

Long-Run Health Consequences of Early-Life Exposure to the 1959-61 China Famine

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ABSTRACT

This paper examines the long-term consequences of early-life malnutrition by exploring the natural experiment created by the 1959-61 Chinese famine, possibly the largest famine in human history. Taking advantage of both the temporal and geographic variation in famine severity, we construct a difference-in-differences estimator to identify the long-term consequences on perceived health and socioeconomic outcomes of early-life exposure to the famine. Using a sample of 1,825 adults born between 1955 and 1966 in rural China from a nationally representative survey – the 2005 Chinese General Social Survey, we find that the China famine had adverse effects on mid-life health but mixed effects on adult socioeconomic achievement for the famine-born persons. In particular, it affected men born into high SES families and women most adversely. We employ China’s century-long son-preference culture and mortality selection to explain these findings.

1. Introduction

Recent years have seen a growing use of a life course approach in health studies, emphasizing the long term impact of what happens during a critical period on subsequent development and health (Kuh et al. 2003). In particular, exposure to adverse environmental influences during developmental critical periods, such as prenatal and early-postnatal malnutrition, may lead to permanent changes in gene expression as well as brain and body function, with lasting effects on later health or disease risk (Barker 1998). It is consequential to understand the effects of malnutrition in early life on adult health and human capital (Barker 2003; Lumey et al. 2011; Victora et al. 2008), given that child undernutrition remains a major public concern not only in many developing countries (Black et al. 2008; de Onis and Blössner 2000; Pelletier et al. 2012), but in some developed countries as well. In U.S., for example, it is estimated that around 16.7 million children under than age of 18 lived in food insecure households in 2011 (Coleman-Jensen et al. 2012).

Yet, it is extremely difficult, if possible at all, to precisely measure nutritional intake during prenatal life, infancy, and early childhood. Alternatively, natural experiments such as famines provide a unique opportunity to study the impact of early-life nutrition deprivation on subsequent health (Brown and Susser 2008), with the 1944-5 Dutch Famine cohort most extensively examined. Compared with the Dutch Famine, the Great Famine in China from 1959 to 1961 lasted much longer and had much severer short-term demographic consequences resulting in an estimated 16-30 million excess deaths (Ashton et al. 1984; Banister 1987; Coale 1981; Peng 1987; Yao 1999). In this study we take advantage of this unique natural experiment investigating its long-term consequences on perceived health and socioeconomic outcomes for the famine cohort (who were born during the famine) in their midlife (when they were 43-46

years old). Previous research on the Chinese famine, mostly relying on samples with limited regional coverage, has yielded mixed findings regarding its long-run health and socioeconomic outcomes (Almond et al. 2007; Chen and Zhou 2007; Gørgens, Meng, and Vaithianathan 2012; Huang et al. 2010; 2012; Luo, Mu, and Zhang 2006; Meng and Qian 2009; Mu and Zhang 2011; St. Clair et al. 2005; Xu et al. 2009; Yang et al. 2008).

Drawing on the life course perspective, we use nationally representative data from the 2005 Chinese General Social Survey (CGSS) to investigate the long run health and socioeconomic consequences of early-life exposure to the 1959-61 China famine. We use a difference-in-differences method taking advantage of the temporal and regional differences in famine intensity. Recognizing the importance of social contexts in shaping how early life experiences relate with later life chances (Elder, Johnson, and Crosnoe 2003), we examine famine effects separately for four different subgroups classified by gender and childhood SES. Quantile regression models are utilized to assess the extent of mortality selection. Our study shed light on the relationship between early-life nutrition deficiency and later health in China, a large developing country that suffered the largest famine in human history (Ashton et al. 1984) and has experienced the nutrition transition and dramatic socioeconomic transformations in recent decades. This study also serves as an important step in assessing the health-care needs of the cohort born during the 1959-61 famine, who are now moving through their retirement ages.

The paper is organized as follows. We first introduce the life course framework for studying the long term effects of famine and review empirical evidence from the Dutch and Leningrad famine studies. Next, we provide historical accounts and empirical findings of the 1959-61 China famine. This is followed by a description of the data, sample, measures, and analytical strategies. Adopting a difference-in-differences approach, we then estimate famine

effects on adult perceived health and socioeconomic outcomes. We conclude with a discussion of the key findings.

2. Background

2.1. Early Life as a “Critical Period” and Evidence from the Dutch and Leningrad famine

Inspired by the life course perspective, the “critical period” model proposed in health studies suggests that the same life event may lead to different life trajectories later on depending on at which life stage the event is experienced (Kuh et al. 2003). In particular, an adverse environment *in utero* is hypothesized to be particularly devastating with lasting effects on health in adulthood (Barker 1995; 1998).

The Dutch hunger winter (1944-5) and the siege of Leningrad (1941-4) are two extensively studied famines that provide key evidence for the “critical period” model but with conflicting findings. Surviving adults prenatally exposed to the Dutch famine had higher mortality up to age 50, higher coronary heart disease risk, reduced glucose tolerance, higher BMI, worse self-rated health, and increased risk of developing psychological disorders (Brown et al. 2000; Neugebauer, Hoek, and Susser 1999; Ravelli et al. 1999; Roseboom et al. 2000a; 2000b; 2001a; 2001b; 2003). In contrast, the Leningrad famine did not see significant long-term effects: intrauterine malnutrition was not associated with glucose intolerance, dyslipidaemia, hypertension, or cardiovascular disease in adulthood (Stanner et al. 1997; Stanner and Yudkin 2001). The Leningrad famine not only lasted longer than the Dutch famine, but was preceded and followed by relatively shortage of food. Under the influence of mortality selection, therefore, estimates of the Leningrad famine impact based on data of survivors may be biased towards zero (Roseboom 2000a; 2000b). These different findings illustrate the complex interplay between

historical events, social forces, and biological mechanisms, emphasizing the importance of examining the famine effects in the unique Chinese context with a different cultural background (e.g., son preference, see below) and social stratification system.

