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9

Long-Term Effects of Early-Life Development
Evidence from the 1959 to 1961 China Famine

Douglas Almond, Lena Edlund, Hongbin Li, and Junsen Zhang

9.1 Introduction

The dramatic success of China's One Child Policy in reducing fertility catapults the question of population aging to center stage. As China's dependency ratio increases, the health and productivity of those of working age will play key roles. So far, attention has generally focused on investments in these "working age" cohorts that occur after birth (e.g., educational investments). This chapter focuses instead on the prenatal environment and its impact on health and economic outcomes in adulthood, exploiting the 1959 to 1961 Chinese famine (henceforth, "the Famine") as a natural experiment in maternal stress and nutrition.

While starvation on the scale of the Famine may seem remote, maternal malnutrition is not. In the twenty years following the Famine, average nutrition was little improved from the 1930s (White 1991). Smil (1981) noted that "Chinese food availability has remained virtually static for at least half a century." Meat remained scarce and diets were heavily reliant on grains, which accounted for 90 percent of energy and 80 percent of protein (Smil 1981). Disruptions in grain production brought "permanent malnutrition

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to at least 200 million peasants" since the mid-1960s (Smil 1981). Food rationing, first introduced in 1953, was used as a tool to encourage compliance with the One Child Policy (Li and Cooney 1993).

Even after the precipitous decline in fertility during the late 1970s and 1980s, poor nutrition persisted, especially in rural areas and among girls. Between 1987 and 1992, the height of children in urban areas increased five times as fast as rural areas, attributable in part to "more inequitable distribution of the economic resources for nutrition" (Shen and Chang 1996). Similarly, Hesketh, Ding, and Tomkin (2002) found that diets were less varied and nutritional deprivation was more common in rural areas of eastern China—anemia (Hb $\leq$ 110 gl^{-1}) was 50 percent more common than in the rapidly-developing cities. Moreover, more than three-quarters of those with anemia in rural areas were girls: 19 percent were anemic versus 4.8 percent for rural boys. Fully 55 percent of rural girls were moderately anemic (hemoglobin concentrations below 120 gl^{-1}), versus 21 percent of rural boys.

Our inquiry is motivated by a growing literature finding the pre- and perinatal periods critical to morbidity and lifespan. Pioneered by Barker (1992), the "fetal origins hypothesis" linked cardiovascular mortality to maternal nutritional status. Later research has honed in on maternal stress as triggering biological responses in the growing fetus that programs for a life in a resource-poor environment (Gluckman and Hanson 2005). However, the bulk of empirical evidence derives from animal experiments; evidence for humans is surprisingly scarce (see e.g., Rasmussen [2001]; Walker et al. [2007]). Omitted factors (e.g., parental abilities and attitudes) can generate positive associations between measures of fetal health and adult socioeconomic outcomes in the absence of a controlled experiment. Therefore, the "most compelling examinations of the fetal origins hypothesis look for sharp exogenous shocks in fetal health that are caused by conditions outside the control of the mother" (Currie 2009, 102).

Observing cohorts born during 1956 to 1964 in the 2000 Chinese Population Census (1 percent sample), we find that men were 9 percent more likely to be illiterate, 6 percent less likely to work, and 6.5 percent less likely to be married if exposed to the Famine in utero. Women were 7.5 percent more likely to be illiterate and 3 percent less likely to work, and tended to marry men with less education, if exposed in utero. We also find that fetal exposure to the Famine substantially reduced the cohort's sex ratio (fewer males), suggesting greater male vulnerability to maternal malnutrition. Perhaps most intriguingly, we find an "echo effect" of the Famine on the next generation: children whose mothers were exposed prenatally also register Famine impacts. In particular, Famine-exposed mothers were more likely to give birth to daughters. To our knowledge, ours is the first study to trace the offspring sex ratio to the in utero environment of the parent.

To test the robustness of our findings, we pursue two additional approaches. First, we utilize geographic variation in Famine severity to generate comparisons *within* birth cohorts. Here, estimates of Famine damage will be confounded by events experienced later in life (e.g., the Cultural Revolution 1966 to 1976) insofar as these events replicated the geographic variation in Famine intensity *and* differentially impacted those cohorts in utero during the Famine. Second, while the Famine was endemic in mainland China (affecting both urban and rural areas), Hong Kong, then a British colony, was spared. The Famine resulted in a large inflow of mainland Chinese into Hong Kong. We can therefore observe whether children of mainland immigrants exposed to the Famine register intergenerational damage using Hong Kong's natality data, derived from the universe of Hong Kong birth certificates.[1] Results from these two additional approaches corroborate the findings from across-cohort comparisons in the Census data: damage to a broad spectrum of outcomes persists forty years after the Famine.

In addition to the potential for remedial investments (Heckman 2007), two factors lead us to believe our estimates of long-term damage are conservative (i.e., biased toward zero). First, the selective effects of the Famine are likely to cull the relatively weak. Second, the comparison group was also affected by the Famine: older cohorts experienced it directly and younger cohorts were the children of Famine survivors. Assuming that these adjacent cohorts were also negatively affected by the Famine, our estimated effects are of the incremental effect of acute maternal malnutrition, as opposed to, for example, starvation while an infant or toddler, or from being born to a mother who starved prior to her pregnancy.

China is experiencing rapid economic growth and, perhaps ironically, this rapid transition may exacerbate the health consequences of maternal (or grand-maternal, see following) malnutrition as the "thrifty phenotype" finds itself in a resource-rich environment. One reason for long lasting, even intergenerational effects, is that a girl is born with all her eggs, which means that daughters and the eggs for their children, future grandchildren, share in utero environment. Another reason is that gene expression is affected by the early life environment, and therefore, the mother's status (health and otherwise) has epigenetic effects. Therefore, while rapid economic growth holds the promise of greater access to education and health care, this newfound affluence also poses health challenges akin to those faced by (especially) minority populations in the United States: obesity, type II diabetes, and hypertension.

The remainder of the chapter is organized as follows. Sections 9.1.1 to 9.1.3 describe the background of the Famine and review the related literature. Section 9.2 describes the 2000 Chinese Population Census and the 1984 to 2004 Hong Kong Natality files. Section 9.3 reports descriptive and

1. These certificates record country of birth of the mother. Among Hong Kong mothers who immigrated from the mainland, those exposed to the Famine in utero had worse birth outcomes than other mainland emigrants.

regression results, along with a discussion of potential biases. Section 9.4 concludes.

9.1.1 Famine Background

The Famine ranks as the worst in recorded history. Between 18 and 30 million died due to the "systemic failure" of Mao's Great Leap Forward (Li and Yang 2005). The Famine began in the fall of 1959 and impacted all regions of China. Grain output dropped 15 percent in 1959 and another 15 percent in 1960 (Li and Yang 2005, 846). By 1962, birth and death rates had returned to normal levels.

