Echo Effects of Health Shocks: The Intergenerational Consequences of Prenatal and Early-Life Malnutrition during the Great Leap Forward Famine in China [*]

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Abstract

Relatively few studies have examined the "echo effect" of health shocks related to prenatal and early-life malnutrition, that is, whether the legacy of such shocks is transmitted to the next generation. This study addresses this gap by leveraging extreme malnutrition during the Great Leap Forward famine in China, and by examining its intergenerational consequences. Using a difference-in-differences framework, we estimate the effect of the famine on a wide range of outcomes of children of mothers who were exposed *in-utero* and in early-life including income, education, and employment, indicators that have not been considered in detail before. Using a refined measure of famine exposure at the prefecture level in rural areas, and by exploiting rich data on those directly affected and their children, we find that on average, the famine had negative echo effects on second-generation outcomes. These echo effects are primarily due to adverse impacts on daughters. Mechanisms include impacts of the famine on the human capital of mothers, and suggestive evidence of son preference. Our results withstand a battery of robustness, specification and falsification checks.

Keywords: *In utero* effects, Early-life impacts, Great Leap Forward famine, Malnutrition, Intergenerational impacts, Daughters, Sons, Labour market, China

JEL Codes: I15, J62, I32, P36, N45

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Section 1. Introduction and literature

The Foetal Origins hypothesis attributed to Barker (2007) postulates that nutritional deprivation experienced prenatally can have long-lasting implications. This hypothesis has been applied by economists in a variety of contexts both in the developed and developing world, and they have found that early-life experiences have important effects on human capital outcomes later in life. An explanation is that prenatal exposure to adverse environments "programs" the foetus to develop particular metabolic characteristics, likely through effects on the epi-genome. One stream of the literature has used exposure to famine as a natural experiment to test this, exploiting famines across a variety of settings including 19th-century crop failures in Sweden and Finland, the Siege of Leningrad of 1941–44, the Dutch Hunger Winter of 1944–45, the Chinese Great Leap Forward (GLF) famine of 1959–61, and the Bangladesh famine of 1974 (Lumey *et al* 2011). Among these, the Chinese GLF famine stands out for its intensity and duration. The health and education impacts of the GLF famine on those who were either directly exposed *in utero* or exposed at very young ages are well analysed.[1] The overall conclusion of these studies is that the famine caused significant impairment in human capital. The few instances of positive impacts were attributed to positive selection or selection in mortality among those who survived (Gorgens *et al*. 2012, Xu *et al*. 2016).

An important question is whether there is an "echo effect" of extreme shocks related to prenatal malnutrition. That is, when the cohort conceived or born during famines starts to bear children of their own, do the health or socio-economic consequences of the famine pass on to their offspring who have not been directly affected? There are two reasons why the first generation's early-life malnutrition shocks may influence outcomes of the second generation. First, the child of a famine-born parent may suffer due to famine-induced irregularities in the parental reproductive system. Indeed, epidemiologists have shown that adverse *in-utero* experiences may permanently affect maternal growth and development and alter the mother's metabolism providing an adverse environment for her fetus (Drake & Walker 2004). Second, parents born during famine may develop worse outcomes, which, by altering the environment in which their children are raised, lead to lower achievements in the second generation.

The possibility of an intergenerational echo effect of the GLF famine was initially documented by Almond *et al*. (2010). Such an echo effect might be more salient for the children of women who suffered prenatal malnutrition during the famine. This is because girls are born with their complete reproductive genetic material that would carry imprints of the famine, or may have been conditioned by it. Importantly, these genetic pre-determinants cannot change over the life course. Hence, the fact that women are born with their complete “genetic coding” with little possibility of correcting insults suffered very early on can have intergenerational consequences.[2]

Empirical research examining the intergenerational effect of the GLF famine on offspring outcomes is relatively sparse and mostly focuses on early-life health and education outcomes of children. Using data from the China Health and Nutrition Surveys (CHNS), Fung and Ha (2010) studies the effects of famine on both the generation who were directly exposed in utero and the next generation. They find negative intergenerational effects on height-for-age and weight-for-age but no significant effects on years of schooling. Using data from the Monitoring Social and Economic Development of West China and province-level excess death rates (EDR) to capture famine intensity, Zhang (2012) finds that children of women exposed to famine are more likely to be overweight and to have lower educational attainment. Kim *et al*. (2014) examines the effect of famine on offspring level of schooling using Chinese Census data in 2000 and province-level EDR to measure famine intensity. Recognizing that the province-level EDR is likely to suffer from measurement error, they instrument this indicator with weather shocks and find lower schooling attainment in the second generation. Tan *et al*. (2017) uses data from the China Family Panel Studies and province-level EDR as the famine intensity measure to estimate intergenerational effects on children’s cognitive abilities. They find children born to female survivors were not affected, but daughters of male survivors have lower cognitive scores. Finally, Wu (2016) uses China Health and

Retirement Longitudinal Study (CHARLS) data and province-level EDR to analyse intergenerational impacts on children's education and finds that, contrary to the literature, those who had at least one parent exposed were likely to attain a higher educational level. To the best of our knowledge, only one study focuses on evaluating intergenerational famine effects on offspring's economic and labour market outcomes during adulthood. Using data from the CHNS and provincial weighted EDR as an estimate of famine intensity, Kim *et al*. (2010) finds that children of those who were directly exposed to the famine work fewer hours and earn lower wages.

Hence, research to date provides limited evidence on the intergenerational consequences of the famine on children's economic and labour market outcomes. This may be due to the paucity of national representative data that captures both generations and provides in-depth information on outcomes. Further, studies document conflicting results. One reason for such discrepancy may be the use of a famine exposure measure that is at an aggregate level. The famine intensity measure used throughout the intergenerational literature – province-level EDR – may conflate estimates in rural and urban locales and may not recognise substantial within-province variation in famine intensity. Such discrepancy in results might also arise due to measurement error in individual-level famine intensity - most data sets in these studies do not contain information on respondents' birthplace, thus the province in which the respondent is currently resident is used as a proxy to construct individual-level famine intensity. The direction of bias related to this type of measurement error is unknown.

It is important, both from a research and policy standpoint, to carefully document evidence on the long-term spill over effects of this disaster on subsequent generations in terms of their income and work propensities. For example, Cook *et al*. 2019 finds that the influenza pandemic of 1918 impacted two generations of offspring of survivors in the United States, and from a policy standpoint, posits that such biosocial influences may be mechanisms that explain the multigenerational persistence of poverty. A comprehensive understanding of similar long-run dynamics is key to addressing the equity consequences of the GLF famine in China.

Our study tests the hypothesis that early-life shocks from the GLF famine had an echo effect on the next generation by focusing on mothers who were affected in early-life – although we consider fathers as well in results not reported, we hypothesize that mothers that suffered malnutrition in important prenatal stages have the relatively higher likelihood of transmitting their possibly defective genetic imprint to the next generation. Moreover, women born during the famine constitute a more representative sample than men born during the famine, as the latter are likely to be positively selected given the fragility of male fetuses (Sanders and Stoecker 2015). We examine the intergenerational consequences of the famine on children's economic and labour market outcomes using the CHARLS data. Our identification exploits substantial variation in famine intensity across both time and areas (cities/prefectures) in a difference-in-differences (DID) framework, and considers various labour market indicators for children in the second generation including income, education, and employment.

Our study contributes to the literature on the long-term consequences of the famine in several ways. First, while some studies have documented intergenerational effects of the famine in terms of children's early-life health and educational factors, there is limited evidence on labour market outcomes when children reach adulthood. This is perhaps due to paucity of detailed data spanning such a long period for both generations. By focusing on later-life outcomes such as income and employment in adulthood, we address the subsequent question of whether the famine had an even longer-term impact on the second generation (beyond impeding schooling as documented by the literature).

Second, the CHARLS data allow us to use an improved measure of famine exposure. In the CHARLS data, respondents' places of residence and birthplaces are known at the prefecture-level[3] which allows us to match respondents to famine severity measures in their prefecture of birth. Following Xu *et al*. (2016), we use Chinese census data to construct prefecture-level cohort size shrinkage index (CSSI) indicators that vary by rural and urban areas. This type of cohort size-based measures are relatively better than mortality-based measures alone as they capture changes in both mortality and fertility dynamics induced by the famine. As depicted in Figure 1, the intensity of the famine varied across the provinces of China. This province variation is usually used to identify famine effects. Figure 2 depicts the prefecture/city-level variation in famine severity using CSSI measures in our data. Comparing Figure 2 to Figure 1, relying on information at the CSSI level of granularity allows relatively wider variation in measures of famine intensity.

Third, we strive to paint a comprehensive picture of intergenerational famine effects by examining a range of labour market measures including education, income, and employment, disaggregating these by gender of the child. Furthermore, we offer evidence on a range of potential mechanisms underlying the intergenerational effects we document by using rich information on mothers (and their spouses) who were exposed in early-life.

Although we consider a variety of outcomes as discussed above, we motivate our initial analysis by spotlighting one catchall measure of labour market performance, whether the child has ever worked, and plot the impact of the famine on the propensity to ever work of children of famine survivors who are 15-40 years old (Figure A1). These non-parametric results show that girls with mothers who experienced more intense famine have relatively lower predicted probabilities of ever having worked than girls with mothers exposed to less intense famine, especially in the early years. The differentials are relatively less salient for boys. The deficit evident for girls deserves consideration as the literature clearly documents that penalties incurred at these early years amplify over time. The negative impact on girls in this measure resonates across the other economic indicators we study, underlining that detrimental echo effects are relatively more evident among daughters of mothers who survived the famine (results for sons are on average less severe or measured imprecisely). This may be due to positive selection of sons born to mothers exposed to the famine in regions that were hard-hit (Kraemer 2000; Sanders and Stoecker 2015), and/or due to son preference. As we demonstrate in detail below, our results are robust to a variety of empirical checks and specification and falsification tests.

Section 2. Institutional background

The GLF famine in China from 1959–1961 was one of the worst in human history, and is estimated to have caused about 15–30 million excess deaths (Ravallion 1997). From 1958-1961, the Communist Party of China launched the “Great Leap Forward” movement aimed at rapidly transforming the country from a predominantly agrarian one to an industrialized socialist economy. A massive campaign was initiated to adopt radical economic and social policies to accelerate the process of industrialization by “squeezing” the agricultural sector. It is believed that the famine was caused by a combination of factors including declines in grain production due to bad weather, excessive procurement by the state, delayed response to food shortages, weakened production incentives due to the widespread collectivization program of 1958, and resource diversion towards massive industrialization (Chen and Zhou 2007; Meng *et al*. 2015).

The GLF famine had features that facilitate causal analysis. First, there was substantial variation in intensity across regions and across time with rural areas being hit the hardest. Although consistently high, mortality rates peaked in early 1960 (Becker 1996). The severity of the famine varied sharply across *and* within provinces. Second, there was little migration across regions. The Chinese government adopted the family register system, the “Hukou” system, to control the movement of people between urban and rural areas in 1958. During this time, nearly all rural Hukou residents were collectivized into village communal farms. The communes were managed in a quasi-military fashion and migration was prohibited. Therefore, almost no migration was possible from rural areas during the famine.

Section 3. Data

3.1. Study sample

We use data from the CHARLS, a national representative longitudinal study of individuals aged 45 and older in China. The survey includes rich information on economic standing, physical and psychological health, demographics and social networks of aged persons. Importantly, the CHARLS questionnaire contains a "Family" section that collects information on the respondent's children, parents and siblings. From the information on children, we construct child-specific income and labour market outcomes. We use information on CHARLS respondents and their spouses for parent-specific variables. Importantly, the CHARLS data contain information on the respondent's prefecture of birth, which allows us to measure individual-specific famine exposure at this disaggregated level.

The baseline wave of CHARLS was collected from 2011-2012 (Wave 1) and includes 10,257 households with 17,708 individuals in 150 counties/districts across approximately 120 prefectures/cities in 28 provinces. These individuals were re-surveyed in 2013 (Wave 2) and in 2015 (Wave 3). We use the baseline sample for most of the analysis and rely on subsequent waves to impute missing values of key time-invariant variables.

For purposes of analyses, we include female respondents born between 1953-1956 and 1959-1962. These consists of those born during the famine (1959-1962) and those born three to six years before the famine (1953-1956). We treat the 1962 cohort as being exposed to the famine, as they may have been *in utero* during the famine. As explained in detail below, our control birth cohorts include those born well before the famine to mitigate confounding effects from mothers who may have been exposed at early ages (0-3 years), and to reduce other influences arising from differences in fertility and mortality trends in years that immediately followed the famine. We also only include respondents who were born in rural areas. This is because the impact of the famine was primarily felt in rural areas whereas urban areas were more insulated due to the presence of food support programs. Further, given Hukou induced restrictions on migration, concentrating on rural areas provides a clean sample free from sorting-related selection dynamics. Finally, we focus on the biological children of CHARLS female respondents in our study sample.[4]

3.2. Child-specific variables

We construct a range of dependent variables to capture outcomes including children's educational attainment, income level, and work status. Further, consistent with the literature, we construct a set of child-specific variables to be used as controls including age, age squared, gender, birth order, and birth quarter of the year. We also include the child's Hukou status (agricultural or non-agricultural Hukou) to account for the labour market differences between rural and urban areas. One might argue that child's Hukou status may also be partially affected by the famine. As a robustness check, we exclude this control variable from the estimation. The results are very similar in terms of the coefficient sign, magnitude and statistical significance, but the model-fit is lower than in our main results.[5]

Table A1 presents descriptive statistics of these child-specific variables separately for male and female children and for the combined sample. We begin by discussing the dependent variables in Panel A. Since child income was reported in categories, we analyze the mid-points of these groupings. The average values of the mid-points are 23,053 yuan for male children and 23,658 yuan for female children. A slightly lower percentage of daughters have completed high school as compared to sons (28.7% versus 29.3%), are currently working (77.9% versus 88.6%), or have ever worked before (88.8% versus 92.0%).