2.2. The 1959-61 China Famine and Its Short- and Long-Term Health Consequences

One of the largest human catastrophes, the 1959-61 China famine has received much scholarly attention. Lin and Yang (2000) argued that the Chinese famine was jointly determined by the urban biased policies and the decline in food availability. To extract as much agricultural surplus as possible to facilitate the heavy-industry-oriented development strategy, rural people were forced to deliver quotas at prices set by the government, thus bearing most of the consequences of food supply reduction (Coale 1981; see Figure 1). Following previous studies (Chen and Zhou 2007; Huang et al. 2012; Li et al. 2010; Meng and Qian 2009; Mu and Zhang 2011), we therefore focus on rural sample in our analysis. Key to the paper, exposure to the famine – determined by birth date and province of birth – is an exogenous shock out of one's control, enabling us to identify the famine effect.

[Figure 1 about here]

Earlier studies on the Chinese famine revealed a sudden increase in mortality during the famine years (Figure 1). The estimated total number of premature deaths during the famine ranged from 16.5 to 30 million (Ashton et al. 1984; Banister 1987; Coale 1981; Peng 1987; Yao 1999). A sharp increase in miscarriages and stillbirths during that time was also reported using retrospective data (Cai and Wang 2005).

In terms of long-term impacts, an analysis of the 1988 Chinese national fertility survey data showed no differences in mortality up until late 20s and early 30s among the 1954-58 pre-

famine cohort, the 1959-62 famine cohort, and the 1963-67 post-famine cohort (Song 2009), which might be partially explained by mortality selection at earlier ages. Other studies found negative impacts for other health outcomes. For example, using the difference-in-differences technique, Chen and Zhou (2007) showed that Chinese rural people born in 1959 suffered most severely in terms of height reduction, who would have grown 3.03cm taller in the absence of the famine. Controlling for mortality selection explicitly, Gørgens and the colleagues (2012) reported similar findings. Also using the difference-in-differences approach, Luo and her colleagues (2006) found that born during famine years led to a higher probability of overweight among rural women. Meng and Qian (2009) adopted an instrumental variables method and their two-stage least squares estimates revealed that exposure to famine at ages 1-3 reduced height by 1.3% (2.1 cm), weight by 4.4% (2.4 kg), and upper arm circumference by 3.4% (0.8cm), but no effect was found for hypertension, BMI, or weight-for-height. In an ingenious design, Almond and his colleagues (2007) found that mothers born in 1961 in mainland China who later migrated to Hong Kong were 8% more likely to give birth to a child of low birth weight (<2,500 grams), whereas no significant effects were detected for their Hong Kong born counterparts. To the extent that the emigrants are in general healthier and/or from higher status families, they might underestimate the true famine effect.

Previous studies have examined a wide range of health outcomes including disability, obesity, height, weight, weight-for-height, hypertension, and mental health. However, almost all of them are based on samples collected from a few provinces, limiting generalizability. Further, few studies have examined perceived health (Lumey, Stein and Susser 2011), although self-assessed health is a well-recognized predictor of subsequent mortality (Idler and Benyamini 1997). To the best of our knowledge, only one paper has studied the effects of prenatal exposure

to the Dutch famine on adults' perceived health, and none has done in the context of the Chinese famine. We extend the existing small literature by examining self-assessed health in the Chinese context using a nationally representative sample.

2.3. Gender Differences in the Famine Effects on Subsequent Health

The long-term famine effects appeared to be more pronounced among women than among men in China (Almond et al. 2007; Gørgens et al. 2012; Luo et al. 2006; Mu and Zhang 2011; Ravelli et al. 1999; Yang et al. 2008). Much of previous research found a significant famine effect on women but not men in reduced height (Gørgens et al. 2012), higher disability rate (Mu and Zhang 2008), and higher odds of being overweight (Luo et al. 2006; Yang et al. 2008). Huang et al. (2012), for example, reported that compared with unexposed women born in 1963, women born during the famine years had increased risk of mental illness, whereas men born during the famine showed no difference in the risk of mental illness from their counterparts born in 1963. Mortality selection and differential treatment offer two explanations of such gender differences (Mu and Zhang 2011).

First, men biologically tend to exhibit greater vulnerability to prenatal insult than women (Kline, Stein, and Susser 1989; Kraemer 2000). Evidence of men's higher excess mortality during natural disasters is well-documented in China and elsewhere (see Macintyre 2002; Jayachandran 2006; Sen 1981; Song 2009). As a result, men survivors are more likely to come from the upper tails of the health distribution than women survivors, leading to a more attenuated famine effect estimate for men than for women.

Second, the differential treatment hypothesis suggests that sharper resource constraints during hard times force parents to allocate resources to the more valued children who are always

sons in the traditional Chinese society, where only sons can carry the family name, and sons instead of daughters are expected to provide support for elderly parents. Given the lack of the formal social security system in rural China, parents needed to rear at least one son for the sake of old age (Croll 2000). Hence, girls might experience severer malnutrition during the famine.

In sum, despite pointing to different sources, both mortality selection and differential treatment lead us to hypothesize that rural women suffered more from the Chinese famine than rural men:

Hypothesis 1: The 1959-61 China famine had more negative effects on mid-life perceived health for rural women than for rural men.

2.4. Long-Term Socioeconomic Impacts of Early-life Exposure to the Famine

A nutritional shortage may have an adverse effect on schooling and economic outcomes. However, existing literature is inconsistent regarding the famine effect on adult socioeconomic status (SES). No systematic influence of the Dutch famine was found on cognitive ability or income later in life (Stein and Susser 1975; Scholte, van den Berg, and Lindeboom 2012). Studies drawing on rural samples reported that the 1959-61 China famine had no effect on working hours (Meng and Qian 2009; Shi 2011), but led to reduced educational attainment, labor force participation, and farming income (Almond et al. 2007; Chen and Zhou 2007; Meng and Qian 2009). Given prior evidence, we develop our second hypothesis.

Hypothesis 2: Individuals born during the 1959-61 China famine had lower socioeconomic status in adulthood than those born after the famine.