While weather conditions contributed to the Famine, the radical economic policies of the Great Leap Forward were chiefly to blame (Lin 1990; Li and Yang 2005). In a breakneck attempt to overtake Britain and eventually the United States, labor was diverted from agriculture to industry while grain procurement from rural areas was increased. At the same time, collectivization of agricultural production resulted in shirking and falling productivity (Lin 1990). The political climate encouraged provincial leaders to overstate grain production and despite widespread starvation, China was a net grain exporter throughout 1960 (Yao 1999; Lin and Yang 2000).

Famine intensity varied by region (Peng 1987). Rural death rates rose to 2.5 times pre-Famine levels. Urban residents fared better but were not spared, death rates in the peak year 1960 were 80 percent above pre-Famine levels (China Statistical Press 2000). Central provinces such as Anhui, Henan, and Sichuan were the worst hit, while northeastern provinces such as Heilongjiang and Jilin were relatively spared. By 1961, death rates had returned to normal in more than half of the provinces, but remained high in, for instance, the southern provinces Guangxi and Guizhou (close to Hong Kong).

9.1.2 Famine Studies: Epidemiology

The best epidemiological evidence to date linking maternal nutritional deprivation to subsequent adult outcomes derives from the cohort in utero during the 1944 to 1945 Dutch famine. The seminal study found limited effects at age eighteen (Stein et al. 1975). However, at middle age, this cohort exhibited a broad spectrum of damage including: self-reported health (Roseboom, Meulen, and Roseboom et al. 2001); coronary heart disease morbidity (Roseboom, Meulen, Ravelli et al. 2001; Bleker et al. 2005); and adult antisocial personality disorders (Neugebauer, Hoek, and Susser 1999). Moreover, it emerges that poor nutrition in early to mid-pregnancy is the most deleterious to health outcomes (Painter, Roseboom, and Bleker 2005). These, and studies of the 1866 to 1868 Finnish Famine and the Nazi Seige of Leningrad, have focused exclusively on health outcomes.

Epidemiological findings from the Chinese Famine include heightened risk of schizophrenia (St. Clair et al. 2005) and obesity among women (Luo, Mu, and Zhang 2006).

9.1.3 Famine Studies: Economics

A number of recent studies evaluating the Famine's impact on the socioeconomic outcomes of survivors have used the China Health and Nutrition Surveys (CHNS) (Chen and Zhou 2007; Meng and Qian 2006; Gorgens, Meng, and Vaithianathan 2005). The CHNS, which began in 1989, is a panel data set of health and economic outcomes of approximately 4,000 Chinese households from nine provinces (out of thirty-one provinces or province-level administrative regions). The small sample size combined with the collapse of fertility during the Famine necessitates the inclusion of ages well after birth as "treated."[2] However, broad "early childhood" hypotheses make it difficult to reject alternative explanations. The possibility that events at other ages—for instance the subsequent Cultural Revolution and the forced "rustification" of students in outlying areas—confounds results is a concern.

Chen and Zhou (2007) considered those up to age six as treated. They proxied Famine intensity by the province-level death rate in 1960 and found the Famine thus measured to have resulted in stunting of those born in 1955, 1957, 1959, 1960, and 1962, with the largest height reductions for the 1959, 1960, and 1962 birth cohorts. Moreover, they found reduced labor supply of those born in 1959 and 1960, and lower wealth as measured by the size of residence for birth cohorts 1958 and 1959.

Meng and Qian (2006) considered the following birth cohorts as potentially affected: 1952 to 1954, 1955 to 1958, 1959 to 1960, with cohorts born 1961 to 1964 as the reference group. Using reductions in cohort size as a proxy for Famine severity (assumed to occur through Famine mortality), their ordinary least squares (OLS) estimation returned mixed results, and little evidence for a particularly strong effect for the 1959 to 1960 cohort. Instrumenting for cohort size, using per capita grain production in 1997, they found a small negative effect on education, but a substantial (25 percent) reduction in hours worked for the 1959 to 1960 cohort.

Gorgens, Meng, and Vaithianathan (2005) studied adult heights of cohorts exposed to the Famine in childhood. They argued both that children who survived the Famine did not show any stunting and that stunting did occur. They reconcile these two arguments by a third: Famine mortality was concentrated among shorter people. The net effect of stunting and selection, the authors argued, made the height of survivors appear unchanged. However, the claim that no stunting is observed among survivors is controversial (Chen and Zhou 2007; Yan 1999; Morgan 2006).

2. In 1960, 105 rural CHNS respondents and 62 urban CHNS respondents were born, with sixty-six and forty-five, respectively, in 1961 (Chen and Zhou 2007, table 2).

9.2 Data

Our primary data set is the 2000 Population Census of China.[3] The 1 percent sample includes more than 11 million records and has not (to our knowledge) been used to evaluate long-term effects of the Famine.[4] Outcomes include educational attainment, labor market status, and residence information of respondents. Demographic information includes sex, birth year and month, and marriage and fertility information (see the appendix).

Unlike preceding Census surveys and the CHNS data, the 2000 Census records the province of birth, eliminating the potential for confounding due to internal migration.[5] The 2000 Census captures Famine cohorts near age forty, and therefore near the flat portion of their occupation and earnings profile. Moreover, it is the first Census to capture near-complete fertility histories of women born during the Famine.[6] We restrict the analysis to those born during 1956 to 1964, a subsample that includes three pre-Famine years and three post-Famine years (death rates peaked in 1960 but were elevated in 1959 and 1961 as well, see figure 9.1). Our relatively narrow birth interval is intended to increase the similarity of the unobserved later-life factors and their effects on Census outcomes.

Our second data source is the natality microdata for Hong Kong (1984 to 2004), derived from the universe of birth certificates. These data include information on maternal country of birth. Restricting the sample to mothers of singletons either born in mainland China or Hong Kong in the years 1957 to 1965 yields some 600,000 records, approximately one-third of whom immigrated from the mainland. The Hong Kong data provide an important control group since all of mainland China was afflicted by the Famine (Cai and Feng 2005).

9.2.1 Measuring the Famine

We use two measures of famine intensity: death rates and average month of birth.

Death Rates

We use the all-age death rate (China Statistical Press 2000) by year and province to calculate two (mortality-based) proxies of Famine intensity. We have data for twenty-nine out of the thirty-one provinces (or province-level divisions).

3. Conducted by the Chinese National Bureau of Statistics for mainland China.

4. Shi (2006) used a 0.1 percent subsample of the 2000 Census.

5. Of those born during 1956 to 1964, 6 percent reported moving from another province since birth, with another 10 percent relocating to towns within the province of birth.

