The Lasting Impact of Mothers' Fetal Malnutrition on Their Offspring: Evidence from the China Great Leap Forward Famine*

Seonghoon Kim
Department of Economics, Ohio State University
kim.2390@osu.edu

Quheng Deng
Chinese Academy of Social Sciences
Beijing, China
dengqh@cass.org.cn

Belton M. Fleisher
Department of Economics, Ohio State University
410 Arps Hall, 1945 N. High Street, Columbus, OH 43210
&
Center for Labor Market and Human Capital Research, Central University of Finance and Economics, Beijing, China & IZA
fleisher.1@osu.edu

Shi Li
School of Economics and Business, Beijing Normal University
Beijing, China
lishi@bnu.edu.cn

November 12, 2010

* We thank Avraham Ebenstein, Simon Chang, Jikun Huang, Thomas Kniesner, Scott Rozelle, and participants of seminars at the Center for Chinese Agricultural Policy of the Chinese Academy of Sciences and Ohio State University for valuable comments. Members of the Friday Working Group, Will McGuire, Kerry Tan, and Kent Zhao patiently listened to many presentations of the material and made valuable comments throughout.

Abstract

We investigate whether the effects of mothers' *in utero* and early-infancy malnutrition extend to their children (the second generation). Specifically, we explore whether the second generation's accumulation of human-capital is negatively impacted by their mothers' malnutrition *in utero* or in early infancy. Using the China Famine as a natural experiment, we find that the second generation experiences lower probabilities of entering both junior and senior secondary school, and the magnitude of this effect is similar for both male and female offspring. The estimated impact on entrance to senior secondary school is smaller than that on entrance to junior secondary school. All our estimations include variables to control for year-varying and province-varying fixed effects. Our results for junior secondary school are robust to controls for mother's acquired schooling and socio-economic status. In addition, two-step estimation using instrumental variables to account for time-varying, province-specific omitted variables correlated with provision of schooling, health care, and related variables in mother's birth province yield results that are consistent in sign, although larger in magnitude, than those obtained with ordinary probit or linear probability regressions. We believe that our research is novel in supporting the existence of an important second-generation multiplier of policies that support the nutrition of pregnant women and infants in any country where nutritional deficiencies remain.

Key Words: Fetal origin, Malnutrition, Health, Schooling, Barker hypothesis, China Famine

JEL Classification: I12, J16, P36

1. Introduction

We investigate whether mothers' *in utero* and infant malnutrition adversely impact the human capital of their offspring (the second generation). While much has been learned about the long-term effects of malnutrition on adult outcomes of the first generation (Barker, 1992 and much subsequent research), much less is known about second-generation outcomes. Because the cost of acquiring additional units of human capital is a decreasing function of the stock (including health capital) beginning in the prenatal period (Behrman et al., 2004), any influence of first generation malnutrition on fetal development of the second generation is likely to reduce the payoff to public and private investments in schooling, training, and other forms of human capital investment. It follows that the existence of second-generation effects on human capital development implies a multiplier for policies that support the nutrition of pregnant women and infants. The China Great Leap Forward famine (China Famine), generally recognized as the worst in world history as measured by mortality and length (Li and Yang, 2005), provides a natural experiment from which information on second-generation effects of malnutrition can be obtained.

There is substantial evidence in the literature that poor infant health, often associated with infant malnutrition, portends serious consequences for the development of human capital throughout an individual's life (Alderman, et al., 2001; Handa and Peterman, 2007; Oreopoulos, et al., 2008; Currie, et al., 2010). It should not be surprising that poor infant health may frequently be associated with mother's malnutrition, and we suggest two potential paths through which first-generation malnutrition shocks may impact the second generation: First, the child of a famine-born mother (or of a mother who experienced famine in early infancy) may suffer due to famine-induced defects in the mother's ova[1] (direct channel—see figure 1). Second, women born around the time of famine tend to acquire lower social and economic status (SES) than those born outside the famine period and this in turn may lead to lower human capital development among their children than the children would otherwise acquire (indirect channel).

[1]Epidemiological studies suggest that "adverse *in utero* experiences may permanently affect maternal growth and development, altering [the mother's] metabolism in such a way as to provide an adverse environment for her fetus (Drake and Walker, 2004)." During the *in utero* and early post-birth stages of life, the body directs available nutrition first toward survival and then for other physical needs such as scheduled brain and body development or maintaining daily functions (Steckel, 1995, Behrman et al., 2004).

Deficiencies in scheduled brain and body development in a woman's prenatal and early infancy periods of life are likely to have cumulative effects on the cost of her future investments and, hence, her lifetime accumulation of human capital. Thus, acquired schooling, earning capacity, income, available marriage partners, and other factors affecting a woman's child-rearing potential are likely to be negatively impacted by *in utero* and early infancy exposure to famine (Victoria et al. 2008). Although our data do not allow us to precisely isolate direct and indirect channels of early-life malnutrition effects, our estimation results are quite robust to controls for mother's SES and schooling. Even though it would be difficult if not impossible with our data to separately identify the two channels through which a mother's *in utero* or early infancy malnutrition may negative effect here children's development, both channels represent important social phenomena that have important policy implications.

Our major contribution to the literature is to identify effects of mothers' *in utero* or early-life malnutrition on their children—the second generation.[2] We do this using the China famine associated with the Great Leap Forward as a natural experiment using a sample of children of women who were born during the China famine. While it is impossible to measure the severity of individual-level malnutrition directly, our key assumption is that the excess death rate around the famine years is a reasonable proxy for the severity of malnutrition. We follow the literature with this assumption. We discuss the measure of excess death rates in more detail in the data section. Also, we acknowledge that there could be many potential sources of bias which can confound the identification of the second-generation effects of early-life malnutrition. We discuss these issues in the methodology section. In order to account for unobserved heterogeneity, we use both two-way fixed effect (2FE) and instrumental variables (IV) approaches. Our choice of instruments is categorical weather dummies, kindly supplied by the authors of Li and Yang (2005).