Panel B reports the summary statistics for child-specific independent variables. The average age is 28.4 years, and 54.4% of children are male. Female children are more likely to be first-born compared to male children (43.1% versus 41.1%), and are more likely to be born in the first and the third quarters of the year. 85.0% of the children have agricultural Hukou status which is not surprising given they are born to mothers whose birthplace was rural. Female children are somewhat less likely to have an agricultural Hukou as compared to male children (84.4% versus 85.6%).

3.3. Famine exposure measures

Two types of famine intensity measures have been used in the literature. The first is based on famine-caused mortality increases (Lin and Yang 2000, Chen & Zhou 2007, Almond *et al*. 2010, Kim *et al* 2014) primary among which is province-level famine-induced EDR calculated as the difference between mortality in famine years and mortality in non-famine years. The second type of famine intensity measure is a cohort measure of all types of famine-induced cohort attrition that occurred during the famine (Huang *et al* 2010, Meng *et al* 2015, Xu *et al* 2016, Chen and Yang 2019). There are several issues that have been noted with the mortality-based famine intensity estimates. EDRs are based on government officially reported mortality rates that may be subject to measurement error and some degree of under-reporting (see Xu *et al*. 2016, Chen and Yang 2019). Alternatively, cohort size-based famine severity measures utilize public-use samples of the Chinese Population Census that are known to be of high quality. Hence, cohort size-based severity measures calculated from high quality census data may be more objective than measures based on officially reported mortality rates. Second, famine may cause not only excessive deaths but also change fertility dynamics through lost or postponed birth. Mortality-based measures would thus reflect only one aspect of such variations (Song 2013).

Following work in Xu *et al*. (2016), we construct cohort-size based measures of famine intensity using the one-percent sample of the 1990 China Population Census data at the prefecture level that vary by rural and urban areas. This measure of famine exposure allows us to capture within-province variation and both mortality and fertility dynamics.

As detailed in Xu *et al*. (2016), our CSSI measure for the i^{th} prefecture is calculated as:

$$CSSI_i = \frac{N_{nonfamine}^{i} - N_{famine}^{i}}{N_{nonfamine}^{i}} \qquad (1)$$

Where $N_{nonfamine}^{i}$ denotes the average cohort size of those born during the three years preceding the famine (1956–58) and the three years after the famine (1962–64), and N_{famine}^{i}

denotes the average cohort size of those born during famine years (1959–61).[6] A relatively high value of $CSSI_i$ indicates a larger reduction in cohort size, thus greater famine intensity.[7] This prefecture-level CSSI is used as our main famine intensity measure in all regressions that follow. In order to demonstrate sensitivity of our results to use of the prefecture-level CSSI measure, we use province-level CSSI and province-level EDR in robustness checks in order to provide evidence that concerns inherent to use of an estimated measure are less of an issue in this study. Table A2 lists weighted mean CSSI measures by prefecture/cities in our data for mothers born between 1959 and 1962 whose birthplace is rural. It is clear that there is substantial within-province variation in famine intensity across cities.[8]

To construct individual-level famine exposure measures, we matched prefecture-level CSSIs and provincial CSSIs to respondents based on their birth prefectures and provinces. The descriptive statistics of famine exposure for female respondents (mothers who were exposed in early-life) are reported in Panel A of Table A3. The first measure is the linear version of $CSSI_i$. We use the non-linear version of $CSSI_i$ to ease interpretation of results in our DID models. This non-linear version conditions on $CSSI_i$ being at its 75th percentile value or higher in rural areas.[9] Respondents' exposure to the famine also depends on their year of birth and Panel A reports summary statistics for these indicators. Comparing proportions born in each cohort from 1953-1962, a slight drop in births is evident in the famine years of 1959 and 1960 followed by an increase post-famine in 1962.

3.4. Other mother-specific variables

We construct mother-specific variables for use as controls in the child outcome models or as outcomes in the mechanisms analyses, and look to Almond (2006) and Cook *et al*. (2019) for guidance on these measures. These mother-specific variables include age, age squared, an indicator for having completed high school or above, income per capita, an indicator for currently having any chronic health conditions, the number of chronic conditions, an indicator for having had any natural abortions or stillbirths, percent of her sons (daughters) mainly cared for by herself at age 0-2 years, and percent of her sons (daughters) mainly cared for by herself at age 3-5 years. Panel B of Table A3 presents these descriptive statistics. On average, mothers' age is 53.8 years. Around 7.0% of mothers have completed high school or more. While 67.4% of mothers report having chronic conditions, the average number of chronic conditions is 1.3. On average, mothers were the main caregiver for 26% of her sons and 20% of her daughters in their early ages.

3.5. Spouse-specific variables

Panel C of Table A3 presents descriptive statistics for spouse-specific variables used in the mechanisms analysis. Focusing on the non-famine related measures, spouses are a few years older than mothers with a mean age of 56.1 years, and 18.1% have completed high school or higher. 64.7% of spouses report having a chronic condition and the average number of such conditions is 1.2.

Section 4. Empirical methodology

4.1. Model and specifications

Exploiting the variation in famine exposure across birth cohorts and across prefectures, we use a DID model to identify the impact of the famine on outcomes of the second generation. Essentially, we compare child outcomes of those mothers who were exposed *in utero* and in early-life to higher intensity of famine to outcomes of those whose mothers were exposed to lower intensity or not exposed. Most papers studying the GLF famine use birth cohorts born before and after the famine as the control group. We include only birth cohorts who were born well before the famine as control in our study to mitigate potential selection arising from differences in fertility and mortality trends in years that followed the famine. As noted in Currie and Vogl (2013), individuals conceived after the famine may have been affected by fertility responses to the famine. Using post-famine birth cohorts in the control group would mean, at the very least, that the composition of parents with children is different between the treatment and control groups. Hence, to identify impacts cleanly, we only use birth cohorts born three to six years before the famine as the control group. In robustness checks, we include both pre-famine cohorts (1953-1956) and post-famine cohorts (1963-1966) as the control group.[10]

The treatment group includes cohorts born during the famine years. Further, given the length of human gestation periods, mothers born from January to October 1962 could also have been partially exposed to the famine. Therefore, we include the 1962 birth cohort in the treatment group. Those born in the control time period of 1953-1956 would be 3-6 years old when the famine began, and some proportion of this group would themselves be at critical stages of development. Here we consider the first 3 years as the crucial early-life period as the literature suggests (see Currie and Vogl 2013). For instance, 2/3rd of adult height is determined by the age of 2 or 3 and 80% of adult brain capacity is developed by age 2 (Knickmeyer *et al*. 2008). Therefore, while the relatively older children in our control group may still be impacted, younger children who are thought to constitute the most at-risk group are less likely to be so. We acknowledge that to the extent that the relatively older children in the control group may have been adversely affected by the famine, the estimates that we report for the treated group will be influenced by this fact. However, given the structural break in China with Chairman Mao's ascension in 1949, and the fact that the further we go back in time from the start of the famine, the greater the possible influence of unobservables, we strike a balance between these factors and choose 1953-1956 as the control group. The fact that some children in the control group may be impacted post-birth by the famine is an issue that also affects other studies of the GLF famine including Chen and Zhou (2007), Meng and Qian (2009), and Li and An (2015). Moreover, as noted above, including post-famine birth cohorts in the control group as many studies also do is likely to be even more problematic.

We consider the following specification:

$$y_{ijkt} = \beta_1 + \beta_2 S_k + \beta_3 T_{jt} + \gamma_1 (T_{jt} \times S_k) + \beta_4 X_{ij} + \beta_5 P_{ij} + \alpha_t + \varepsilon_{ijkt} \quad (2)$$

where y_{ijkt} is the outcome for child *i* of parent *j* who was born in prefecture/city *k* in year *t*. S_k denotes famine severity in prefecture/city *k* and is measured by CSSI in equation (1), which is our preferred famine intensity measure. To ascertain the robustness of our main results, we also estimate the above specification using province-level CSSI and province-level EDR as sensitivity checks. In our main specification, we use a non-linear form of CSSI as the treatment variable for three reasons. First, a binary treatment variable can ease the interpretation of results in a DID framework. Second, using linear form of CSSI may engender bias due to the impact of outliers. Since we use a disaggregated prefecture-level CSSI instead of an aggregated province-level CSSI, the influence of outliers is less likely to be muted in our data. Lastly, we expect that the treatment effect is likely to be nonlinear in this setting and indeed observe a nonlinear pattern after examining the famine impact over the CSSI distribution in detail for each of the outcomes. This is shown in Figure 3 where experimenting with different CSSI cut-offs reveals that in the case of all of our outcomes, impacts are not evident until CSSI exceeds its 70th percentile value. Hence, in our main specification, S_k is a dichotomized measure created based on the 75th percentile value of CSSI in rural areas. $S_k = 0$ ("less intense") if the respondent's birth prefecture/city CSSI measure is lower than its 75th percentile value in rural areas, and $S_k = 1$ ("more intense") if the respondent's CSSI measure equals or exceeds this threshold. A further supporting reason for choosing the 75th percentile value is due to the wide exposure to famine experienced in our study sample. According to data from the Life History Survey of CHARLS, 82% of our study sample reported having experienced starvation, while 13% reported that at least one family member starved to death. As an additional check, we also estimated the specification using the 80th percentile value of CSSI as a cut-off. In general, we find that this results in coefficients that are similar in magnitude to those that result with use of the 75th percentile value.

T_{jt} is a dummy with value 1 if parent j was born during the famine years (1959-1962), and zero otherwise. X_{ij} are controls for maternal and child characteristics described above, P_{ij} are maternal birth province fixed-effects, and α_t is a set of maternal birth cohort fixed-effects.[11] Regressions are weighted to national levels using weights provided in the CHARLS data. Standard errors are clustered at the maternal birth-province level. The coefficient on the interaction term of the famine severity S_k and treatment dummy T_{jt}, γ_1, is the parameter of interest, which represents the average effect of intense famine over the famine years. These are identified from variation in famine intensity across prefectures/cities in a given year, and from variation in mothers' birth years in any given prefecture/city.

To allow for differential effects of famine exposure across years from 1959-1962, we follow Chen and Zhou (2007) and interact famine severity and each of the birth cohort dummies separately in a related specification:

$$y_{ijkt} = \beta_1 + \beta_2 S_k + \beta_3 \sum_{t=1959}^{1962} C_{jt} + \sum_{t=1959}^{1962} \gamma_t (C_{jt} \times S_k) + \beta_4 X_{ij} + \beta_5 P_{ij} + \alpha_t + \varepsilon_{ijkt} \quad (3)$$

where C_{jt} represents mother's birth year cohort dummies for those born during the famine years. The coefficients γ_t on the interactions of famine severity and maternal birth cohort dummies represent the effect of intense famine on each birth cohort born in year *t* during the famine period. Results from Equation (3) are presented in the Supplementary Materials section.

It is useful to carefully hypothesize how the cohorts born in the famine years may be differentially impacted *in utero* and post-birth. Simplifying a lot, and assuming that the critical window of early-life is the first three years, those born in the control years of 1953 – 1956 are 3 to 6 years old when the famine begins, and thus relatively unaffected (they would still have suffered some level of deprivation of course as we note above, but less than children who are even younger). Next, separating the famine years and considering these individually, those born in 1959 would have been exposed *in utero* and would have experienced two years of post-natal exposure, while those born in 1960 would also have been exposed *in utero* and suffered up to a year of post-natal exposure before the famine ends. Since 1960 was the worst year, exposure *in utero* and in the additional year of post-natal life for this cohort may have been especially intense. Those born in 1961 would have been exposed prenatally and *in utero*, but would have little or no post-natal exposure, while those born in 1962 will have some *in utero* exposure, but little exposure post-birth. Summarizing, although all four birth cohorts would have experienced some level of prenatal and/or post-natal exposure, there are reasons to believe that the estimates for the 1961-1962 cohorts should be slightly weaker than the estimates for the 1959-1960 cohorts. We interpret the treatment year estimates reported in the Supplementary Materials section using this lens.

We end this section by noting that we estimate equations (2) and (3) for all children, and separately for male and female children. This is important for two reasons. First, there may be positive selection of male foetuses when it comes to negative shocks of this scale (Sanders and Stoecker 2015). Second, there may be differential investments in boys compared to girls after birth because of social norms such as son preference. These nuances would be lost if we did not consider offspring outcomes by gender of the child. It is important to underline here that although positive selection from excess male mortality has been noted in response to shocks, we do not find evidence for this in our sample. This is because when we tested whether the famine had impacts on natural abortions or stillbirths experienced by mothers, these impacts were uniformly insignificant.[12] Hence, the sample of children we study is likely random. Furthermore, this suggests that environmental factors play a larger role in explaining the gender-disaggregated results we document as compared to biological channels. We discuss this in detail below.

4.2. Tests of the identifying assumptions

We test the validity of the identifying assumptions in several ways and follow recent papers in this regard including Bharadwaj *et al*. (2020). First, we check for selection on observables for our sample of children with mothers born before or during the famine. If selection of this nature is present, births in famine years do not constitute a representative sample. To ensure that births in famine years are comparable to those in pre-famine years, we consider samples of children of respondents born in the pre-famine years (1953-1956) and during the famine (1959-1962), and test whether these samples differ on observables. This is accomplished by regressing famine treatment status, that is, mothers born in the pre-famine years or during the famine, on all child-specific and respondent-specific variables and province dummies, and then testing for the joint significance of child-specific controls. Table 1 reports these results.

The estimates in Table 1 confirm that children born to mothers who were born in the famine years are not systematically different from children born to mothers whose years of birth preceded the famine. Few of the child-specific variables are significant across the columns in this table, and F-tests results indicate that these variables are jointly insignificant. Hence we are confident that the impacts we measure are attributable to the famine rather than to differences in child characteristics across these samples.