2.5. Childhood SES as a Moderating Context

The consequences of social disruptions such as famines, wars, and ethnic cleansing, and how the negative impacts are distributed across social groups are the focus of many empirical studies. Strauss and Thomas (1998) showed that the heights of Vietnamese adult men and women increased very rapidly for cohorts born between 1925 and 1955; but remained unchanged for the birth cohorts from the early 1950s to 1975 (the Vietnam war period). In particular, the worst off were hit hardest by the war as reflected by the declined growth in attained height. Findings from this line of studies indicate that, in addition to biological pathways, social forces are at work in social disruptions such as famines.

Desirable resources, food in our case, are not equally distributed across social groups. Therefore, exposure to a famine is not equivalent to exposure to malnutrition, due to unobserved household conditions at the time of the famine. In other words, even born in famine eras, some were able to manage food shortage, for example because the household belongs to the wealthy class. Consequently, the long-term famine effects are unlikely to be homogeneous across social groups because people in differing social statuses have differential exposures to risks and resources which may in turn exacerbate or buffer the famine effects. In the Chinese setting, the stratification system of the Maoist period had been based on a hierarchy of functionally unspecialized cadres directing the labors of a fairly uniform mass of peasants. Anecdotal evidence suggests that during the famine, local party cadres often abused the power they held, saving themselves and their families at the expense of others, whereas famished peasants had nowhere to turn (Dikötter 2010). Given the vulnerability of men in prenatal survival chances and the son preference cultural in rural China, we hypothesize that the buffering role of high social origins is more pronounced for men:

Hypothesis 3: The 1959-61 China famine had more negative effects on mid-life perceived health for those of low social origins than those of high social origins, especially among men.

3. Data and Methods

3.1. Data

We use data from the 2005 Chinese General Social Survey (2005 CGSS, hereafter). Initiated in 2003, the CGSS is an annual or biannual survey that provides rich information on Chinese people's socioeconomic achievement and quality of life. The 2005 CGSS was carried out jointly by the Hong Kong University of Science and Technology and Renmin University of China. It used multistage stratified random sampling to generate a nationally representative sample of the adult population in both rural and urban China (Wu, Ip, and Li 2012). The sample consists of 10,372 individuals aged 18 to 69, with 6,098 and 4,274 individuals from urban and rural areas, respectively. The 2005 CGSS is ideal for our study because of its relatively large sample size, national coverage, and detailed information on sociodemographic characteristics and health measures.

3.2. Sample

The analytic sample of this study consists of 1,825 individuals born in rural areas between 1955 and 1966. Following Qian and Hodson (2011), we use father's occupation to determine whether respondents were born in rural or urban areas. If paternal occupation was "doing farm work" when the respondent was 14, we classify the respondent as born in rural areas. Given the rare social and geographic mobility before the late 1970s and the tradition of children living with fathers in China, father's occupation when the respondent was 14 is a good indicator

of birth place. Among the 2,924 observations born between 1955 and 1966, 1,825 (62.41%) are classified as rural-born individuals.

We define those born between 1955 and 1958 as the *pre-famine cohort*, those born between 1959 and 1962 as the *famine cohort*, and those born between 1963 and 1966 as the *post-famine cohort*. People born in 1962 are included in the famine cohort because some of them were in gestation during the famine which lasted through late 1961. Although the Chinese famine lasted for three years, its exact duration varied across regions (Huang et al. 2010). Due to the lack of information on birth month, we cannot distinguish for the 1962 birth cohort who had prenatal famine exposure from those who did not. A similar problem exists for the 1959 birth cohort. To the extent that the misclassified persons (i.e., persons born in 1959 or 1962) are more akin to the pre-famine (or post-famine) than to the famine cohort, we underestimate the true famine effect because as presented later, famine had no impact on the pre-famine cohort, and the post-famine cohort were by construction not affected by the famine. Another problem is selection at birth: birth rate declined by nearly 50 percent during the famine period, compared with “normal” years (Ashton et al. 1984). Were couples with high SES or better health more likely to delay childbearing, thereby confounding the relationship between early-life exposure to famine and later health? Almond et al. (2007) used census data reporting that the 1959-61 cohort were actually born by better educated mothers than adjacent cohorts, and healthier parents were more likely to succeed in giving birth during the famine, suggesting an underestimate of the true famine effects in our study.

3.3. Measures

3.3.1. Outcomes

The 2005 CGSS surveyed eight health measures modified based on the SF-36 instrument. The SF-36 is a commonly used instrument with 36 items measuring health-related quality of life across eight dimensions of health (Ware 2000). Health-related quality of life measures from SF-36 have been found to be powerful predictors of hospitalization, morbidity, and mortality (Fan et al. 2002; Lowrie et al. 2003; Rumsfeld et al. 1999). Further, the Chinese SF-36 is a valid and reliable instrument for evaluating both physical and mental health status (Wang et al. 2008).

The original wordings for the eight health measures in the 2005 CGSS are: During the past one month, (1) how would you rate your health in general? (2) has your health limited your daily life, e.g., walking, or stair climbing? (3) has your health limited your work, within or outside household? (4) do you feel any pain in your body? (5) how would you rate your energy in general? (6) have you been bothered by emotional problems such as feeling anxious, depressed or irritable? (7) has your physical and emotional health limited your social activities with family, friends, neighbors or groups? and (8) has your emotional health limited your usual activities related to work, study, or others?

Factor analysis shows that the eight items reflect a single underlying concept (results not shown, Rust and Golombok 2009). Therefore, we sum up the eight items to create one composite measure – *general health*, the health outcome used for the following analysis. When constructing the general health measure, we reverse-coded the eight items so that higher scores indicate better health. We also rescaled the self-rated health and bodily pain items from 1-6 to 1-

5, so that each of the eight items contributed an equal share to the composite measure. The Cronbach's alpha for this measure is 0.94, indicating high reliability.

Socioeconomic status in adulthood is measured through *years of schooling* and *personal income*, two indicators widely used to capture individual SES (Adler et al. 1994; Hauser and Carr 1995). We take the natural log of income to correct for right skewness.