We find that children whose mothers were affected by the China Famine are less likely to enter junior and senior secondary schools. We estimate that the probability that female offspring of mothers who were born in the most severely famine- impacted rural areas in1960 will enter junior secondary school is at least 2 percentage points less than that of the offspring of mothers who were born in non-famine years. Similar results are obtained for rural male offspring. This

[2] We focus on mothers, because all ova are produced *in utero*, while sperms are not produced until after birth.

estimate implies approximately a 3 percent reduction in the proportion of the children of mothers from the most severely famine-impacted provinces that will enter junior secondary school. The impact on senior high-school entrance is much smaller, and that on urban youth is negligible, as expected. Our research supports the existence of an important multiplier of policies that support the nutrition of pregnant women and infants in any country where nutritional deficiencies remain.

The rest of this paper is organized as follows. The next section discusses methodological issues and presents our analytical framework. Section 3 reviews literature related to the impact of the famine on first-generation human capital and labor market outcomes; section 4 describes the data and sample selection; section 5 reports the estimation results, and section 6 concludes, with policy implications and suggestions for further research.

2. Methodology

Our major hypothesis is that the net impact of a mother's *in-utero* and early infancy malnutrition on the development of her offspring is negative. Our approach is to use provincial weighted excess death rates as a measure of mothers' exposure to *in utero* and early childhood malnutrition in probit regression analysis of the probability that their children (the second generation) enter junior or senior secondary school.[3]

Econometric Model. Our basic model for identifying the impact of famine on the outcomes listed above is represented by the following equation:

$$Y_{ijkl} = \beta \mathrm{WEDR}_{jkl} + \gamma X_i + \delta_j + \tau_l + \varepsilon_{ijkl} \tag{1}$$

where the subscripts *i* represents an individual, *j* a birth year, *k* a birth month, and *l* a birth province.

- Y_{ijkl} is a second-generation individual *i*'s variable of interest, specifically junior or senior secondary school entrance;
- WEDR_{jkl} is a measure of famine intensity (malnutrition) - the weighted excess death rate by year, month and province of birth for person *i*'s mother who was born in year *j*,

[3] By "secondary school" we refer to what is literally designated "middle school" in Chinese. Junior middle school corresponds roughly to 6th to 8th grades, or what is often referred to as "middle school" in the United States.

province l and month k. The variable WEDR is the best approximation available to us for the availability of nutrition to our sample of mothers, and the use of death rates as a proxy for malnutrition is standard in the China Famine literature[4]. It is calculated as the difference between the annual provincial death rate and the mean provincial death rate between 1956-1958 following Chen and Zhou (2007). An underlying assumption is that the famine's effects on caloric intake are proportional to excess mortality. Following Almond et al. (2008a), the death rate for each observation is weighted according to the number of months a second-generation's mother was *in utero* during year j and in year j-1 for individuals born in the first 8 months of year j (based on a 9-month gestation period). In Figure 2, we see that death rates are quite stable before 1958, and they abruptly surge during the China Famine of 1959-1961. Province-specific death rates from 1954 through 1966 are reported in table 1.

- δ_j is a province-specific fixed effect which captures time-invariant province-specific characteristics, and
- τ_l is a year-specific fixed effect which captures year-specific characteristics that are constant across provinces;
- X_i is a vector of household characteristics variables such as house type, size of house, and number of children.

Our main goal is to estimate β. Since we do not specify the full structure of school entrance decisions of children, i.e., utility of mother and children, budget and time constraints, and various forms of uncertainty, we do not have a precise theoretic interpretation of β. It captures the effects of a mother's early-life malnutrition on her child's junior/senior secondary school entrance through all channels of the decision making process, including utility, biological and budget constraints, and uncertainties.

Econometric Challenges

There are several sources of measurement-error and other biases in our data.

Famine Impact on Fecundity and Survival. Necessarily, estimates of second-generation

[4] To our knowledge, the only exception is Meng and Qian (2009). They used county-level change in population as a measure of famine severity.

effects of mothers' *in utero* or early infancy malnutrition are conditional on conception and survival of both first generation mothers and of their offspring. It is likely that during the China Famine, both behavioral and health factors affected fecundity and decisions to marry and to have children (the first generation). In addition, surviving women conceived under adverse conditions may bear traits that have affected their fecundity, their desire to conceive and bear children (the second generation), and the survival probabilities of their (second-generation) children (Chen and Zhou, 2007). During the famine period, birth rates dropped significantly while death rates surged. Peng (1987) argued that about 25 million potential births were lost or delayed due to the China Famine because of adverse health and economic impacts on the famine-exposed child-bearing generation. We believe that our inability to control for unobserved heterogeneity related with child-bearing decisions of first-generation mothers is likely to bias our empirical results against rejecting the null of no famine impact on the second generation. This belief is based on our conjecture that those who were born during the China Famine are more likely to have had parents living in an area that was not as severely affected as other regions in the same province[5], and/or parents of higher socioeconomic status at the timing of their conception, both of which factors are likely to have contributed positively the innate traits and life outcomes of (first-generation) children born during the famine period. In a recent working paper, Shi (2008) studied fertility selection around the China Famine period. He found positive selection among famine-born cohorts, that is, famine-born cohorts have better innate traits than others. In other words, estimate of famine effects are obscured when the fertililty selection is not controlled. Shi's (2008)'s finding suggests that our estimates will be a lower bound of the famine effects.

In the absence of controlled-experimental data, we recognize that estimates of second-generation effects are conditional on unobserved and (in human populations) probably unobservable intervening conditions. In the remainder of this paper, we recognize that all estimation and interpretation is conditional on the presence of possible conception and survival biases affecting both the first- and second generations. We believe, as stated above, that our inability to observe these conditions biases our estimation results against rejecting the null hypothesis of no malnutrition effects.