Second, an important assumption for the DID model is that of parallel trends. That is the treatment and control groups should have been on comparable (parallel) paths until the famine occurred, and should not have been diverging before then. To ensure this, we compare those whose mothers' were subject to more intense famine with those whose mothers' experienced the less intense famine in the pre-famine years (1953-1956). These results are presented in Appendix A (available in Supplementary Materials).

To further ensure the lack of pre-trends, we follow Bharadwaj *et al*. (2020) and estimate equation (3) for all children's outcomes. Figure 4 plots the coefficients on the interaction of famine intensity and respondent's year of birth variables (γ_t) with their corresponding 95% confidence intervals for all outcomes, separately for boys and girls. It is clear from Figure 4 that prior to the famine, there was little to no difference in the work propensities of children in cities/prefectures that differed subsequently in terms of how intensely mothers experienced the famine. In each case of Panel A that considers boys alone, in all years before the start of the famine, the plotted coefficients are not significantly different from zero. This is also true in each case of Panel B for girls. Figure 4 thus broadly indicates that areas with more intense famine were on a comparable trajectory in terms of child outcomes as compared to areas with less intense famine, before the famine occurred.

Third, we check to ensure the absence of selective fertility in our study sample. That is, parents with characteristics that could potentially explain our results should not have selected into having children in the time-period we consider. For example, if mothers of low socio-economic status predominantly chose to have children during 1959-1962, then labour market impacts on children could be explained by this. We first check this descriptively by utilizing life histories information in the data.[13] These data reveal that 93% of the respondents reported that the famine-induced food shortages did not result in behaviors such as putting off marriages, postponing fertility, inability to give birth and/or having an abortion. Next to test for selective fertility formally, we follow Buckles and Hungerman (2013) and Bharadwaj *et al*. (2020) to estimate equation (2) with mother and child characteristics as the outcomes. These results are presented in Table 2 and show that the famine had little impact on relevant characteristics that could, in of themselves, explain children's outcomes.[14] Across mother's age, mother's literacy status, mother's marital status, and child-specific characteristics such as age, gender, marital status and Hukou type, the estimated coefficients on the interaction terms reported in Table 2 are insignificant.

Section 5. Results

5.1. Intergenerational effects of early-life famine exposure

We present our main results from estimating equation (2) in Table 3. Appendix B (available in Supplementary Materials) reports results from equation (3). Table 3 presents results separately for daughters (Panel A), sons (Panel B), and all children (Panel C). Each column reports coefficients from a separate regression on specific outcome variables. All regressions include the full set of controls discussed above but in the interests of conserving space, we report only the key variables of interest (β_2, β_3 and γ_1).

We begin by considering results for daughters presented in Panel A of Table 3. The first column relates to child's income level where we analyze the mid-points of finely defined income categories. Column (2) relates to child's educational attainment, specifically, whether the child has completed high school or higher. Column (3) indicates whether the child is current working, while Column (4) indicates whether the child has ever worked before. Results in Panel A of Table 3 report that daughters born to mothers who experienced severe famine in early-life earn substantially less, are unlikely to attain high school or higher, are less likely to be currently working, and are less likely to have ever worked before (these impacts are all statistically significant). In particular, such daughters have an income level that is 7,528 Yuan lower than their counterparts.[15] Relative to mean income in the sample, this represents a 31.8% decline. Daughters of mothers who experienced severe famine are 14.7 percentage points less likely to have high school or higher education (51.2% lower relative to the mean), and their probability of currently working is 9.5 percentage points lower (about 12.2% decline relative to the mean). Their probability of ever having worked before is 8.1 percentage points lower as compared to the control group of daughters, which represents a 9.1% decrease relative to the mean value of this outcome.

Taken together with the results in Appendix B in Supplementary Materials, the intergenerational impacts of the famine on these outcomes of daughters indicate that on average, income, education, and work propensities are lower among daughters whose mothers were born during 1959-1962 in more severely affected regions as compared to daughters with mothers who do not have these characteristics. The overall negative effect on income and schooling outcomes may be attributed to daughters of mothers born in 1960, the most intense year of the famine.

We tested the sensitivity of these estimates to use of a different cut-off value (median) and to use of the CSSI measure in linear form. In keeping with Figure 3 discussed above, we find that when the median is used as the cut-off value, while the sign of the coefficients remains the same in general, they are less precisely estimated. We also find that when we use the linear specification for CSSI, the results point in the same direction of treatment effects (overall negative effect on outcomes predominantly for daughters), but are measured with noise.[16] With the evidence in Figure 3, the Life Histories data discussed above, and given that the 75th percentile cut-off is naturally interpreted as the upper quartile of the distribution, we adopt this threshold as our main specification and interpret results as the treatment effect of being exposed to severe famine.

Results for male children are presented in Panel B of Table 3, and some effects resonate with those found in Panel A for female children. Results show that boys born to mothers who experienced severe famine earn less, are less likely to complete high school or above, and are less likely to have ever worked before (none of these effects are significant). Considering these impacts in conjunction with those for sons reported in Appendix B, we conclude that on average, daughters experienced worse economic and labour market outcomes across a range of measures as compared to sons (although the magnitude of some of the effects experienced by sons and measured with precision is quite large).

Panel C of Table 3 presents results for the combined sample of daughters and sons of mothers who survived the famine. Many of the results from the daughters sample in Panel A resonate with those in Panel C. In particular, children of mothers who experienced severe famine earn 7,842 Yuan less (33.6% decline relative to the mean). Those with mothers born in the famine years have lower educational attainment, and are 4.9 percentage points less likely to have ever worked as compared to their counterparts (5.4% decline relative to the mean). Given the relatively few precise estimates for sons in Panel B, we conclude that the impacts in Panel C are mostly due to effects on daughters.

5.2. Mechanisms

We consider different mechanisms that may underlie the estimated impacts. The first works through human capital impacts of the famine on mothers who were exposed in early-life. The second works through potential marriage market sorting of these mothers. We subsequently check for mechanisms that may work through the children's sample – evidence of biological factors and selection through mother's lack of reproductive success, and evidence for environmental factors including differences in caregiving by the mother in a child's early years and son preference. To check for human capital impacts of the famine on mothers exposed in early-life, we evaluate a set of mother-specific outcomes including education, per capita income, an indicator for having any chronic conditions, and the total number of chronic conditions. For marriage market sorting mechanisms, we consider similar human capital outcomes of the spouses of mothers. We estimate models for these outcomes of mothers and their spouses using the same DID specifications as before.

We present results on the impact of mothers' exposure to famine on their human capital in Panel A of Table 4. The results show that mothers who experienced severe famine are 10.2 percentage points less likely to complete high school or above (column (1)). Panel A of Table S3 (available in Supplemental Materials) reports results for the disaggregated birth cohorts.

Column (3) presents impacts on mother's per capita income where the result in Panel A shows that mothers born in famine years have 3,554 Yuan less than other comparable mothers (31.7% decline relative to the mean). Column (3) reports results for mother's probability of having any chronic conditions, and column (4) reports results on log total number of chronic conditions. The probability of having any chronic conditions is higher for treated mothers, though the effect is not precisely estimated. Mothers who experienced severe famine also have a higher number of chronic conditions as reported by the combined estimate in column (5). These combined and disaggregated results underline that the famine eroded mother's education and health to a measurable extent.

We present results on the impact of maternal exposure to famine on their spouse's measures in Panel B of Table 4. Panel B of Table S3 reports corresponding results for spouses' disaggregated birth cohorts. Columns (1) to (5) in Panel B of Table 4 shows insignificant effects when cohorts are combined. However, this is not the case in Appendix C, which discusses the separated birth cohort impacts. In summary, the results in Table 4 and Appendix C indicate that mother's exposed in early-life have lower levels of schooling and worse health outcomes, and have spouses who also have reduced educational attainment but somewhat better health measures.

Could biological factors play a role in explaining the results we document? In order to test for this, we analyze whether mothers exposed to the famine report lack of reproductive success. The

CHARLS Life History data collects information on whether mothers had any natural abortions or stillbirths; the mean for this variable is 9.4% in the sample. The results are shown in column (1) of Table A4 and indicate that mothers' famine intensity has no differential impacts on this measure. This provides further evidence that the sample of children we study is not selected along these specific dimensions, and biological factors alone may not be explanatory.

We next consider environmental factors, and given the data at our disposal, evaluate two in particular: differences in caregiving in early-life by the mother by gender of the child, and evidence for son preference. Columns (2) through (5) in Table A4 report results for differences in mother being the main caregiver of her children disaggregated by child gender and age. As is shown, there is little evidence that famine exposed mothers behaved in a manner that was systematically different in terms of this measure between sons and daughters in early ages.[17]

Finally, could son preference play a role? In order to answer this, we follow the methodology in Tan *et al*. (2017) and evaluate impacts on daughters conditional on the household composition of children, while controlling for the total number of sons and daughters in the household (household size). These results are reported in Table 5. Panel A shows estimates from our main results in Panel A of Table 3 (daughter sample) with the additional control for household size. As evident, the coefficients are very close, if not exactly the same as those reported in Panel A of Table 3. The subsequent panels in Table 5 then report results for different sub-samples: those households with daughters only, those with daughters and sons, and those with daughters and younger sons. Comparing across Panels A, B, C and D, we see that our results for daughters arise in households with daughters and sons, especially younger born sons. Households with daughters and younger brothers are those that are more likely to have son preference as compared to households with only daughters. Although not definitive, the differences in results across the panels of Table 5 provide suggestive evidence that the stronger negative impact on daughters of famine affected mothers that we document may originate due to son preference, and the relatively larger penalties that such preference exerts on daughters. The preferential treatment of boys that son preference engenders implies that the early-life environment for daughters may have been relatively worse.

5.3. Robustness checks

We conduct robustness checks to assess how sensitive our results are to different measures of famine intensity. We begin by considering how results vary when we use the aggregate cohort size-based measure of famine exposure, province-level CSSI. Results for the mother-daughter sample are reported in Appendix D (available in Supplementary Materials). Appendix D also reports results when famine intensity is measured with province-level EDR constructed using the same methodology as in Chen and Zhou (2007). Taken together, it is reassuring to see similar results from these provincial-level checks.

As noted before, we conduct robustness exercises by including both pre- and post-famine cohorts as the control group. We obtain similar results to our main estimates in Table 3 when the control group is modified to include the 1953-1956 and 1963-1966 birth cohorts, especially for the sample of daughters and the combined sample. As shown in Table A5, the coefficients have similar signs and magnitudes.

We conclude by noting that we test for unobserved trends that vary by region and maternal birth cohorts. Results are similar in size but lose statistical significance for some outcomes if birth prefecture/city-level fixed-effects are used in place of mother's birth province fixed-effects. Results also remain approximately in the same ballpark but lose statistical significance for some outcomes if we add interactions of mother's birth province fixed-effects and mother's birth year fixed-effects.[18]

5.4. Falsification test

We present falsification tests that serve to demonstrate the validity of our DID design. We accomplish this by selecting birth cohorts from 1953-1956 as our "treated" group and birth cohorts from 1949-1952 as "control".[19] The 1953-1956 time period preceded the famine by 3 to 6 years and thus, no treatment impacts should be evident. Appendix E (available in Supplementary Materials) confirms that this is the case.

Section 6. Conclusion

This study examines the intergenerational echo effect of the GLF famine on economic and labour market indicators of children of female famine survivors born in rural areas who would have experienced prenatal and early-life malnutrition. We contribute to the literature by focusing on later-life child outcomes such as income and employment, and by using a finer measure of famine exposure and rich data on those directly exposed and their progeny. Difference-in-differences estimates of child outcomes that include educational attainment, income, and work propensities reveal that impacts are evident among the second generation today, almost sixty years after the famine. Since the negative impact is observed not only for educational attainment but also for income and work propensities during adulthood, our results indicate that the GLF famine has had an even longer-term effect on the second generation.

Our results underline that the famine exerted adverse intergenerational impacts predominantly on daughters. We find evidence that the negative echo impacts of the famine may have been transmitted to daughters through adverse effects on mothers' education and health. We find no evidence that transmission was through mothers' lack of reproductive success (natural abortions or stillbirths) or differences in caregiving behavior in their children's early-life. In terms of other environmental factors, we find suggestive evidence that cultural factors such as son preference may play a role. To the extent that we find significant negative impacts using the 75th percentile as the cut-off value, our results represent the treatment effect of being exposed to severe famine. We present tests that support the robustness of these results. Alternative estimates using province-level famine intensity measures demonstrate the usefulness of using finer prefecture-level variation in famine exposure, as we undertake in this study.

We acknowledge limitations of our research. First, and as common in other studies of the GLF famine, we do not use first-hand individual level accounts of how the famine was experienced, but proxy for this using CSSI by prefecture and year of birth. Second, although the CHARLS data allows us to gauge prefecture of birth which is an advantage as compared to other studies, these data are still not detailed enough for us to answer questions such as what would the counterfactual socio-economic trajectory of children of mothers who survived the famine have been in the absence of this disaster. Third, given the nature of CHARLS data, we cannot clearly pin-down all channels that explain our results, or determine whether biological or environmental factors alone are key in explaining the gender-disaggregated results we document. Fourth, common to other studies in this area, it is hard for us to clearly differentiate prenatal and post-birth exposure impacts in our famine cohort of 1959-1962. Lastly, our study relies on a relative small sample, which leads to less precision in some of the estimates. Unfortunately, we are not aware of any other data source that allows us to estimate the intergenerational legacy of famine on children's economic and labour market outcomes during their adulthood with a larger sample size. Despite this, our study uses a novel methodological lens to add to the literature on the intergenerational consequences of the GLF famine.

Evidence that this disaster has long-run detrimental consequences necessitates awareness and action to mitigate these effects. Without effective ameliorative strategies to support and remedy some of these harmful consequences, it is possible that the negative fallout of the GLF famine will be experienced by future generations, which may further contribute to the persistence of intergenerational poverty and inequality. This is especially so as our analysis reveals that daughters in the second generation were relatively more affected as compared to sons, and as is well recognized in the literature, mother's health and well-being is of primary importance in ensuring the human capital and overall success of her children.

