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Descriptive Finding

The 1918 influenza pandemic and subsequent birth deficit in Japan

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Abstract

BACKGROUND
Recent research has documented fertility decline after the peak of pandemic-associated mortality during the 1918 influenza pandemic. Yet the time interval between the mortality peak and the dip in fertility and its contributing mechanisms remains a line of debate.

OBJECTIVE
This study examines the inter-temporal association between pandemic-associated mortality and subsequent birth deficit in Japan in order to shed light on the current debate about the impact of the 1918 influenza pandemic on human fertility.

METHODS
Seasonally and trend-adjusted monthly data on deaths, births, and stillbirths in Japan are used to compute cross-correlations between deaths, births, and stillbirths.

RESULTS
The analysis revealed a negative and statistically significant association between deaths (d) at time t and births (b) at time $t + 9$ ($r_{db}(9) = -.397, p < .0001$), indicating that excessive birth deficits occurred nine months after pandemic-associated mortality peaked. Additionally, there was a positive and high contemporaneous correlation between pandemic-associated stillbirths (s) and excess mortality ($r_{ds}(0) = .929,\ p < .0001$).

CONCLUSIONS
In contrast to earlier research that suggests that late first-trimester embryonic loss was the primary link between pandemic-associated mortality and future births, the findings of this paper suggest that a combination of reduced conceptions and embryonic losses during the first month of pregnancy were an important mechanism linking pandemic-associated mortality with subsequent depressed fertility.

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1. Introduction

The 1918 influenza pandemic, variously known as the “mother of all pandemics” (Taubenberger and Morens 2006) for its impact on global population and the “forgotten pandemic” (Crosby 2003) for the relative lack of attention researchers have paid to it, is one of the “big three” pandemics in recorded history (Langford 2002; Patterson 1983). Demographic research on the subject has focused heavily on patterns of mortality, paying relatively little attention to the equally important phenomenon of fertility. What little research there is on the impact of the 1918 influenza on human fertility has found a link between excess mortality during the pandemic period and subsequent changes in births and birth rates. For example, Mamelund's research on Norway observed a dip followed by a baby boom (Mamelund 2004), while Bloom-Feshbach and colleagues (Bloom-Feshbach et al. 2011) found a birth deficit 6−7 months after pandemic-associated deaths peaked in Scandinavia and the USA. Mamelund (2004, 2012) argues for social as well as behavioral mechanisms as drivers of pandemic-associated changes in fertility. By contrast, Bloom-Feshbach et al. emphasize biological mechanisms and embryonic loss in the late stage of the first trimester as contributors to subsequent birth declines.

This study utilizes data from Japan to determine whether there is a link between pandemic-associated excess mortality and later births, to evaluate the length of the time-lag between changes in excess mortality and future births, and to explore the mechanisms (i.e., socio-behavioral, biological, or both) at play in this link. This study makes two contributions to the literature. First, the statistical analysis reveals a nine-month lag between pandemic-associated excess mortality and subsequent birth declines. Second, our findings from the Japanese dataset augment a growing body of literature on the 1918 influenza pandemic, which has traditionally been centered on the Western experience but is now expanding to encompass the experiences of non-western countries.

The 1918 influenza pandemic claimed more than 50 million lives around the world (Johnson and Mueller 2002). Japan and several other major population centers in Asia, including India and Indonesia, were not spared the ravages of the pandemic (Chandra 2013a, 2013b; Chandra, Kuljanin, and Wray 2012). Earlier research indicated that Japan experienced a low death rate of between 0.64% and 0.71% (calculations based on Patterson and Pyle 1991 and Johnson and Mueller 2002) during the pandemic compared to most European countries and all known Asian death counts. However, a recent study argued that the total pandemic-associated population loss of 1.97−2.2 million, which includes excess deaths and reduced births, demonstrating that the Japanese experience was similar to those of other countries (Chandra 2013a). The pandemic also caused an excess of stillbirths in Japan (Nishiura 2009). In a pattern similar to that of its colony, Taiwan (Chandra and Yu, 2015), Japan experienced two major waves of mortality during the pandemic, the first between October 1918 and February 1919 with a peak in November 1918, and the second between October 1919 and February 1920 with a peak in January 1920 (Ding 2008; Richard et al. 2009). According to official reports from the Japanese Sanitary Bureau, a total of over 19.2 million infected cases were reported during the first outbreak, resulting in over 204,000 deaths and a death rate of approximately 1.06% (Central Sanitary Bureau 1920). During the second wave, in January 1920 alone there were 1,333,000 infected cases and 55,000 deaths (Central Sanitary Bureau 1920). Although the influenza virus entered Japan through seaports and the pandemic first broke out in coastal cities, the remoteness of rural areas did not protect them (Central Sanitary Bureau 1920; Nishiura and Chowell 2008; Rice 2003).