Measurement Error. We recognize that the variable WEDR measures the nutrition

[5] We do not have data on these sub-provincial impacts of the famine.

available to individual mothers with error. One source of error is that WEDR is a weighted average of annual death rates for a province. This error-in-variables (EIV) problem leads to attenuation bias against rejecting the null hypothesis of no effect when the null is false.

Rural-Urban Migration. Another source of bias is related to classifying families according to whether they live in rural or urban areas. Although we can identify a mother's birth province, we cannot identify whether her place of birth was rural or urban. It is well known that the impact of the famine on available nutrition was far less for urban than for rural families. Indeed, one reason for the severity of famine in rural areas was forced procurement of food for transfer to urban population and for exports to support imports of machinery and related physical capital (Li and Yang, 2005).[6] Thus, WEDR will reasonably well capture the severity of the China Famine for rural residents. Unfortunately, the 2000 Population Census data do not provide any information regarding urban-rural migration[7]. We work around this problem by focusing on the rural sample. Another advantage of focusing on the rural sample is that rural areas were less affected by the Cultural Revolution, which may confound the adverse effects of famine, than were people residing in urban locations (Meng and Qian, 2009). However, if there has been selective rural-urban migration, the rural sample may have lost first-generation mothers with traits that favor human capital accumulation in themselves and their offspring, and this selectivity would bias estimation results based on the rural sample in favor of rejecting the null of no malnutrition effect.

Other Omitted Variables. Perhaps a more serious problem than simple measurement error or identifying mothers' rural or urban birth place is that WEDR may be correlated with unobserved local government actions that influence mothers' and children's health and other

[6] We conjecture that some mothers we classify as urban have changed their residence from rural to urban locations in order to obtain better schooling for their offspring, and this motivation may be stronger for children about to enter senior secondary school. But mothers who bring their children to an urban area may be required to send them to (generally inferior) migrant schools or pay higher fees for standard schools if they do not possess the appropriate hukou. However, some rural mothers who migrated to urban areas at one time have returned to their rural homes in order to guide children when they are enrolled in school (Connelly et al, 2010a and 2010b). An unobserved omitted "motivation" variable could bias our estimation results if it is correlated with WEDR.

[7] Deng and Gustafsson (2006) show that the proportion of original rural-hukou holders in total urban residents was 20.3% using the 2002 wave of urban China Household Income Panel (CHIP) data. For married women born from 1954 to 1966, the proportion is 18.1%.

forms of human capital. The behavioral determinants of famine are well documented in both the theoretical and empirical literature (Sen, 1981a, 1981b; Lin and Yang1998, 2000; Li and Yang, 2005; Meng et al., 2010). Variation in nutritional insufficiency is likely to be due not only to climatic and policy shocks exogenous to local government decisions, but also to the ways in which governments at various levels behaved, including deciding how much grain output to report.[8] It is plausible that provincial and local government decisions that partially explain local famine severity are correlated with policies toward public health, education, and other publicly provided services that affected first- or second-generation human-capital formation. We conjecture that omission of these variables from OLS regression would bias our estimates in favor of rejecting the null of no famine impact on the second generation. In order to avoid this and other sources of omitted variable bias, all of our estimation results include dummy variables for mother's birth province and mother's birth year. We believe that these fixed effects are likely to control for much and perhaps most intertemporal and interprovincial variation in omitted variables that independently have led to higher schooling levels for either the first- or second generation.

However, if there exist time-varying unobserved provincial characteristics correlated with WEDR, our estimates will be still biased. We deal with this problem of unobserved heterogeneity by instrumenting WEDR with five dummy variables representing time- and province-varying weather conditions as used by Li and Yang (2005). These variables are derived from a retrospective survey conducted by Li and Yang as described in an Appendix to their paper.[9] The critical identifying assumption is that weather conditions when a first-generation mother was *in utero* or early infancy affect the human capital investment decisions of the second-generation only through the first generation mothers' weighted excess death rates. The instrumental variables pertain to a period well before the birth dates of our second-generation sample and by their nature are very unlikely to be correlated with residuals of the second-generation human-capital and labor market outcome regressions. The Wald test statistics of exogeneity of the instruments in table 3 support that the instruments are valid. Moreover, the first-stage estimates

[8] We thank Scott Rozelle for emphasizing this point. One of the causes of local food insufficiency was over-reporting of production, which led to increased grain forced procurement. (Li and Yang, 2005 and other references document the importance of excessive forced procurement.)

[9] We are grateful to the authors for generously providing these data.

shown in table 4 provide strong evidence that the instruments can "explain" much of the GLF famine.

3. Related Literature

The motivating theme for much of the literature relevant to this study is conceptually based on the Barker hypothesis, also known as the fetal origin hypothesis (Barker, 1992). The Barker hypothesis states that a variety of human characteristics are determined *in utero*. Researchers have documented a number of long-term adverse effects of malnutrition *in utero* or in infancy on first-generation outcomes in adults born during several major famines,[10] These include physical impacts such as heart diseases and stunted height, mental problems such as schizophrenia, and economic outcomes, such as house size, household income, and related variables (Almond et al., 2008a, 2008b; Behrman et al., 2004; Chen and Zhou, 2007; Fung, 2009; Luo et al., 2006; Meng and Qian, 2009; Mu and Zhang, 2008; Roseboom et al., 2001; Shi, 2008; Yamauchi, 2008). However, there has been little research on second-generation impacts of famine[11]. Almond, et al. (2008) find an increase in the ratio of female children among second-generation births, from which they infer support for the Trivers-Willard hypothesis (Trivers and Willard, 1973); Fung and Ha (2009) find negative outcomes on height-for-age in the offspring age 0-18 of women born during the China Famine. They also find negative effects on weight-for-age and years of schooling, but only for girls.