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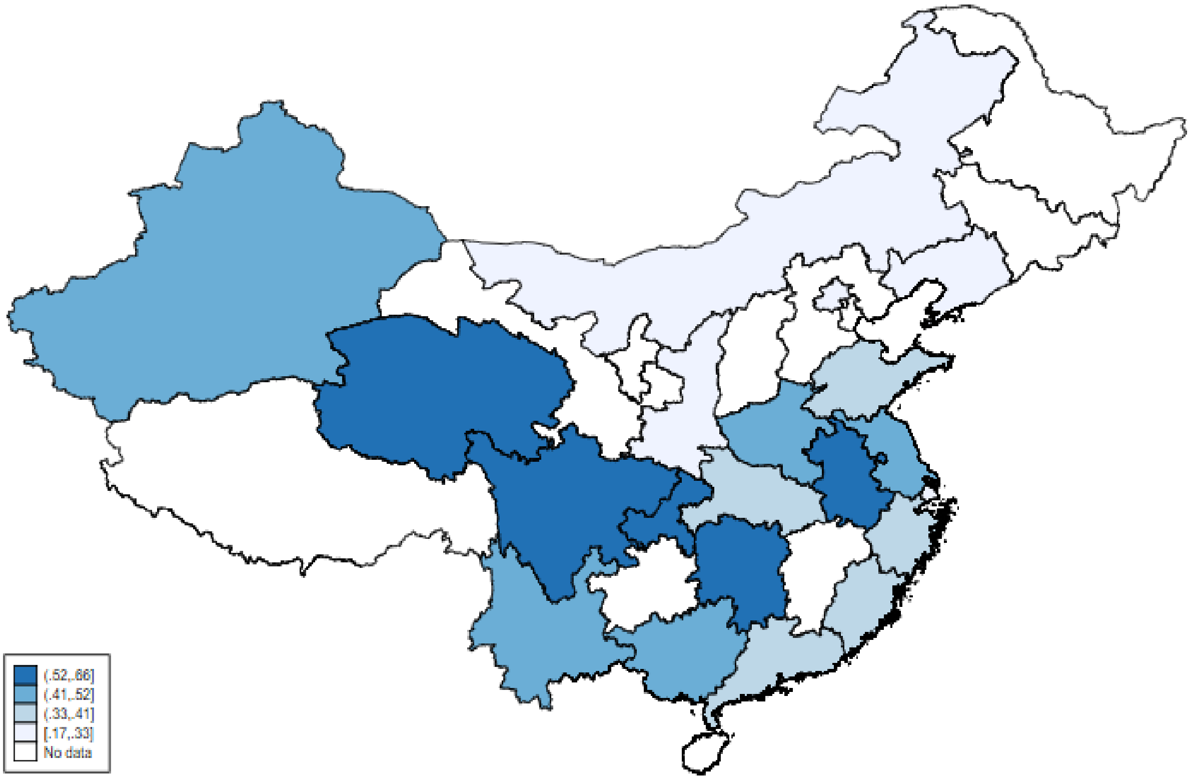
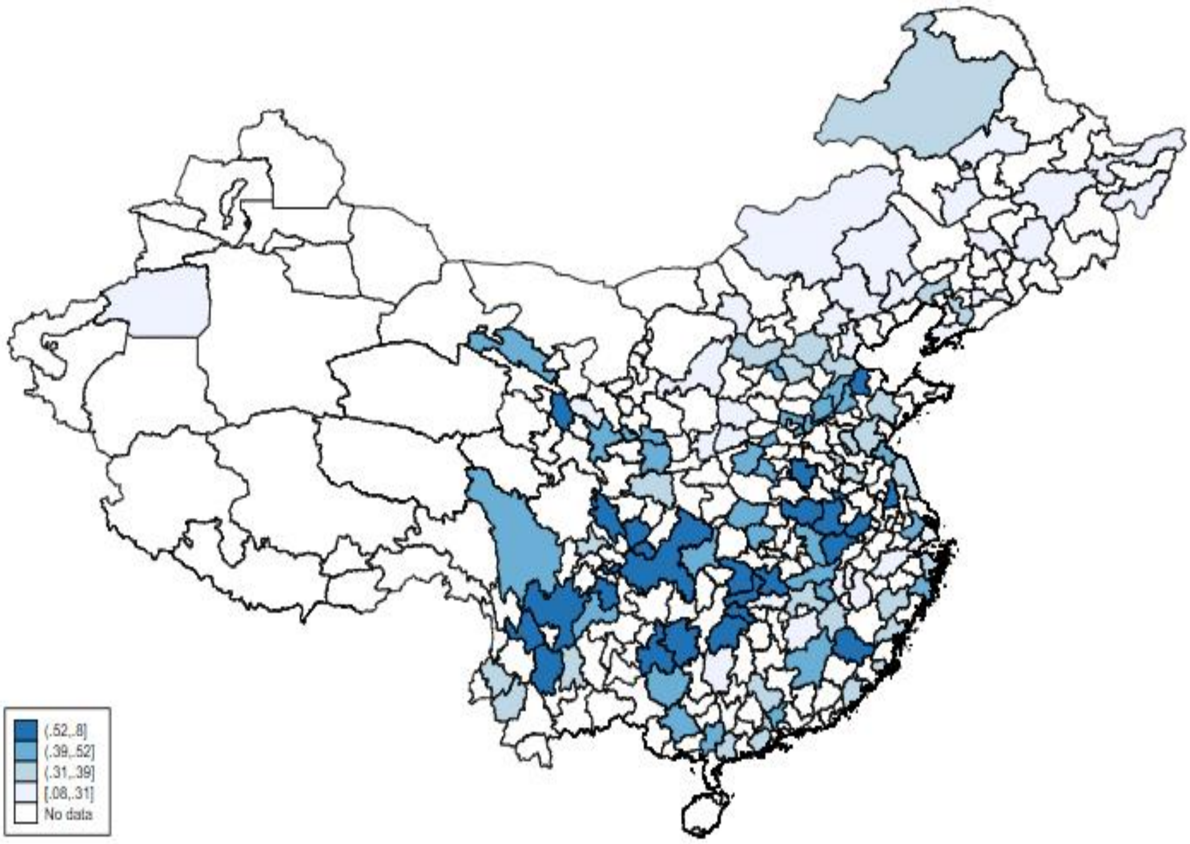
Figure 1: Provincial level cohort size shrinkage indices



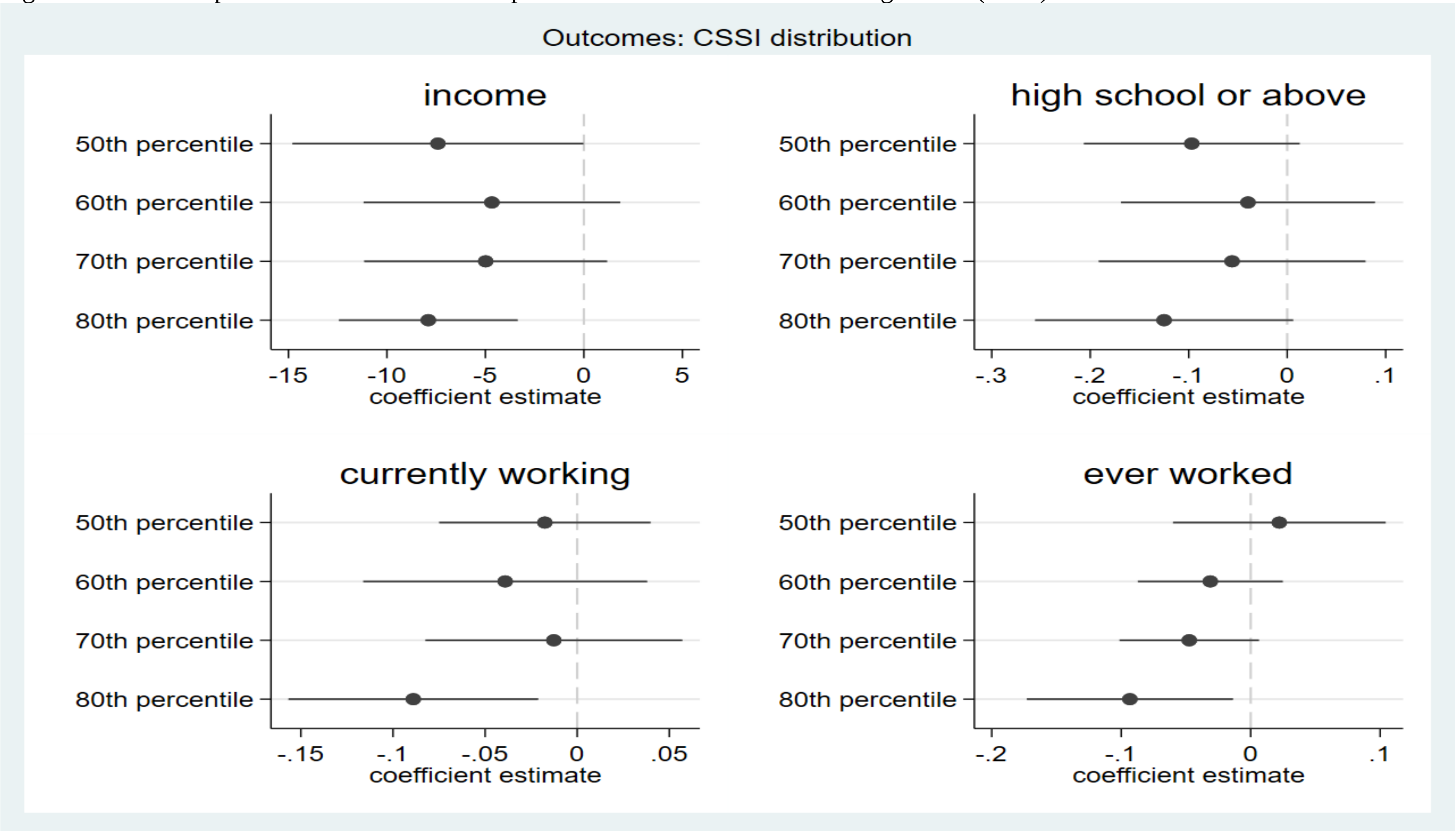
Note: Authors' calculations.