2. Data and methods

The data for this study included monthly figures on deaths, births, and stillbirths from 1913 to 1925 from the *Annual Report of the Central Sanitary Bureau of the Department for Home Affairs of the Imperial Japanese Government* (Central Sanitary Bureau 1920). These data enabled us to analyze the temporal association between monthly deaths, births, and stillbirths during the 1918 influenza pandemic in order to evaluate how pandemic-associated deaths impacted subsequent birth outcomes. Figure A-1 in the Appendix contains plots of the raw data for the period 1918–1920 for deaths, stillbirths, and births. Because the data are not stratified by other interesting demographic criteria such as socioeconomic status or age (including, for births and stillbirths, gestational age), the analysis focuses on the aggregate statistics of deaths, births, and stillbirths only.

We employed techniques in time-series econometrics to perform our analysis. First, we seasonally adjusted the raw data from 1913 to 1925 to tease out seasonal patterns and long-term trends in deaths, births, and stillbirths using the PROC X12 procedure in SAS (US Bureau of the Census 1999; SAS Institute, Inc. 2015). This procedure was implemented using an adjustment for the inevitable outliers associated with the influenza pandemic. The residual components of the data extracted from the seasonal adjustment process constitute monthly figures for excess or deficient births, deaths, or stillbirths. These residual components were used in the subsequent analysis because we believe that they best represent the anomalous death, birth, and stillbirth outcomes associated with the pandemic. We then computed pairwise cross-correlation functions, which describe correlations between monthly deaths and the two other variables (i.e., births and stillbirths) at different time lag and lead intervals (Bisgaard and Kulahci 2011) to determine temporal associations among these key demographic variables during the pandemic period. Following Bisgaard and Kulahci (2011) cross-correlation functions are formally defined as

$$r_{db}(k) = \frac{c_{db}}{s_d s_b}, \text{ and } \; r_{ds}(k) = \frac{c_{ds}}{s_d s_s}$$

where

$$C_{db} = \begin{cases} \dfrac{1}{n}\displaystyle\sum_{t=1}^{n-k}(d_t - \bar{d})(b_{t+k} - \bar{b}), k = 0, 1, 2, \dots, 12 \\ \dfrac{1}{n}\displaystyle\sum_{t=1}^{n+k}(b_t - \bar{b})(d_{t-k} - \bar{d}), k = 0, -1, -2, \dots, -12 \end{cases}$$

$$C_{ds} = \begin{cases} \dfrac{1}{n}\displaystyle\sum_{t=1}^{n-k}(d_t - \bar{d})(s_{t+k} - \bar{s}), k = 0, 1, 2, \dots, 12 \\ \dfrac{1}{n}\displaystyle\sum_{t=1}^{n+k}(s_t - \bar{s})(s_{t-k} - \bar{s}), k = 0, -1, -2, \dots, -12 \end{cases}$$

In the expressions above, d_t represents the monthly death series, which predicts or is predicted by b_t, the monthly birth series, and s_t, the monthly stillbirth series. k is the number of time lags or leads between deaths and the two other variables. We estimated cross-correlations with lags or leads up to 12 months ($-12 \leq k \leq 12$) using data for the period 1916 to 1921. All data series were pre-whitened to eliminate autocorrelation bias (Bisgaard and Kulahci 2011). Null hypotheses of 0-correlation were tested for the cross-correlations obtained from the above analysis.

3. Results

Figure 1 shows the seasonally and trend-adjusted monthly death and birth series for Japan between 1918 and 1920, the time interval when the pandemic occurred. The plot shows two exceptional peaks in deaths during this period, one in November 1918 and the other in January 1920. This pattern is consistent with the findings from previous research that Japan experienced two major waves of pandemic-associated mortality, with the first wave being the more severe of the two (Richard et al. 2009). More importantly for the purpose this study, a trough in births occurred in August 1919, nine months after pandemic-associated mortality peaked in November 1918. A second birth deficit was also observed in October 1920, 9 months after the second mortality peak in January 1920. These observations visually support the notion of a 9-month lag between deaths and births during the pandemic period, as distinct from the 6−7 month lag observed in Bloom-Feshbach et al. (2011).

