Economics and Human Biology 43 (2021) 101064

Contents lists available at ScienceDirect

Economics and Human Biology

journal homepage: www.elsevier.com/locate/ehb

What doesn't kill her, will make her depressed

Yanan Li [a,1], Naveen Sunder [b,*,1]

[a] Business School, Beijing Normal University, 1720 Houzhu Building, No. 19 XinJieKouWai Street, Haidian District, Beijing 100875, China
[b] Department of Economics, Bentley University, AAC Room 187, 175 Forest St., Waltham, MA, 02452, United States

ARTICLE INFO

JEL classification:
I1
I12
I31
J13
N35
O12

Keywords:
Famine
Difference-in-differences
Mental health
Fertility
China

ABSTRACT

In this paper we study the long run effects of the 1959–61 Chinese Famine on mental health outcomes. We focus on cohorts that were born during the famine and examine their mental health as adults, when they are roughly 55 years of age. We find that early-life exposure to this famine leads to a large statistically significant negative impact on women's mental health, while there is limited effect on men. This gender differential effect is observed because male fetuses experience a stronger natural selection as compared to female fetuses, which implies that in the longer run, surviving females may exhibit larger detrimental effects of early-life famine exposure. Thus, the observed effects are a composite of two well-established factors, the survival of the fittest and the Fetal Origins hypothesis.

1. Introduction

Mental health disorders are a growing public health challenge worldwide. Among different forms of mental health disorders (such as anxiety, bipolar, eating disorders and schizophrenia), depression contributes most significantly to the global disease burden. With around 264 million people suffering from depression in 2017, it is the third largest cause of disability across the world (James et al., 2018). Mental well-being is a key determinant of economic and social outcomes, such as labor productivity, employment and earnings and mortality (Oswald et al., 2015; Frijters et al., 2014; Graham and Pinto, 2019). Given the severe mental health burden across the globe, and its negative socio-economic impacts, the causes and consequences of depression merit attention.

Mental health is shaped by a number of factors, such as the environment (like extreme heat), adverse events (like wars) and socio-economic characteristics like income shocks, education, religion and familial death (Li and Sunder, 2020; Adhvaryu et al., 2017, 2019; Singhal, 2018; Fruehwirth et al., 2019; Avendano et al., 2020). In addition to these factors, another key determinant of psychological well-being over the life course is early life nutrition. It has been shown that in-utero and early childhood are critical phases for both physical and mental development (Almond and Currie, 2011; Almond et al., 2018), and malnutrition during these periods may cause permanent deficits/anomalies in the brain and the nervous system (de Rooij et al., 2010). Additionally, prenatal nutritional deficiency leads to the reprogramming of postnatal brain gene expression, which in turn contributes to an increased risk of adult mental illness (Hales and Barker, 2001; O'Neil et al., 2014).

While there exists a large body of literature examining the deleterious effects of early life famine exposure on physical health outcomes (for detailed reviews see Lumey et al., 2011; Li and Lumey, 2017), relatively less empirical evidence exists on the effects of famine-induced fetal malnutrition on long-run adult mental well-being, especially in a developing country context. In this paper we address this by analyzing the long run (more than five decades later) effects of the 1959–61 Chinese Famine on mental health outcomes of people who were in-utero or born during the famine years. We use a difference-in-differences (DID) approach to estimate the effects of this famine on cohorts born during the famine years. Our empirical strategy leverages two sources of variations – an individual's timing of birth and the famine severity in different province-years. In all our specifications, we control for a

* Corresponding author.
E-mail addresses: yananli@bnu.edu.cn (Y. Li), nsunder@bentley.edu (N. Sunder).
[1] Both authors have contributed equally in all stages of the preparation of this manuscript.

https://doi.org/10.1016/j.ehb.2021.101064
Received 19 January 2021; Received in revised form 4 July 2021; Accepted 13 September 2021
Available online 17 September 2021

variety of other socio-economic factors at the individual, household and province/county level that could shape mental health outcomes.

The 1959–61 Chinese famine provides a special case for studying the long-term effects of early life deprivation not only because of its long time span (lasting almost three years), but also due to its unprecedented severity, scope of incidence, and its significant regional variation. Its effects varied considerably across regions due to differences in population density, weather and the efficacy of government response. In particular, rural areas suffered the most due to this famine, and hence our analysis focuses on rural populations (Lin and Yang, 2000; Meng et al., 2015).

Our results suggest negligible overall long-run mental health effects of the famine for rural cohorts that were born during the famine. But these aggregate null effects conceal substantial gender heterogeneity. We find that more than five decades after the famine, women born during the famine years in rural areas of higher famine-intensity provinces report more mental stress (five percentage points) than comparable women in lesser intensity provinces. On the other hand, we observe that the corresponding effects for men born around the same time is small (one percentage point) and statistically insignificant. We posit that these gender-differentiated effects are mediated by a combination of two factors: (1) survival of the fittest, and (2) the enduring detrimental effects of famine on those who survive. The former relates to the fact that male fetuses have a higher risk of mortality as compared to female fetuses due to their biological fragility (Kraemer, 2000; Mizuno, 2000). This sex-specific difference in mortality is accentuated in conditions of extreme stress (like famines), and leads to more women surviving as compared to men. This pattern was observed in the case of the 1959–61 famine in China – there was overall a very large excess mortality among famine cohorts, and the areas that were worse affected had more female fetuses surviving than male ones (Song, 2012). The higher rates of survival for female fetuses is also linked to the Fetal Origins Hypothesis suggested in (Barker, 1990), according to which in-utero shocks can alter the epigenome in favor of survival, but comes at the cost of a higher likelihood of developing various diseases in later stages of life. In our case these two effects put together translate into women being more likely to survive the adverse event (famine), but then suffering a higher risk of negative health consequences later in life, as demonstrated by the adverse effects on mental health that we find.

Further, we demonstrate that the observed findings are robust to the use of different measures of mental health (the CESD scale and the Kessler index), non-linear empirical specifications, multiple (objective) measures of famine severity, and analyses based on different data sources. As a placebo check we show that cohorts that were unaffected by the famine (born after famine years) experienced no negative effects, akin to a parallel trends assumption.

This analysis makes several contributions. First, our paper adds to the literature examining the long-term mental health impact of childhood exposure to famines in a developing country context. Previous studies have largely focused on developed countries (Brown et al., 2000; Bertoni, 2015), or have examined impacts that are temporally closer to the famine. In establishing mental health effects more than five decades after the famine, we show that these pernicious effects may persist across the life course of an individual. Second, it complements the large evidence on the effects of in-utero shocks on later life outcomes (Almond and Currie, 2011). In particular, this study is in the lines of recent evidence on the role of different kinds of in-utero factors in shaping adulthood mental health outcomes (Dinkelman, 2017; Adhvaryu et al., 2017, 2019). Further, our findings augment the evidence base on the gender-differentiated effects of in-utero and early childhood shocks. Women are better able to survive extreme in-utero (or early life) conditions such as severe famines, epidemics and slavery (Kraemer, 2000; Zarulli et al., 2018) but might suffer long-term adverse impacts later in life. The existing studies have mainly documented the gender-differentiated effects on physical health outcomes such as height, cardiovascular disease, diabetes, other chronic conditions, metabolic syndromes among other measures of physical health (Chen et al., 2014; Mu and Zhang, 2011; Zheng et al., 2012; Hu et al., 2017; Gørgens et al., 2012; Chang et al., 2018; Grey et al., 2021; Fan and Qian, 2015). This study complements this literature by bringing forth evidence on the gender-differentiated effects of famine on mental health.

This paper also documents the pernicious effects of the Chinese famine, and thus adds to the associated literature (See Li and Lumey, 2017 for a review). The outcomes that have been looked at include per capita GDP (Gooch, 2017), cognitive functions (He et al., 2018; Kim et al., 2017), being overweight and having difficulty with daily life activities (Cui et al., 2020), among others. This analysis contributes to the relatively scant body of literature that has examined the effects of this famine on psychological well-being (St Clair et al., 2005; Song et al., 2009; Huang et al., 2013; Cui et al., 2020).[2] We build on this body of work in three critical ways – (1) we explore effects 50+ years after exposure to the famine using nationally representative datasets,[3] something that is absent in the literature, (2) we use multiple objective measures of famine intensity based on administrative data,[4] and (3) we further improve upon existing studies by introducing evidence on the impacts of famines on depressive symptoms, using two internationally recognized and validated measures of depressive symptoms, CES-D and K-6 indices.

2. Background

The Chinese Famine lasted for three years (1959–1961), and claimed the lives of about 15–30 million people, mostly in rural areas (Chen and Zhou, 2007). Primarily, the famine has been attributed to three factors – the decline in food availability, urban bias in food entitlements, and an inflexible and regressive government procurement policy (Lin and Yang, 2000; Meng et al., 2015). In 1959, the total food supply suddenly dropped by 15%, and in 1960 and 1961 it fell further to about 70% of the pre-famine (1958) level. Meanwhile, the government procurements, which were biased towards urban areas, were set in advance and were not adjusted to account for this shortfall. This meant that when the actual output fell below expected levels, there was insufficient per capita food consumption in rural areas, even in those that are were previously productive (Meng et al., 2015).

The famine not only increased death rates but also significantly reduced fertility rates. According to Peng (1987), pre-famine total fertility rates for women (below 39 years of age) was 5.6 births (per woman), but it declined sharply in the famine years. In 1961 total fertility dropped to its lowest level, 3.06, before it started increasing again in 1962. Overall, it has been estimated that the famine caused about 25 million lost or postponed births (Peng, 1987).