Figure 2: Prefecture/city level cohort size shrinkage indices



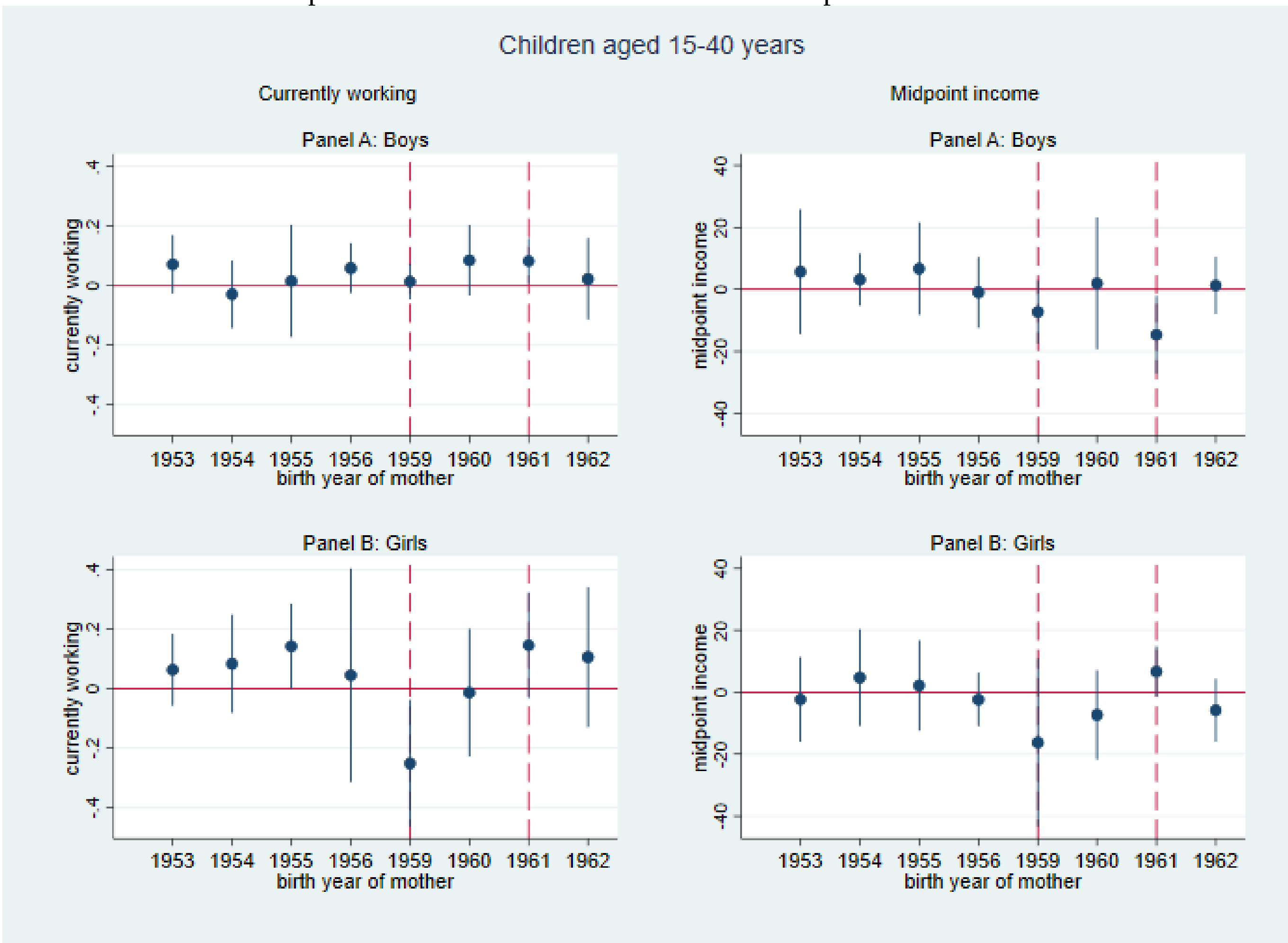
Note: Authors' calculations

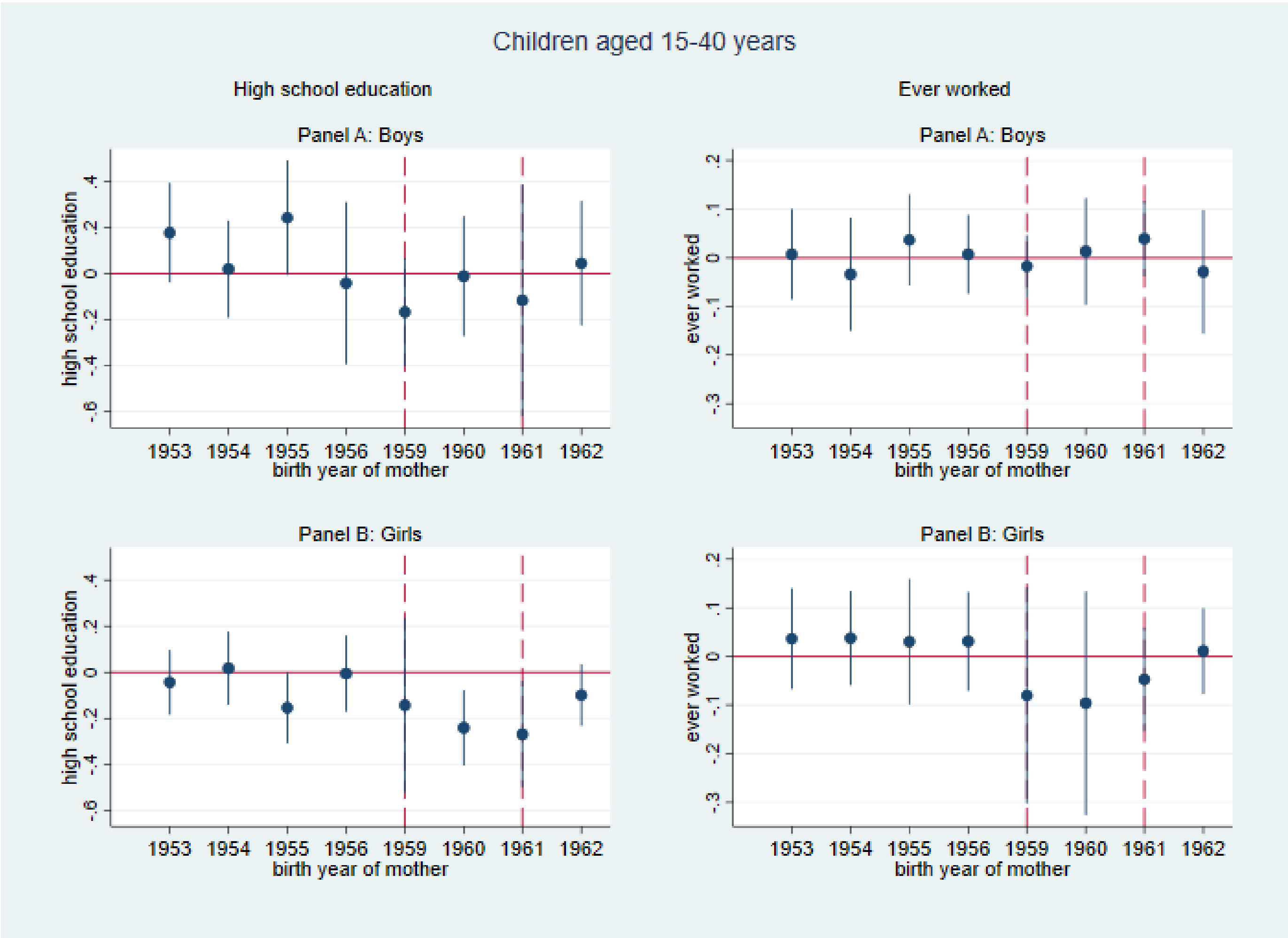
Figure 3: Famine impact over the distribution of prefecture-level cohort size shrinkage index (CSSI): All outcomes



Notes: Sample includes children born to respondents with year of birth in the 1953-1956 and 1959-1962 time windows, whose birthplace was rural. Regressions include all child-specific characteristics such as age, age squared, birth order, Hukou status, and quarter of birth, and respondent-specific characteristics including mother's year of birth and mother's year of birth squared, and mother's birth cohort fixed-effects. Regressions include province fixed-effects and are weighted to national levels using weights provided in the CHARLS data. Standard errors are clustered by province. Each point is the interaction coefficient from a regression where (combined) birth cohort dummies from 1959-1962 are interacted with an indicator that mother's birth city CSSI is 50th percentile, 60th percentile, 70th percentile or 80th percentile or higher in rural areas. Figure plots 90% confidence intervals.

Figure 4: Impact of mother's famine exposure on children's outcomes: Check for pre-trends





Notes: For purpose of illustration in this figure only, sample includes children born to respondents with year of birth in the 1952-1956 and 1959-1963 time windows, whose birthplace was rural. This sample is slightly larger than our main study sample used in estimations, which includes children born to respondents with year of birth in the 1953-1956 and 1959-1962 time windows, whose birthplace was rural. Regressions include all child-specific characteristics such as age, age squared, birth order, Hukou status, and quarter of birth, and respondent-specific characteristics including mother's year of birth and mother's year of birth squared, and mother's birth cohort fixed-effects. Regressions include province fixed-effects and are weighted to national levels using weights provided in the CHARLS data. Standard errors are clustered by province. Each point is the interaction coefficient from a regression where birth cohort dummies from 1953-1956 and 1959-1962 are interacted with an indicator that mother's birth city CSSI is 75th percentile or higher in rural areas. Figure plots 95% confidence intervals.

Table 1: Representativeness of samples of children born in the pre-famine and during famine years

	Mothers born in pre-famine years (1953-1956)	Mothers born during famine (1959-1962)
	(1)	(2)
Child's age in years	0.020*	-0.006
	(0.010)	(0.005)
Child's age in years squared	-0.000*	0.000
	(0.000)	(0.000)
Child is male	0.012	-0.005
	(0.013)	(0.007)
Child’s birth order	-0.001	-0.004
	(0.009)	(0.004)
Child has agricultural Hukou	-0.035	0.025**
	(0.027)	(0.012)
Child's month of birth is in the second quarter	0.005	-0.000
	(0.016)	(0.007)
Child's month of birth is in the third quarter	0.005	-0.008
	(0.021)	(0.010)
Child's month of birth is in the fourth quarter	0.004	-0.002
	(0.022)	(0.010)
Joint significance of child-specific controls (χ^2 (8))	1.220	1.270
	[0.332]	[0.306]
N	2,892	2,892
R-squared	0.609	0.889

Note: Sample includes children born to mothers with year of birth in the pre-famine years (1953-1956) or during the famine (1959-1962), whose birthplace was rural. Regressions also include mother’s year of birth, mother’s year of birth squared, and a constant term. Regressions include province fixed-effects and are weighted to national levels using weights provided in the CHARLS data. Standard errors clustered by province are reported in parentheses. The square brackets denote the *p*-values of the χ^2 tests of the joint significance of the child-specific controls. Significance: *** p<0.01, ** p<0.05, * p<0.1.

Table 2: Tests for selective fertility

	Mother's age (1)	Mother is illiterate (2)	Mother is married (3)	Mother's HH income pc (4)	Child's age (5)	Child is male (6)	Child is married (7)	Child has ag. Hukou (8)
Mother birth year 1959-1962	-6.334***	-0.151**	-0.018	4.154**	-5.478***	-0.003	-0.249***	0.015
	(0.107)	(0.057)	(0.033)	(1.553)	(0.295)	(0.022)	(0.018)	(0.026)
Mother's birth city CSSI is 75th percent.	0.095	0.044	0.020	1.667	1.381*	0.051	-0.048	-0.123**
or higher in rural areas (INTFAM)	(0.142)	(0.080)	(0.044)	(1.440)	(0.747)	(0.033)	(0.040)	(0.057)
INTFAM x birth 1959-1962	0.032	-0.186	-0.044	-2.929*	-0.409	-0.034	0.049	-0.002
	(0.171)	(0.111)	(0.092)	(1.615)	(0.666)	(0.044)	(0.044)	(0.055)
N	1,533	1,533	1,533	1,516	3,321	3,295	3,266	3,003
R-squared	0.884	0.112	0.034	0.072	0.299	0.011	0.087	0.044

Note: Sample includes children born to mothers with year of birth in the 1953-1956 and 1959-1962 time windows, whose birthplace was rural. Regressions include a cohort dummy for mothers born from 1959 to 1962 whose birthplace was rural and province fixed-effects, and are weighted to national levels using weights provided in the CHARLS data. Standard errors clustered by province are reported in parentheses. Significance: *** p<0.01, ** p<0.05, * p<0.1.

Table 3: Intergenerational impacts of mother's exposure to famine on children's economic and labour market outcomes

	Midpoint of child and spouse's income categories (in `000s)	Child has high sch. or higher	Child is currently working	Child has Ever Worked
	(1)	(2)	(3)	(4)
Panel A: Daughters				
Mother birth year 1959-1962	19.208**	0.038	0.000	-0.050
	(8.640)	(0.073)	(0.054)	(0.046)
Birth city CSSI is 75th percentile or higher in rural areas (INTFAM)	3.712	0.079	0.063	0.116*
	(2.318)	(0.074)	(0.053)	(0.062)
INTFAM x birth 1959-1962	-7.528***	-0.147*	-0.095**	-0.081**
	(2.627)	(0.078)	(0.038)	(0.038)
Mean of the outcome	23.658	0.287	0.779	0.888
N	1,098	1,194	1,187	1,188
R-squared	0.169	0.255	0.086	0.136
Panel B: Sons				
Mother birth year 1959-1962	9.823	0.002	0.004	0.020
	(8.374)	(0.084)	(0.050)	(0.033)
Birth city CSSI is 75th percentile or higher in rural areas (INTFAM)	0.788	0.128**	-0.033	0.006
	(4.810)	(0.049)	(0.056)	(0.024)
INTFAM x birth 1959-1962	-7.802	-0.154	0.031	-0.007
	(4.695)	(0.092)	(0.053)	(0.034)
Mean of the outcome	23.053	0.293	0.886	0.920
N	837	878	883	883
R-squared	0.266	0.326	0.201	0.268
Panel C: All children				
Mother birth year 1959-1962	16.038**	0.023	-0.004	-0.022
	(7.749)	(0.052)	(0.040)	(0.032)
Birth city CSSI is 75th percentile or higher in rural areas (INTFAM)	2.860	0.108*	0.038	0.072
	(2.771)	(0.055)	(0.037)	(0.043)
INTFAM x birth 1959-1962	-7.842**	-0.157**	-0.045	-0.049*
	(3.106)	(0.056)	(0.033)	(0.028)
Mean of the outcome	23.321	0.290	0.837	0.906
N	1,935	2,072	2,070	2,071
R-squared	0.186	0.272	0.073	0.125

Note: Sample includes children born to female respondents with year of birth in the 1953-1956 and 1959-1962 time windows, whose birthplace was rural. Regressions include all child-specific characteristics such as age, age squared, child with agricultural Hukou status, birth order and quarter of birth, and mother-specific characteristics including birth year, birth year squared. Regressions include maternal birth province fixed-effects and are weighted to national levels using weights provided in the CHARLS data. Standard errors clustered by maternal birth province are reported in parentheses. Significance: *** p<0.01, ** p<0.05, * p<0.1.

Table 4: Potential mechanisms

	Spouse's birth city CSSI is 75th percentile or higher	Has high sch. or higher	Per capita income (in `000s)	Has any chronic conditions	Natural log of the number of chronic conditions
	(1)	(2)	(3)	(4)	(5)
Panel A: Impact of mother's exposure to famine on their outcomes					
Mother birth year 1959-1962		0.098	0.153	0.041	0.049
		(0.059)	(2.649)	(0.091)	(0.092)
Birth city CSSI is 75th percentile or higher in rural areas (INTFAM)		0.035	1.462	-0.022	-0.096
		(0.027)	(1.314)	(0.066)	(0.073)
INTFAM x birth 1959-1962		-0.102***	-3.554**	0.095	0.181**
		(0.035)	(1.562)	(0.074)	(0.070)
Mean of the outcome		0.073	11.222	0.674	0.297
N		1,366	1,348	1,303	1,303
R-squared		0.077	0.092	0.063	0.079
Panel B: Impact of mother's exposure to famine on spouse's outcomes					
Mother birth year 1959-1962	0.005	0.018	-1.112	0.049	0.020
	(0.039)	(0.058)	(3.093)	(0.094)	(0.077)
Birth city CSSI is 75th percentile or higher in rural areas (INTFAM)	0.931***	0.012	1.567	-0.098*	-0.089
	(0.017)	(0.048)	(1.477)	(0.050)	(0.053)
INTFAM x birth 1959-1962	0.018	-0.076	-2.972	0.009	0.081
	(0.026)	(0.052)	(1.963)	(0.059)	(0.072)
Mean of the outcome	0.195	0.181	11.486	0.647	0.171
N	1,214	1,242	1,235	1,192	1,192
R-squared	0.897	0.117	0.095	0.074	0.078

Note: Sample includes female respondents with year of birth in the 1953-1956 and 1959-1962 time windows, whose birthplace was rural. Regressions include mother-specific exogenous characteristics including birth year, birth year squared, and mother's birth province fixed-effects and are weighted to national levels using weights provided in the CHARLS data. Standard errors clustered by province are reported in parentheses. Significance: *** p<0.01, ** p<0.05, * p<0.1.