3.3.2. Explanatory Variables

As will be elaborated in 3.4. Analytical Strategy, we exploit variations in famine intensity along two dimensions: birth cohort and region (province). We described the construction of cohort groups (pre-famine, famine, and post-famine) in 3.1. Data. Regional variation in famine severity is captured by the province-level excess death rate provided in Yang (1996: p. 38), calculated as the gap between the death rate in 1960 (the severest year) and the average death rate in the three years before 1959 (the first year of the famine). The severity of the famine varied considerably and idiosyncratically across provinces, ranging from 1.3 per thousand in Tianjin to 56.7 per thousand in Anhui (Figure 2). We also experimented with three other measures of famine intensity (Huang et al. 2012): cohort size shrinkage index, excess mortality index (mortality difference between famine years and nonfamine years 1956-58), and fertility reduction index. Huang and the colleagues found that different indices were highly correlated at the province level. Not surprisingly, our results did not change substantively with alternative measures of famine intensity. To confirm that what excess death rate captures is not variation across provinces in such key determinants of health as economic development or health infrastructure, we tested for changes in physicians per 10,000 population and hospital beds per 10,000 population from 1956-58 to 1960. Neither was associated with province-level famine intensity ($p = .30$ and $.85$ from Spearman's rank test). We did not find a good economic indicator,

but Meng and Qian (2009) reported that the grain procurement system caused the famine to be severer in regions that typically produced more grain (usually the more economically developed areas).

[Figure 2 about here]

3.3.3. Moderators

Women and men, as well as persons of low and high SES origins, were affected by the Chinese famine in different manners. To reflect such contextual differences, we run separate models for the following four groups: low childhood SES men, high childhood SES men, low childhood SES women, and high childhood SES women. Given the decisive role of political power in shaping life chances during the Mao era (Walder 1989), especially in rural areas, childhood SES is measured by father's party membership.

3.4. Analytical Strategy

To identify the effects of early-life malnutrition due to the famine, one widely used strategy is to take advantage of both the temporal and geographic variation in famine intensity (see Chen and Zhou 2007; Huang et al. 2012; Luo et al. 2006). Specifically, one could track health outcomes for individuals residing in less severely affected provinces born during/before and after the famine, and then compare these differences with the corresponding differences for individuals residing in more severely affected provinces. This comparison produces the “difference-in-differences” estimator (DID) (Angrist and Pischke 2009):

$$\Delta^2 = (Y_{Severe}^{FAMINE} - Y_{Severe}^{POST}) - (Y_{LessSevere}^{FAMINE} - Y_{LessSevere}^{POST}) \quad (1)$$

where the subscript “Severe” denotes residing in a province that was severely affected by the 1959-61 famine (as measured by excess death rate), and the superscript denotes born in the famine period or after the famine period. Y indicates the outcome (general health, schooling years, and logged income). The estimator in Equation (1) assumes that, were it not for the Chinese famine, differences in adult health/SES between famine- and post-famine-cohort would have been similar across provinces.

The difference-in-differences estimates can be conveniently computed in the regression framework using a continuous measure of famine severity level:

$$Y_{ij} = \beta_0 + \beta_1 pre_{ij} + \beta_2 famine_{ij} + \beta_3 edr_j + \gamma_1 (edr_j \times pre_{ij}) + \gamma_2 (edr_j \times famine_{ij}) + \varepsilon_{ij} \quad (2)$$

where Y_{ij} denotes the health (Hypotheses 1 and 2) or SES (Hypothesis 3) outcomes for individual j born in province i . pre and $famine$ are two dichotomous variables indexing born in pre-famine years (1955-1958) and born in famine years (1959-1962), respectively. We use excess death rate, edr_j , to proximate province-level famine severity. Key to the current study is γ_2 , the coefficient for the interaction term, which, in the difference-in-differences setting, captures the causal effect of famine exposure *in utero* or infancy on health in adulthood. As hypothesized, we expect to see a significant and negative γ_2 .

The general health measure follows a negative binomial distribution, so we fit a negative binomial regression with the DID interaction included as the key predictor (See Huang et al. 2012 for a similar approach). Given the non-linearity nature of count models, we report marginal effects, which can be interpreted as the incremental effects of the predictor of interest when all other predictors are set at the sample mean. Schooling years and logged personal

income are modeled using ordinary least squares (OLS) regressions. The standard errors are clustered at the province level to account for correlation between observations within the same province. Missing data do not exceed 6% for any variable. Below, we report models where listwise deletion is used, but multiple imputations yielded nearly identical results (available upon request).

4. Results

4.1. Descriptive Statistics

Table 1 reports descriptive statistics by cohorts and gender. Slightly more than half (54%) of the respondents are women. Respectively, 630 (35%), 443 (24%), and 753 (41%) people are from pre-famine, famine, and post-famine cohorts. The post-famine cohort reports the highest level of health across all health measures, regardless of gender. ANOVA tests show significant cohort differences for eight out of nine health measures (the only exception is mental health). Overall men report significantly higher scores than women for all health indicators. When disaggregated by birth cohorts, pre- and post-famine cohort men have significantly better health than women for all health measures, whereas in the famine cohort, only general health, physical functioning, vitality, and role-emotional health significantly differ by gender, suggesting that the gender differentials in health are least pronounced in the famine cohort.

Descriptively, men have higher adult SES than women. Across all three cohorts, men have significantly higher income and more education than women. ANOVA tests show significant cohort variations in educational attainment, with the famine-cohort men receiving considerably more schooling than adjacent cohorts. In contrast, childhood SES measured through father's party membership does not vary by gender or cohort.

[Table 1 about here]

4.2. Long-term Famine Effects on Midlife Health

Models 1 and 2 in Table 2 present difference-in-differences estimates for men and women, respectively. The 1959-61 Chinese famine did not appear to affect men's midlife health (Model 1), but as expected in Hypothesis 1, famine had a significant adverse effect on midlife health for women: each additional 1‰ increase in excess death rate due to the famine resulted in a lowered general health at a rate of 10.7% ($1 - 0.893 = .107$, $p < .05$). These estimates take into account time-invariant differences between provinces and any inherent cohort differences. To put this into perspective, consider Sichuan (excess death rate 38.1‰) – a severely affected province, and Heilongjiang – a less severely affected province (excess death rate 2.9‰). For no other reasons than being unluckily born in Sichuan and being exposed to a severer famine as a consequence, the reduction in general health score was on average 82.3% ($1 - \text{EXP}[\log(.893) * (38.1 - 2.9)]$) more for Sichuan-born women than for women born in Heilongjiang.