While the entire country was affected by the famine, its severity varied across regions. Due to the aforementioned urban bias in the food procurement system, the decline in food availability during the famine years was worse in rural areas. This was further exacerbated by the fact that the famine coincided with the Great Leap Forward, an economic and social campaign led by the Chinese Commune Party during 1958–1962. During this time, there was large-scale collectivization efforts, especially in rural areas where people largely worked in agricultural collectives and were provided food through communal dining halls (rather than cooking in their private kitchens). Also, private stores of grain were banned, and rural-to-urban migration was restricted through

[2] Mostly due to better data availability, the mental health effects of the 1944 Dutch famine have been more thoroughly analyzed (Brown et al., 2000; Bertoni, 2015).

[3] In contrast, Huang et al. (2013) used survey data between 2001 and 2005 from four provinces to study the impact of early life exposure to the Chinese Famine on mental illness.

[4] This is in contrast to the potentially endogenous measure of hunger used in Cui et al. (2020).

a strictly enforced household registration system (Hukou). Put together, this contributed to a sizeable food shortage in rural areas, which heightened the intensity of the famine.

The famine's effect also varied significantly at the provincial level, due to both natural and institutional factors. For instance, the death rate in 1959 ranged from 6.9 per thousand people in Shanghai to 47 per thousand people in Sichuan province Table A3. The province-level heterogeneity is largely attributed to different extents of radicalism of provincial leaders in the implementation of the national policies during the leap period (Bramall, 2011; Houser et al., 2009). In our empirical strategy, we account for these regional differences.

3. Data

3.1. Mental health

The primary source of data for this analysis comes from the China Family Panel Survey (CFPS). The CFPS is a nationally representative dataset that collects information on economic activity, family dynamics, migration and health, among other topics. The survey was conducted in 25 out of 31 provinces in mainland China.[5] In this analysis we focus on information related to physical and mental health conditions of individuals who were 50+ years of age at the time of the survey. This analysis largely draws from the 2012 and 2014 waves of CFPS, and our sample consists of 5509 individuals coming from 3860 households.

The key outcome of interest in our analysis is mental health, which we measure in multiple ways. The main measure is the Center for the Epidemiological Studies of Depression scale (CESD), which is a validated screening tool for detecting depressive symptoms, and is suitable to be used across different racial, gender and age groups (Weissman et al., 1977). This scale has been used widely in studies on developing country contexts, such as China (Cui et al., 2020; Scheffel and Zhang, 2019; Zhang et al., 2017), South Africa (Fernald et al., 2008) and Vietnam (Singhal, 2018), in addition to many developed countries. The CESD-20 index is based on 20 components, that are listed in Table A1. Individuals are asked about the frequency with which they experience each item during the past week. The responses are coded on a four-point scale, ranging from zero ("never or less than one day") to three ("most of the time (5–7 days)"). The CESD index for an individual is calculated as the sum of the responses to each of the items.[6] Therefore, the total score can range from zero to 60 for the CESD–20 index, with higher scores indicating increased levels of depressive symptoms (worse mental health).

Additionally, we create two related outcomes – logcesd20 (which is the natural log of the CESD-20 measure), and svrstress20 (a categorical variable indicating severe stress, which takes a value of one when the value of the CESD-20 index is greater than or equal to 20[7]). While the original measurement is based on 20 items, there is a shorter 10-item version of the CESD that has also been shown to have similar predictive accuracy (Andresen et al., 1994). Analogous measures using the CESD-10 are also used in the analysis. The main results are based on the CESD-20 measure, but in robustness checks we show that our results largely persist when we use the CESD-10 measure.[8] Table A2 provides some summary statistics related to these indices. In our sample, 27% of the subjects reported experiencing severe stress based on the CESD-10 index, and the corresponding number is 23% based on the CESD-20 index.

We also supplement the main analysis with a second dataset – the China Health and Retirement Longitudinal Study (CHARLS). CHARLS is a representative survey of the Chinese population for ages 45 and above. Its focus on relatively older age groups makes it suitable to examine the long-term effects of the famine,[9] and we use the 2015 survey wave in our analysis. This dataset is particularly suited to our analysis as it focuses on relatively older age groups (interviews over 25,000 people of ages 45 and above), and has a large rural focus (78% of the sample has rural hukou). In addition to information on the components of the CESD-10 measure, the CHARLS dataset also contains extensive information on people's socioeconomic status during childhood.

3.2. Famine severity

The key independent variable in this analysis is famine exposure, which we conceptualize using two different approaches. The first is the provincial-level excess death rate (EDR), which is defined as the difference of death rates in 1960 (the worst year of the famine) and the average death rate in the three years immediately preceding the famine, 1956–1958. The intuition behind this measure is that the severity of the famine in a province can be proxied by the increased (or the excess) deaths that were caused due to it. Hence, we compare the death rate during the peak famine year (1959–61) with its level in the pre-famine period (Chen and Zhou, 2007). This measure is calculated based on death rate data reported in the Statistical Yearbook of China 1991 (State Statistical Bureau, 1990), which we provide in Table A3.[10] Table A3 illustrates that the provincial death rates in the pre-famine (in or before 1958) and post-famine (in or after 1962) were relatively stable, as compared to the marked increase experienced during the famine years (1959–1961). While the average national EDR was around 12 per 1000 people, there was significant provincial variation (standard deviation = 14 per 1000 people, see Fig. 1 for the spatial distribution of excess death rates).

The second measure of famine severity is the cohort size shrinkage index (CSSI), which is defined as the ratio of the size of the famine cohorts relative to the size of the temporally neighboring non-famine cohorts. The cohort size shrinkage index is computed using $1 - F_{famine}/F_{nonfamine}$, where F_{famine} is the total number of people born during the famine years, 1959–1961. The size of surrounding non-famine cohorts, $F_{non\ famine}$, is the average of the total number of people born in a three-year period before (1956–1958) and a three-year period after the famine (1962–1964). We calculate this measure using information from the one percent sample of China's 1990 population census (akin to Huang et al., 2013). The mean of this measure is 0.37, and the standard deviation is 0.12. Its value is interpreted in the following way – a value of 0.63 on the CSSI (as in Anhui province – see Table A3) indicates that among people alive in 1990, the size of the cohort of people born during the three famine years (1959–1961) was 63% less than that of people born in the three years preceding or following the famine. Hence, this index is directly proportional to the severity of the famine – the higher the value of this index, the higher the intensity of the famine in that region. Additionally, like the EDR measure, this also exhibits significant spatial heterogeneity (Fig. 1).

These two measures, EDR and CSSI, are both credible measures of famine severity that have been previously used in multiple studies (Huang et al., 2013; Xu et al., 2016; Chen and Zhou, 2007). They are both directly proportional to famine intensity, and in fact, in our sample

[5] Six provinces (Tibet, Hainan, Inner Mongolia, Qinghai, Ningxia and Xinjiang) have very few observations, and hence are excluded from this analysis.

[6] For the positive questions, the coding is reversed so that a higher score indicates poorer mental health.

[7] The cut-off 20 is recommended by the existing literature (Blank et al., 2004; Vilagut et al., 2016).

[8] There have been four waves of CFPS surveys conducted in every other year since 2010, but the full information on the CESD-20 scale was collected only in the 2012 round, and hence our main results are based on this wave of the survey.

[9] Other analyses have used CHARLS data for examining the effects of the Chinese Famine (e.g. Cui et al., 2020; Xu et al., 2018, 2016; Kim et al., 2017; Li et al., 2018).

[10] This dataset has been previously used in other studies (Peng, 1987; Lin and Yang, 2000; Houser et al., 2009).

the correlation coefficient between the two measures is 0.88, suggesting a large degree of overlap between the two. This overlap can also be seen in Fig. 1, which indicates that the mapping of famine severity across provinces using the two measures is very similar.

4. Empirical strategy

Our empirical strategy is akin to a standard difference-in-differences model. To estimate the long-term effect of early life exposure to the 1959–1961 famine, we leverage two sources of variations – an individual's birth cohort, and the provincial differences in the intensity of the famine. The difference between our estimates and a standard DD strategy is that we use a continuous measure of the intensity of treatment (i.e., famine intensity) and thereby capture more variation in the treatment status. Our method is similar to the approach adopted in other studies examining the impact of this Chinese famine (Chen and Zhou, 2007; Huang et al., 2013; Kim et al., 2017). The estimation equation takes the following form:

$$Y_{ipk} = c + \sum_{k=1954}^{1961} \beta_k Cohort_k * Intensity_p + Cohort_k + \mathrm{Prov}_p + \delta X_{ipk} + \varepsilon_{ipk} \quad (1)$$

k (k = 1954–1964); $Intensity_p$ is a measure of famine intensity in province p during the Great Chinese Famine, which in our case is indicated by EDR and CSSI; $Cohort_k$ is a binary indicator that takes a value of one for individuals born in year k; $Prov_p$ is a set of province dummies; X_{ipk} is a set of covariates including gender, hukou status at age 3 (SES indicator) and an ethnicity indicator for being Han Chinese; c is a constant term and ε_{ipk} is the error term. In effect, our specification controls for any cohort-specific[11] and province-specific factors, thus ruling these out as potential confounders. In order to account for the potential correlation of observations within the same province, we report standard errors clustered at the provincial level.