First-generation effects. Almond et al. (2008a) use data from the 1% sample of 2000 China Population Census (which is our principal data source) to show that among individuals born around the time of the China Famine, adult literacy, house size, working ability, and the probability of being married are all less than those characteristics of the general population who were born outside the famine period. Shi (2008) also finds similar results on adult outcomes using the same 2000 China Population Census data and provides evidence implying that only healthier women conceived children during the famine, while otherwise similar, but weaker, women began conceiving shortly after the famine. The main contribution of Shi (2008) is to

[10] Famines in the recent history that have been the subject of such research include the Irish Potato famine of the 19th century, the Dutch famine of the second World War, the Ethiopia famine (1984-1985, 1998-2000), the Somali famine (1991-1993).
[11] Studies of birth outcomes and physical growth include those of Fung (2009); Gorgens, Meng, and Vaithiannathan, (2007); and Currie and Moretti (2005).

show that the long-term effects of famine experience on the first generation become stronger when fertility selection is accounted for. Using data from the China Health and Nutrition Survey (hereafter, CHNS), Chen and Zhou (2007) and Meng and Qian (2009) provide evidence that those who experienced the China Famine *in utero* or in infancy have lower height, supply less labor, and receive lower earnings, and have other characteristics indicating a negative impact on their human capital. With the same data, Fung (2009) finds that women who experienced the famine in early life are more likely to have a higher body mass index (BMI) and to be obese. The literature investigating people born around the Dutch famine yields similar results: Roseboom et al. (2001) and Bleker et al. (2005) show that fetal malnutrition negatively affected physical health outcomes in later lives.

Prenatal exposure to famine has been shown also to have negative impacts on mental health. For example, Susser et al. (1992) show that those who experienced the Dutch Famine *in utero* exhibited a two-fold increase in the risk of schizophrenia. A negative impact on adult antisocial personality disorders is also reported among those exposed to the Dutch Famine *in utero* (Neugebauer, Hoek, and Susser, 1999). Clair et al. (2005) find similar results among the China Famine cohort.

Second-generation effects. There are very few studies of second-generation effects of fetal malnutrition and even fewer studies that explore second-generation effects on acquired schooling. Two studies based on the China Famine report some second-generation effects. Almond et al. (2008a) report an increase in the ratio of female births in the second generation based on a 1% sample of 2000 China Population Census—quite surprising at first sight when one considers China's well-known son preference. The authors interpret this increase in female births to be consistent with the Trivers-Willard hypothesis, which states that "evolution would favor parental ability to vary the sex ratio of offspring according to condition: parents in poor condition would biologically favor daughters and parents in good condition would favor sons" (Trivers and Willard, 1973). Almond and Chay (2003) show that U.S. black women who had favorable early-life conditions are less likely to have low birth weight children. Fung and Ha (2009) study the second generation effects of early-life malnutrition and find adverse second-generation effects of individuals whose mothers were born during the China Famine, such as lower height-for-age, lower weight-for-age, and fewer years of schooling. They use the 1989, 1991, and 1993 CHNS waves in which the offspring of famine-born cohorts are mostly very young. Consequently, later-life schooling outcomes can be observed only infrequently. A problem with the Fung and Ha study is that their choice of a 6-18 years age range for their sample could be problematic. One troublesome issue is that the mothers of offspring who are older than 12 years in these data must have conceived them at very early ages. For example, a child who was 15 years old in 1989 and whose mother was born in 1960, during the China famine, was conceived when the mother was only 14 years old. Those mothers who conceived their children in their adolescent years might be different from other women in terms of unobserved heterogeneity, and sample selection suspicions rear their ugly heads.

There are a few studies of second-generation effects of a mother's early-life malnutrition that do not rely on famines as natural experiments. Second-generation outcomes examined include birth weight, height, cardiovascular diseases, test scores, and other markers (Emanuel et al., 2004; Drake and Walker, 2004; Currie and Moretti, 2007). Drake and Walker (2004) argue that adverse fetal environments such as malnutrition may harm maternal development which changes maternal metabolism and through her fetus. Figure 1 illustrates the propagation mechanism of intrauterine growth shock from a mother (i.e., a shock to a mother when she was *in utero*) to her child.

4. Historical Background, Data and Sample Selection

In 1958, Mao Zedong initiated an ambitious but reckless economic and social experiment, the Great Leap Forward (GLF) movement, which was intended to transform rural China into industrial China and thus to catch up with Russia in a quarter century and the United States in half a century (Li and Yang, 2005). The China Famine was a direct consequence of the GLF movement interacting with other poorly designed government policies that included excessive grain forced procurement which in turn was encouraged by local cadres' incentives to exaggerate output and the government's ignorance of local conditions as well as exports of grain for foreign exchange to procure imports of required physical capital (Lin and Yang, 2000). These negative influences interacted with severe weather conditions to produce a decline in China's grain output of 15% in 1959 and an additional 16% in 1960 (Li and Yang, 2005). The sudden collapse of grain supply along with minimal will to redistribute grain among rural areas resulted in around 16-30 million excess deaths between 1959 and 1961 (Li and Yang, 2005; Luo et al. 2006; Chen and Zhou, 2007). The famine was widespread all over China but exhibited large regional variation (Table 1). Moreover, urban bias on the part of the Communist regime meant that urban residents suffered much less, because they had preferential access to food supplies (Lin and Yang, 2000).

After realizing the severity of the famine, the Communist party changed course in January 1962. Agricultural output rebounded and grain imports increased. Equally or more important, grain forced procurement was reduced. Death rates dropped quickly andbirth rates rebounded, although in a more complex fashion (figure 2). After increasing sharply in 1962 and 1963, birth rates started to drop in 1964; this fluctuation suggests the influence of selective child-bearing decisions of parents (Shi, 2008).