[Table 2 about here]

In Models 3-6 in Table 2, we disaggregate the sample into four groups based on gender and childhood SES (measured by father's party membership). The Wald test indicates that the size of the difference-in-differences interaction terms for the four groups are significantly different from each other ($p = .0002$). In particular, we find that the 1959-61 famine had significant adverse effects on midlife health for men of high social origins and for women of low social origins. Recall Model 1 showed that men as a whole were not affected by early-life exposure to the famine, but this null finding masks some heterogeneity along the dimension of social origins. Among men whose fathers were party members, each additional 1‰ increase in

excess death rate led to a lower general health of men born during the famine by a rate of 21.3% (1 - .787, $p < .001$, Model 4), compared with men born after the famine, while no significance was found for men of low social origins (Model 3). Wald test shows that the difference in the interaction term between Models 3 and 4 is significant ($p = .0003$), suggesting that for men, the effects of early-life malnutrition due to the famine are contingent on family background. We discuss mortality selection as a potential explanation in 5. Discussion.

A different pattern emerges for women where we find the famine effect is significant and negative only for those who were born into low SES families. Among women whose fathers were not party members, each additional 1‰ increase in excess death rate brought about by the famine resulted in a lowered general health by a rate of 11.2% (1 - .888, $p < .05$, Model 5) for women born during famine years, compared with women born after the famine. Unlike men, however, the difference in the interaction term between Models 5 and 6 does not reach any conventional significance level based on a Wald test ($p = .628$), indicating that early-life malnutrition adversely affected women's midlife health, regardless of their family background. Taken as a whole, Hypothesis 3 is largely supported.

In contrast to what has been found for the famine cohort, we observe neither statistically significant nor substantively important famine effect for the pre-famine cohort (the pre by edr interaction), despite their longer exposure to the famine, lending support to the idea that it is the *timing* of exposure to adverse environments – *in utero* and/or early infancy – that is the primary driving force of later health.

Table 2 presents the adverse famine effects using a cohort categorization. Yet born in which year is particularly vulnerable? Replacing the three cohort indicators with birth year

dummies (1955, 1956, ..., 1962), we find that men of high childhood SES born in 1959 (.342, $p < .01$, not shown), 1960 (.782, $p < .001$, not shown), and 1961 (.505, $p < .001$, not shown), women of low childhood SES born in 1962 (.877, $p < .05$, not shown), along with women of high childhood SES born in 1959 (.563, $p < .001$, not shown), were significantly and negatively affected by the famine. By comparison, men of low childhood SES born in 1961 seemed to enjoy better health than their counterparts born after the famine (1.171, $p < .05$, not shown).

4.3. Long-term Famine Effects on Midlife Health: Quantile Regression

Famine effects may be different for survivors located in different areas in the health distribution (Chen and Zhou 2007; Meng and Qian 2009). Figure 3 plots estimates from negative binomial quantile regressions (from the 10th to the 90th percentile) for men from low SES families, men from high SES families, and women, respectively. We do not separate women by family background because previously we showed that the famine effects did not differ by childhood SES for women. In Figure 3, point estimates from quantile regressions are denoted by circles and are connected in a solid line, with their 95% point-wise confidence band represented by the grey area around the solid line. We present famine effects in log odds, so zero indicates no significant famine effects and negative values indicate adverse famine insults.

[Figure 3 about here]

Quantile regressions can be helpful in assessing the extent of mortality selection (Meng and Qian 2009). Assuming that it is the strongest who survive, mortality selection should be largest in lower quantiles. As such, with high levels of mortality selection, the estimated famine effects in the lower quantiles are attenuated towards zero because we are comparing individuals in the control group (post-famine cohort) with those in the treatment group (famine cohort) who

would be healthier on the distribution absent the famine-induced selection. In contrast, the mortality selection bias is smaller in magnitude for individuals in the higher quantiles because those individuals have more comparable control groups.

The contrast between men of low social origins and men of high social origins is striking in Figure 3. In no quantile were significant famine effects found for men born into low SES families. In fact, we observe positive values in the lower quantiles (from 10th to 40th), lending support to mortality selection as argued before. Men born into high SES families, however, were adversely affected by early-life exposure to the famine across the board, with such effects particularly strong in the lower quantiles. Similarly, the Chinese famine significantly lowered women's midlife health across the distribution: the famine effects were statistically significant and negative except in the 70th and 80th quantiles.

4.4. Long-term Famine Effects on Schooling Years and Income

For both gender and regardless of childhood SES, born during the 1959-61 Chinese famine had no effects on schooling years (Panel A in Table 3). However, when using individual birth years, we find that except for women of low childhood SES, born in 1961 led to more schooling years. Born in 1959 resulted in lower schooling years for men from high SES families.

[Table 3 about here]

In terms of income, born during the famine yielded higher income for men of high childhood SES (0.025, $p < .05$), but lower income for women of low childhood SES (-0.023, $p < .01$) (Panel B in Table 3). When using individual birth years, born in 1961 or 1962 led to higher income for men, and born in 1959 or 1962 led to lower income for women.

5. Discussion

This paper exploits temporal and regional variations in the severity of the 1959-61 China famine to estimate the long-term health and socioeconomic consequences of early-life malnutrition due to the famine. We use a nationally representative sample of 1,825 individuals born in rural China between 1955 and 1966, and examine a composite self-perceived general health measure composed of eight dimensions (self-reported health, physical functioning, role-physical, bodily pain, vitality, mental health, social functioning, and role-emotional). Employing the difference-in-differences technique, our findings indicate that exposure to acute malnutrition early in life had negative effects on health in mid-life, especially for women and men of high social origins. Our findings are consistent with the main principles of the life course perspectives that emphasize the importance of timing and contexts of life experiences in shaping subsequent life chances (Elder, 1998; Elder, Johnson & Crosnoe, 2003; Umberson et al. 2010).