Individuals born in rural areas between the years 1954 and 1964 comprise the main sample of our analysis, which consists of 5509 observations, of which 2805 are female and 2704 are male. The coefficients of interest are represented by β_k, which measure the impact of the famine on mental health outcomes for each birth cohort k. In this analysis, we largely restrict our attention to the cohorts that were either in gestation or born during the famine years (1959–1961). Consistent with medical and economic evidence, these cohorts are expected to suffer the largest consequences of the deprivation caused by the famine.

5. Results

We start by looking at the effects of the famine on individuals of both genders. Table 1 presents results using both the EDR and the CSSI measures. The results in columns 1–3 suggest that there were limited effects of famines (as measured by EDR) on the cohorts born during the famine years (1959–1961). For the CESD-20 outcome, the interaction coefficients (between EDR and birth year) are largely positive, but the effects are largely statistically insignificant. The results are consistent to the use of other related outcome measures – log(CESD-20) and a categorical variable for Severe Stress (=1 if CSED20 $\geq$ 20). A similar pattern is observed in columns 4–6 when we use CSSI to proxy famine severity. An increase in famine intensity (as measured by CSSI) by one unit increases CESD-20 score by 0.6 points, a result that is statistically significant at the 10% level. Broadly the findings from this table suggest that there was an overall negative effect of famine on mental health, but the results are only marginally statistically significant.

To further probe this result, we split the sample by gender and examine the effects on women and men separately. The intuition for this comes from prior studies that have documented gender differentiated impacts of famines. Studies have found that while female fetuses and infants are more likely to survive famines (Kraemer, 2000; Zarulli et al., 2018), the adverse effects could persist later in life and become relatively more salient for females than for males (Chen et al., 2014; Zheng et al., 2012; Hu et al., 2017). These effects can be further exacerbated in a context like China where son preference is prevalent. Like in many other developing countries, Chinese families used to favor sons and invest more in sons than daughters (Mu and Zhang, 2011), especially in the pre-One Child Policy era. As early childhood malnutrition has a diminishing effect on children's cognitive functions (Ampaabeng and Tan, 2013), the famine might reinforce the gender gap in parental investment, thus exacerbating the effects of the famine on women.

Table 2 presents results from regressions that estimate the long-term effect of the Chinese famine on mental health of men and women separately. We report the coefficients of the interaction terms between excess death rate (measure of famine intensity) and the year of birth. Results in Column (1) of Table 2 clearly suggest that cohorts born during the famine years in areas of higher famine intensity have worse mental health as compared to those who were born during the same time in lesser affected regions. For example, the 1959 birth cohort has a CESD-20 score that is 0.9 points higher for every increase in famine intensity (EDR) by 0.01. Note that here we have controlled for a number of other individual, household, provincial and time-specific factors that might confound our analysis.

On the other hand, no such adverse impacts of the famine are observed for the male sample (column 4, Table 2). That is, men born during the famine years in higher intensity provinces do not face significantly higher mental health harm in adult life, as compared to men born in famine years in lower intensity cohorts. This implies that the Chinese famine led to differentially worse mental health among female survivors, but limited such effects on male survivors. Additionally, the negative effects on women's mental health are not only statistically significant but also economically meaningful. These findings are consistent with Huang et al. (2013) who also find that the famine's detrimental effect on well-being was maximum on the 1959 birth cohort, and was minimal on other cohorts.

A similar pattern is observed in Table 3 where we use the CSSI to proxy famine severity instead of the EDR measure. Columns 1–3 in Table 3 suggest females born during the famine (especially the 1959 birth cohort) experience worse mental health outcomes in the long run, while there are negligible effects on men (columns 4–6) born around the same time.

We conduct placebo checks to ensure that the effects we observe are truly driven by the Chinese famine, and not by other factors. We investigate whether the Chinese famine had an effect on people born in post famine years (1963–1967). We do so by running the main estimation model (described in Eq. 1) on a sample of people born between 1963 and 1967. One would expect that since these cohorts were born after the famine, they would not show any effects. The results from this check are shown in Table 4, and are in line with our expectations – there is no statistically significant effects on any mental health outcome for both men and women.

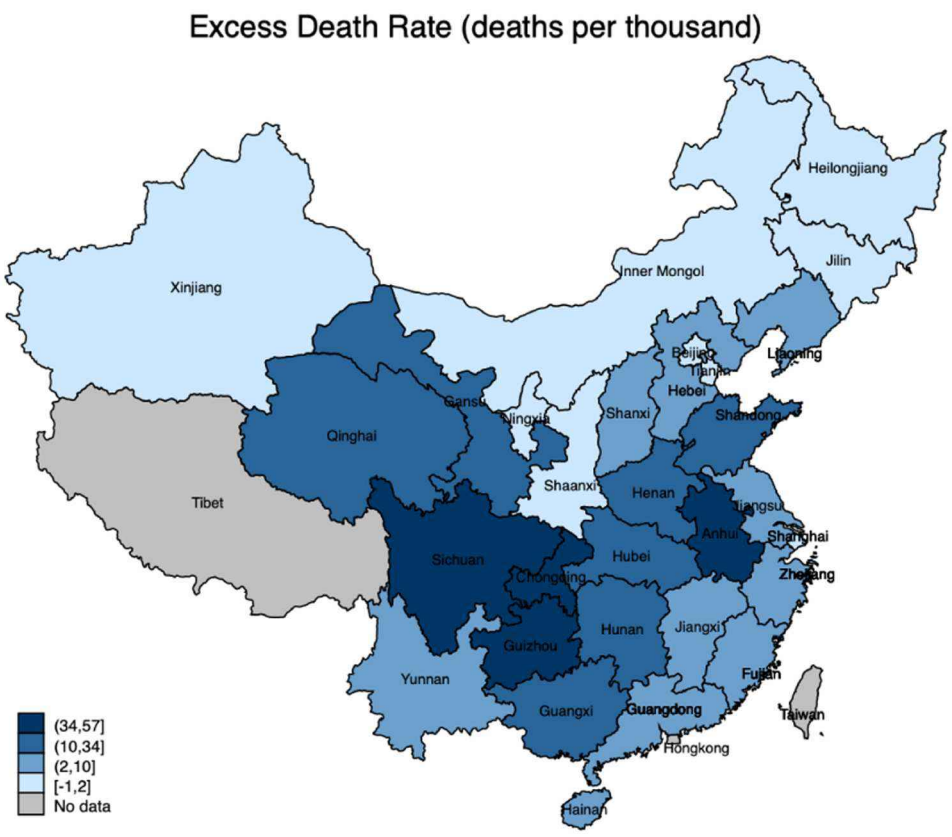
We also conduct a number of robustness checks to probe the sensitivity of the results to changes in different parts of the empirical strategy.

6. Robustness checks

6.1. Alternative dataset

One potential concern is that the results we observe could be an artifact of the CFPS dataset we use, and might not be observed in other datasets. To placate such concerns, we show that our results do not

[11] This effectively controls for all factors common among individuals born in that year, which includes average mental health status of all individuals born in that particular year. Since the majority of our results are based on split-sample analyses, we in effect control for gender-specific average mental health status of individuals born in a specific year.



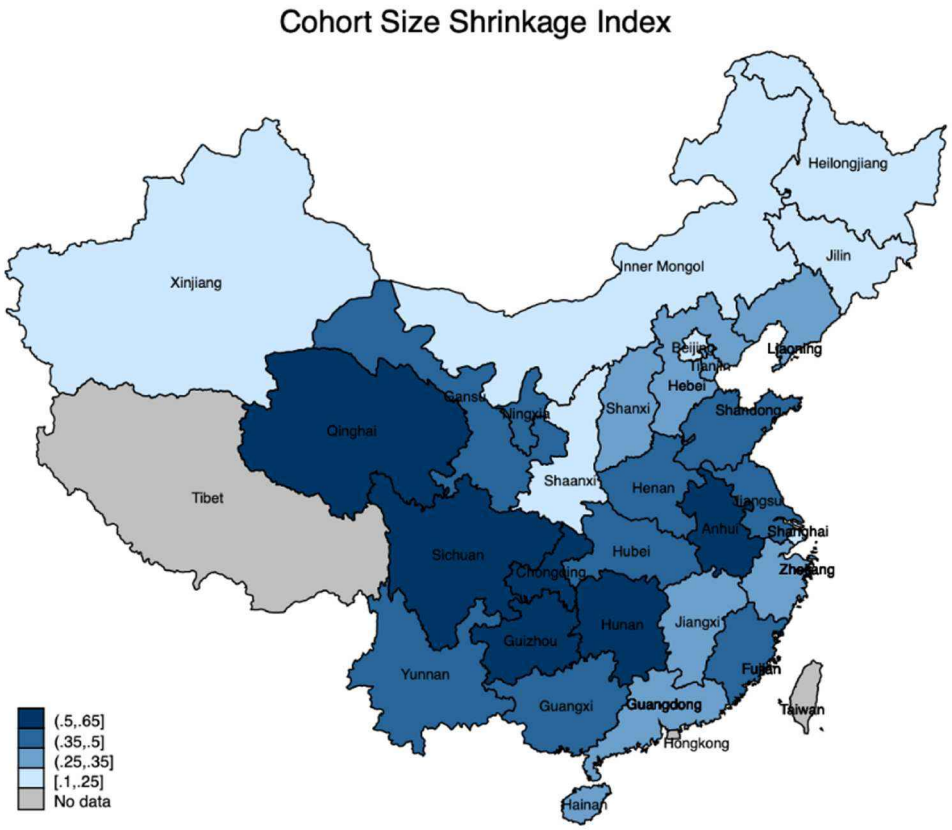


Fig. 1. Famine intensity measures across provinces. *Note:* This figure plots the spatial distribution of famine intensity across provinces in China. The top panel measures famine intensity by excess death rates, the difference of death rates in 1960 (the worst year of the famine) and the average death rate during 1956–1958, extracted from Lin and Yang (2000). The bottom panel measures famine intensity by cohort size shrinkage index, which is the ratio of the size of famine cohorts relative to the size of surrounding non-famine cohorts, extracted from Huang et al. (2013).

change significantly when we use the China Health and Retirement Longitudinal Study (CHARLS) dataset, instead of the CFPS data. The CHARLS dataset has information on the components of the CESD-10 measure, the construction of which has been explained earlier. Using this measure as the mental health outcome with EDR to proxy famine intensity, we find the same pattern as the main results – women born in the famine years have considerably worse long-run mental health (Table 5, columns 1–3) while the men born during the same period suffer no such negative consequences (Table 5, columns 4–6).