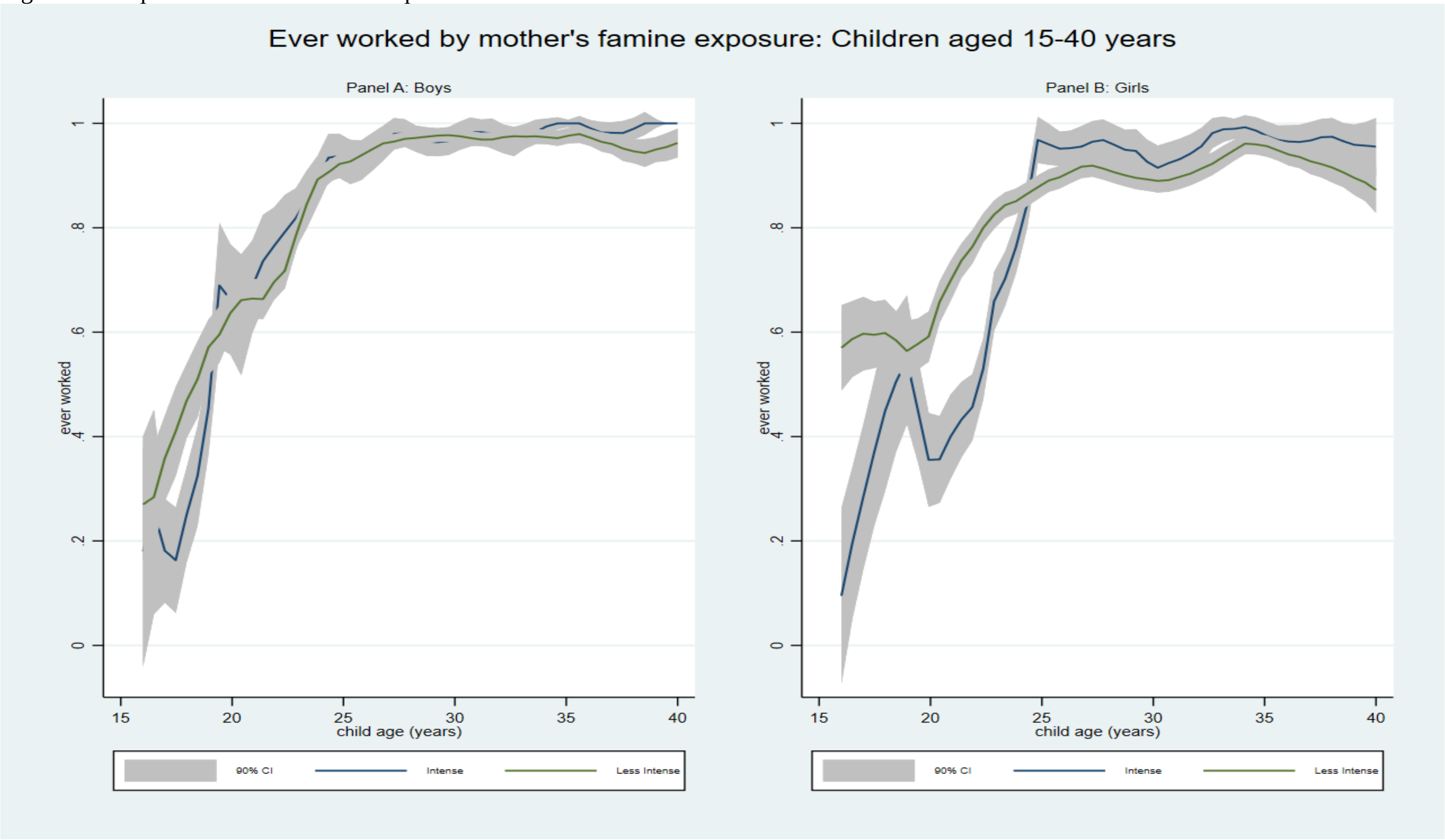
Table 5: Intergenerational impacts of mother's exposure to famine on economic and labour market outcomes of daughters in the full sample and in disaggregated samples

	Midpoint of child & spouse's income categories (in `000s)	Child has high sch. or higher	Child is currently working	Child has ever worked
	(1)	(2)	(3)	(4)
Panel A: Full sample				
Mother birth year 1959-1962	19.284**	0.036	0.000	-0.050
	(8.730)	(0.073)	(0.054)	(0.046)
Birth province CSSI is 75th per.	4.142*	0.069	0.062	0.114*
or higher in rural areas (INTFAM)	(2.297)	(0.071)	(0.053)	(0.062)
INTFAM x birth 1959-1962	-7.628***	-0.144*	-0.094**	-0.081**
	(2.704)	(0.077)	(0.037)	(0.037)
N	1,098	1,194	1,187	1,188
R-squared	0.171	0.259	0.086	0.136
Panel B: Households with daughters only				
Mother birth year 1959-1962	14.676	-0.073	0.191	0.154
	(13.099)	(0.195)	(0.135)	(0.157)
Birth province CSSI is 75th per.	-9.592	-0.130	0.069	0.093*
or higher in rural areas (INTFAM)	(6.037)	(0.198)	(0.081)	(0.052)
INTFAM x birth 1959-1962	-0.699	0.098	0.045	-0.163*
	(7.420)	(0.236)	(0.105)	(0.094)
N	217	229	227	227
R-squared	0.389	0.383	0.266	0.260
Panel C: Households with daughters and sons				
Mother birth year 1959-1962	19.185*	0.046	-0.033	-0.083
	(10.986)	(0.079)	(0.081)	(0.071)
Birth province CSSI is 75th per.	6.974**	0.115*	0.082	0.120*
or higher in rural areas (INTFAM)	(3.054)	(0.060)	(0.059)	(0.061)
INTFAM x birth 1959-1962	-9.775**	-0.195**	-0.162***	-0.068*
	(3.516)	(0.071)	(0.052)	(0.034)
N	881	965	960	961
R-squared	0.162	0.294	0.104	0.155
Panel D: Households with daughters and younger sons				
Mother birth year 1959-1962	26.334*	-0.015	-0.136	-0.126
	(14.863)	(0.105)	(0.104)	(0.086)
Birth province CSSI is 75th per.	6.477	0.119	0.126*	0.145**
or higher in rural areas (INTFAM)	(4.163)	(0.076)	(0.064)	(0.069)
INTFAM x birth 1959-1962	-13.971***	-0.274***	-0.207***	-0.122**
	(4.812)	(0.097)	(0.063)	(0.051)
N	584	646	644	643
R-squared	0.189	0.293	0.108	0.157

Note: Sample includes children born to mothers with year of birth in the 1953-1956 and 1959-1962 time windows, whose birthplace was rural. Regressions include child-specific characteristics such as age, age squared, birth order, Hukou status, quarter of birth, and total number of sons and daughters in the household, and mother-specific characteristics including mother's year of birth and mother's year of birth squared, and birth cohort dummies from 1959 to 1962. Regressions include a constant term and province fixed-effects, and are weighted to national levels using weights provided in the CHARLS data. Standard errors clustered by province are reported in parentheses. Significance: *** p<0.01, ** p<0.05, * p<0.1.

PAPER APPENDIX

Figure A1: Impact of mother's famine exposure on whether children ever worked



Notes: Sample includes children born to respondents with year of birth in the 1949 to 1969 time window, whose birthplace was rural. Graphs are weighted to national levels using weights provided in the CHARLS data. "Intense" denotes areas where mother's birth city CSSI has a value that is higher than the 75^{th} percentile or higher in rural areas, "less intense" denotes areas where mother's birth city CSSI is less than its 75^{th} percentile value in rural areas. Figure plots 90 percent confidence intervals.

Table A1: Summary statistics for children

	Male Children			**Female Children**			**Combined**		
	Mean	*Std. dev*	*N*	*Mean*	*Std. dev*	*N*	*Mean*	*Std. dev*	*N*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A: Child's outcomes									
Midpoint of child and spouse's income categories (`000s Yuan)	23.053	24.989	1918	23.658	27.766	1597	23.321	26.256	3515
Child has completed high school or higher	0.293	0.455	1973	0.287	0.452	1706	0.290	0.454	3679
Child is currently working	0.886	0.318	1983	0.779	0.415	1711	0.837	0.369	3694
Child has ever worked before	0.920	0.271	1983	0.888	0.315	1712	0.906	0.292	3695
Panel B: Child-specific characteristics									
Age in years	28.393	5.433	2016	28.468	5.276	1742	28.427	5.362	3758
Age in years squared	835.659	312.470	2016	838.222	307.613	1742	836.827	310.227	3758
Male	1.000	0.000	2016	0.000	0.000	1742	0.544	0.498	3758
Birth order is first born	0.411	0.492	2016	0.431	0.495	1742	0.420	0.494	3758
Birth order is second born	0.366	0.482	2016	0.344	0.475	1742	0.356	0.479	3758
Birth order is third born	0.151	0.358	2016	0.155	0.362	1742	0.153	0.360	3758
Birth order is fourth born or higher	0.071	0.257	2016	0.070	0.255	1742	0.071	0.256	3758
Month of birth is in the first quarter	0.186	0.390	1031	0.213	0.410	1374	0.201	0.401	2405
Month of birth is in the second quarter	0.231	0.422	1031	0.196	0.397	1374	0.211	0.408	2405
Month of birth is in the third quarter	0.237	0.425	1031	0.250	0.433	1374	0.244	0.430	2405
Month of birth is in the fourth quarter	0.346	0.476	1031	0.341	0.474	1374	0.343	0.475	2405
Has agricultural Hukou status	0.856	0.352	1763	0.844	0.363	1637	0.850	0.357	3400

Notes: Sample includes all children born to respondents with year of birth in the 1953-1956 and 1959-1962 time windows, whose birthplace was rural. Statistics are weighted to national levels using weights provided in the CHARLS data. Column headings denote gender of the child.

Table A2: Mean value of city cohort size shrinkage (CSSI) indices.

Province	City	CSSI	Province	City	CSSI	Province	City	CSSI
Anhui	Anqing	0.685	Hunan	Changde	0.546	Sichuan	Meishan	0.689
Anhui	Bozhou	0.546	Hunan	Loudi	0.585	Sichuan	Mianyang	0.632
Anhui	Chaohu	0.800	Hunan	Shaoyang	0.546	Sichuan	Nanchong	0.641
Anhui	Fuyang	0.546	Hunan	Yiyang	0.558	Sichuan	Neijiang	0.629
Anhui	Huainan	0.331	Hunan	Yueyang	0.613	Sichuan	Yibin	0.632
Anhui	Liuan	0.711	Jiangsu	Lianyungang	0.418	Tianjin	Tianjin	0.462
Chongqing	Chongqing	0.586	Jiangsu	Suzhou	0.544	Xinjiang	Akesu	0.071
Fujian	Fuzhou	0.388	Jiangsu	Yancheng	0.340	Yunnan	Baoshan	0.332
Fujian	Ningde	0.375	Jiangsu	Yangzhou	0.540	Yunnan	Chuxiong	0.552
Fujian	Putian	0.339	Jiangxi	Ganzhou	0.403	Yunnan	Kunming	0.381
Fujian	Zhangzhou	0.356	Jiangxi	Jingdezhen	0.381	Yunnan	Lijiang	0.378
Gansu	Dingxi	0.498	Jiangxi	Jiujiang	0.400	Yunnan	Lincang	0.358
Gansu	Pingliang	0.514	Jiangxi	Nanchang	0.457	Yunnan	Zhaotong	0.387
Gansu	Zhangye	0.449	Jiangxi	Shangrao	0.253	Zhejiang	Huzhou	0.308
Guangdong	Guangzhou	0.405	Jiangxi	Yichun	0.351	Zhejiang	Lishui	0.394
Guangdong	Jiangmen	0.385	Jilin	Siping	0.267	Zhejiang	Ningbo	0.380
Guangdong	Maoming	0.377	Liaoning	Anshan	0.389	Zhejiang	Taizhou	0.384
Guangdong	Qingyuan	0.377	Liaoning	Chaoyang	0.248			
Guangdong	Foshan	0.405	Liaoning	Dalian	0.305			
Guangdong	Shenzhen	0.446	Liaoning	Jinzhou	0.381			
Guangxi	Guilin	0.586	Neimenggu	Chifeng	0.119			
Guangxi	Hechi	0.515	Neimenggu	Hulunbuir	0.264			
Guangxi	Nanning	0.445	Neimenggu	Xilingol	0.163			
Guangxi	Yulin	0.334	Qinghai	Haidong	0.568			
Guizhou	Qiandongnan	0.564	Shaanxi	Baoji	0.238			
Guizhou	Qiannan	0.536	Shaanxi	Hanzhong	0.347			
Hebei	Baoding	0.315	Shaanxi	Weinan	0.254			
Hebei	Chengde	0.207	Shaanxi	Yulin	0.108			
Hebei	Shijiazhuang	0.349	Shandong	Binzhou	0.546			
Heilongjiang	Jixi	0.133	Shandong	Dezhou	0.510			
Henan	Anyang	0.514	Shandong	Jinan	0.405			
Henan	Jiaozuo	0.437	Shandong	Liaocheng	0.426			
Henan	Pingdingshan	0.448	Shandong	Linyi	0.302			
Henan	Puyang	0.519	Shandong	Weihai	0.427			
Henan	Xinyang	0.501	Shandong	Zaozhuang	0.347			
Henan	Zhengzhou	0.475	Shanxi	Linfen	0.174			
Henan	Zhoukou	0.549	Shanxi	Xinzhou	0.178			
Hubei	Enshi	0.522	Shanxi	Yangquan	0.456			
Hubei	Huanggang	0.446	Shanxi	Yuncheng	0.238			
Hubei	Jingmen	0.407	Sichuan	Ganzi	0.463			
Hubei	Xiangfan	0.396	Sichuan	Liangshan	0.549			

Notes: Sample includes mothers with year of birth in the 1959 to 1962 time window, whose birthplace was rural. Table reports weighted means. Author’s calculations.