First of all, the timing of famine exposure matters for midlife health. The Chinese famine lasted three years, rendering it challenging to conduct a sharp contrast distinguishing the *in utero* effect from the infancy effect (Almond and Currie 2011). Nevertheless, we show that those born before the famine were not affected by the famine in any significant way, and among women, the lasting famine effects on health were concentrated in the 1961 and 1962 birth cohorts. Since the 1959-61 famine peaked in 1960 and remained to be severe in 1961 (Peng 1987), the 1961 and 1962 birth cohorts spent most of the fetal time during the severest famine period, which has left marks on their health several decades later. Indeed, this finding is particularly remarkable if we take into account of (1) mortality selection, that is, these two cohorts – especially the 1961 birth cohort – should be composed of the fittest babies, and (2) misclassification of famine exposure that some of the 1962 birth cohort may actually not be

exposed to the famine *in utero*. This finding lends support to the critical period notion that early life especially *in utero* conditions have long-lasting effects on or even program later health (Barker 1995; 1998). Recently, De Rooij et al. (2010) found that being exposed to the famine during the first trimester (the first three months of pregnancy) is the most important critical period. This explains why even a few weeks' exposure to the famine had such a shaping effect on later health for women from the 1962 birth cohort.

In addition, long-term famine effects vary across social groups. Consistent with previous studies, women seem to bear the brunt of the negative famine consequences. Mortality selection and differential treatment are two potential explanations, as reviewed before. A truncated sample containing only those who were still alive in 2005, our data are not suitable and we do not attempt to quantify the extent of selectivity. However, other studies provide some insights. Exploring heterogeneity in the culture of son preference across nineteen large ethnic groups, Mu and Zhang (2011) showed that mortality selection was the driving force for the observed gender difference in famine impact on disability rate. Differential social treatment is also possible, especially in rural China, where sons were treated more favorably than daughters. Unfortunately, we cannot test this hypothesis directly given that the 2005 CGSS did not collect information regarding family resource allocation (e.g., sibling compositions). Nevertheless, we want to mention that prenatal sex identification through ultrasound B machines was not possible before the 1980s in China (Zeng 1993), so women born in the 1959-61 famine were protected from unfavorable treatment at least *in utero*, and any gender differences resulting from differential treatment are most likely to be due to parental neglect after birth rather than *in utero*.

Social origins is another contextual factor shaping the long term consequences of famine. A common theme emerging from disaster studies is that social forces operate even in the

seemingly neutral natural disasters, with low SES group hit most heavily in those events (Strauss and Thomas 1998). Given this, it is surprising that many previous famine studies did not incorporate family background into the analytic framework. What have we gained by explicitly taking into account family SES as an important contextual factor? Along with prior studies we found a null famine effect for men, but when disaggregated by family SES, a noticeable adverse famine effect on midlife health was identified among men from high SES families, significantly greater than among men from low SES families. Is it against the general pattern detected in previous literature? Not necessarily. We resort to an interplay between biological and social forces to explain this seemingly counterintuitive finding: differential mortality selection by family background. During the famine period, high SES families were more likely to mobilize resources obtaining more food, which was not the case for low SES families. Given men's greater biological vulnerability to prenatal insult, rural men from low SES families were subject to especially severe mortality selection. Quantile regressions provide key supportive evidence to this argument: we observe a declining trend of the estimated famine effects from lower to higher quantiles for men born into low SES families, suggesting high levels of mortality selection which yielded a very robust group of survivors in the lower quantile (see the first plot of Figure 3). Among men born into high SES families, they were adversely affected across the board but the effect was particularly severe in the lower quantile, indicating many of the weakest were able to survive but their health was nevertheless permanently harmed (see the second plot of Figure 3). In contrast to men, we find no significant difference in the negative famine effects between high SES women and low SES women, possibly due to less prenatal mortality selection among women and widespread gender discrimination regardless of family background.

Unlike several studies mentioned shortly, except for income among low childhood SES women, we did not find the 1959-61 China famine had any negative consequences on income or education. We propose possible reasons. Meng and Qian (2009) reported that *in utero* exposure to famine caused an 8.6% (0.6 years) reduction in educational attainment, but this actual refers to the effects estimated on the 90th percentile which they argue as a way to correct for mortality selection. We do not follow this in our analysis. Chen and Zhou (2007) found that the 1959 and 1960 cohorts had lower annual working hours and lower farming income because of the famine. Our results differ from theirs probably because we rely on a national-representative sample instead of the eight provinces they examined. In still another study, Almond et al. (2007) used census data but the large sample size almost guaranteed significant findings. The effect sizes reported in their study were small.

This study has several limitations. First, since the 2005 CGSS did not collect birth place information, we have to rely on father's occupation when the respondent was 14 to obtain the rural sample. Although the tight administrative control virtually eliminated unauthorized rural-to-urban migration in the pre-reform era (Wu and Treiman 2004), we are not sure to what extent this measure accurately captures places of origin. Second, the long duration of the Chinese famine makes it impossible to conduct a sharp contrast distinguishing the *in utero* effect from the infancy effect. Studies based on other famines that are short and abrupt might shed more light on such distinctions. Third, our findings about the long-term effect of the Chinese famine may not necessarily suggest similar health consequences of other famines.

Despite these limitations, our study extends previous research on the long-term consequences of famine in general and of the 1959-61 China famine in particular. To our knowledge, no previous studies have used a nationally representative sample to examine the

effects of the Chinese famine on perceived health, an important predictor of subsequent mortality. Our findings add nuances to previous famine research by revealing who bear the most negative consequences of the famine, through the confluences of biological and social forces. Having experienced one of the largest famines in human history, the famine-cohort persons are now moving through their retirement ages. Our study suggests the necessity of paying special attention to this cohort, with programs designed specifically towards their needs particularly helpful for them aging healthily.