6.2. Alternative measures of mental health

Mental health can be measured using other indices, apart from the CESD-20 index that we use in the main set of results. One of these alternatives is the CESD-10 index, which we construct using the CFPS data (year 2012).

Results in Table A4 suggest that the pattern of our main results are preserved – there are adverse mental health effects for women born during the famine years (Table A4). Another alternative measure of mental health is the Kessler-6 index. The Kessler psychological distress index (K6) is calculated based on mental well-being questions from the 2014 round of CFPS (more details can be found in Kessler et al., 2002; Kessler et al., 2003). This index ranges from zero to 24, with higher values indicating lower well-being. We also create an indicator for psychological distress – which takes a value of one if the individual K6 score is above six. Again, the pattern of the main results are largely retained with females born in 1959 experiencing maximal negative impacts (see Table A5).[12]

We also consider other subjective measures of well-being in our analysis. These include responses to the following questions – "Are you satisfied with your life? (responses are on a scale of 1–5)", "How confident are you about the future? (responses are on a scale of 1–5)" and "Whether one can perform the following tasks independently – (1) eat, (2) kitchen activities, (3) take public transportation, (4) shopping, (5) cleaning and (6) laundry and (7) outdoor activities (responses are coded as Yes = 1 and No = 0 for each of them)". The responses on the life satisfaction and confidence questions are reported on a one to five scale, with higher scores indicating better well-being. The independence index is an aggregation of the indicators on the seven listed daily activities, and it ranges from zero to seven with higher values indicating lower dependency. The results from this analysis are presented in Table A6 – females born during famine years perform worse on each of these measures of subjective well-being, affirming our main results.

6.3. Other measures of famine severity

In addition to the two objective measures of famine severity that we use in our main analysis (EDR and CSSI), we probe the robustness of our results to another measure of famine intensity – the Weighted Death Rate (WDR). For any given individual, the WDR is defined as the weighted average of the province-year specific exposure to the famine depending on the individual's in-utero exposure to the famine. For example, if an individual was born in February of 1960, then the WDR would equal the sum of 2/9th of the annual death rate (ADR) of 1960 and 7/9th the ADR of 1959. Therefore, the value of WDR for individual i born in province p in year y in month m can be expressed as:

$$WDR_{pym} = {}^{m}_{9}(ADR_{p,y}) + {}^{9-m}_{9}(ADR_{p,y-1}) \quad (2)$$

This measure has been used previously to study the effects of the Chinese famine on physical health (Kim et al., 2017). We use this as a robustness check of our main analysis. In particular, we run the following regression specification:

$$Y_{ipym} = c + \beta WDR_{pym} + Cohirt_{k} + \mathrm{Prov}_{p} + \delta X_{ipy} + \varepsilon_{ipym} \quad (3)$$

Here the coefficient of interest is β which gives us the effect of WDR (famine severity) on the outcome of interest. The results from this analysis are presented in Table A7. They suggest that the famine had large negative effects on mental health – an increase in WDR by 0.1 increases CESD-20 scores for women by almost 0.3 points, while it increases the probability of being severely stressed by 3%, a result that is statistically significant at the 10% level. The results are similar when county fixed effects are used (columns 4–6) instead of province fixed effects (columns 1–3). This largely suggests that an increase in WDR (worse famine) leads to worse mental health, which is consistent with our main findings.

6.4. County fixed effects

In our main specification we control for province fixed effects. It might be the case that there are sub-provincial factors that might be correlated with famine intensity and mental health, which might bias our findings. Ideally, controlling for such sub-provincial factors might reduce this bias. Therefore, in a robustness check we add county fixed effects to our empirical specification, which plausibly accounts for a fair degree of the sub-provincial variation, and attenuates this bias. The results from this check are presented in Table A8 – with both the EDR measure (columns 1–3) and the CSSI measure (columns 4–6), women born in 1959 show worse mental health outcomes, in line with the main findings.

6.5. Other omitted factors

It is possible that both early life exposure to the famine and later life outcomes are simultaneously dependent on childhood socioeconomic backgrounds. We account for this by using individual and household-level covariates as controls in our regression specifications. As an additional sensitivity check, we expand this set of control covariates by leveraging the rich nature of the CHARLS data, which includes information on family socioeconomic status from when the interviewee was younger. In particular, we create the following ten indicators of childhood socioeconomic status, following Cui et al. (2020): household availability of cleaner cooking fuels (coal, gas or electricity as opposed to biomass fuels), availability of clean water, availability of electricity, death of biological father/mother, male/female guardian's main occupation, biological father/mother's education, and any of parents being a Communist Party member. We then aggregate these ten indicators into a composite index using Polychoric Principal Component Analysis, a more reliable measure than standard PCA when the variables are discrete (Kolenikov and Angeles, 2009). Including the first principal component as an additional control, we re-estimate Table 5 for the female sample. These results are presented in Table A9, and are in line with our main findings.

It is also possible that there are some *local* factors that might have simultaneously shaped both famine intensity and long-run outcomes of residents. Any such confounders would bias our findings. To account for such factors, in our main analysis we control for time-invariant local factors at the provincial level through province fixed effects, in addition to the other individual and household level covariates. This should potentially reduce some of these biases. Further, in a robustness check

[12] In fact, we have conducted additional analysis using the CFPS dataset to show that the famine had a gender-differentiated effect on physical health. Here, we particularly look at the impact of the famine on height, underweight status (if a person's BMI is smaller than 18.5) and whether the individual has any chronic disease. We find that women born during the famine suffered negative effects on these outcomes, while there were no statistically significant effects among men born in the same period (tables are available on request). Therefore, these results also follow a similar pattern to our mental health findings, thus confirming that these gender differentiated effects are not restricted to only mental health outcomes.

Table 1
Impacts of the famine on mental health.

VARIABLES	(1) CESD-20 Full	(2) Log CESD-20 Full	(3) SvrStress20 Full	(4) CESD-20 Full	(5) Log CESD-20 Full	(6) SvrStress20 Full
EDR*Born1959	0.38	0.04	0.01			
	(0.28)	(0.02)	(0.01)			
EDR*Born1960	0.28	0.03	0.01			
	(0.29)	(0.03)	(0.01)			
EDR*Born1961	0.17	0.03*	0.00			
	(0.23)	(0.02)	(0.02)			
CSSI				0.32	0.02	-0.00
CSSI*Born1959				0.66*	0.06**	0.02
				(0.35)	(0.03)	(0.02)
CSSI*Born1960				0.40	0.04	0.02
				(0.39)	(0.04)	(0.01)
CSSI*Born1961				0.15	0.05*	0.00
				(0.39)	(0.03)	(0.02)
Observations	5509	5509	5509	5509	5509	5509
R-squared	0.108	0.107	0.073	0.106	0.106	0.072

Note: Based on data from the 2012 round of CFPS. Columns 1–3 use excess death rates as a measure of famine intensity in the province of birth and Columns 4–6 use the cohort size shrinkage index. The CESD-20 measure ranges from 0 to 60, with higher values indicating worse mental health. The SevStress20 variable is a categorical variable that takes a value of 1 when the CESD-20 is greater than 20. Sample is restricted to those born in rural areas during 1954–1964. Control variables include hukou at age 3, ethnicity, province of birth and birth year fixed effects. Standard errors are clustered at the province level. *** significant at the one percent level, ** significant at the five percent level, * significant at the 10% level.

Table 2
Gender heterogeneous impacts of the famine (EDR) on mental health.

Variables	(1) CESD-20 Female	(2) Log CESD-20 Female	(3) SvrStress20 Female	(4) CESD-20 Male	(5) Log CESD-20 Male	(6) SvrStress20 Male
EDR*Born1959	0.90**	0.07***	0.05**	0.14	0.02	–0.01
	(0.35)	(0.02)	(0.02)	(0.44)	(0.04)	(0.02)
EDR*Born1960	–0.41	–0.01	–0.02	0.99	0.08	0.04**
	(0.36)	(0.02)	(0.03)	(0.64)	(0.05)	(0.02)
EDR*Born1961	–0.12	0.01	0.02	0.56	0.06*	–0.02
	(0.45)	(0.03)	(0.03)	(0.42)	(0.04)	(0.02)
Observations	2805	2805	2805	2704	2704	2704
R-squared	0.079	0.081	0.054	0.083	0.086	0.054
Mean Dep. Var.	15.43	2.63	0.29	12.17	2.38	0.16

Note: Based on data from the 2012 round of CFPS. Famine intensity in the province of birth is measured by excess death rates, the difference of death rates in 1960 (the worst year of the famine) and the average death rate during 1956–1958. Columns 1–3 report impacts for female and columns 4–6 report impacts for male. The CESD-20 measure ranges from 0 to 60, with higher values indicating worse mental health. The SevStress20 variable is a categorical variable that takes a value of 1 when the CESD-20 is greater than 20. Sample is restricted to those born in rural areas during 1954–1964. Control variables include hukou at age 3, ethnicity, province of birth and birth year fixed effects. Standard errors are clustered at the province level.
***, ** and * denote significance at the 1, 5, and 10% levels, respectively.