Data. Our data are taken from the 0.1% China Census of Population 2000, and the sample covers 31 provinces with 1.18 million observations. Tibet and Hainan are dropped because the required mortality data are not available.[12] A unique advantage of the 2000 census is the availability of birth provinces, which makes it possible to relate offsprings' data to the province-specific famine exposure of their mothers. [13]Our sample represents all children with mothers born in the period 1954 through 1996 (five years before and after the China Famine). Further restrictions limit children's ages as appropriate for the schooling level studied. For example, in exploring the effect of mothers' malnutrition on the probability of their offspring entering junior secondary school, we include only children age 13-15.

We divide our sample into eight subgroups, with the most fundamental division being between urban and rural residents, because the China Famine was primarily a rural phenomenon. The rural and urban samples are further divided into male and female offspring, and children age 13-15 (for junior secondary school entrance) and 16-18 (for senior secondary school entrance). Sample statistics are presented in tables 2a (for offspring age 13-15) and 2b (for offspring age 16-18). The first column in each table shows the sample mean weighted excess deaths per 1,000

---

[12] Chongqing is treated as part of Sichuan. It was upgraded to metropolitan status in 1997. Hainan could be treated as part of Gangdong, but it was upgraded to a province in 1988, much earlier. We choose to delete Hainan to avoid errors that would occur over a much longer stretch of the time period covered in our data than would be case for Chongqing and Sichuan.

[13] We estimated similar regressions using the 2005 Census, treating hukou province as birth province; the estimation results are generally similar even though error in measuring actual birth province is greater in the 2005 data, which do not record mother's birth province.

persons (WEDR) for each year covered by our data, 1954 through 1966.[14] [15] The mean WEDR over the sample years for the 13-15 age group is -1.24 and reaches a high of 8.46 in the year 1960, while for the older age group, the mean is 1.13, and the series reaches a high of 8.46 in 1960.[16]

The other sample statistics shown in tables 2a and 2b are the proportion of mothers in each subgroup who were born in each year, and the proportion of offspring who entered the specified schooling level in each year. The sample distribution across mothers' birth years is related to the age of the offspring subgroups, with the frequency of birth years of the younger group of offspring tending to peak in the mid-1960s and the frequency of birth years of the older group of offspring tending to peak in the years prior to 1960. There is a visible decline in the frequency of birth years during the famine years 1959-1961 among mothers with rural residence in the year 2000, but any tendency of a decline in the frequency of births in the famine years is not obvious among urban-residing mothers. This pattern is consistent with the China Famine's being by and large a rural phenomenon.

The proportion of offspring entering the two schooling levels—junior secondary school and senior secondary school—is of course larger for the lower schooling level, and it is larger for the urban offspring than for rural offspring, with the urban-rural gap much larger for senior secondary school than for junior secondary school. The mean proportion of rural males entering junior secondary school is slightly larger than that for rural females, but the gender gap is negligible among urban offspring. Among rural offspring, a higher proportion of males than females entered senior secondary school, but among urban offspring, the gap is reversed, with 74.2% on average of females entering secondary school compared to only 70.7% of males. Within all the eight subgroups, there is a downward trend across mothers' birth year in the proportion of offspring entering each level of schooling. We attribute this decline not to a falling level of schooling attainment, but rather to declining average age of the offspring as mothers'

---

[14] In results not reported in this paper, we checked the robustness of our results to an alternative sample-period specification in which the birth-year window is 1956 through 1964 (a shorter birth-year window). The results are in general similar or stronger

[15] We show only the values of mean WEDR for the samples of rural males, because the values of this variable differ by very little across the various subsamples.

[16] While mean WEDR is by definition 0 when the units of observation are provinces and years, it can deviate from 0 due to sample variation in birth dates and number of offspring born in each year and province.

birth year moves from 1954 through 1966. Our inclusion of dummy variables for mothers' birth year in all our estimations should control for this age-related phenomenon.

5. Estimation Results

Our ordinary and two-stage (IV probit) estimation results are reported in tables 3a through 3d. The four tables contain our results for female and male offspring's entrance into junior and senior secondary school, respectively. First-stage estimations results for the two-stage probits are shown in table 4.

Rural Youth. In tables 3a through 3d, we report estimated probit coefficients and their *z*-values, and for the WEDR variable, we show in braces the marginal probability impact of entering the specified school level calculated at the mean value of the WEDR variable. We also multiply the marginal probability coefficient by one standard deviation of WEDR in the specified subgroup and show this calculation in braces as the fourth item in all of the WEDR cells. For example, in table 3a, column (1), for rural females' junior high-school entrance, the number -0.016 in the top cell, fourth row indicates that a one standard deviation in WEDR is associated with a reduced probability of entering junior secondary school of 1.6 percentage points for rural female second-generation offspring. Another metric for the size of this impact is to multiply the marginal probability (in braces) by the mean value of WEDR in the year 1960, the peak of the China Famine induced death rates. This calculation yields a product of approximately 2.7 percentage points. In other words, the probability that female offspring of mothers who were born in 1960 will enter junior secondary school is 2.7 percentage points less than that of the offspring of mothers who were born in non-famine years[17]. Both of these measures may be compared to the average proportion of rural females who entered junior secondary school during the sample period, approximately 70 percent in each year. The estimated famine impact on the probability that rural males will enter junior secondary school (table 3b) is similar to that for rural females.

In the first columns of tables 3a through 3d, we see that the estimated probit coefficients are uniformly negative, and they generally statistically significant in all ordinary probit

[17] Note that WEDR is actual death rates minus average death rates over the period1956-1958. By construction, the mean excess death rate is zero, but a downward long term trend in death rates means that WEDR tends to be negative after the GLF period.

regressions for rural offspring entering junior- or senior secondary school. However, the magnitude of the WEDR coefficient is much smaller in the senior high-school regressions than in those for entrance into junior secondary school..

In the second columns, we note that the signs and magnitudes of the estimated probit coefficients for junior high-school entrance are generally robust to the inclusion of variables that represent families' economic status—housing type, housing area, and number of offspring. However, the inclusion of the housing and offspring variables leads to a substantial decline in WEDR's statistical significance for senior high-school entrance.