Figure 1: Seasonally and trend adjusted monthly death and birth counts: Japan, 1918−1920

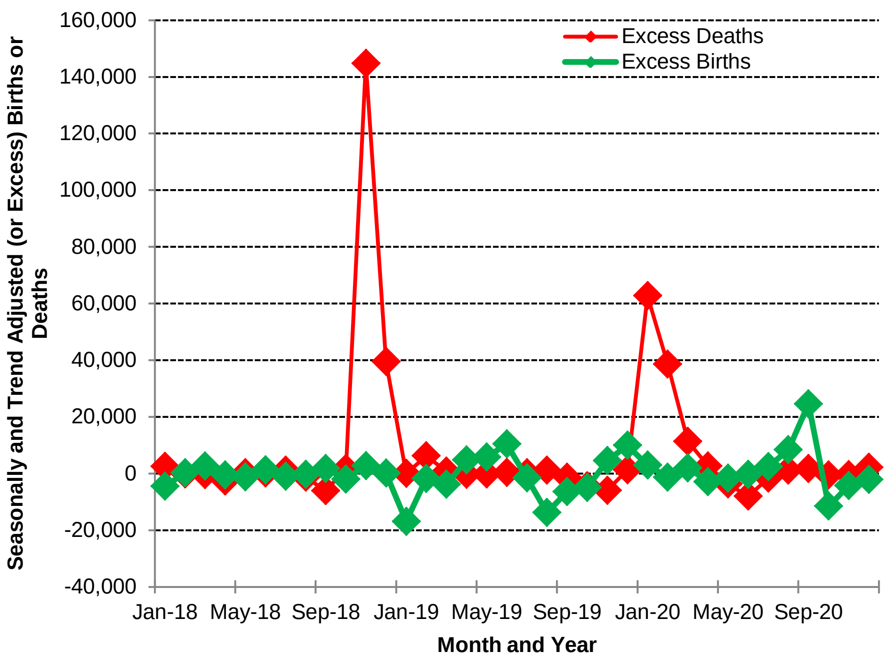
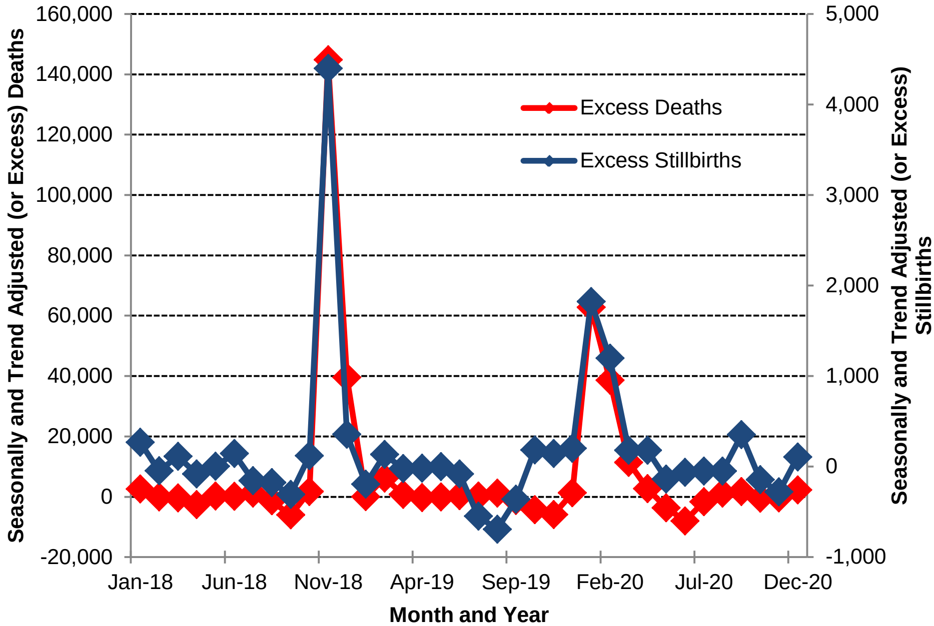


