for presentation at the 2019 meetings of the Population Association of America; please do not cite or quote without the authors' permission. Direct correspondence to Elaine Hernandez, Indiana University, Department of Sociology, Ballantine Hall 744, 1020 E. Kirkwood Avenue, Bloomington, IN 47405-7103 or email ehernan@indiana.edu.

In utero exposure to maternal infection during the prenatal period may not only have an effect on infant health, it may have lasting effects on health over the life course. Infectious pandemics offer one vantage point to isolate the effects of *in utero* exposure to maternal infection on adult morbidity and mortality, the developmental origins of adult health and disease. According to fetal origins theory (Barker 1995), *in utero* exposure to nutritional deprivation and, potentially, infection increases the chances of developing chronic health conditions in adulthood. Recent evidence lends weight to this theory, with *in utero* exposure to the 1918 pandemic linked to increased rates of physical disability, cardiovascular problems, cancer, and metabolic disorders (Almond 2006; Almond and Mazumder 2005; Bengtsson and Helgertz 2015; Mazumder et al. 2010). In spite of the growing evidence that *in utero* exposure to nutritional deprivation and maternal infection impact adult morbidity, we know less about the effects on life expectancy, particularly by timing of exposure (i.e., pregnancy trimester).

We address this gap by using newly available data linking (1) monthly data on city level influenza mortality with (2) U.S. census (1910, 1920, and 1940) and (3) mortality records to assess the effect of *in utero* exposure to the 1918 influenza pandemic on life expectancy in the United States. Our approach will enable increased specificity with regard to the trimester-specific effects of *in utero* exposure to infection/stress on life expectancy, and will allow us to compare exposure in the periods just prior to and after pregnancy. Aside from this novel contribution, by linking to the 1940s Census we are able to obtain information about adult socioeconomic attainment, which allows us to examine whether the relationship between fetal exposure and timing of death operates through socioeconomic pathways. Importantly, our linked data will allow us to examine whether these effects differ by maternal socioeconomic status, race, and geographic location.

Data

U.S. Mortality Statistics, 1909-1920

We obtain city-to-city and temporal variation in influenza exposure through the digitization of mortality statistics for the period 1909-1920. The source material includes monthly number of deaths due to influenza over the entire period for 24 states and over 30 cities, reported separately by race. Although the 1918 influenza pandemic spread over the world in a very short period, there was local variability in the timing of rates of influenza. The data allow us to capture distinct differences in when the virus reached certain areas of the US, for how long the mortality remained elevated, and its intensity (i.e. how much influenza mortality increased in that city).

U.S. Census Data and Social Security Death Master File

We combine several sources of individual level data. Our point of departure is the 1920 full-count US Census, from which we select all males born between 1910 and 1920. In order to measure prenatal influenza exposure, we select individuals born (and in 1920 still residing) in a city for which we have information on influenza mortality. From the 1920 Census, we also obtain information on the individual's race and socioeconomic background (the latter expressed as parents' occupational attainment). Using state-of-the-art methods of record linkage, we link the baseline population to the 1940 full-count Census, from which we obtain information on the individual's own educational attainment, occupation, and income. Newly-produced training data, exploiting not only individual-level but also family-level information, enables us to significantly improve the precision of our linking procedure, primarily through reducing the number of false positives. Using the same procedure, we link the population that we successfully linked across the 1920-1940 Census to the Social Security Death Master File (SSDMF), from which we obtain

the individual’s time of death. From this source, we also obtain the individual’s exact date of birth, which allows us to precisely measure the time during gestation that the individual was exposed to the influenza pandemic. Details on our linking timeline are included in the Appendix.