6. A mere 0.3 percent of women born in 1960 reported having a child between November 1999 and October 2000. For comparison, 14.8 percent for women born in 1976 had a child in the same period.

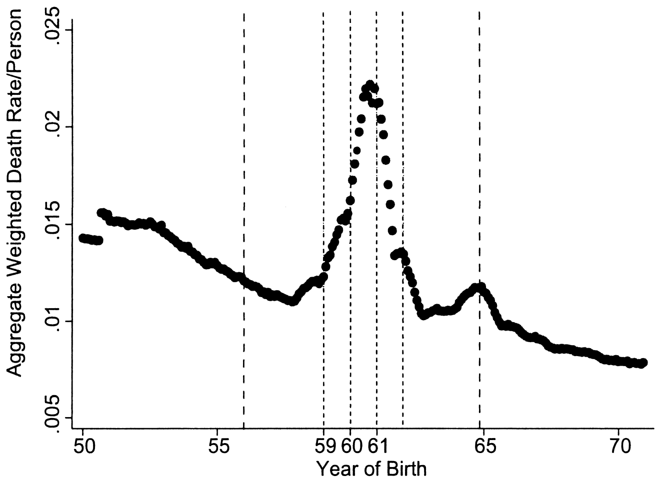

Fig. 9.1 Aggregate weighted death rate by year and month of birth, mainland China
Note: Authors' calculations based on all age death rates by year and province as reported by China Statistical Press (2000).

- First, for every person, we calculate the weighted average of the death rate in the province of birth for the duration of the fetal period, henceforth "weighted death rate" or wdr_{jt}. For example, a person born in January 1960 in Beijing is assigned one-ninth of Beijing's 1960s mortality rate and eight-ninths of Beijing's 1959s mortality rate. This weighted death rate ranged from 0.005 to 0.069 (per person).
- Second, we collapse this weighted death rate by month of birth, thus calculating a population-weighted national average for each month and year, henceforth "aggregate weighted death rate," or awdr_t. During the study period, this measure ranged from 0.010 (in 1963) to 0.022 (at the end of 1960), a difference of 0.012. Thus measured, those born toward the end of 1960 and early 1961 were exposed to the greatest Famine intensity in utero (figure 9.1).

Average Month of Birth

In the northern hemisphere, famines tend to be most severe during the winter months. This reduces fertility disproportionately in the latter half of the calendar year, thereby lowering the average month of birth (Stein et al. 1975).[7] This proxy applied to the 2000 Census indicates 1960 as the worst year for mainland China (figure 9.2); that is, consistent with the mortality data. Because immigrants to Hong Kong were a highly selected group, both geographically (the Famine hit bordering provinces later) and due to the

7. Authors' tabulation of appendix table 4 data in Stein et al. (1975).

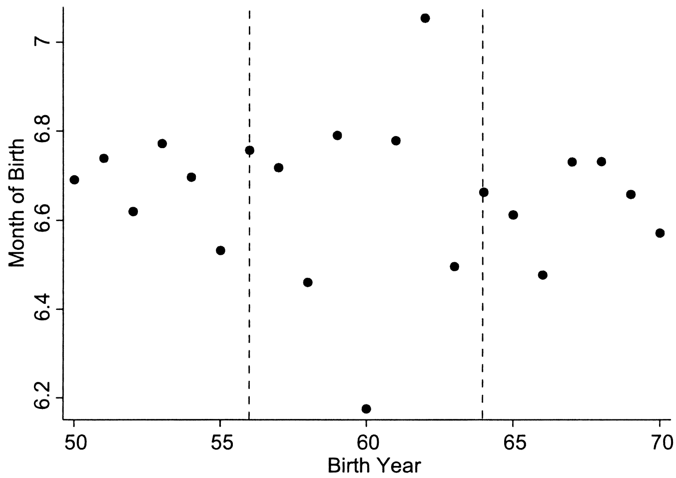

Fig. 9.2 Average month of birth, mainland China
Source: 2000 Census.

particular migration policies in place (further described in section 9.3.5), we cannot rely on mainland mortality data in the Hong Kong analysis.[8] To obtain a proxy for when the Famine peaked for this group of immigrants, we use average month of birth. This proxy indicates 1961 as the worst Famine year for Hong Kong mothers born in the mainland (figure 9.3). As expected of the "control group," there was *no* corresponding change for Hong Kong natives (figure 9.4).

9.3 Results

9.3.1 Descriptive Results

We begin by presenting unadjusted outcomes by quarter of birth (for all Chinese) in the four panels of figure 9.5. These figures indicate that those born around 1960 had worse socioeconomic outcomes than the cohort trend would predict. Recall that this cohort was in utero during the period with the highest death rate, as measured by the weighted death rate (figure 9.1). In 2000, the 1960 birth cohort was more likely to be: (a) not working at the time of the Census; (b) supported by other household members; (c) living in a smaller home and; (d) parents of girls. For some of these outcomes, departures from the cohort trend appear in the adjacent cohorts as well.

8. Natality data for Hong Kong identify Mainland immigrants, but not their province of birth (nor province of last residence).

