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Pandemic influenza and the gender imbalance: Evidence from early twentieth-century Japan

A growing body of the literature has found evidence that fetal exposure to adverse health shocks is associated with negative socioeconomic and health outcomes later in their life (Prinz 2018). In addition, the short-run relationship between health shocks, particularly weather shocks, *in utero* and birth outcomes (particularly lower birthweight) has also been widely studied (Zhang 2017). The findings in both the long-run and the short-run strands of the literature are closely related because a lower birthweight can be associated with worse socioeconomic outcomes later in life.

In contrast to these studies, however, mortality selection *in utero* has not attracted broad coverage in economics literature. One exception is the study by Valente (2015), who tested a biological proposition named the Trivers-Willard hypothesis, which argues that fetal exposure to adverse health shocks disturbs the gender balance at birth because reproductive success of males is more vulnerable than that of females (Trivers and Willard 1973). Valente found that fetal exposure to civil conflict in Nepal is associated with a higher probability of miscarriage and relatively low male births compared to female births (i.e., lower secondary sex ratio). Maintaining the natural gender balance is important in an economy because the adult sex ratio imbalance leads to skewed marriage in terms of age and assortative matching as well as other demographic conditions such as out of wedlock fertility (e.g., Angrist 2002). Considering this scarcity of research, we aim to bridge the gap in the body of knowledge by investigating the associations between fetal exposure to pandemic influenza and mortality selection *in utero*.

Using a comprehensive dataset of vital statistics in Japan, we find that fetal exposure to pandemic influenza between 1918-1920 decreased the proportion of males at birth. The culling effect was concentrated on exposure during the first trimester of the pregnancy, and the estimated magnitude suggests that such exposure could have decreased the proportion of males at birth by up to 1.6%. Our results from the analyses using the complete census on annual infant mortality by gender indicate that such a reduction in male births during pandemics might be associated with a "scarring" mechanism under which the distribution of fetal health endowment shifts to the left. We also find evidence that shocks in the post-neonatal period due to pandemic influenza might have persisted into childhood. The estimated magnitude is approximately 0.24% in the maximum case, accounting for 50% of the standard deviation.

This study contributes to the wider literature in the following two ways. First, it is the first one to use pandemic influenza as an exogenous shock to test mortality selection *in utero*. Further, it is the first study to use a set of complete censuses on births in a developing economy. Second, this study is the first to investigate the persistency of fetal shocks on the sex ratio of children. Investigating the long-term effects of fetal exposure to pandemics on the sex ratio is important given that maintaining the natural gender balance in an economy is preferable, as discussed earlier.