Table 3
Gender heterogeneous impacts of the famine (CSSI) on mental health.

VARIABLES	(1) CESD-20 Female	(2) Log CESD-20 Female	(3) SvrStress20 Female	(4) CESD-20 Male	(5) Log CESD-20 Male	(6) SvrStress20 Male
CSSI*Born1959	1.27**	0.10***	0.07**	0.20	0.04	–0.01
	(0.51)	(0.03)	(0.03)	(0.54)	(0.05)	(0.02)
CSSI*Born1960	–0.32	–0.01	–0.02	1.11	0.09	0.05**
	(0.49)	(0.04)	(0.04)	(0.79)	(0.07)	(0.02)
CSSI*Born1961	–0.10	0.04	0.02	0.45	0.06	–0.02
	(0.82)	(0.06)	(0.04)	(0.61)	(0.06)	(0.02)
Observations	2805	2805	2805	2704	2704	2704
R-squared	0.077	0.079	0.052	0.080	0.085	0.053
Mean Dep. Var.	15.43	2.63	0.29	12.17	2.38	0.16

Note: Based on data from the 2012 round of CFPS. Famine intensity in the province of birth is measured by cohort size shrinkage index, the ratio of the size of famine cohorts relative to the size of surrounding non-famine cohorts, extracted from Huang et al. (2013). Columns 1–3 report impacts for female and columns 4–6 report impacts for male. The CESD-20 measure ranges from 0 to 60, with higher values indicating worse mental health. The SevStress20 variable is a categorical variable that takes a value of 1 when the CESD-20 is greater than 20. Sample is restricted to those born in rural areas during 1954–1964. Control variables include hukou at age 3, ethnicity, province of birth and birth year fixed effects. Standard errors are clustered at the province level. ***, ** and * denote significance at the 1, 5, and 10% levels, respectively.

Table 4
Placebo – impacts of the famine on females born in post famine years.

Variables	(1) CESD-20 Female	(2) Log CESD-20 Female	(3) SvrStress20 Female	(4) CESD-20 Female	(5) Log CESD-20 Female	(6) SvrStress20 Female
EDR*Born1963	–0.02	–0.04	0.00			
	(0.52)	(0.04)	(0.02)			
EDR*Born1964	0.34	–0.01	0.02			
	(0.53)	(0.04)	(0.02)			
EDR*Born1965	0.08	–0.03	0.00			
	(0.50)	(0.04)	(0.03)			
EDR*Born1966	–0.03	–0.02	–0.01			
	(0.53)	(0.04)	(0.02)			
CSSI*Born1963				–0.12	–0.06	0.01
				(0.73)	(0.06)	(0.04)
CSSI*Born1964				0.33	–0.03	0.03
				(0.68)	(0.06)	(0.03)
CSSI*Born1965				0.20	–0.03	0.02
				(0.69)	(0.05)	(0.04)
CSSI*Born1966				0.00	–0.04	–0.00
				(0.70)	(0.05)	(0.03)
Observations	1662	1662	1662	1662	1662	1662
R-squared	0.103	0.100	0.068	0.102	0.100	0.068

Note: Based on data from the 2012 round of CFPS. This table investigates whether the Chinese famine had an effect on females born in post famine years (1963–1967). Sample is restricted to females born in rural areas during 1963–1967. Columns 1–3 use excess death rates as a measure of famine intensity in the province of birth and columns 4–6 use the cohort size shrinkage index. The CESD-20 measure ranges from 0 to 60, with higher values indicating worse mental health. The SevStress20 variable is a categorical variable that takes a value of 1 when the CESD-20 is greater than 20. Control variables include hukou at age 3, ethnicity, province of birth and birth year fixed effects. Standard errors are clustered at the province level.
*** significant at the one percent level, ** significant at the five percent level, * significant at the 10% level.

Table 5
Robustness analysis: gender heterogeneous impacts of the famine (EDR) – CHARLS data.

Variables	(1) CESD-10 Female	(2) Log CESD-10 Female	(3) SvrStress10 Female	(4) CESD-10 Male	(5) Log CESD-10 Male	(6) SvrStress10 Male
EDR*Born1959	–0.42	–0.08	–0.02	–0.30	–0.06	–0.05
	(0.42)	(0.06)	(0.03)	(0.47)	(0.08)	(0.03)
EDR*Born1960	0.66**	0.10***	0.10***	0.63	0.06	0.06
	(0.30)	(0.04)	(0.02)	(0.53)	(0.06)	(0.05)
EDR*Born1961	0.72**	0.11***	0.08***	0.19	–0.00	0.01
	(0.28)	(0.03)	(0.03)	(0.18)	(0.04)	(0.01)
Observations	1372	1372	1372	1442	1442	1442
R-squared	0.082	0.081	0.076	0.066	0.067	0.039
Mean Dep. Var.	9.02	2.02	0.40	6.79	1.73	0.27

Note: Based on data from the 2015 round of CHARLS. Famine intensity in the province of birth is measured by excess death rates, the difference of death rates in 1960 (the worst year of the famine) and the average death rate during 1956–1958. Columns 1–3 report impacts for female and columns 4–6 report impacts for male. The CESD-10 measure ranges from 0 to 30, with higher values indicating worse mental health. The SevStress10 variable is a categorical variable that takes a value of 1 when the CESD-10 is greater than 10. Sample is restricted to those born in rural areas during 1956–1963. Control variables include hukou at age 3, ethnicity, province of birth and birth year fixed effects. Standard errors are clustered at the province level.
***, ** and * denote significance at the 1, 5, and 10% levels, respectively.

we show that our results are not sensitive to including county fixed effects, which control for time-invariant differences at a sub-province level (and hence potentially account for more of these local differences).

Even so, it is possible that differences across provinces in policies adopted after the famine could bias our estimation. The direction of such a bias is apriori unclear – if relatively worse affected regions adopted policies that helped people overcome the challenges of the famine, then it would bias us towards not finding any effects, hence leading us to underestimate the true famine effect. Having said that, past studies have found no evidence of the presence of any such systematic differences in post-famine policy across provinces (Kim et al., 2017; Meng et al., 2015).

Further, there might be concerns that our estimates of the famine impacts are con-founded by the adverse influence of the 1966–1976 Cultural Revolution. Since the Cultural Revolution was majorly an urban phenomenon, it would not be expected to affect our results on the effects of the Chinese famine, which mainly affected rural populations.

7. Threats to identification

There might still remain some factors that might possibly confound our results. In this section we discuss some of these factors and their potential implications on our findings.

7.1. Selective fertility

During the famine years, childbearing fell substantially (Ashton et al., 1992; Peng, 1987)[13] This change in fertility could be associated with socio-economic characteristics, which might then potentially drive our results. We argue that this concern is not important in our context due to the fairly egalitarian socio-economic structure of rural China around the famine years. This uniformity in socio-economic status of rural households in China arose because of a series of systematic reforms that were implemented starting in the 1950s. For example, there were a number of collectivization policies that consolidated property rights and banned the private ownership of agricultural means of production.[14] There were other drastic measures taken to ensure further equality among rural populations, including the fact that villagers were mandated to eat all meals in commune kitchens, where the government supplied all the food (Chen and Zhou, 2007). Put together, the likelihood that our results are being driven by differential selection into childbearing is rather low.

Having said that, one might still argue that the fertility fall between 1959 and 1961 could be associated with other (potentially unobserved) aspects of socioeconomic status. It is possible that parents who decided to have children during these years might systematically vary from the general pool of potential parents. In such a scenario, it is most likely that children born during the famine would have come from families with better socio-economic and nutritional conditions. Such children would themselves have better endowments, which would in turn imply that we would be less likely to find any effects of the famine on these children. That is, we would be less likely to reject the null hypothesis of zero impact of fetal/early life exposure to the China Famine and would bias our results in a downward direction. This would make our findings underestimates of the true famine effect.

7.2. Selective migration

The intensity of the famine varied significantly across provinces. Central provinces were the worst hit, while northeastern provinces were relatively spared (see Fig. 1). If people were able to migrate from severely impacted areas to less-impacted regions, then that would affect the validity of our impact estimates. This is because selective migration would imply that the characteristics of the people left behind in severely affected regions would vary from the ones that were able to relocate. But this is not a major concern as there were strict Hukou regulations prohibiting the free movement of people across the country, especially in the case of rural to urban migration. This led to an overall low level of inter-provincial migration – it is estimated that it was only around 0.3–0.7% of the total population migrated across provinces between the years 1959 and 1963 (Chen and Zhou, 2007). Having said that, government-planned migration still occurred even during the most restrictive periods of China's centrally planned economy, but its magnitude was too small relative to the total population (see Liang and White, 1996) to have a considerable effect on our findings.