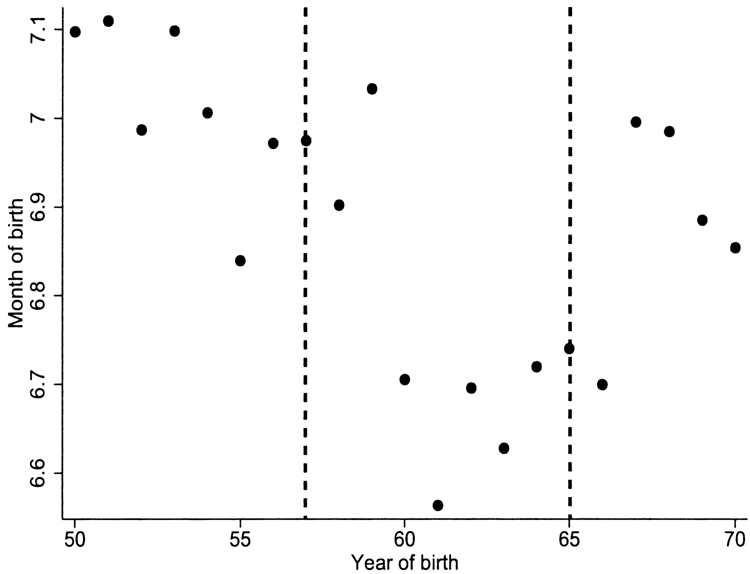

Fig. 9.3 Average month of birth, Hong Kong mothers born in Mainland

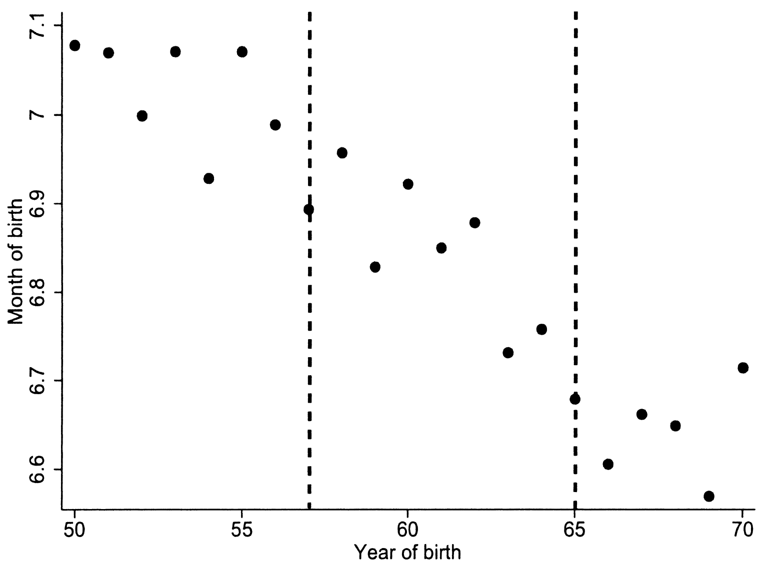

Fig. 9.4 Average month of birth, Hong Kong mothers born in Hong Kong

Source: Hong Kong natality microdata.

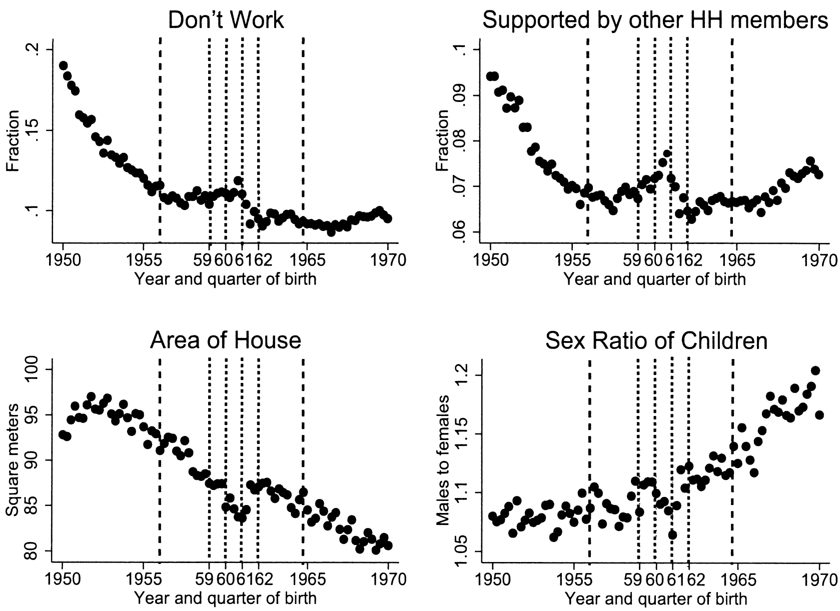

Fig. 9.5 Census outcomes by year and quarter of birth
Source: 2000 Census.

This pattern mirrors the 1959 to 1961 duration of the Famine, with a peak in 1960.

A final descriptive pattern of note is the rise in the sex ratio for the cohorts born up until 1960 and the sharp drop for the cohorts born in 1960 and 1961. The maleness of the late 1950s birth cohorts is in line with the suggestion that infant and toddler girls were disproportionately denied food. That the 1960 and 1961 cohorts are notably female is consistent with maternal malnutrition disproportionately penalizing male offspring, a mechanism that toward the end of the Famine may have dominated post-natal discrimination against daughters.

9.3.2 Regression Results

To investigate systematically how adult outcomes vary with prenatal Famine exposure, we focus on the cohorts born during 1956 to 1964 and estimate by OLS:

$$(1) \qquad y_{it} = \beta_0 + \theta \times \text{awdr}_t + \beta_1 \times \text{YOB} + \beta_2 \times \text{YOB}^2 + \beta_3 \times \text{YOB}^3 + \lambda_{province} + \varepsilon_{it},$$

where y_{it} denotes the outcome for individual i born in period t, awdr_t denotes the aggregate weighted death rate by birth year and month of birth t,[9]

9. See section 9.2.1.

and YOB denotes birth year. We enter YOB as a cubic to control for the nonlinear cohort/age effects apparent in the four panels of figure 9.5. Finally, we include a vector of province dummies, $\lambda_{province}$. Thus equation (1) allows for a flexible cohort profile within a narrowly-defined birth interval, and assesses whether the prenatal death rate contributes additional explanatory power, as reflected by $\hat{\theta}$. We estimate equation (1) separately for men and women. We do not include dummies for the month of birth, given its apparent endogeneity in figure 9.2. (However, inclusion of month of birth dummies does not alter the basic results from estimating [1] and [2]; results are available on request.)

Results from estimating equation (1) for the 2000 Census outcomes are reported in tables 9.1 through 9.3. Table 9.1 shows a consistent deleterious effect of prenatal Famine exposure on labor market outcomes. Greater famine intensity is associated with a higher likelihood of being illiterate and not working. During the Famine, awdr increased by 1.2 percentage points, implying, for example, that the most Famine-exposed cohorts were 7.5 percent (0.5052 × 0.012/0.081) [women] and 9 percent (0.1585 × 0.012/0.021) [men] more likely to be illiterate; 3 percent (0.4714 × 0.012/0.189) [women] and 5.9 percent (0.4017 × 0.012/0.082) [men] more likely to not work; and 13 percent (0.0448 × 0.012/0.004) [women] more likely to be disabled. Men in utero during the Famine were 9 percent more likely to be supported financially by other household members ("Dependent"), and the figure for women was 4 percent.