In column (3), we add mother's completed school years to the probit regressions. Again, the signs and magnitudes of the WEDR coefficient are generally robust, with the magnitude of the coefficient falling by approximately 15% relative to that in column (2) and by about 25% relative to that in column (1). In table 3a column (3) we see that an increase in mother's schooling of one year is associated with a 3.2 percentage point increase in the probability that her daughter enters junior secondary school. Multiplying this probability by one standard deviation in the sample distribution of mothers' schooling indicates that a one standard deviation change in mother's schooling is associated with nearly 9 percentage point change in the probability of her daughter's entering junior secondary school. The number in double braces is the product of one standard deviation in WEDR and the coefficient of WEDR in a 2-way FE regression of mother's schooling on WEDR, multiplied by marginal effect of mother's schooling on the probability of her daughter's entering junior secondary school (calculated at the mean of mothers' schooling). It indicates that a one standard deviation increase in WEDR reduces mother's schooling sufficiently to reduce the probability that a daughter will enter secondary school by 0.2 percentage points. Although we do not claim this calculation to be an unbiased estimate of the indirect effect of WEDR on second-generation entrance into junior secondary school (operating through mother's schooling attainment), we note that the number is much smaller than the estimated direct impact of WEDR (operating through inheritance of "ability") on entering junior secondary school.[18] This observation, along with the modest reduction in the estimated direct

[18] This interpretation is unbiased if mother's schooling and her children's schooling decisions are made independently, and if the indirect effect of fetal malnutrition works only through mother's schooling level.

impact of WEDR when various SES variables are added to the benchmark regression of column (1) suggests to us that there is a significant direct effect of fetal malnutrition on second-generation human capital, and that this effect is large relative to indirect impacts coming through adverse effects on mothers socio-economic status. The implication is that early-life malnutrition can last over generations.

As discussed above, unobserved heterogeneity can bias our estimates if there is an omitted-variable arising from failure to consider time-varying province-specific factors that affected both famine severity and variables associated with mothers' socioeconomic status. All of the estimates reported in this paper include dummy variables for mother's birth year and province. These fixed effects will control for province- and year-specific characteristics whether we can observe them or not, but it will not eliminate a bias caused by time-varying province-level unobserved heterogeneity. To account for this possibility, we have conducted two-stage IV-probit estimation in which WEDR is treated as an endogenous variable.[19] The instruments are dummy variables based on interviews conducted by Wei Li and Dennis Yang and reported in their paper (Li and Yang, 2005) cited above. The first-stage regression results do not vary much across our four subsamples, and we report only results for the rural subgroups in table 4. The explanatory power of the weather dummies is high, and the estimated coefficients are all positive (in relationship to weather reported as "very good") with their magnitudes for "bad" and "very bad" being substantially larger than the magnitudes for "good" and "average". This result is reasonable and expected because the China Famine was partly caused by crop shortfalls that were in part due to unusually bad weather.[20]

The two-step probit estimation results are generally robust to alternative specifications of included regressors, and the Wald-test statistic of exogeneity of our instruments indicates that it is difficult to reject the null that the weather dummies are valid exogenous variables. To save space, we report the 2-stage probit results only for the simplest specification of the school-entrance equations. In table 3a, for female offspring entering junior secondary school, the estimated probit coefficients of WEDR are much larger in absolute value than their oridinary-probit counterparts, and they are statistically significant by conventional standards. For example,

[19] See Cameron and Trivedi (2005).

[20] Officially, the Communist party has named the China Famine as "the three years of natural disaster."

a one standard deviation increase in WEDR reduces the probability of entering junior secondary school reduces by 13 percentage points for rural females and by 17.5 percentage points for rural males. This estimated impact from the two stage probit estimation results is more than 4 times larger than implied by the ordinary probit estimation results. The increase in the absolute value of the estimated magnitude of the WEDR coefficient is consistent with there being substantial error in using WEDR as a proxy for famine effects, but it is not consistent with our supposition that omitted variables impart a negative bias our ordinary probit estimates.[21] One possibility, which we cannot explore except in conjecture, is that the retrospective weather data collected by Li and Yang (2005) is itself biased by "selective recall" on the part of those who were interviewed. It may be appealing to blame famine on the weather and thus report bad weather to shift any blame away from responsibility for decisions that might have exacerbated the impact of bad crops on food availability. However, we do not observe an increase in the absolute value of the negative impact of famine on entering senior secondary school (discussed below), and the hypothetical self-serving recall error we describe would presumably have a similar impact on those choosing senior secondary school as on those choosing junior secondary school Since this is the first study to investigate the effects of the China Famine exposure on second-generation junior/senior secondary school entrance decisions, it is hard to compare our estimates with others.[22]

For senior secondary school entrance, the two-stage probit estimates are quite insignificant. Moreover, the economic significance of two-stage probit estimates for senior secondary school entrance is also small, compared to the two-stage probit estimates for junior secondary school entrance. For example, based on the most significant and largest estimate, a one standard deviation increase in WEDR reduces the probability of entering senior secondary school by only 1.3 percentage points for rural males. For rural females, the sign is positive although it is not statistically different from zero. This result, in conjunction with the generally smaller and less robust estimates obtained from the ordinary probit estimation compared to junior high-school entrance, leads us to conclude that the null of negligible impact of mother's *in*

[21] The estimated coefficient of WEDR is robust to estimation in ordinary least squares and two-stage least squares as an alternative to estimation with probit and 2-step probit.

[22] Fung and Ha (2009) studies the effects of famine exposure on years of schooling of the offspring of those born during the famine. They did not find statistically significant or economically significant effects.

utero malnutrition on the likelihood of her offspring entering senior secondary school cannot be rejected.