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Table 1: Descriptive Statistics, by Cohort and Gender

	Total (N =1,825)		Pre-Famine Cohort (N =630)			Famine Cohort (N =443)			Post-Famine Cohort (N = 752)			Cohort Differences (13)	
	Men (1)	Women (2)	(3)	Men (4)	Women (5)	(6)	Men (7)	Women (8)	(9)	Men (10)	Women (11)		(12)
Outcomes													
Health													
General Health Scale (8 - 40)	33.19	31.30	***	32.62	29.97	***	32.74	31.32	*	34.05	32.22	***	***
	6.33	6.80		6.32	7.07		6.67	6.71		6.05	6.50		
Self-rated Health (1 - 5)	3.64	3.38	***	3.61	3.20	***	3.53	3.44		3.74	3.48	**	**
	1.08	1.08		1.07	1.06		1.09	1.06		1.09	1.08		
Physical Functioning (1 - 5)	4.38	4.16	***	4.31	3.99	***	4.34	4.13	*	4.46	4.29	**	***
	0.90	0.96		0.91	1.00		0.96	0.95		0.85	0.91		
Role- Physical Health (1 - 5)	4.35	4.14	***	4.25	3.95	***	4.31	4.13		4.47	4.29	**	***
	0.93	0.99		0.94	1.07		1.00	0.95		0.88	0.93		
Bodily Pain (1 - 5)	4.22	3.99	***	4.14	3.83	***	4.14	3.94		4.35	4.13	**	***
	1.05	1.07		1.07	1.11		1.11	1.08		0.97	1.02		
Vitality (1 - 5)	3.79	3.52	***	3.71	3.36	***	3.71	3.49	*	3.92	3.66	***	***
	1.04	1.08		1.03	1.10		1.10	1.07		1.00	1.06		
Mental Health (1 - 5)	4.09	3.86	***	4.03	3.77	**	4.01	3.88		4.20	3.90	***	
	0.97	1.03		0.96	1.08		0.98	1.00		0.96	1.01		
Social Functioning (1 - 5)	4.37	4.12	***	4.31	3.93	***	4.34	4.17		4.45	4.24	**	***
	0.87	0.95		0.86	1.00		0.92	0.94		0.83	0.91		
Role-Emotional Health (1 - 5)	4.36	4.12	***	4.26	3.94	***	4.36	4.15	*	4.46	4.23	***	***
	0.88	0.96		0.88	1.01		0.89	0.91		0.86	0.93		
SES													
Years of Schooling	8.42	6.17	***	8.01	5.40	***	9.07	6.13	***	8.45	6.73	***	**
	3.67	4.30		3.66	4.60		3.50	4.38		3.74	3.96		
Logged Personal Income in 2004	8.48	7.68	***	8.35	7.57	***	8.58	7.65	***	8.56	7.76	***	
	1.36	1.93		1.31	2.08		1.33	1.84		1.41	1.88		
Predictors													
Excess Death Rate (‰)	15.21	15.09											
	14.28	14.31											
Father's Party Membership	0.08	0.09		0.08	0.10		0.10	0.06		0.08	0.10		
	0.28	0.29		0.27	0.30		0.30	0.24		0.27	0.30		
Sample Size	838	987		324	306		195	248		319	433		

Notes: 1. For each variable, the first row shows means and the second row shows standard deviations.

2. We test whether there is gender difference within each of the following samples: total sample, pre-famine-cohort, famine-cohort, and post-famine-cohort. Results are shown in columns 3, 6, 9, and 12, respectively. We also use ANOVA to test whether there is cohort difference (i.e., pre-, famine-, and post-cohort), and results are shown in column 13.

* $p < .05$; ** $p < .01$; *** $p < .001$

Table 2: Difference-in-Differences Estimates of the Long-Run Effects of Early-Life Exposure to the 1959-61 Chinese Famine on Midlife Health

	Model 1: Men	Model 2: Women	Model 3: Men, Low Childhood SES	Model 4: Men, High Childhood SES	Model 5: Women, Low Childhood SES	Model 6: Women, High Childhood SES
Excess Death Rate (EDR)	0.942+ (0.031)	0.998 (0.017)	0.934+ (0.035)	1.038 (0.039)	0.996 (0.017)	0.996 (0.057)
Cohort (Ref. = Post-famine Cohort)						
Pre-famine Cohort	0.389* (0.165)	0.069** (0.059)	0.519 (0.272)	0.123 (0.327)	0.063** (0.054)	0.097 (0.211)
Famine Cohort	0.248+ (0.189)	1.939 (1.219)	0.220+ (0.202)	0.814 (1.508)	1.976 (1.493)	4.942 (12.274)
EDR *						
Pre-famine Cohort	0.959+ (0.023)	1.030 (0.041)	0.950 (0.030)	1.033 (0.095)	1.033 (0.044)	1.044 (0.099)
Famine Cohort	1.005 (0.040)	0.893* (0.043)	1.037 (0.059)	0.787*** (0.036)	0.888* (0.046)	0.933 (0.078)
Observations	838	987	734	67	859	84

Note: Standard errors in parentheses.

*** p<0.001, ** p<0.01, * p<0.05, + p<0.1

Table 3: Difference-in-Differences Estimates of the Long-Run Effects of Early-Life Exposure to the 1959-61 Chinese Famine on Schooling Years and Income

	Model 1: Men, Low Childhood SES	Model 2: Men, High Childhood SES	Model 3: Women, Low Childhood SES	Model 4: Women, High Childhood SES
Panel A: Schooling Years				
Excess Death Rate (EDR)	-0.037*** (0.010)	-0.046 (0.063)	-0.026 (0.020)	0.018 (0.024)
Cohort (Ref. = Post-famine Cohort)				
Pre-famine Cohort	-0.382 (0.375)	-0.371 (1.637)	-0.780 (0.604)	-1.383 (1.811)
Famine Cohort	0.020 (0.535)	2.439 (1.592)	-0.228 (0.504)	1.862 (2.721)
EDR *				
Pre-famine Cohort	-0.005 (0.027)	-0.028 (0.067)	-0.045 (0.027)	-0.018 (0.088)
Famine Cohort	0.025 (0.026)	0.000 (0.066)	-0.035+ (0.020)	-0.067 (0.101)
Constant	8.929*** (0.330)	10.019*** (1.378)	7.064*** (0.365)	7.775*** (0.794)
Observations	734	67	859	84
R-squared	0.027	0.140	0.050	0.047
Panel B: Income (Logged)				
Excess Death Rate (EDR)	-0.026*** (0.005)	-0.033*** (0.007)	0.001 (0.007)	0.007 (0.007)
Cohort (Ref. = Post-famine Cohort)				
Pre-famine Cohort	-0.285 (0.169)	-1.760* (0.828)	-0.006 (0.329)	0.516 (0.394)
Famine Cohort	-0.127 (0.160)	-0.452 (0.324)	0.186 (0.219)	0.102 (0.645)
EDR *				
Pre-famine Cohort	0.009 (0.012)	0.034 (0.028)	-0.019 (0.016)	-0.018 (0.014)
Famine Cohort	0.010 (0.012)	0.025* (0.009)	-0.023** (0.008)	-0.017 (0.021)
Constant	8.888*** (0.144)	9.749*** (0.204)	7.762*** (0.263)	8.027*** (0.334)
Observations	703	66	794	75
R-squared	0.052	0.206	0.016	0.024

Note: Standard errors in parentheses.