The Census does not have any direct measure of earnings, but there is information on housing, which may serve as a wealth proxy. Thus measured,

Table 9.1 **2000 Census: Labor and housing outcomes for 1956–1964 birth cohorts**

	Illiterate	Don't work	Disabled	Dependent	House area
			Women		
Mean	0.081	0.189	0.004	0.119	87.162
awdr	0.5052**	0.4714***	0.0448*	0.3972***	–220.1528***
	[0.2169]	[0.1530]	[0.0250]	[0.1354]	[48.4753]
N	786,156	786,156	786,156	786,156	772,260
			Men		
Mean	0.021	0.082	0.006	0.019	83.933
awdr	0.1585*	0.4017***	0.0657	0.1399**	–104.7566**
	[0.0784]	[0.1131]	[0.0426]	[0.0674]	[38.3963]
N	818,103	818,103	818,103	818,103	790,342

Notes: awdr = aggregate weighted death rate by birth year and month. Mean = mean of dependent variable. Standard errors clustered at province of birth in square brackets.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

Table 9.2 **2000 Census, marriage market outcomes, 1956–1964 birth cohorts**

	Unmarried	Never married	Spousal ed.[a]	Marriage age[b]	Household head[c]
			Women		
Mean	0.061	0.004	9.057	269.237	0.118
awdr	0.2608	–0.0013	–6.3342**	67.4994**	–0.0998
	[0.1632]	[0.0249]	[2.4652]	[28.5417]	[0.1633]
N	786,156	786,156	685,989	783,015	786,156
			Men		
Mean	0.090	0.039	8.060	290.898	0.870
awdr	0.4902***	0.2676**	–0.1692	125.1309***	–0.5145**
	[0.1285]	[0.1035]	[2.5349]	[28.5395]	[0.2302]
N	818,103	818,103	683,041	785,927	818,103

Notes: awdr = aggregate weighted death rate by birth year and month. Mean = mean of dependent variable. Standard errors clustered at province of birth in square brackets.

[a]Includes head-spouse couples only. Education is in years.

[b]Marriage age is in months.

[c]Includes those residing in family units (i.e., excludes those residing in collectives).

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

greater fetal Famine exposure reduced adult economic status (table 9.1, last column).

We also estimate equation (1) for marriage market outcomes (table 9.2). While marriage was nearly universal for women, inspection of who they married reveals that the Famine-exposed women married men with less education. For men, both the extensive and intensive margins were affected. Men were 6.5 percent ($0.4902 \times 0.012/0.09$) more likely to be unmarried and 8.2 percent ($0.2676 \times 0.012/0.039$) more likely to never have married. Moreover, they married at older ages (1.5 months) and were 0.7 percent ($0.5145 \times 0.012/0.87$) less likely to head their households.

The poor marriage market outcomes are unlikely to be driven by conventional supply and demand factors. As cohorts born during the Famine were substantially smaller than adjacent cohorts, the "marriage squeeze" would work in their favor (see also Brandt, Siow, and Vogel [2007] for a discussion and similar evidence from the 1990 China Census).[10]

Prenatal famine exposure also raised male (relative to female) mortality as evidenced by survival around age forty. The most exposed cohort was 1.5 percent age points (1.3147×0.012) more female (table 9.3, column [1]). The most striking finding, however, is that prenatally exposed women bore more girls, the offspring of the most Famine-exposed were 0.4 percentage points

10. For both men and women, the three smallest cohorts 1950 to 1970 were those born 1959 to 1961.

Table 9.3 **2000 Census: Sex ratio outcomes, 1956–1964 birth cohorts**

		Women[b]	
	Male[a]	Sons/kids	No child
Mean	0.51	0.548	0.007
awdr	–1.3147***	–0.3194**	0.0712
	[0.2651]	[0.1368]	[0.0503]
N	1,604,259	773,291	786,156

Notes: awdr = aggregate weighted death rate by birth year and month. Mean = mean of dependent variable. Standard errors clustered at province of birth in square brackets.

[a]Dummy: equals 1 if respondent was male.

[b]Pertains to children borne.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

(0.3194 × 0.012) less male (column [2]).[11] To anticipate results, the Hong Kong data (derived from birth certificates) corroborate this pattern.

9.3.3 Geographic Variation in Famine Intensity

The second test of our hypothesis isolates the geographic variation in the Famine and makes comparisons exclusively within (annual) birth cohorts. This approach reduces the potential for confounding from later-life events with age-specific effects (e.g., if the Cultural Revolution, launched in 1966, delayed school entry among six-year-olds). Here, confounding by such later-life events would require their geographic variation to mirror the Famine (while also replicating the Famine's cohort effects).[12] We estimate by OLS:

$$y_{itj} = \beta_0 + \theta \times \text{wdr}_{tj} + \gamma_{yob} + \lambda_{province} + \varepsilon_{itj}, \tag{2}$$

where θ is the parameter of interest, t denotes year and month of birth, and j the province of birth. The mortality rate is the weighted death rate (wdr_{jt}) previously described for the individual's birth date (year and month) and province of birth. As in equation (1), we include vectors of province of birth dummies ($\lambda_{province}$), and, as the goal is to isolate the geographic variation in health induced by the Famine, we absorb the average differences for each birth year by including a vector of year of birth dummies (γ_{yob}).

Results from estimating equation (2) provide distinct evidence of Famine damage: regional differences in outcomes for the Famine cohort line up

11. Similar results are obtained when the logit transform of the proportion of male children is the dependent variable.

12. In contrast to the Famine, urban residents were more affected by the Cultural Revolution than rural residents. In addition, the Cultural Revolution lasted ten years and therefore impacted a broader span of birth cohorts.

Table 9.4 2000 Census: Cross-sectional variation in famine severity, labor market, and housing outcomes, 1956–1964 birth cohorts

	Illiterate	Don't work	Disabled	Dependent	House area
			Women		
wdr	0.1659	0.0953	0.0418***	0.0755	–58.9501**
	[0.1269]	[0.1657]	[0.0116]	[0.0917]	[22.0095]
N	764,786	764,786	764,786	764,786	751,352
			Men		
wdr	0.1231*	0.1628**	0.0585***	0.0321	–52.1040*
	[0.0688]	[0.0666]	[0.0170]	[0.0376]	[28.5949]
N	795,408	795,408	795,408	795,408	768,522

Note: Standard errors clustered at province of birth in square brackets.
***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

with regional differences in malnutrition (tables 9.4 through 9.6). Table 9.4 shows that local famine severity indeed corresponds to the magnitude of damage in Census outcomes. Women born in high-Famine areas had larger increases in disability rates and larger reductions in house sizes. For men, differences in literacy, work status, disability, and house size correspond to Famine severity in the expected direction.

The magnitude of damage obtained from estimating equation (2) is generally either similar to that found with equation (1), or somewhat smaller. Famine-exposed women were again about 13 percent ($0.0418 \times 0.012/0.004$) more likely to be disabled, and the corresponding figure for men was 12 percent ($0.0582 \times 0.012/0.006$). As for housing, the Famine is estimated to reduce the residence size by slightly under 1 square meter ($58.95 \times .012$), with a similar effect for men. For men, illiteracy increased 7 percent and the likelihood of not working increased 2.4 percent.

Again, men from high-Famine areas were less likely to be married (3.5 percent), more likely to never have married (5 percent), married older (.8 months), and were less likely to head their households (.7 percent) (table 9.5). For women, the point estimates have the expected signs, but are not statistically significant. Finally, table 9.6 shows that coefficients for the sex ratio are significant in the expected direction, but roughly one-third the size of the corresponding estimates in table 9.3.