We conjecture that there are reasons why the explanatory power of mother's malnutrition on the likelihood of her children entering senior secondary school is in fact smaller than that for junior secondary school. One reason is that variation in traits favoring higher levels of educational achievement is wider as the level of schooling increases. To illustrate, suppose that there are ten traits necessary for a child to enter primary education and that if one of these traits is damaged due to the mother's *in utero* malnutrition, the probability of the child's entering junior secondary school reduced by 10 percentage points; if there are 20 traits necessary for a child to enter senior secondary school, then having one damaged trait might reduce the probability of entering senior secondary school by 5%, and so on. To take a somewhat extreme example, a much higher proportion of the population is basically able to complete junior secondary school satisfactorily than is able to obtain a Ph.D. in economics (or to be somewhat less parochial) than in theoretical physics. In addition to variation in innate characteristics that favor entering secondary school, variation in acquired characteristics is like to rise with age. One reason for increased variation in acquired characteristics is that schooling quality at lower levels contributes to success at higher levels of schooling. Moreover omitted variables associated with government quality that contributed to famine severity also are correlated with school quality, tuition support, and so on, and the ordinary probit estimates for senior high-school attendance are negatively biased, as discussed above.

Thus the probability that an individual achieves higher levels of schooling declines as the level of schooling rises, along with the impact of a mother's *in utero* nutrition shock on school attendance.

While we believe our conjectures based on bias due to migration of school dropouts, individual characteristics that contribute differentially to senior high-school entrance, and omitted variable bias are plausible explanations of our empirical findings , more research is required to establish why our estimated effects of early life malnutrition on second-generation school attendance is considerably smaller for the senior secondary school entrance decision than for the decision to enter junior secondary school.

***Malnutrition in Mother's Early Infancy*.** We also investigate whether *post-utero*, early infancy, malnutrition has a negative impact on the second generation. It is possible that malnutrition effects on a first-generation mother's development could be quite severe in the period after her birth as well as *in utero*, because human growth is at its maximum velocity between 0-2 years of age. Thus we report probit results in which the WEDR during mothers' first and second years of life is used alone as an independent variable or jointly with the WEDR while mothers were *in utero*. In table 3a, columns 4-6, we see that for second-generation daughters entering junior secondary school there is a negative impact of malnutrition during both their first- and second years of their mother's life on the probability of entering junior secondary school. In table 3b we see that for sons there is evidence of a negative, although statistically insignificant by ordinary standards, impact of first-year mother's malnutrition on the probability of entering junior secondary school. But curiously, we obtain a positive estimate of WEDR during male offsprings' mother's second life year. The difference between the estimate for girls and boys is consistent with an hypothesis that families favored their sons at the expense of daughters during the famine. However a gender gap does not appear for senior high-school entrance. For both female and male offspring, when WEDR during the mother's period *in utero* is interacted with WEDR during the mothers' second life year, the impact of WEDR when mother was *in utero* is quite robust.

When WEDR during mothers' first or second life year is added to the senior high-school probits for rural offspring, the estimated coefficients are all negative, but not statistically significant.

Urban Youth. The estimated coefficient of WEDR is never negative for the urban second generation, and *z*-statistics range from a low of 0.74 (for urban males entering junior secondary school) to a high of 1.90 (for urban females entering junior secondary school).[23] As discussed above and documented in the literature, the China Famine was primarily a rural phenomenon, and the province-wide death rates we observe do not accurately represent the famine impact on the urban population.

[23] We do not report 2-stage probit estimation results for the urban samples, but they are available upon request. We find no evidence that the positive estimated coefficients of WEDR are attributable some kind of omitted-variable or endogeneity bias.

Migration. As discussed in the methodology section, we believe that using a province-wide measure of the impact of malnutrition for the urban subsample generally biases our estimates against rejecting the null hypothesis of no malnutrition effect on the urban second generation compared to the alternative hypothesis that there are negative impacts of famine-induced malnutrition on second-generation offspring's school attainment. However, if there has been selective rural-urban migration, the rural sample may have lost first-generation mothers with traits that favor human capital accumulation in themselves and in their offspring, and such selectivity would bias estimation results for the rural sample in favor of rejecting the null of no malnutrition effect.

Unfortunately, the 2000 Census data do not provide information on rural-urban migration, but we do have information on whether province of current residence is different than province of birth. Approximately 2.5 percent of the urban sample and 0.9 percent of the rural sample's mothers were born in different provinces than their residence in 2000. We can safely assume that the vast majority of the small proportion of the rural sample who are interprovincial migrants were born in rural areas, and these mothers' birth areas are therefore correctly identified as rural. Moreover, if even half of the urban interprovincial migrants were born in rural locations, then only slightly more than 1 percent of the urban sample would properly be classified as rural. Thus, the overall proportion of a correctly identified rural sample that would include observations that we now improperly classify as urban is clearly less than 1 percent. However, it is impossible know whether individual severely impacted rural locations are disproportionately the birthplaces of misclassified urban residents, because selective outmigration may not have been random with respect to famine severity.

To gain some insight into whether our estimates are biased by errors in classifying rural-born mothers as urban, we have added a dummy variable equal to 1 if mother's birth province is not the province of her residence in the year 2000, and its interaction with WEDR. The estimated coefficient of WEDR for both male and female rural youth entering junior secondary school is quite robust to the inclusion of the inter-provincial migration variables in the ordinary probit regressions(column (7)). For urban males and females entering junior secondary school we added the migration variables to the 2-step probit regressions to see whether the positive estimated coefficients of WEDR are possibly attributable to ignoring the influence of inter-provincial migration (column (10)). In the rural samples, the coefficient of WEDR is somewhat smaller and lower in statistical significance when the interprovincial migration variables are included. It is quite interesting to note that for urban females, the interaction of mother's interprovincial migration with WEDR is quite large and statistically significant, suggesting perhaps that mothers from high death-rate provinces who migrated out of those provinces to urban areas were highly motivated to send their daughters (although not their sons) to junior secondary school, but further speculation is beyond the scope of this study. In the urban sample, we again observe that the estimated coefficient of WEDR is robust to inclusion of migration variables; moreover, we also note a significant, large estimated coefficient for urban daughters entering junior secondary school similar in sign to the ordinary probit estimate, but much larger in magnitude.