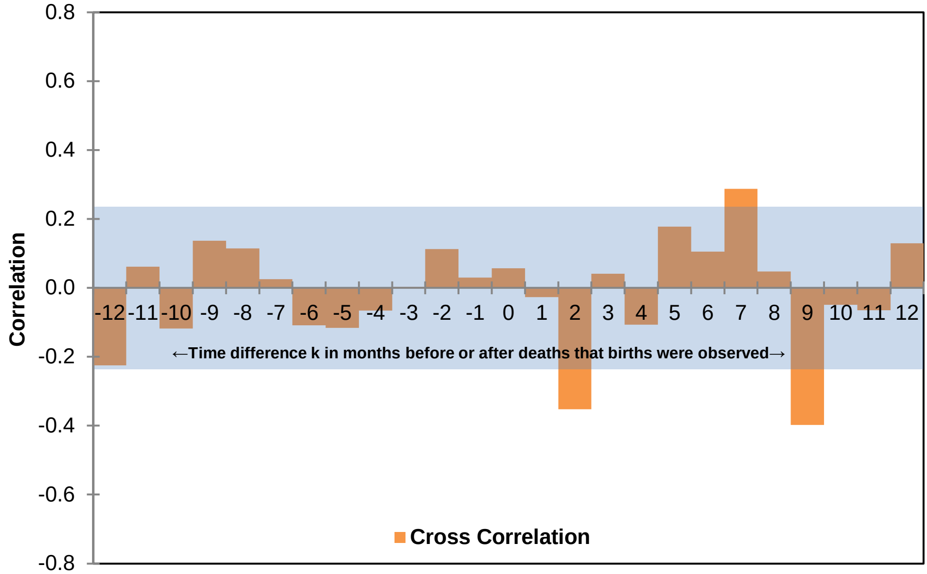
Figure 2 presents the seasonally and trend-adjusted monthly death and stillbirth series during the pandemic period. The graph shows a striking temporal synchronicity between deaths and stillbirths. When mortality peaked in November 1918 and January 1920, so did stillbirths.

Figure 2: Seasonally and trend-adjusted monthly death and stillbirth counts: Japan, 1918−1920



Next, we computed the cross-correlation functions to statistically test and verify our observation of the 9-month lag. Figure 3 shows the cross-correlations between seasonally and trend-adjusted deaths and births at k-month lags or leads ($-12 \leq k \leq 12$), represented by the bars. The bands around the bars indicate the confidence intervals of two standard errors under the null hypothesis that the cross-correlation is equal to zero. Figure 3 shows a negative and statistically significant correlation between deaths at time t and births at time $t + 9$ ($r_{db}(9) = -.397$). This suggests that higher mortality at a time point predicts fewer births in 9 months. The null hypothesis of a 0-cross-correlation coefficient was rejected for only two of the other cross-correlations: $t + 2$ ($r_{db}(2) = -.352$) and $t + 7$ ($r_{db}(7) = .288$). In other words, higher mortality at time t also predicts fewer births two months later, and more births 7 months later.

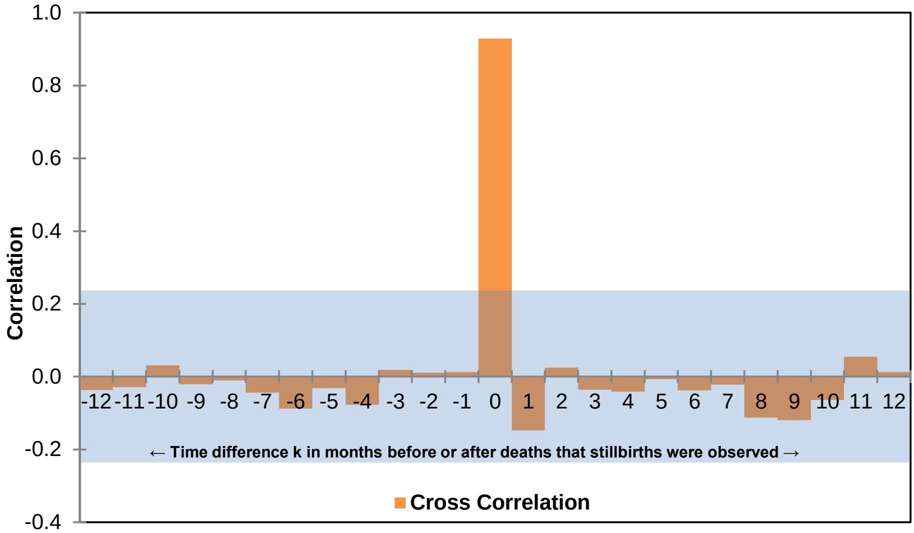
Figure 3: Cross-correlation coefficients for monthly deaths and births: Japan, 1916−1921



Note: The shaded areas are the confidence intervals of two standard errors, calculated across the set of lags and leads for –12≤ k ≤12.

