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Journal of Health Economics

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Does *in utero* exposure to illness matter? The 1918 influenza epidemic in Taiwan as a natural experiment[☆]

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ARTICLE INFO

Article history:

Received 29 October 2012

Received in revised form 30 April 2014

Accepted 19 May 2014

Available online 4 June 2014

JEL classification:

I12

N35

I19

Keywords:

1918 influenza

Fetal origins hypothesis

Height

Education

Disease and mortality

ABSTRACT

This paper tests whether *in utero* conditions affect long-run developmental outcomes using the 1918 influenza pandemic in Taiwan as a natural experiment. Combining several historical and current datasets, we find that cohorts *in utero* during the pandemic are shorter as children/adolescents and less educated compared to other birth cohorts. We also find that they are more likely to have serious health problems including kidney disease, circulatory and respiratory problems, and diabetes in old age. Despite possible positive selection on health outcomes due to high infant mortality rates during this period (18%), our paper finds a strong negative impact of *in utero* exposure to influenza.

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1. Introduction

The fetal origins hypothesis proposed by Barker in 1992 posits that “certain chronic conditions later in life can be traced to the course of fetal development.” There is some evidence in the medical literature suggesting that poor fetal conditions can increase the risk of schizophrenia (Brown et al., 2004) and cardiovascular disease and hypertension (Barker, 1990, 1998; Langley-Evans, 2001). However, it is not an easy task to establish a causal link between the *in utero* environment and long-term outcomes. For

example, there could be unobserved characteristics of mothers or families associated with the poor *in utero* environment, which could also have an impact on one’s long-term outcomes. To tackle this identification issue, Almond (2006) investigates the long-term impact of the 1918 influenza pandemic in the United States. The sudden, unexpected and brief nature of the 1918 influenza pandemic sets up a natural experiment to test the fetal origins hypothesis. He shows that cohorts *in utero* during the peak of the influenza pandemic exhibited lower educational attainment, lower income, lower socioeconomic status, a higher physical disability rate, and higher welfare income compared with the adjacent cohorts. Almond also uses maternal mortality rates as a proxy for the severity of the pandemic and finds that those who were born in more highly affected areas were less educated.

Building on Almond’s work, this paper employs a similar empirical strategy but with Taiwanese datasets. Taiwan was a colony of Japan between 1895 and 1945, and the Japanese colonial government compiled detailed regional-level and aggregate-level data that includes pandemic severity, mortality, and government expenditure on public health and education. It was estimated that nearly 770,000 people (1/5 of the total population) contracted the influenza strain, and influenza had a mortality toll in Taiwan of about 25,000 people in 1918 (Ding, 2008).

[☆] We thank Jerome Adda, Josh Angrist, Alan Barreca, Dan Bennett, John Bonin, Ken Chay, Aimee Chin, Willa Friedman, Seema Jayachandran, Ted Joyce, Ted Miguel, Tom Vogl, and conference participants at NBER-SI Health Economics Session, PacDev, NEUDC, MIEDC, AEA, and Academic Sinica and seminar participants at LSU, SFU, MIT, Texas A&M, CUHK and the Center for Chinese Agricultural Policy for their helpful comments and suggestions. Financial support from the National Science Council, Taiwan (NSC 99-2410-02-250-MY2) is appreciated. We thank Jason Chien-Yu Lai and Tzu-Yin Hazel Tseng for their excellent research assistance. We thank Ian Downing for his careful editorial support. We thank the editor and two anonymous referees for thoughtful and thorough comments.

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There are a few features about Taiwan that make it an interesting case in which to test the fetal origins hypothesis. During the Colonization, Taiwan suffered from very high infant mortality rates (16–18%),¹ and nearly 25% of newborns did not live past five years. With the presence of other infectious diseases such as plague, cholera, and malaria, the environment in Taiwan was much less salubrious than that of the United States or most other countries that have been used to test the fetal origins hypothesis. The finding in this paper is of high relevance to present-day sub-Saharan Africa and other developing countries with high infant/child mortality rates and various infectious diseases. The surviving pandemic cohorts in Taiwan could be healthier than non-pandemic cohorts if the selection effect (*i.e.*, the culling of the weakest) dominates the scarring effect of the flu (Bozzoli et al., 2009). Thus, whether we find a negative outcome among those who were *in utero* during the influenza outbreaks becomes an empirical question.

We also make a few specific contributions to the literature:

1. Compared to the previous literature, we provide a comprehensive picture of health and cognition outcomes over the lifecycle of the relevant birth cohort. We utilize a historic dataset from the 1920s and 1930s to provide a snapshot of the pandemic-affected cohorts' height in pre-teen and teenage years. Height is particularly interesting since several studies suggest that adult height can depend in part on *in utero* environment (Ericson and Kallen, 1998; Hack et al., 2002) and height is found to be associated with one's cognitive ability and labor market outcome (Case and Paxson, 2008). We follow the same cohorts into the 1980s, and use the 1980 census to examine educational attainment.² In addition, the 1989 Survey of Health and Living Status of the Elderly was used to examine a wide set of long-term health problems, including heart disease, respiratory problems, and diabetes.³
2. In many parts of the world (including the United States, Europe, and Japan), there were two waves of influenza in 1918 and in

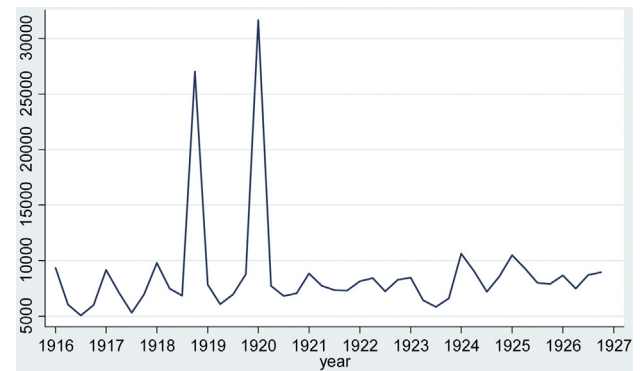


Fig. 1. Quarterly influenza-related death tolls in Taiwan.
Data Source: Dynamic Census of Taiwanese Population 1916–1926.