7.3. Selective mortality

It could also be the case that there was some kind of (socio-economic) selection effects that determined the children who ended up surviving the famine. Such a scenario would bias our impact estimates. Among children of both genders, it is most likely the case that those with the highest health endowments would be most likely to survive. This would mean that in the long run (five decades later), these healthier children would be less likely to show any effects of the famine, and hence would bias our estimates towards zero. Therefore, if there were selective mortality then our estimates should be considered an underestimate.

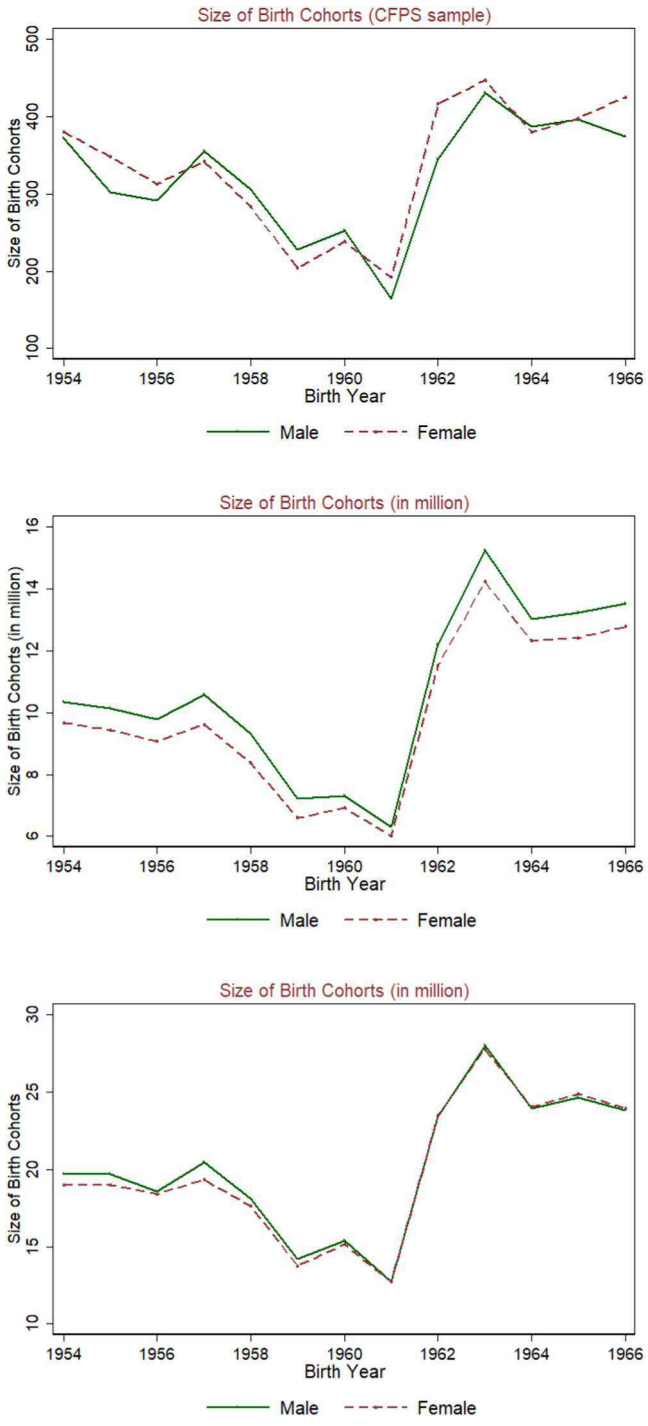


Fig. 2. Size of birth cohort across different surveys. *Note:* This figure plots the size of birth cohorts during 1954–1966, using different data sets. The top panel uses our analysis sample from CFPS 2012. The middle pattern presents a similar pattern using the 1990 census data and the bottom panel uses 2005 census data.

[13] This drop in fertility can also be observed using the CFPS data. The top panel of Fig. 2 shows that between 1958 and 1959 there is a sharp decline in the number of births, and this pattern continues in 1960 and 1961. This is followed by a rapid increase in 1962, after which birth cohort sizes stabilize. The same pattern is visible when using the 1990 census data and the 2005 census data (middle and bottom panels of Fig. 2).

[14] These included the 1952 Land Reforms, the Agricultural Collectivization (between 1953 and 1956) and 1958 Leap Forward.

7.4. Measurement error in famine intensity

It is possible that there is nontrivial measurement error in the different province-level measures of famine intensity which might bias our results. Such measurement error typically introduces attenuation bias, which makes the coefficient estimates closer to zero. Therefore, this type of measurement error would bias us against finding any significant effects. The fact that we still find effects further demonstrates the strength of our findings.

8. Discussion and conclusion

The Chinese Famine (1959–61) was one of the biggest event of its kind, and past studies have found that it has had an effect on a variety of educational, health and labor market outcomes (Almond and Currie, 2011; Chen and Zhou, 2007; Meng et al., 2015; Gooch, 2017; Shi, 2011). In this paper, we estimate the long-term effects of this famine on mental health outcomes. We use a difference-in-differences approach that leverages two sources of variations – the birth cohort of the individual and the famine intensity in their birth province. We find that there were negligible overall effects of the famine on mental health. But these overall findings conceal sizeable gender heterogeneity in impacts. Results suggest that women born during famine years experienced worse mental health outcomes in their late 50s, while men born in the same cohorts did not suffer any such harm.

The results we find are both economically and statistically significant, and demonstrate the large and pervasive effects of the Chinese famine. This also adds to the literature that explores the role of adverse health shocks in early childhood in shaping health outcomes in adulthood. Additionally, these findings are consistent with previous studies that find enduring effects of early-life shocks in women but not men (Maccini and Yang, 2009; Mu and Zhang, 2011; Yang et al., 2008).

We hypothesize that our results are due to a combination of two factors – (1) the higher mortality risk among male fetuses, especially under conditions of stress (like famine), and (2) the importance of fetal and early-life conditions in shaping later life outcomes. Part of our findings can be attributed to the sex-selective mortality experienced during the in-utero and infancy periods. Due to the biological fragility of male fetuses, they are at greater overall risk of mortality (across the life cycle) as compared to females (Kraemer, 2000; Mizuno, 2000). This sex-specific fetus mortality becomes more salient in conditions of extreme stress, and leads to an abrupt decline in the ratio of males to females among birth cohorts in gestation during the Chinese famine (Mu and Zhang, 2011; Song, 2012). Such selection effects can also exist after birth – newborn girls were able to survive extreme famines better than newborn boys (Zarulli et al., 2018). Therefore, the "selection" effect of the famine, which posited that only the robust individuals would survive the famine, was stronger among males than among females. This mortality selection in part explains why male survivors have better health than the unaffected birth cohorts while female survivors are worse off than their unaffected counterparts (Mu and Zhang, 2011). Our results might also be driven by the well-recognized Fetal Origins Hypothesis (Barker, 1990), that states that in-utero shocks can change the epigenome in favor of survival, but this may come at the cost of a higher likelihood of developing various diseases in later stages of life. Prenatal nutritional deficiency leads to the reprogramming of post-natal brain gene expression, thus increasing the risk of adult mental illness (Hales and Barker, 2001; O'Neil et al., 2014). For female survivors in our sample, this fetal origins adverse effect of the famine dominates the mortality selection effect, leading to worse mental health later in life. Since women are about twice as likely as men are to develop depression during their lifetime (Kuehner, 2017; Albert, 2015), our results imply that the higher risk of women to suffer from depression is further exacerbated by additional in-utero famine exposure.

With accelerating global climate change, famines and other extreme weather events are happening at increasing frequency and at larger scales. In the wake of this, it is important for policymakers to understand the potential longer-term effects of such events on health outcomes of survivors. Our study shows that these negative effects may persist almost five decades after the event. This evidence supports policies and programs that are targeted towards high-risk populations, and suggests that these targetted initiatives might have large bang-for-the-buck in the longer run (because of their potential for reducing health care expenditures in the long-run). Our results also speak to the potential long-term gains that can be realized by reducing maternal and child deprivation during gestation and in infancy, especially in a context like China. The findings suggest that the benefits of such interventions are experienced even five decades later.

Appendix A. Additional Figures and Tables

Please find the appendix Section here.

Table A1
Component items of the CESD indices.

Items	Description	CESD-10	CESD-20
1.	I was bothered by things that usually don't bother me	X	X
2.	I did not feel like eating, my appetite was poor.		X
3.	I felt that I could not shake off the blues even with help from my family or friends.		X
4.	I felt I was just as good as other people.		X
5.	I had trouble keeping my mind on what I was doing.	X	X
6.	I felt depressed.	X	X
7.	I felt that everything I did was an effort.	X	X
8.	I felt hopeful about the future.	X	X
9.	I thought my life had been a failure.		X
10.	I felt fearful.	X	X
11.	My sleep was restless.	X	X
12.	I was happy.	X	X
13.	I talked less than usual.		X
14.	I felt lonely.	X	X
15.	People were unfriendly.		X
16.	I enjoyed life.		X
17.	I had crying spells.		X
18.	I felt sad.		X
19.	I felt that people dislike me.		X
20.	I could not get going.	X	X

Note: This table lists the 20 items that form the CESD-20 index. We also indicate the subset of items included in CESD-10 indices, which are used in different parts of the analysis.

Table A2
Summary statistics of CESD indices.