Figure 4 presents the cross-correlation coefficients between the seasonally and trend-adjusted death and stillbirth series at different time lags or leads. The graph shows a very high positive correlation between deaths and stillbirths at time t ($r_{ds}(0) = .929$), indicating that when excess mortality was high, so were excess stillbirths. The cross-correlations for all other lags and leads were not significantly different from 0.

Figure 4: Cross-correlation coefficients for monthly deaths and stillbirths: Japan, 1916−1921



Note: The shaded areas are the confidence intervals of two standard errors, calculated across the set of lags and leads for –12≤ k ≤12.

4. Discussion

The findings in this paper contribute to the ongoing debate about the mechanisms linking elevated deaths during the 1918 influenza pandemic and subsequent fertility decline. While Mamelund (2004, 2012) contended that a fertility decline should occur nine months after mortality peaked, caused by changes in reproductive behavior and conceptions in particular, Bloom-Feshbach and colleagues (Bloom-Feshbach et al. 2011) used mortality, morbidity, and fertility data from Denmark, Norway, Sweden, and the U.S. to identify an average time lag of 6.1 to 6.8 months between the observed mortality peaks and the subsequent fertility trough, concluding that late first-trimester embryonic losses precipitated by the pandemic were the primary driver of depressed fertility.

Our study on Japan demonstrates the statistically significant 9-month time lag suggested by Mamelund and recently demonstrated in Chandra and Yu (2015), providing empirical support for (i) a role for the mechanism of reduced conceptions (Mamelund 2004, 2012) and (ii) embryonic loss during the first month of the first trimester of pregnancy before it was clinically detectable, a common phenomenon observed by Wilcox and colleagues (Wilcox et al. 1988). We suspect that the positive cross-correlation between excessive deaths and births seven months later is possibly a result of unusually high pre-term births, again precipitated by the pandemic. However, because data on the gestational age of babies at birth are unavailable, it is not possible to confirm this. The significant and negative cross-correlation between deaths and births two months later may have been the result of stillbirths in the seventh month of gestation at the height of the pandemic. It is also possible that many women in the third trimester of pregnancy died during the pandemic, including (and perhaps especially) women who were in the seventh month of pregnancy, thus contributing to the birth trough observed two months after the mortality peak − a well-known fact about the age distribution of deaths during the 1918 pandemic period is the unusually high mortality rate among adults in the prime of life, including women of peak childbearing age (15−44 years old), forming a W-shaped age-specific death rate in contrast to the U-shaped distribution commonly observed in influenza epidemics (Noymer and Garenne 2000; Taubenberger and Morens 2006). In sum, the results suggest that, in addition to the two above observations, the mechanisms of reduced conceptions and embryonic losses in the first month of the first trimester of the pregnancy, rather than elevated embryonic losses in the late stage of the first-trimester, are the dominant ones linking mortality and fertility.

5. Conclusion

The 1918 influenza pandemic has attracted the interest of epidemiologists due to its global impact on the human population. While the focus of the pandemic has been on its epidemiologic characteristics and therefore morbidity and mortality, its effect on human fertility, while less well studied, is of great importance. While the literature has consistently shown that reduced fertility ensued in the aftermath of the pandemic, the mechanisms that contributed to this link remain a subject of debate. The current study advances the literature by providing empirical evidence using vital statistics from Japan. Our analysis shows that there is a temporal association between excess mortality and an ensuing fertility decline nine months later during the pandemic period, supporting Mamelund’s (Mamelund 2004, 2012) argument of reduced conceptions. The results do not support late first-trimester embryonic loss as a mechanism linking pandemic-associated deaths with subsequent births as argued by Bloom-Feshbach et al. (Bloom-Feshbach et al. 2011). These findings have policy implications for reproductive health.

Specifically, based on their findings, Bloom-Feshbach et al. suggested that public health officials should introduce influenza vaccinations for pregnant women to protect them and their fetuses from infection. Our findings from Japan do not support such a policy recommendation.

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Appendix

Figure A-1: Raw data on births, deaths, and stillbirths: Japan, 1918−1920