Rural Versus Urban

We also estimate the aforementioned models separately for those born in rural versus urban areas. We find a Famine effect on the labor and marriage market outcomes for both areas, although the effects for the rural sample were larger (presumably reflecting the greater severity of the Famine in rural

Table 9.5 **2000 Census: Cross-sectional variation in famine severity, marriage market outcomes, 1956–1964 birth cohorts**

	Unmarried	Never married	Spousal ed.[a]	Marriage age[b]	Household head[c]
			Women		
wdr	0.0505	0.0217	0.0794	14.7224	–0.0701
	[0.0623]	[0.0130]	[1.5906]	[19.9378]	[0.1297]
N	764,786	764,786	668,672	761,879	760,726
			Men		
wdr	0.2666***	0.1555**	1.5938	67.6296***	–0.5089***
	[0.0696]	[0.0634]	[1.3770]	[22.8696]	[0.1183]
N	795,408	795,408	665,857	764,670	779,087

Notes: wdr = Weighted average death rate for the gestation period, assuming nine month gestation. Varies by province and month and year of birth. Standard errors clustered at province of birth in square brackets.

[a]Includes head-spouse couples only. Education is in years.

[b]Marriage age is in months.

[c]Includes those residing in family units (i.e., excludes those residing in collectives).

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

Table 9.6 **2000 Census: Cross-sectional variation in famine severity, sex ratio outcomes, 1956–1964 birth cohorts**

		Women[b]	
	Male[a]	Sons/kids	No child
wdr	–0.3264**	–0.1693**	0.0325
	[0.1390]	[0.0797]	[0.0251]
N	1,560,194	752,418	764,786

Note: Standard errors clustered at province of birth in square brackets.

[a]Dummy: equals 1 if respondent was male.

[b]Pertains to children borne.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

areas). For both rural and urban areas, we find that the Famine reduced the sex ratio of the in utero cohort and again in the next generation (results available from authors).

Province of Residence

Finally, we note that estimates reported in tables 9.1 through 9.6 are essentially unchanged when fixed effects for the 2000 province of residence are included along with the province of birth dummies.

9.3.4 Potential Biases

As the Famine both raised mortality and reduced fertility, Famine cohorts were approximately 25 to 50 percent smaller than neighboring cohorts in the 2000 Census. To the extent that Famine-induced mortality was negatively selective, as would seem most plausible (especially insofar as health is concerned), estimates of damage to survivors are downward biased.

Negative selection into fertility is a greater potential concern, since this could generate the appearance of effects absent any true damage (i.e., upward bias). However, historical evidence suggests that the Famine, unlike the subsequent Cultural Revolution, hit poorer individuals the hardest (see, e.g., Cai and Feng [2005]). The Dutch Famine provides further evidence: fathers of children conceived in the winter of 1944 and 1945 were more likely to have nonmanual occupations (Stein et al. 1975).

Direct evidence on selection into fertility is available from the China Fertility surveys (conducted in 1985 and 1988), which include information on the respondent's mother's educational attainment (further information in the appendix). Plotting the share of women whose mothers had no education, primary or less, secondary or more, or who did not know their mother's education, the 1959 to 1961 birth cohorts do not appear any worse than adjacent cohorts (figure 9.6). If anything, maternal education for the 1959 to 1961 birth cohorts was better than for adjacent cohorts.

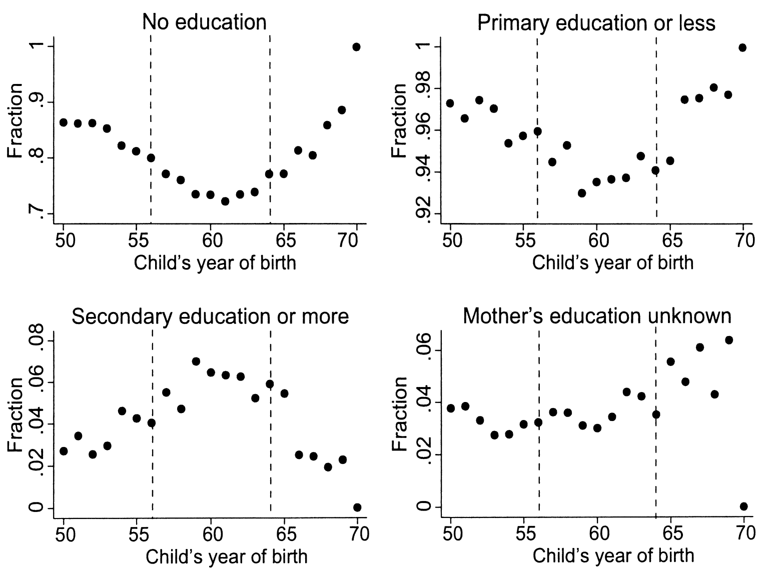

Fig. 9.6 Mother's education by child's (respondent) year of birth

Source: China Fertility surveys 1985/87.

Note: For mother's education unknown, the universe is all respondents. For the remainder, the universe is those who knew their mother's education.

Cohorts born after the Famine may constitute a better control group than those born in the 1950s (who were exposed to higher mortality rates and malnutrition in childhood). Reestimating equations (1) and (2) on the sample restricted to birth cohorts 1959 to 1964, we obtain similar, if not slightly stronger, results (available upon request).

Another possible source of bias is that those born during famines may be born to more fecund women or parents who favor offspring quantity over quality. Whereas we cannot control for parental preferences (other than note, as before, that the maternal education of the Famine cohorts was, if anything, better than that of adjacent cohorts), we can investigate sibship size using a recent survey: the 2005 Urban Chinese Education and Labor Survey conducted by the Ministry of Education in twelve cities in China, covering some 10,000 households.[13] The 1959 to 1961 cohorts do not appear to have more siblings (figure 9.7). Rather, these birth cohorts are on a negative trend (linear and decreasing in year of birth).[14]

However, high infant and juvenile mortality during the Famine years and no effect on sibship size suggests catch-up fertility in the years following the Famine, which would tend to depress the outcomes of those born in the early 1960s. The fact that we found similar, if not stronger, results when we restricted the sample to the 1959 to 1964 cohorts as noted earlier, suggest that cohort-size effects from bunching of fertility had a limited impact on adult outcomes.

9.3.5 Birth Outcomes in Hong Kong

A shortcoming of the analysis using the 2000 (mainland) Census is the want of a truly unexposed control group. Hong Kong Natality data offer a potential solution to this problem. Communist China severely restricted out-migration, a policy that was temporarily and dramatically suspended during a six-week period in the spring of 1962 when a large number of mainlanders entered Hong Kong (Burns 1987). Among the refugees were mainland-born children, who themselves show up as parents in the 1984 to 2004 Hong Kong Natality files. The migration of mainland residents to Hong Kong, during and in the years after the Famine, provides a common environment for those affected by the Famine (mainland immigrants) and those who were not (Hong Kong-born).