	CFPS			CHARLS		
	Female	Male	Full	Female	Male	Full
CESD-10	8.10	6.24	7.19	9.02	6.79	7.88
SevereStress10	0.35	0.20	0.27	0.40	0.27	0.33
CESD-20	15.43	12.17	13.83			
SevereStress20	0.29	0.16	0.23			
N	2805	2704	5509	1372	1442	2814

Note: The CESD-10 measure ranges from 0 to 30, while the CESD-20 measure ranges from 0 to 60. Higher values indicate worse mental health. The SevereStress10 variable is a categorical variable that takes a value of 1 when the CESD-10 is greater than 10. The SevereStress20 variable is a categorical variable that takes a value of 1 when the CESD-20 is greater than 20.

Table A3
Death rates (per thousand) and famine intensity.

Province	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	Excess Death Rate	Cohort Size Shrinkage Index
Beijing	8.6	9.5	7.7	8.2	8.1	9.7	9.1	10.8	8.8	8.1	8.3	6.8	7.2	1.1	0.2
Tianjin	9.3	9.9	8.8	9.4	8.7	9.9	10.3	9.9	7.4	7.3	7.8	6.2	6.9	1.3	0.3
Hebei	12.1	11.6	11.3	11.3	10.9	12.3	15.8	13.6	9.1	11.2	10.9	8.7	8.7	4.6	0.3
Shanxi	14.7	12.9	11.6	12.7	11.7	12.8	14.2	12.2	11.3	11.4	14	10.4	10.3	2.2	0.3
Neimenggu	20.9	11.4	7.9	10.5	7.9	11	9.4	8.8	9	8.5	11.8	9.3	8.1	0.6	0.2
Liaoning	8.6	9.4	6.6	9.4	6.6	11.8	11.5	17.5	8.5	7.9	9.3	7.1	6.2	4.0	0.3
Jilin	10.4	9.9	7.5	11.3	9.1	13.4	10.1	12	10	9.4	12.6	9.7	8.6	0.8	0.2
Heilongjiang	11.1	11.3	10.1	12.7	9.2	12.8	10.6	11.1	8.6	8.6	11.5	8	7.4	-0.1	0.2
Shanghai	7.1	8.1	6.8	10.5	5.9	6.9	6.8	7.7	7.3	7	6.1	5.7	5.3	-0.9	0.2
Jiangsu	12.2	11.8	13	6	9.4	14.6	18.4	13.4	10.4	9	10.1	9.5	8.1	8.9	0.4
Zhejiang	13.4	12.6	9.5	10.3	9.2	10.8	11.9	9.8	8.6	7.9	9.2	8.1	7.1	2.2	0.4
Anhui	16.6	11.8	14.3	9.3	12.3	16.7	68.6	8.1	8.2	7.9	8.6	7.2	7.1	56.6	0.6
Fujian	10.9	8.9	8.4	9.1	7.5	7.9	15.3	11.9	8.3	7.4	8.6	7.3	7.1	7.0	0.4
Jiangxi	14.2	16.2	12.5	7.9	11.3	13	16.1	11.5	11	9.8	10.9	9.4	8.5	5.5	0.4
Shandong	11.7	13.7	12.1	11.5	12.8	18.2	23.6	18.4	12.4	11.8	12	10.2	9.9	11.5	0.4
Henan	13.3	11.8	14	12.1	12.7	14.1	39.6	10.2	8	9.4	10.6	8.5	8.2	26.7	0.5
Hubei	15.9	11.6	10.8	11.8	9.6	14.5	21.2	9.1	8.8	9.8	10.9	10	9.7	10.5	0.4
Hunan	17.5	16.4	11.5	9.6	11.7	13	29.4	17.5	10.2	10.3	12.9	11.2	10.2	18.5	0.5
Guangdong	11.2	10.6	11.1	10.4	9.2	11.1	15.2	10.8	9.4	7.6	8.3	6.8	6.4	5.0	0.4
Guangxi	15.2	14.6	12.5	12.4	11.7	17.5	29.5	19.5	10.3	10.1	10.6	9	7.5	17.3	0.5
Sichuan	8.4	9.2	10.4	12.1	25.2	47	54	29.4	14.6	12.8	13.9	11.5	10.8	38.1	0.6
Guizhou	8.8	8.1	7.5	8.8	13.7	16.2	45.4	17.7	10.4	9.4	10.5	8.4	9.2	35.4	0.5
Yunnan	16.7	13.7	15.2	16.3	21.6	18	26.3	11.8	10.9	14.1	15.2	13	10.8	8.6	0.4
Shaanxi	11	10.5	9.9	10.3	11	12.7	12.3	8.8	9.4	10.6	15.6	13	12.9	1.9	0.3
Gansu	11.6	11.9	10.8	11.3	21.1	17.4	41.3	11.5	8.3	10.4	15.6	12.3	11.5	26.9	0.5
Qinghai	13.3	14.1	9.4	10.4	13	16.6	40.7	11.7	5.4	8.4	15.5	9.1	9.8	29.8	0.5
Ningxia	13.1	10.2	10.6	11.1	15	15.8	13.9	10.7	8.5	10.2	13.4	9.3	9.4	1.7	0.4
Xinjiang	16.8	14.4	14.2	14	13	18.8	15.7	11.7	9.7	9.4	16.3	11.1	9.4	2.0	0.2

Note: The death rates in 1954–1964 are extracted from Lin and Yang (2000). Excess death rates are the difference of death rates in 1960 (the worst year of the famine) and the average death rate during 1956–1958. Cohort size shrinkage index is the ratio of the size of famine cohorts relative to the size of surrounding non-famine cohorts, extracted from Huang et al. (2013).

Table A4
Robustness analysis: using 10-item CESD indices to measure mental health (females only).

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	CESD-10	Log CESD-10	SvrStress10	CESD-10	Log CESD-10	SvrStress10
EDR*Born1959	0.51*	0.08**	0.05*			
	(0.25)	(0.03)	(0.03)			
EDR*Born1960	–0.22	–0.01	–0.01			
	(0.22)	(0.04)	(0.01)			
EDR*Born1961	0.09	0.03	0.01			
	(0.30)	(0.04)	(0.03)			
CSSI*Born1959				0.60*	0.09**	0.06*
				(0.34)	(0.04)	(0.03)
CSSI*Born1960				–0.22	–0.00	–0.02
				(0.27)	(0.05)	(0.02)
CSSI*Born1961				0.14	0.05	0.01
				(0.50)	(0.06)	(0.04)
Observations	2835	2835	2835	2835	2835	2835
R-squared	0.060	0.057	0.048	0.057	0.055	0.046

Note: Based on data from the 2012 round of CFPS. Sample is restricted to females born in rural areas during 1954–1964. The main set of results have all used 20-item CESD indices as measures of mental health. We examine the robustness of the results to the 10-item version of CESD indices. The CESD-10 measure ranges from 0 to 30, with higher values indicating worse mental health. The SevStress10 variable is a categorical variable that takes a value of 1 when the CESD-10 is greater than 10. Columns 1–3 use excess death rates as a measure of famine intensity in the province of birth and Columns 4–6 use the cohort size shrinkage index. Control variables include hukou at age 3, ethnicity, province of birth and birth year fixed effects. Standard errors are clustered at the province level. *** significant at the one percent level, ** significant at the five percent level, * significant at the 10% level.

Table A5
Robustness analysis: using the Kessler-6 index to measure mental health (females only).

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	K6	Log K6	SvrStress-K6	K6	Log K6	SvrStress-K6
EDR*Born1959	0.36	0.01	0.04**			
	(0.24)	(0.05)	(0.02)			
EDR*Born1960	–0.14	–0.04	0.01			
	(0.41)	(0.09)	(0.02)			
EDR*Born1961	0.59*	0.08	0.05**			
	(0.29)	(0.06)	(0.02)			
CSSI*Born1959				0.59*	0.05	.05***
				(0.30)	(0.06)	(0.02)
CSSI*Born1960				0.07	–0.01	0.02
				(0.43)	(0.08)	(0.02)
CSSI*Born1961				0.54	0.06	0.05**
				(0.40)	(0.08)	(0.02)
Observations	2761	2761	2761	2761	2761	2761
R-squared	0.066	0.070	0.032	0.064	0.068	0.033
Mean Dep. Var.	3.96	1.21	0.06	2.89	0.95	0.03

Note: Based on data from the 2014 round of CFPS. Sample is restricted to females born in rural areas during 1954–1964. We examine the robustness of the results to the alternative measure of mental health, Kessler Psychological Distress Scale (Kessler-6). This index ranges from zero to 24, with higher values indicating lower well-being. The SevStress-K6 variable is a categorical variable that takes a value of 1 when the Kessler-6 index is greater than 6. Columns 1–3 use excess death rates as a measure of famine intensity in the province of birth and Columns 4–6 use the cohort size shrinkage index. Control variables include hukou at age 3, ethnicity, province of birth and birth year fixed effects. Standard errors are clustered at the province level. *** significant at the one percent level, ** significant at the five percent level, * significant at the 10% level.

Table A6
Robustness analysis: other measures of life satisfaction and daily functioning (females only).