Table A3: Summary statistics for mothers

	Mean	*Std. dev*	*N*
Panel A: Mother's famine exposure measures			
Birth city cohort size shrinkage index (CSSI)	0.425	0.131	1366
Birth city CSSI is 75th percentile or higher in rural areas	0.214	0.410	1366
Year of birth is 1953	0.131	0.337	1566
Year of birth is 1954	0.153	0.360	1566
Year of birth is 1955	0.142	0.349	1566
Year of birth is 1956	0.120	0.326	1566
Year of birth is 1959	0.095	0.293	1566
Year of birth is 1960	0.091	0.288	1566
Year of birth is 1961	0.112	0.315	1566
Year of birth is 1962	0.156	0.363	1566
Panel B: Mother-specific variables			
Age in years	53.788	3.334	1566
Age in years squared	2904.272	356.864	1566
Completed high school or above	0.073	0.260	1563
Income per capita (`000s)	11.222	18.422	1546
Has any chronic conditions	0.674	0.469	1491
Number of chronic conditions	1.346	1.393	1491
Had any natural abortions or stillbirths	0.094	0.292	1403
Percent of her sons at age 0-2 years mainly cared for by her	0.256	0.339	1401
Percent of her sons at age 3-5 years mainly cared for by her	0.259	0.339	1401
Percent of her daughters at age 0-2 years mainly cared for by her	0.199	0.299	1401
Percent of her daughters at age 3-5 years mainly cared for by her	0.197	0.297	1401
Panel C: Spouse-specific variables			
Birth city cohort size shrinkage index (CSSI)	0.416	0.133	1289
Birth city CSSI is 75th percentile or higher in rural areas	0.195	0.396	1289
Age in years	56.088	4.803	1429
Age in years squared	3168.897	552.632	1430
Completed high school or above	0.181	0.385	1430
Income per capita (`000s)	11.486	17.827	1422
Has any chronic conditions	0.647	0.478	1372
Number of chronic conditions	1.186	1.270	1372

Notes: Sample includes all respondent mothers with year of birth in the 1953-1956 and 1959-1962 time windows, whose birthplace was rural. Statistics are weighted to national levels using weights provided in the CHARLS data and report unique values for each respondent.

Table A4: Impacts of mother's exposure to famine on lack of reproductive success and children's caregiving

	Mother has had any natural abortions or stillbirths	Mother main caregiver of			
		Sons		Daughters	
		0-2 years	3-5 years	0-2 years	3-5 years
	(1)	(2)	(3)	(4)	(5)
Mother birth year 1959-1962	0.059	0.022	0.017	-0.027	-0.026
	(0.057)	(0.055)	(0.055)	(0.051)	(0.051)
Birth city CSSI is 75th percentile	-0.021	0.063**	0.066**	0.040	0.038
or higher in rural areas (INTFAM)	(0.041)	(0.028)	(0.027)	(0.039)	(0.039)
INTFAM x birth 1959-1962	0.001	-0.043	-0.047	-0.016	-0.015
	(0.031)	(0.052)	(0.051)	(0.056)	(0.052)
N	1,254	1,253	1,253	1,253	1,253
R-squared	0.030	0.034	0.035	0.046	0.042

Note: Sample includes children born to mothers with year of birth in the 1953-1956 and 1959-1962 time windows, whose birthplace was rural. Regressions include child-specific characteristics such as age, age squared, birth order, Hukou status, and quarter of birth, and mother-specific characteristics including mother's year of birth and mother's year of birth squared, and birth cohort dummies from 1959 to 1962. Regressions include a constant term and province fixed-effects, and are weighted to national levels using weights provided in the CHARLS data. Standard errors clustered by province are reported in parentheses. Significance: *** p<0.01, ** p<0.05, * p<0.1.

Table A5: Intergenerational impacts of mother's exposure to famine on outcomes of daughters using both pre-famine (1953-1956) and post-famine (1963-1966) cohorts in the control group

	Midpoint of child and spouse's income categories (in `000s)	Child has high sch. or higher	Child is currently working	Child has ever worked
	(1)	(2)	(3)	(4)
Panel A: Daughters				
Mother birth year 1959-1962	3.222	0.012	0.083**	0.052**
	(2.407)	(0.040)	(0.032)	(0.019)
Birth city CSSI is 75th percentile	2.895	0.121*	0.028	0.105**
or higher in rural areas (INTFAM)	(2.345)	(0.061)	(0.043)	(0.047)
INTFAM x birth 1959-1962	-7.134**	-0.149**	-0.043	-0.077**
	(3.102)	(0.067)	(0.050)	(0.030)
N	1,441	1,561	1,553	1,554
R-squared	0.138	0.254	0.088	0.138
Panel B: Sons				
Mother birth year 1959-1962	4.581	-0.000	0.020	0.031
	(4.641)	(0.045)	(0.031)	(0.025)
Birth city CSSI is 75th percentile	1.998	0.121***	-0.002	0.023
or higher in rural areas (INTFAM)	(3.741)	(0.036)	(0.042)	(0.029)
INTFAM x birth 1959-1962	-9.610*	-0.228**	0.101	0.067
	(4.779)	(0.106)	(0.071)	(0.067)
N	1,068	1,113	1,119	1,119
R-squared	0.246	0.277	0.314	0.375
Panel C: All children				
Mother birth year 1959-1962	4.078	0.012	0.065**	0.051***
	(2.563)	(0.040)	(0.026)	(0.018)
Birth city CSSI is 75th percentile	2.909	0.136***	0.034	0.067*
or higher in rural areas (INTFAM)	(2.048)	(0.048)	(0.035)	(0.038)
INTFAM x birth 1959-1962	-8.017**	-0.201***	0.022	-0.001
	(3.427)	(0.060)	(0.047)	(0.050)
N	2,509	2,674	2,672	2,673
R-squared	0.157	0.244	0.105	0.167

Note: Table reports estimates when both pre-famine (1953-1956) and post-famine (1963-1966) cohorts are used in the control group. Sample includes children born to female respondents with year of birth in the 1953-1956 and 1959-1966 time windows, whose birthplace was rural. Regressions include all child-specific characteristics such as age, age squared, child with agricultural Hukou status, birth order and quarter of birth, and mother-specific characteristics including birth year, birth year squared. Regressions include maternal birth province fixed-effects and are weighted to national levels using weights provided in the CHARLS data. Standard errors clustered by maternal birth province are reported in parentheses. Significance: *** p<0.01, ** p<0.05, * p<0.1.

Endnotes

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[1] Outcomes for this population that have been studied include excess male mortality (Almond *et al*. 2010), physical health as proxied by height and BMI (Fung and Ha 2010), hypertension (Huang *et al*. 2010), blood pressure, hyperglycemia and metabolic syndrome (Li *et al*. 2011a, 2011b), overall mortality (Song 2010), subjective health indicators for disability, physical pain, vitality and mental health (Fan and Qian 2015), physical health and cognitive abilities (Kim *et al* 2017) and economic indicators such as labour supply and income (Meng and Qian 2009).
[2] For this reason, we focus on mothers in this study. However, we did consider impacts of father's exposure on both sons and daughters as well. These results were mostly measured with error and are available on request.
[3] On average, each province in China consists of about 10 prefectures and each prefecture consists of about nine counties.
[4] In our estimation sample, 98 percent of children are either the biological children of the respondent and their spouse or the biological child of the respondent alone.
[5] These results are available on request.
[6] We use cohort sizes during both pre- and post-famine years to construct the CSSI because this provides a better counterfactual of expected cohort sizes in the absence of the famine. We experimented with slightly different windows of pre- and post- famine years and our CSSI measures were relatively consistent. In the end, we follow the framework in equation (1) as this is the same as in Xu *et al*. (2016).
[7] The CHARLS implemented a separate Life History Survey in a subsequent wave which includes questions related to experience with the famine. We use these data to check the integrity of our CSSI measure. Descriptively, the response to these life history questions is consistent with our prefecture-level CSSI measure: respondents who report experiencing starvation (and those with family members who starved to death) due to famine have significantly higher CSSI measures; the CSSI measure increases as respondents report larger numbers for those who perished due to food shortages.
[8] For example, in Shanxi province that borders northern Inner Mongolia, city-level exposure varied from 0.174 in Linfen to 0.456 in Yangquan. In Sichuan province where the famine was more severe, exposure varied from 0.463 in Ganzi to 0.689 in Meishan.
[9] We justify our use of this cut-off below.
[10] The results of this robustness check are provided in Table A5 in the Appendix.
[11] In another check, we controlled for child current residential province fixed-effects in addition to these maternal fixed-effects. The estimated effect signs are identical and the effect sizes and statistical significance levels are very similar to our main results. Results are available on request.
[12]Zeng *et al*. (1993) notes that sex detection technologies and thus sex-selective abortions became widespread in China only after the mid-1980s. Further, Das Gupta and Li (1999) notes that health care access for mothers and children is likely to have been limited around the time of the famine in China.
[13] One question in the Life History Survey asked the respondents "During those days, did the food shortage result in any of the following for your family: put off marriage, put off giving birth, could not give birth, artificial abortion, or none of that."
[14] These characteristics are mostly distinct from the other variables that we test as mechanisms. Please see below.
[15] At the 2011 exchange rate of US dollar 1 = 6 Yuan, this is about 2,100 US dollars.
[16] Results available on request.
[17] In results not reported but available on request, there is no difference in terms of her being the main caregiver of her children in general.
[18] The results for these additional robustness checks are available on request.
[19] All we do is shift our control time frame of 1953-1956 and the treated famine time frame of 1959-1962 earlier by a random number of years, in our case, 6 years. The only modification is that instead of starting the control group at 1947 (1953-6), we begin in 1949 to acknowledge the fact that Chairman Mao's coming to power in that year significantly changed political and economic institutions in China thereafter.

SUPPLEMENTARY MATERIALS

Appendix A: Tests for parallel trends

Tests for parallel trends are presented in Table S1. Panel A presents child outcomes measures in places where mothers experienced less intense famine (column 1), in places where mothers experienced more intense famine (column 2), and the differences in the estimates across these two groups (column 3). Panel A shows that outcomes are essentially the same across these areas except for the marginal difference in ever worked. The remaining panels of Table S1 further underline few statistical differences in any child characteristics noted in Panel B across these groups. Panel C shows that this is also true for mother characteristics.

Appendix B: Results

Table S2 presents results of the intergenerational impacts of mother's exposure to famine on children's outcomes, disaggregated by mother's birth cohorts. Results are presented separately for daughters (Panel A), sons (Panel B), and all children (Panel C). Each column reports coefficients from a separate regression on specific outcome variables. All regressions include the full set of controls discussed above but, similar to Chen and Zhou (2007) and in the interests of conserving space, we report only the key variables of interest (β_2 and γ_t).

Regarding child's income, Panel A of Table S2 reports that girls of mothers born in 1960 earn 9,300 Yuan less (39.3% decline relative to the mean), and girls of mothers born in 1962 earn 5,804 Yuan less (24.5% decline relative to the mean), as compared to their counterparts. Considering child work propensities, the probability of currently working is 34.8 percentage points lower (44.7% decrease relative to the mean) for girls of mother born in 1959. Daughters of mothers born in 1961 are 6.8 percentage points less likely (7.7% decrease) to have ever worked before. Daughters of mothers exposed to severe famine in 1960 and 1961 are 21.4 percentage points and 22.8 percentage points less likely, respectively (74.6% and 79.4% declines, respectively), to complete high school or above. In keeping with the hypotheses in Section

4.1., there is some evidence that those born in 1959 – 1960 were relatively more affected than those born in 1961 and 1962. Across the outcomes, negative and significant effects are evident in the first set of years for income, high school or higher, and for whether the child is currently working, and the magnitude of the coefficients is mostly larger than in the second set of years (if results are measured precisely for the same outcome). For instance, income is lower by 9,300 Yuan for daughters with mothers born in 1960 but lower by 5,804 Yuan for daughters with mothers born in 1962.[1]

Considering effects disaggregated by maternal birth cohorts in Panel B of Table S2, boys of mothers born in 1961 earn 19,409 Yuan less (84.2% decline relative to the mean) than their counterparts. These mothers are likely to have been exposed prenatally to intense famine and exposed to some extent post-birth. The probability of completing high school education or higher is 24.4 percentage points lower (83.3% decline relative to the mean) for boys of mothers born in 1959. The estimated effects on work propensities are insignificant for all birth cohorts.

Panel C of Table S2 presents results for the combined sample of daughters and sons of mothers who survived the famine. Many of the results from the daughters sample in Panel A are evident in Panel C. In particular, children of mothers born in 1962 who experienced severe famine earn 5,348 Yuan less (20.4% decline relative to the mean). Those with mothers born in 1960 and 1961 have lower educational attainment, and those with mothers born in 1959 are 16.2 percentage points less likely to work currently as compared to their counterparts. Given the mostly insignificant results for sons in Panel B of this table, we conclude that many of the effects in Panel C for all children may be attributed to the negative effects on daughters.

Appendix C: Mechanisms

Table S3 presents results separately for the impact of the famine on mother's outcomes (Panel A) and on spouses' outcomes (Panel B), disaggregated by famine-exposed birth cohorts. Considering these effects across different cohorts in column (2), treated mothers born in 1959 are 16.4 percentage points less likely to complete high school or above, and treated mothers born in 1960 are 13.1 percentage points less likely to attain this level. Similar negative effects are also evident for mothers born in 1961 and 1962 although these are not precisely estimated.

In column (4) of Table S3, treated mothers born in 1960 are 10.4 percentage points more likely to have chronic conditions; similarly, treated mothers born in 1961 are 20.4 percentage points more likely to have chronic conditions. Results in column (5) indicate that those born in 1961 have a relatively higher number of chronic conditions.