Analytic Approach

The influence of fetal exposure to the 1918 influenza pandemic on adult and late life mortality, either directly or moderated by educational attainment, is modelled by means of survival analysis, assuming a Gompertz distribution. Influenza exposure, as outlined before, is modelled through trimester of exposure, complemented with a set of indicator variables which capture the timing of exposure, either before conception (maternal exposure only) or after birth. During the years closest to the influenza pandemic, exposure periods are defined as six-month periods, whereas the years further away are defined as one-year periods. Since the onset, duration and intensity of the influenza pandemic is state or city specific, what constitutes a certain timing of exposure may, however, differ slightly between individuals who were born in the same month and year, as Figure 1 illustrates. The influenza pandemic hit state A and B during the month of October, but lingered for one month longer in state B. Thus, individual born in August the following year would in state A be considered to have been exposed 0-6 months prior to conception, while in state B, the exposure would be considered to have occurred during trimester one.

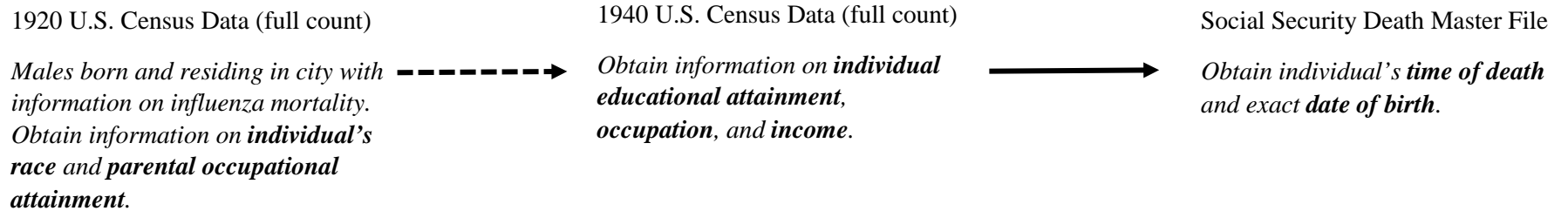
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
State A	-1	Influenza		1	2	3	4	5	6	7	8	9	10
State B	-1	Influenza			1	2	3	4	5	6	7	8	9

Figure 1. Timing of Exposure to the 1918 Influenza Pandemic

All estimated models control for the individual's state, year and month of birth, flexibly specified. In addition, models control for the individual's socioeconomic background, through the parents' occupational attainment, as well as the individual's race. Baseline models focus on the effect on the timing of influenza exposure on the hazard of dying. Models are subsequently extended to also include the individual's own educational attainment, as well as how the effect of the influenza exposure interacts with both the parents and their own attained socioeconomic status. Lastly, models will examine heterogeneities in the effect of influenza exposure, by allowing the effect to differ according to the intensity of the pandemic at the individual's place of exposure.

References

- Almond, Douglas. 2006. "Is the 1918 Influenza Pandemic Over? Long-Term Effects of In Utero Influenza Exposure in the Post-1940 U.S. Population." *Journal of Political Economy* 114(4):672–712.
- Almond, Douglas and Bhashkar Mazumder. 2005. "The 1918 Influenza Pandemic and Subsequent Health Outcomes: An Analysis of SIPP Data." *The American Economic Review* 95(2):258–62.
- Barker, David J. 1995. "Fetal Origins of Coronary Heart Disease." *British Medical Journal* 311(6998):171–74.
- Bengtsson, Tommy and Jonas Helgertz. 2015. "The Long Lasting Influenza: The Impact of Fetal Stress during the 1918 Influenza Pandemic on Socioeconomic Attainment and Health in Sweden 1968-2012." *IZA Discussion Papers*.
- Mazumder, Bhashkar, Douglas Almond, Kyung Park, Eileen M. Crimmins, and Caleb E. Finch. 2010. "Lingering Prenatal Effects of the 1918 Influenza Pandemic on Cardiovascular Disease." *Journal of Developmental Origins of Health and Disease* 1(1):26–34.
- Torche, Florencia. 2011. "The Effect of Maternal Stress on Birth Outcomes: Exploiting a Natural Experiment." *Demography* (4):1473.



Appendix. Data Linking: The 1940 U.S. Census Data and Social Security Death Master File are linked (solid line), and the 1920 U.S. Census Data will be linked with the 1940 Census Data (dotted line) by November 2018.