	(1) Satisfied	(2)Confident Future	(3) Independent AllTasks	(4) Satisfied	(5) Confident Future	(6) Independent AllTasks
EDR*Born1959	–0.20***	–0.16***	–0.10**			
	(0.06)	(0.05)	(0.05)			
EDR*Born1960	–0.08	–0.06	0.07**			
	(0.06)	(0.04)	(0.03)			
EDR*Born1961	–0.02	0.04	–0.02			
	(0.06)	(0.06)	(0.08)			
CSSI*Born1959				–0.16*	–0.15**	–0.09
				(0.08)	(0.06)	(0.06)
CSSI*Born1960				–0.05	–0.03	0.06
				(0.09)	(0.07)	(0.04)
CSSI*Born1961				–0.05	–0.00	0.06
				(0.07)	(0.09)	(0.10)
Observations	2868	2845	2941	2868	2845	2941
R-squared	0.041	0.038	0.023	0.040	0.037	0.023

Note: Based on data from the 2012 round of CFPS. Sample is restricted to females born in rural areas during 1954–1964. We examine the robustness of the results to a series of subjective measures of mental well-being. The variables "satisfied" and "confident future" represent the responses to the following two questions, respectively – "Are you satisfied with your life? (responses are on a scale of 1–5)", "How confident are you about the future? (responses are on a scale of 1–5)". The variable "Independent All Tasks" is an aggregation of the indicators on seven listed daily activities, and it ranges from zero to seven with higher values indicating lower dependency. Columns 1–3 use excess death rates as a measure of famine intensity in the province of birth and Columns 4–6 use the cohort size shrinkage index. Control variables include hukou at age 3, ethnicity, province of birth and birth year fixed effects. Standard errors are clustered at the province level. *** significant at the one percent level, ** significant at the five percent level, * significant at the 10% level.

Table A7
Robustness analysis: using weighted death rates to measure famine intensity (females only).

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	CESD-20	Log CESD-20	SvrStress20	CESD-20	Log CESD-20	SvrStress20
Weighted Death Rate	0.316	0.000	0.027*	0.270	–0.004	0.024*
	(0.300)	(0.018)	(0.013)	(0.340)	(0.021)	(0.013)
Observations	2475	2475	2475	2475	2475	2475
R-squared	0.078	0.079	0.051	0.193	0.228	0.141

Note: Based on data from the 2012 round of CFPS. Sample is restricted to females born in rural areas during 1954–1964. We examine the robustness of the results to the alternative measure of famine intensity, the Weighted Death Rates. This index is defined as the weighted average of the province-year specific exposure to the famine depending on the individual's in-utero exposure to the famine. Control variables include hukou at age 3, ethnicity, province of birth and birth year fixed effects. Standard errors are clustered at the province level. *** significant at the one percent level, ** significant at the five percent level, * significant at the 10% level.

Table A8
Robustness analysis: inclusion of county fixed effects (females only).

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	CESD-20	Log CESD-20	SvrStress20	CESD-20	Log CESD-20	SvrStress20
EDR*Born1959	0.93**	0.08***	0.05*			
	(0.41)	(0.03)	(0.03)			
EDR*Born1960	–0.39	–0.00	–0.02			
	(0.46)	(0.04)	(0.03)			
EDR*Born1961	–0.57	–0.03	0.00			
	(0.50)	(0.03)	(0.03)			
CSSI*Born1959				1.27**	0.10***	0.06*
				(0.58)	(0.03)	(0.03)
CSSI*Born1960				–0.33	–0.01	–0.02
				(0.69)	(0.05)	(0.04)
CSSI*Born1961				–0.78	–0.03	0.00
				(0.78)	(0.05)	(0.04)
Observations	2805	2805	2805	2805	2805	2805
R-squared	0.196	0.223	0.141	0.194	0.221	0.140

Note: Based on data from the 2012 round of CFPS. Sample is restricted to females born in rural areas during 1954–1964. The main set of results have all used province fixed effects. We examine the robustness of the results to the control of county fixed effects. Columns 1–3 use excess death rates as a measure of famine intensity in the province of birth and Columns 4–6 use the cohort size shrinkage index. The CESD-20 measure ranges from 0 to 60, with higher values indicating worse mental health. The SevStress20 variable is a categorical variable that takes a value of 1 when the CESD-20 is greater than 20. Control variables include hukou at age 3, ethnicity and birth year fixed effects. Standard errors are clustered at the province level. *** significant at the one percent level, ** significant at the five percent level, * significant at the 10% level.

Table A9
Robustness check: controlling for childhood socioeconomic status (females only).

Variables	(1) CESD-10 Female	(2) Log CESD-10 Female	(3) SvrStress10 Female	(4) CESD-10 Female	(5) Log CESD-10 Female	(6) SvrStress10 Female
EDR*Born1959	–0.42	–0.08	–0.02			
	(0.42)	(0.06)	(0.03)			
EDR*Born1960	0.66**	0.10***	0.10***			
	(0.30)	(0.04)	(0.02)			
EDR*Born1961	0.72**	0.11***	0.08***			
	(0.28)	(0.03)	(0.03)			
CSSI*Born1959				–0.45	–0.08	–0.02
				(0.68)	(0.09)	(0.05)
CSSI*Born1960				1.02*	0.16**	0.13***
				(0.57)	(0.08)	(0.04)
CSSI*Born1961				0.90**	0.13**	0.11***
				(0.36)	(0.05)	(0.03)
Observations	1372	1372	1372	1372	1372	1372
R-squared	0.082	0.081	0.077	0.083	0.081	0.077

Note: Based on data from the 2015 round of CHARLS. Sample is restricted to females born in rural areas during 1956–1963. We examine the robustness of the results to adding the additional control of childhood socioeconomic status (composite index). Columns 1–3 use excess death rates as a measure of famine intensity in the province of birth and Columns 4–6 use the cohort size shrinkage index. The CESD-10 measure ranges from 0 to 30, with higher values indicating worse mental health. The SevStress10 variable is a categorical variable that takes a value of 1 when the CESD-10 is greater than 10. Standard errors are clustered at the province level. *** significant at the one percent level, ** significant at the five percent level, * significant at the 10% level.

Appendix B. Potential Mechanisms

In this paper we document long-run (more than five decades later) effects of childhood exposure to the Chinese famine on mental health outcomes. There could be several channels that explain the adverse mental health effect of early life exposure to famine, which we discuss below:

1) Phenotype: In-utero and early childhood are critical phases for physical and mental development of an individual, and malnutrition in these periods may cause permanent deficits/anomalies in the brain and the nervous system (de Rooij et al., 2010). It has been established that a lack of food during a famine has adverse effects on diets of mothers, which in turn can have an impact the neurological, immunological, and central nervous system development of their offspring (O'Neil et al., 2014). Additionally, prenatal nutritional deficiency leads to the reprogramming of postnatal brain gene expression, which in turn contributes to an increased risk of adult mental illness (Hales and Barker, 2001; O'Neil et al., 2014).
2) Physical health: There is a large literature documenting the negative effects of in-utero exposure to adverse events on a variety of physical health outcomes, including height (Gørgens et al., 2012), disability (Mu and Zhang, 2011), overweight status (Song et al., 2020; Chang et al., 2018; Yang et al., 2008), metabolic-related chronic conditions (Grey et al., 2021; Chen et al., 2014; Zheng et al., 2012), chronic diseases (Hu et al., 2017) and general health status (Fan and Qian, 2015). Since physical and mental health are correlated, such adverse physical health effects may have further knock-on negative effects on mental well-being. In fact, we use our data to document some of these negative effects of famine on physical health outcomes (see discussions in footnote 11).
3) Other socio-economic factors: Additionally, the mental health effects that we document could also partially have been driven by effects that early childhood famine exposure might have on other intermediate socioeconomic outcomes. Here we explore the role of a few such factors:
   - Education: It is known that childhood famine exposure leads to worse educational outcomes among affected cohorts, especially for women (Lay and Norling, 2020; Ampaabeng and Tan, 2013; Mu and Zhang, 2011). This lower level of education can in turn lead to worse later-life mental health, as has been demonstrated by a growing literature which explores the positive gradient between education and mental health (Courtin et al., 2019; Dursun and Cesur, 2016).
   - Labor market: Akin to the effects on education, studies have documented negative effects on labor market outcomes among individuals affected by the Chinese famine (Chen and Zhou, 2007; Almond et al., 2007). In turn, these adverse labor market outcomes might have further effects on psychological well-being.
   - Marriage: Marriage market outcomes have a profound effect on mental well-being, especially for women (Kim et al., 2015). Studies suggest that the famine cohorts had poor marriage market outcomes in terms of marriage rates. In particular, women married spouses with lower education and later, compared to the non-famine female cohorts, which further affects household wealth later in life (Almond et al., 2007). Therefore, marriage market outcomes are also a plausible channel through which the negative mental health outcomes could have been mediated.
   - Intergenerational effects: If the famine cohorts have lower health and economic in adulthood, then the famine effect could be passed on to their own children, in terms of poor birth outcomes and lower education achievement. The literature seems to suggest that this intergenerational transmission is plausible – children of mothers affected at birth by natural disasters have lower cognitive scores, education achievement and physical health (Cheng et al., 2020). Such worse outcomes for the future generations might in turn affect the mental health of the parents (i.e. the famine cohorts themselves), especially the mothers (Daysal et al., 2020).
4) Son preference: Like in many other developing countries, Chinese families used to favor sons and invest more in sons than daughters (Mu and Zhang, 2011), especially in the pre-One Child Policy era. Parents in such cultures allocate more resources to sons at the expense of daughters, especially when resources are constrained. As early childhood malnutrition has a diminishing effect on children's cognitive functions (Ampaabeng and Tan, 2013), the famine might reinforce the gender gap in parental investment, thus exacerbating the effects of the famine on women.

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