*** p<0.001, ** p<0.01, * p<0.05, + p<0.1

Figure 1: Birth Rate and Death Rate for Rural and Urban China: 1955 - 1966

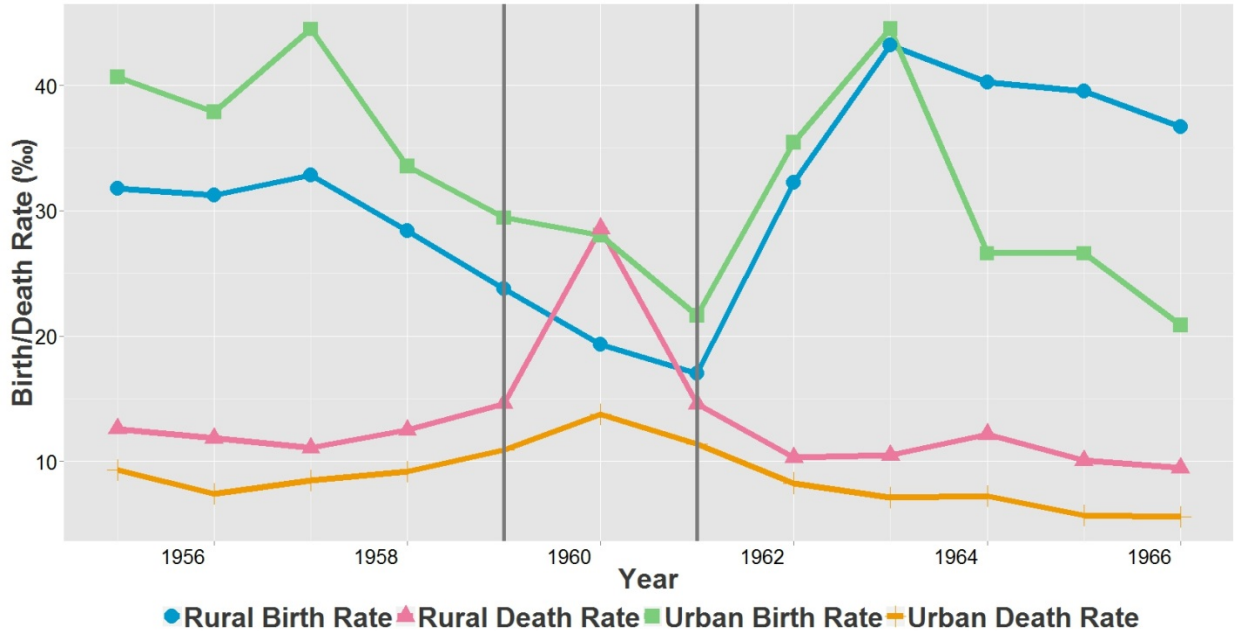


Figure 2: Variation in EDR (Excess Death Rate) Across Provinces

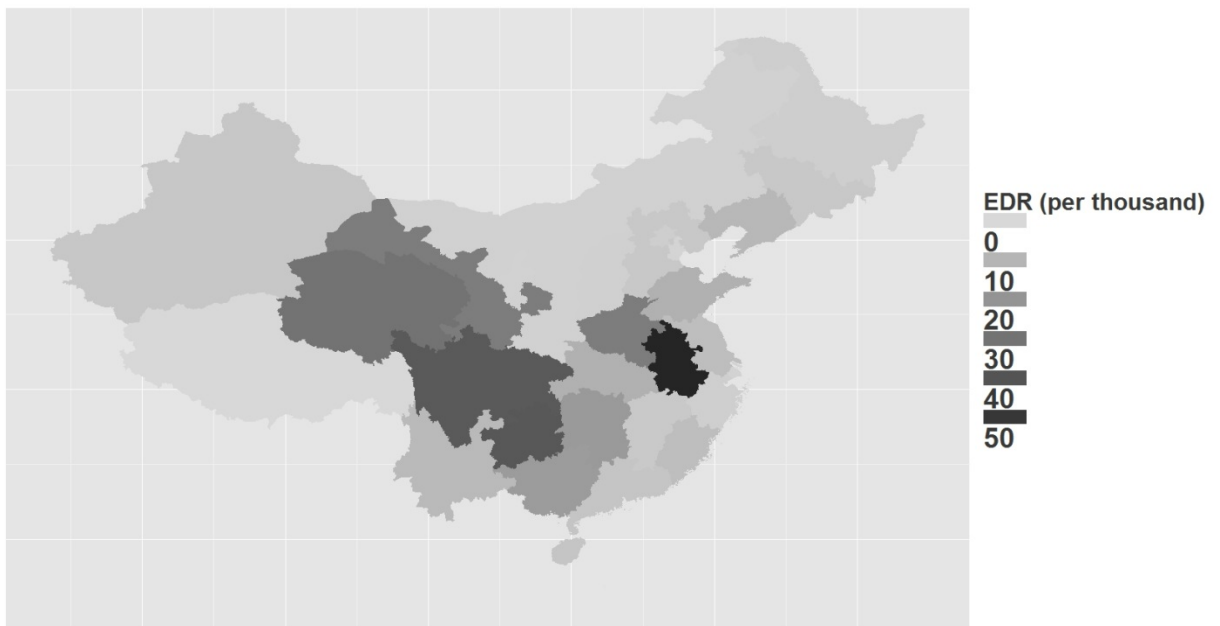


Figure 3: Quantile Regression Estimates of the Famine Effects: by Gender and Social Origins