The effects of mother's exposure on spouse's outcomes are shown in Panel B of Table S3. Focusing first on the impact of mother's exposure on father's treatment status, column (1) reports that mothers' who were exposed to severe famine in 1960 and 1961 are about 5.0 percentage points and 8.3 percentage points, respectively, more likely to marry fathers who were similarly exposed. Columns (2) to (5) show that mothers who were exposed to severe famine tend to marry fathers with worse education outcomes but somewhat better health outcomes on average. Specifically, mothers exposed to severe famine in 1960 have spouses with a reduced likelihood of completing high school (by 15.1 percentage points in column (2) of Panel B) and a reduced likelihood of having any chronic conditions (by a significant 34.8 percentage points in column (4) of Panel B).

Appendix D: Robustness checks

Panel A of Table S4 reports results when we use the aggregate cohort size-based measure of famine exposure, province-level CSSI. These results indicate that overall, some of the patterns revealed by using the prefecture/city-level CSSI are overlooked when we utilize the aggregate province-level CSSI measure.

Panel B of Table S4 reports results when famine intensity is measured with province-level EDR constructed using the methodology in Chen and Zhou (2007). The only difference is that to maintain consistency with our model and to improve clarity, we define EDR in its non-linear form where the indicator takes the value 1 if the underlying continuous EDR variable is equal to or exceeds the 75th percentile cut-off, and is 0 otherwise. Although there is no result for income using this measure, provincial EDR predicts intuitive results for the remaining outcomes. We conclude that overall, the EDR measure performs quite well. However, using our preferred measure, prefecture/city-level CSSI, reveals relatively more precisely measured effects.

Appendix E: Falsification test

Table S5 presents results when we use 1953-1956 as the “treated” group and 1949-1952 as “control.” Since the 1953-1956 time period preceded the famine by 3 to 6 years, no impacts should be evident. For child income, educational attainment, and work propensities, interaction coefficients are all insignificant. The results in Table S5 confirm that those documented in the main results of Table 3 may be attributed to the famine, and that there are few omitted variables that threaten validity.

Table S1: Prefecture/city level average of child and mother's characteristics in rural areas by mother's birth city CSSI indicator in the years before the famine (1953-1956)

	Famine was less intense (1)	Famine was more intense (2)	Difference (3)
Panel A: Child's outcomes			
Midpoint of child and spouse's income categories (`000s Yuan)	23.105 (1.278)	26.815 (2.481)	-3.710 (2.627)
Has completed high school or higher	0.227 (0.022)	0.262 (0.037)	-0.034 (0.043)
Currently working	0.849 (0.019)	0.899 (0.018)	-0.050 (0.034)
Has ever worked	0.923 (0.015)	0.977 (0.009)	-0.054 (0.027)**
Panel B: Child-specific characteristics			
Age in years	30.782 (0.275)	31.052 (0.503)	-0.270 (0.558)
Age in years squared	972.429 (17.275)	990.084 (31.530)	-17.655 (35.013)
Male	0.540 (0.018)	0.574 (0.026)	-0.034 (0.035)
Birth order	1.933 (0.048)	1.769 (0.065)	0.164 (0.092)*
Has an agricultural Hukou	0.867(0.021)	0.797 (0.038)	0.070(0.043)
Month of birth is in the first quarter	0.227 (0.026)	0.232 (0.037)	-0.005 (0.049)
Month of birth is in the second quarter	0.203 (0.019)	0.211 (0.033)	-0.008 (0.038)
Month of birth is in the third quarter	0.252 (0.022)	0.207 (0.025)	0.044 (0.040)
Month of birth is in the fourth quarter	0.318 (0.018)	0.349 (0.040)	-0.032 (0.038)
Panel C: Mother-specific characteristics			
Year of birth	1954.442 (0.053)	1954.389 (0.111)	0.053 (0.111)
Year of birth squared	3819846 (205.696)	3819638 (432.468)	207.489 (434.546)

Notes: Author's calculations. Columns report percentages unless otherwise specified. "Less intense" includes areas where the mother's birth city CSSI measure is lower than its 75th percentile value in rural areas, "more intense" includes areas where the mother's birth city CSSI measure was the 75th percentile value or higher in rural areas. Statistics reported for all years before the famine (1953-1956) and include rural areas as per the mother's place of birth. Weighted to national levels with weights provided in the CHARLS data. Standard errors in parentheses. Significance: *** p<0.01, ** p<0.05, * p<0.1.

Table S2: Intergenerational impacts of mother's exposure to famine on children's economic and labour market outcomes, disaggregated by mother's birth cohorts

	Midpoint of child and spouse's income categories (in `000s)	Child has high sch. or higher	Child is currently working	Child has Ever Worked
	(1)	(2)	(3)	(4)
Panel A: Daughters				
Birth city CSSI is 75th percentile or higher in rural areas (INTFAM)	3.261	0.069	0.073	0.123*
	(2.512)	(0.072)	(0.052)	(0.062)
INTFAM x birth1959	-17.490	-0.116	-0.348***	-0.119
	(11.227)	(0.202)	(0.080)	(0.101)
INTFAM x birth1960	-9.300*	-0.214**	-0.096	-0.117
	(4.706)	(0.092)	(0.108)	(0.103)
INTFAM x birth1961	4.665	-0.228*	0.067	-0.068*
	(5.489)	(0.117)	(0.066)	(0.037)
INTFAM x birth1962	-5.804*	-0.066	-0.004	-0.038
	(3.043)	(0.073)	(0.083)	(0.032)
Mean of the outcome	23.658	0.287	0.779	0.888
N	1,098	1,194	1,187	1,188
R-squared	0.174	0.258	0.096	0.144
Panel B: Sons				
Birth city CSSI is 75th percentile or higher in rural areas (INTFAM)	0.238	0.127***	-0.038	0.007
	(4.786)	(0.045)	(0.056)	(0.026)
INTFAM x birth1959	-9.196	-0.244***	-0.010	-0.019
	(6.442)	(0.086)	(0.036)	(0.020)
INTFAM x birth1960	-2.938	-0.123	0.067	0.015
	(8.142)	(0.126)	(0.073)	(0.055)
INTFAM x birth1961	-19.409**	-0.205	0.064	0.041
	(8.046)	(0.219)	(0.048)	(0.027)
INTFAM x birth1962	-2.556	-0.014	0.020	-0.033
	(5.370)	(0.108)	(0.088)	(0.070)
Mean of the outcome	23.053	0.293	0.886	0.920
N	837	878	883	883
R-squared	0.277	0.350	0.206	0.270
Panel C: All Children				
Birth city CSSI is 75th percentile or higher in rural areas (INTFAM)	2.641	0.105*	0.039	0.077*
	(2.862)	(0.053)	(0.037)	(0.042)
INTFAM x birth1959	-13.692	-0.175	-0.162**	-0.053
	(8.559)	(0.113)	(0.075)	(0.060)
INTFAM x birth1960	-5.327	-0.199***	-0.045	-0.067
	(4.424)	(0.062)	(0.086)	(0.080)
INTFAM x birth1961	-6.529	-0.240*	0.051	-0.029
	(5.461)	(0.125)	(0.037)	(0.024)
INTFAM x birth1962	-5.348**	-0.051	-0.014	-0.049
	(2.297)	(0.075)	(0.050)	(0.038)
Mean of the outcome	23.321	0.290	0.837	0.906

N	1,935	2,072	2,070	2,071
R-squared	0.189	0.281	0.079	0.130

Note: Sample includes children born to female respondents with year of birth in the 1953-1956 and 1959-1962 time windows, whose birthplace was rural. Regressions include all child-specific characteristics such as age, age squared, child with agricultural Hukou status, birth order and quarter of birth, and mother-specific characteristics including birth year, birth year squared. Regressions include maternal birth province fixed-effects and are weighted to national levels using weights provided in the CHARLS data. Standard errors clustered by maternal birth province are reported in parentheses. Significance: *** p<0.01, ** p<0.05, * p<0.1.

Table S3: Potential mechanisms results, disaggregated by mother's birth cohorts

	Spouse's birth city CSSI is 75th percentile or higher	Has high sch. or higher	Per capita income (in `000s)	Has any chronic conditions	Natural log of the number of chronic conditions
	(1)	(2)	(3)	(4)	(5)
Panel A: Impacts of mother's exposure to famine on their outcomes					
Birth city CSSI is 75th percentile or higher in rural areas (INTFAM)		0.034	1.466	-0.018	-0.096
		(0.029)	(1.246)	(0.067)	(0.074)
INTFAM x birth1959		-0.164***	-0.311	0.120	0.172
		(0.053)	(2.780)	(0.128)	(0.118)
INTFAM x birth1960		-0.131**	-1.989	0.104*	0.146
		(0.049)	(2.595)	(0.059)	(0.102)
INTFAM x birth1961		-0.089	-5.117	0.204*	0.260**
		(0.065)	(3.716)	(0.110)	(0.124)
INTFAM x birth1962		-0.047	-4.878	0.041	0.172
		(0.036)	(3.817)	(0.100)	(0.103)
Mean of the outcome		0.073	11.222	0.674	0.297
N		1,366	1,348	1,303	1,303
R-squared		0.081	0.094	0.069	0.082
Panel B: Impacts of mother's exposure to famine on spouse's outcomes					
Birth city CSSI is 75th percentile or higher in rural areas (INTFAM)	0.933***	0.009	1.623	-0.099*	-0.095*
	(0.016)	(0.052)	(1.415)	(0.049)	(0.054)
INTFAM x birth1959	-0.037	-0.062	1.352	0.003	0.040
	(0.073)	(0.075)	(2.962)	(0.106)	(0.080)
INTFAM x birth1960	0.050*	-0.151**	-1.399	-0.348***	-0.399***
	(0.026)	(0.055)	(3.235)	(0.073)	(0.069)
INTFAM x birth1961	0.083***	-0.246*	-5.414	0.075	0.102
	(0.023)	(0.119)	(3.945)	(0.144)	(0.151)
INTFAM x birth1962	0.006	0.057	-4.373	0.109	0.275**
	(0.045)	(0.052)	(3.929)	(0.069)	(0.102)
Mean of the outcome	0.195	0.181	11.486	0.647	0.171
N	1,214	1,242	1,235	1,192	1,192
R-squared	0.898	0.134	0.098	0.083	0.092

Note: Sample includes female respondents with year of birth in the 1953-1956 and 1959-1962 time windows, whose birthplace was rural. Regressions include mother-specific exogenous characteristics including birth year, birth year squared, and mother's birth province fixed-effects and are weighted to national levels using weights provided in the CHARLS data. Standard errors clustered by province are reported in parentheses. Significance: *** p<0.01, ** p<0.05, * p<0.1.

Table S4: Intergenerational impacts of mother's exposure to famine on economic and labour market outcomes of daughters using province-level CSSI and EDR

	Midpoint of child & spouse's income categories (in `000s)	Child has high sch. or higher	Child is currently working	Child has ever worked
	(1)	(2)	(3)	(4)
Panel A				
Birth province CSSI is 75th per.	-4.423*	-0.920***	-0.229***	-0.066***
or higher in rural areas (INTFAM)	(2.477)	(0.029)	(0.032)	(0.018)
INTFAM x birth 1959-1962	-4.289	-0.101*	-0.048	-0.097*
	(3.909)	(0.052)	(0.046)	(0.053)
Panel B				
Birth province EDR is 75th per.	4.944***	-0.040*	-0.090***	0.073***
or higher in rural areas (EDR)	(1.285)	(0.020)	(0.018)	(0.021)
EDR x birth 1959-1962	-3.980	-0.138**	-0.102**	-0.138***
	(2.794)	(0.057)	(0.045)	(0.048)

Note: Sample includes female children born to mothers with year of birth in the 1953-1956 and 1959-1962 time windows, whose birthplace was rural. Regressions include child-specific characteristics such as age, age squared, birth order, Hukou status, and quarter of birth, and mother-specific characteristics including mother's year of birth and mother's year of birth squared, and birth cohort dummies from 1959 to 1962. Regressions include a constant term and province fixed-effects, and are weighted to national levels using weights provided in the CHARLS data. Standard errors clustered by province are reported in parentheses. Significance: *** p<0.01, ** p<0.05, * p<0.1.

Table S5: Intergenerational impacts of mother's exposure to famine on economic and labour market outcomes of daughters: Falsification test

	Midpoint of child & spouse's income categories (in `000s)	Child has high sch. or higher	Child is currently working	Child has ever worked
	(1)	(2)	(3)	(4)
Birth city CSSI is 75th percentile	4.048	-0.043	0.005	0.033
or higher in rural areas (INTFAM)	(5.922)	(0.056)	(0.044)	(0.037)
INTFAM x birth 1953-1956	1.205	0.029	0.015	0.037
	(4.582)	(0.041)	(0.048)	(0.029)

Note: Sample includes children born to respondents with year of birth in the 1949 to 1956 time window, whose birthplace was rural. Regressions include child-specific characteristics such as age, age squared, birth order, Hukou status and quarter of birth, and respondent-specific characteristics including mother's year of birth, mother's year of birth squared, and birth cohort dummies from 1953 to 1956. Regressions include province fixed-effects and are weighted to national levels using weights provided in the CHARLS data. Standard errors clustered by province are reported in parentheses. Significance: *** p<0.01, ** p<0.05, * p<0.1.

Endnotes

[1] We test whether $\gamma_t = 0$ for these birth cohort differentiated treatment effects across the panels of Table S2 and find that we can reject this hypothesis at the 5% level in the case of income, whether the child is currently working or whether the child has ever worked. We cannot reject this hypothesis in the case of education (high school or above) which suggests that the combined effect for this outcome in Panel A of Table 3 is relevant. As discussed above, this coefficient is negative and significant (14.7 percentage point decline) for those born in the famine years of 1959-1962.