The Hong Kong Natality microdata allow us to focus on second-generation birth outcomes, specifically low birth weight and sex. Low birth weight may be a negative outcome because it is a correlate of poor adult health and eco-

13. The 2000 Census does not have information on sibship size. Neither can it be inferred from the relationship variable for a household, since most adult siblings live in different households. Finally, the earliest publicly available Chinese census was conducted in 1982, when the 1959 to 1961 cohorts were in their early twenties.

14. This is confirmed by a regression of sibsize on a dummy for birth cohorts 1959 to 1961, controlling for a linear trend in birth year. The coefficient on this dummy is about zero, with a very large standard error (not reported).

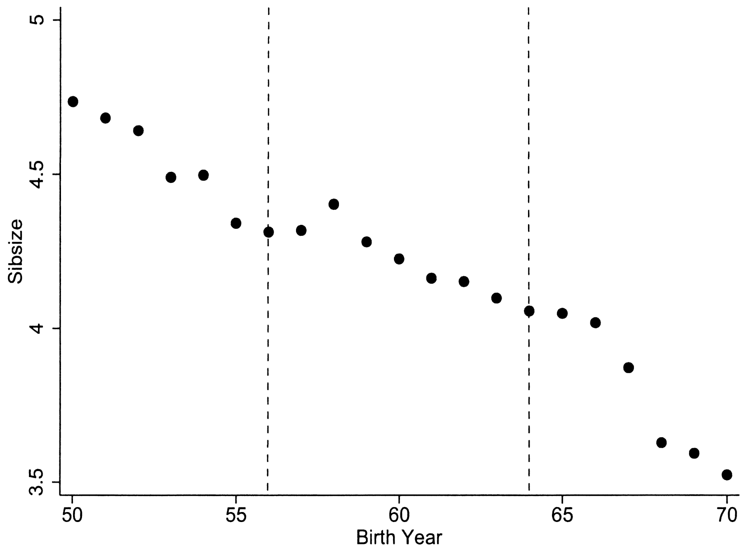

Fig. 9.7 Number of siblings by respondent's year of birth
Source: 2005 Urban Chinese Education and Labor Survey.

nomic performance. As for sex of offspring, a daughter may not be a poor outcome. Still, it may signal poor parental condition; see section 9.4.

We estimate a modified version of equation (1) separately on the subsamples of mainland-born and Hong Kong-born mothers giving birth in Hong Kong during 1984 to 2004. That is, among Hong Kong mothers who immigrated from the mainland, we compare the birth outcomes of mothers exposed to the Famine in utero to other mainland immigrants born before or after the Famine. While migrants are clearly a select group, our identifying assumption here is *not* that migrants are a random sample, but instead that this selection in to migration did not change discontinuously for the cohort of migrants in utero during the Famine.

Dating famine exposure for migrants requires some care. The Hong Kong natality files do not record province of birth for mainland-born mothers, rendering the application of year and province-level mortality rates impossible. Moreover, migrants are likely a selected sample. Therefore, we date Famine exposure by the average month of the immigrant cohorts. Month of birth drops dramatically for mainland-born mothers born in 1961 (figures 9.3 and 9.4). Consequently, we substitute the dummy variable I(1961), which takes on the value 1/100 for those born in 1961, for the death rate ($awdr_t$). A later year for the immigrants to Hong Kong is consistent with the likely geographic selection (more migrants likely from the south, an area that was hit later) and the timing of the migration policy. Again, we do not include month of birth given its apparent endogeneity.

Table 9.7 **1984–2004 Natality outcomes in Hong Kong: Mainland versus Hong Kong-born mothers**

	Mother born			
	Mainland		Hong Kong	
	Low BWT[a]	Son[b]	Low BWT[a]	Son[b]
Mean	0.031	0.52	0.039	0.517
	0.247**	–0.629***	0.014	–0.009
	[0.099]	[0.121]	[0.037]	[0.074]
N	198,452	198,452	393,419	393,419

Notes: Dummy, equals one one-hundredth if mother born in 1961. Mean = mean of dependent variable. Regression results from estimating equation (1) where substitutes for awdr and without the province dummies. The birth weight regressions also include a dummy for the sex of the child. Standard errors clustered by year of birth in square brackets.

[a]Dummy, equals 1 if birth weight was less than 2,500 grams.

[b]Dummy, equals 1 if child male.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

A dummy for the sex of the child is also included when the dependent variable is birth weight, since males are on average heavier than females. The birth interval is shifted forward one year from the mainland Census regressions; that is, we focus on births to parents themselves born during 1957 to 1965.[15] Furthermore, we restrict the sample to singleton births. We find that mothers born in 1961 were 8 percent (0.247/0.030) more likely to give birth to a child of low birth weight (less than 2,500 grams), and 1.2 percent (0.00629/0.52) less likely to give birth to a son than mothers born in adjacent years (table 9.7). No significant effects were detected for the Hong Kong-born mothers, despite their greater numbers.

9.4 Summary and Discussion

We use the Chinese Famine 1959 to 1961 as a natural experiment in maternal stress and malnutrition. Despite some forty years of potential catch-up, cohorts exposed in utero registered substantial damage in the 2000 Census. Higher Famine intensity—by virtue of either time or place of birth—was associated with greater risk of being illiterate, out of the labor force, marrying later (men), and marrying spouses with less education (women).

15. Clearly, mainland-born mothers born after 1962 could not have been part of the Famine-induced wave of immigration in the spring of 1962. It is reassuring that restricting the sample to 1957 to 1961 strengthens our results (available from authors upon request).

Osmani and Sen (2003) argued that maternal malnutrition "rebounds on the society as a whole in the form of ill-health of their offspring—male and females alike—both as children and as adults" (p. 105). Despite its importance, the nutritional status of pregnant women has been found wanting in developing countries (DeRose, Das, and Millman 2000). Nubé and Van Dem Boom (2003) analyzed seventy-five Demographic and Health Survey (DHS) samples, finding that in South/Southeast Asia, "women's nutritional status relative to men's nutritional status compares unfavorably with results from other developing regions . . ." (p. 520). The prevalence of anemia among pregnant women in South Asia is 78 percent (Osmani and Sen 2003). Our results suggest that male-biased nutritional allocations handicap not only future health outcomes, but also future economic outcomes.