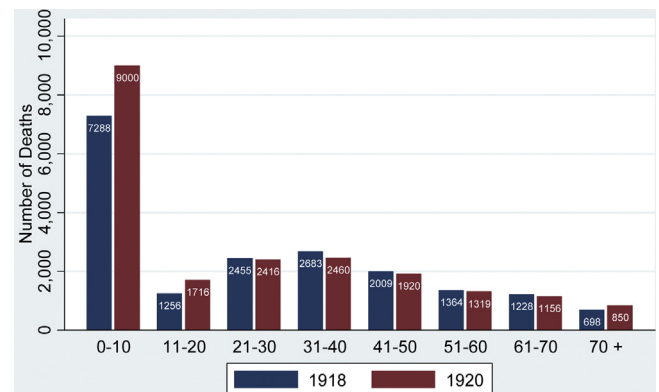


Fig. 2. Influenza-related death tolls for female by age cohorts and year.
Data Source: Dynamic Census of the Taiwanese Population 1918 & 1920.

¹ Among works that examine the 1918 influenza pandemic—*i.e.*, Neelsen and Stratmann (2012) in Switzerland, Nelson (2010) in Brazil, Mazumder et al. (2010) and Almond (2006) in the United States—Taiwan is the worst environment of all, in terms of economic conditions and disease. For example, if we compare the education of the cohorts born during this period, Switzerland has a 17.5% rate and the United States has about a 22% rate of cohorts who completed high school and beyond, while Taiwan has only a 6.5% rate. Brazil has a 5.5 percent rate of this cohort that had completed college education, while only 1.5% of the Taiwanese cohorts completed college. Hospital conditions in Taiwan were harsh. There were approximately 0.21 physicians per 1000 people in the 1920s, compared to approximately 1.3 physicians per 1000 people in the United States (Census Bureau, 1924). According to Tsai (2005), the mortality rate conditional on influenza infection is 3.3% in Taiwan in 1919, higher than the 2.5% mortality rate in the United States and 1.21% in Japan.

² The 1980 census does neither provide direct income nor wealth measures. However, it provides other outcomes including labor force participation and housing conditions. Neither of these outcomes is appropriate for our analysis since the relevant birth cohorts (1919) were 60, which is older than the average retirement age in Taiwan, 55. Thus, it is unclear whether remaining in the labor force at age 60 is in fact desirable. On one hand, those who have been able to accumulate more wealth may retire earlier; on the other hand, the less healthy may also retire early. As for the housing outcome, it is the norm in Taiwan that the elderly live with and are supported by their children upon retirement. Housing is a common form of inheritance. One's housing condition may not only reflect the relevant cohorts' wealth, but may also reflect one's family wealth (be it one's father's, or his children's, wealth). The regression results with these outcomes are available in the web appendix posted on the authors' homepage.

³ Most of the papers in the literature examine one dimension of either long-term health or the socioeconomic effects of *in utero* exposure to the pandemic. For example, Almond and Mazumder (2005) considered a limited set of elderly health outcomes using the Survey of Income and Program Participation, which is not designed for health. Both Mazumder et al. (2010) and Garthwaite (2009) use the National Health Interview Survey, but neither can examine respiratory illnesses due to data limitation.

1920 (Erkoreka, 2010; Johnson and Mueller, 2002; Richard et al., 2009). To our knowledge, among the literature examining the long-term impact of the 1918 influenza pandemic, none of these works have exploited the second wave of influenza. In Taiwan, although the second wave had higher death tolls than the first (see Fig. 1 for influenza-related death tolls), only 5–8% of the total population contracted influenza during the second wave, as opposed to 20% in the first wave (Taiwan Medical Association Journal, 1921). The increase in second wave deaths tolls compared to the first wave was driven mostly by the very young and the very old. The second wave (1920) did not impact as many childbearing-age women as much as the first wave did (See further discussion in Section 3 and Fig. 2). The considerable variation in influenza prevalence between the two waves provides us an additional check to compare the outcomes of cohorts who were *in utero* during the first wave to those who were *in utero* during the second wave.

3. Better identification of treated cohorts. Using the US 1960–1980 Censuses, Almond (2006) has to infer one's birth year based on one's age and quarter of birth (but not the year of birth). Age-heaping is a known problem in the US census: *i.e.*, those born in 1919 could report age 40 rather than age 41 in the 1960 census, leaving the birth year for some to be incorrectly identified (Lleras-Muney, 2005). This issue of age-heaping could possibly bias the results downward. In the Taiwanese census, birth date is recorded by interviewers who verify one's identification card or *hukou* (household registration), so age-heaping would not be an issue (Taiwan Census Report 1980).
4. Due to a lack of Taiwanese involvement in World War I (WWI) and controlling for a detailed set of parents' characteristics, we

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