Empirical evidence on the causal effects of fetal nutrition is surprisingly scarce (see, e.g., Rasmussen [2001]; Walker et al. [2007]). Omitted factors (e.g., parental abilities and attitudes) can generate positive associations between measures of fetal health and adult socioeconomic outcomes in the absence of a causal pathway. Therefore, the "most compelling examinations of the fetal origins hypothesis look for sharp exogenous shocks in fetal health that are caused by conditions outside the control of the mother" (Currie 2009, 102). Clearly, such shocks are different from the chronic malnutrition facing women in developing countries. It is, however, difficult to think of an experimental design that could deliver clear evidence on the effect of chronic malnutrition on humans above what can be inferred from nonexperimental data; for instance, babies born in India weigh on average about 25 percent less than babies born in developed countries (Gluckman and Hanson 2005).

Similarly, our findings offer a fresh perspective on current health and socioeconomic outcomes among adults, positively correlated at both the individual and national levels (see, e.g., Case, Lubotsky, and Paxson [2002]; Cutler, Deaton, and Lleras-Muney [2006]). The mechanism behind this "dual relationship" (Smith 1999) has proved difficult to unravel empirically. Our findings suggest that poor fetal health conditions of the past may be at the nexus of the relationship. Indeed, historical nutritional deprivation in *developed* countries may also undermine outcomes in cohorts born prior to major nutrition-assistance programs for the poor.[16]

Perhaps the most intriguing finding is that Famine exposure lowered the sex ratio of not only the first but also the second generation—prenatally exposed women were themselves more likely to bear daughters. This pro-female effect is all the more noteworthy given the well-documented prevalence of son preference in mainland China. Famine-induced reductions in the sex ratio are consistent with empirical work finding lower sex ratios for

16. Almond, Hoynes, and Schanzenbach (2009) found improvements in birth outcomes (including birth weight) with the introduction of the Food Stamps Program in the United States during the 1960s, particularly among black infants. These cohorts also manifest improved health and educational outcomes in adulthood (Almond and Chay 2006).

unmarried or poorly educated mothers (Almond and Edlund 2007). While the magnitude of the Famine's effect on the sex ratio may appear small, it is several times larger than that associated with marital status in U.S. natality data (Almond and Edlund 2007) and is similar to differences found in survey data between mothers living with a partner around the time of conception and those who were not (Norberg 2004). Thus, small changes in the sex ratio can reflect large differences in maternal circumstance.

Trivers and Willard (1973) proposed that evolution would favor parental ability to vary the sex ratio of offspring according to condition: parents in poor condition would favor daughters and parents in good condition would favor sons. Their argument was based on the observation that while the average number of offspring to males and females equalizes, the reproductive success of a male offspring tends to be more resource-sensitive. Maternal malnutrition has been observed to correlate with more female births (see, e.g., Andersson and Bergström [1998]). Pathways include heightened rates of male fetal deaths, as was found to be the case during the Dutch famine (Roseboom, Meulen, Osmond et al. 2001). Another possibility is that starvation affects early cell division of male and female embryos differentially (Cameron 2004). Fetal "predictive adaptive responses" (to use the terminology of Gluckman and Hanson [2005]) set parameters for the adult individual; for instance, her height, which means that maternal constraints affect not only her children, but also her daughters' children.

Yet another pathway is sex selection. As noted, son preference is prevalent in China, and sex ratios at birth (male to female) have trended upwards since the early 1980s. In this case, low sex ratios of those in utero during the Famine may be a reflection of daughters having been actively chosen (or not deselected) by those of low socioeconomic status (Edlund 1999).

To our knowledge, ours is the first large-scale quasi-experimental evidence of a Trivers-Willard effect in human populations. It is also the first evidence (quasi-experimental or otherwise) of an intergenerational "echo-effect" of maternal status on the sex ratio (to our knowledge). Low offspring sex ratios in two generations underscore the long-term impact of maternal health.

Appendix

Variable Definitions

Census 2000

wdr Weighted death rate for the gestation period, assuming nine month gestation, and province of birth. For example, a person born in January 1960 in Beijing is assigned one-ninth of Beijing's 1960 mortality rate and eight-ninths of Beijing's 1959 mortality rate.

awdr Aggregate weighted average death rate, the wdr collapsed by month and birth year. Thus, it is the population weighted mean of wdr by month and year of birth.

mean Mean of dependent variable.

Province The province of birth. Our results are robust to inclusion of dummies for province of residence.

Illiterate Dummy indicating that the respondent was either illiterate or semiliterate.

Don't work Dummy indicating that the person did not work for more than one hour between October 25 and October 31 (in 2000). This includes those who are on leave from a job, as well as nonworkers.

On leave from job Not working because on leave, training, or seasonal lay-off.

Supported by other HH members/Dependent Main income source was support by other household members.

Disabled Dummy indicating that the person does not work because he/she has "lost ability to work."

House area Area of home, in square meters.

Unmarried Dummy indicating that the respondent was unmarried at the time of the census.

Never married Dummy indicating that the respondent had never married.

Spousal education Includes head-spouse couples only. Education is in years.

Marriage age Age in months at time of first marriage.

Household head Dummy indicating that the respondent was household head. Includes only respondents living in "family type" households (as opposed to "collectives").

Male Dummy indicating that the respondent is male.

Sons/Kids Fraction sons among ever-borne children. Excludes women who had not borne any children.

No kid Dummy indicating that the woman had borne no children.

Child mortality Number of children ever borne minus number of surviving children (at the time of the Census), divided by the number of children ever borne, by year and quarter of birth of mother.

Hong Kong Natality Data

I(1961) Dummy indicating that the mother was born in 1961, scaled by one one-hundredth.

Low BWT Low birth weight. Dummy indicating that child weighed less than 2,500 grams at birth.

China Dummy for whether born in mainland China.

China Fertility Surveys

The China Fertility surveys were carried out in 1985 and 1987 in the following provinces: Hebei, Shaangxi, Liaoning, Guangdong, Guizhou, Gansu; and the municipalities of Beijing and Shanghai. (We have not been able to access data for Shandong.) In total, some 46,000 ever-married women between fifteen and forty-nine years of age were interviewed, providing detailed information on pregnancy history. These data are available from the Office of Population Research, Princeton University, http://opr.princeton.edu/Archive/cidfs/.

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Comment Ronald Lee

In this excellent chapter, important issues are at stake. How do fetal conditions such as maternal nutrition affect later life health, productivity, and general success? Are childhood conditions a mechanism through which low socioeconomic status is transmitted across generations? Does the Trivers-Willard hypothesis from evolutionary theory apply to human populations? The chapter also addresses an important policy issue about the importance of public assistance for pregnant women or women of reproductive age, which may impact the later development and socioeconomic outcomes for their in utero children.

The identification strategy is to analyze the consequences of a huge exogenous shock: the nutritional deprivation caused by the famine in China during the period of the Great Leap Forward. This shock was limited in time

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