6. Concluding Remarks

Researchers have found that the effects of early life malnutrition are durable, widespread, and last through the adult lives of those who are born of mothers who suffered malnutrition *in utero* or in early infancy (the first generation). We investigate whether similar adverse outcomes are found in the second generation: children born of the first-generation mothers. The China Famine, a tragic event in world history, provides a unique opportunity to examine the link between malnutrition and social, economic, and the health outcomes of those who experience malnutrition *in utero* or in infancy and of their progeny. Our empirical strategy, consistent with studies based on famine data, is to use an indirect measure of malnutrition, the weighted excess death rate by year, month and province of birth for the (first-generation) mothers in our sample.

A potentially serious problem in using a measure of death rates as a proxy for malnutrition is that our measure be correlated with unobserved local government actions that influence mothers' and children's health and other forms of human capital, thus biasing our estimation results in favor rejecting the null hypothesis of no malnutrition effect on first- and second generation outcomes. We deal with omitted-variable concern by include dummy variables for mother's birth province and mother's birth year in all regressions. We believe that these fixed effects are likely to control for much and perhaps most intertemporal and interprovincial variation in omitted variables that independently have led to higher schooling levels for either the first- or second generation. Furthermore, in order to account for time-varying province-level confounding factors, we have employed a 2-stage probit procedure using data on provincial weather conditions as instruments.

We find that children whose mothers were affected by the China Famine are less likely to enter junior and senior secondary schools. A lower bound on the probability that female offspring of mothers who were born in the most severely famine- impacted rural areas in1960 will enter junior secondary school is 2 percentage points less than that of the offspring of mothers who were born in non-famine years. Similar results are obtained for rural male offspring. This estimate implies approximately a 3 percent reduction in the proportion of the children of mothers from the most severely famine-impacted provinces entering junior secondary school. Our lower bound estimates are based on ordinary probit regressions in which measures of mother's SES including current family, household, and schooling characteristics are held constant. Interestingly, our 2-step probit estimates yield substantially larger negative estimates of the impact of malnutrition on second-generation junior high-school entrance than do the ordinary probit estimates. Thus we treat the ordinary probit estimates as a lower bound on the true impact.

The estimated impact on senior high-school entrance is much smaller, and that on urban youth is negligible, as expected. We conjecture that the relatively small, or negligible, estimated impact of mothers' malnutrition on their children's entrance into senior secondary school is due to several possible factors that include the (i) large set of characteristics that influence entering higher levels of schooling, (ii) and the possible importance of omitted variables relating to local government characteristics and the quality and support of local schools.

Our research supports the existence of an important magnifier for policies that support the nutrition of pregnant women and infants in any country where nutritional deficiencies remain. According to the 2009 United Nations Millennium Development Goals Report, one-quarter of children in the developing regions are underweight and more than one-third of child deaths worldwide are associated with under-nutrition. China, recognizing the importance of the child malnutrition issue, has recently taken steps to improve the nutritional status of children. One example is that the National Program of Action for Child Development in China aims to reduce the example is that the National Program of Action for Child Development in China aims to redu ce the number of malnourished children under age 5 by a 25% in 2010. If policy makers do not take into account these second-generation effects of early-life malnutrition, they are likely to underestimate the long-term benefits of their pro-nutrition policy interventions

We have identified significant effects of malnutrition last into the second generation, and our estimates do not capture the full impact over the full lifetimes of those affected. To measure these effects it would be necessary to separate the impacts of prenatal and perinatal malutrion and to follow the second-generation impacts into adulthood, middle- and old age. Such research would require data for mother's birth place of second-generation adults who no longer live with their parents, and it would require observing the current second generation, most of whom are still young, through their life cycles. Impacts on the development of chronic physical and mental illnesses in the second generation remain to be identified.

References

Alderman, Harold, Behrman, Jere R., Lavy, Victor, and Menon, Rekha, 2001. "Child health and School Enrollment: A Longitudinal Analysis." *The Journal Human Resources* 36, 185-205.

Ashton, B., Kenneth, H., Piazza, A., and Zeitz, R., 1984. "Famine in China, 1958-1961." *Population and Development Review* 10(4): 613-645.

Almond, Douglas, Lena Edlund, Hongbin Li, and Junsen Zhang, 2008a. "Long-Term Effects of The 1959-1961 China Famine: Mainland China and Hong Kong." NBER Working Paper No. 13384

Almond, D. and Mazumder, B., 2008b. "The Effects of Maternal Fasting During Ramadan on Birth and Adult Outcomes." NBER Working Paper No. 14428

Behrman J.R., Harold Alderman and John Hoddinott. 2004. "Hunger and Malnutrition, Copenhagen Consensus Challenges and Opportunities." In *Global Crises, Global Solutions*, ed. Bjorn Lomborg. Cambridge (UK): Cambridge University Press.

Cameron, A. Colin and Trivedi, Pravin K. 2005. *Microeconometrics*.New York: Cambridge University Press.

Cameron, A. Colin, and Trivedi, Pravin K. 2009. *Microeconometrics Using Stata*. College Station , Texas: Stata Press.

Chen, Y., L. and Zhou, A. 2007. "The Long-term Health and Economic Consequences of the 1959–1961 Famine in China." *Journal of Health Economics* 26(4)

Clair, D., M. Xu, P. Wang, Y. Yu, Y. Fang, F. Zhange, X. Zheng, N. Gu, G. Feng, P. Sham, and L. He. 2005. "Rates of Adult Schizophrenia Following Prenatal Exposure to the Chinese Famine of 1959–1961." *JAMA* 294(5): 557–562.

Connelly, Rachel, Roberts, Kenneth, Zheng, Zhenzhen, 2010a. The Role of Children in the Migration Decisions of Rural Chinese Women. Working Paper. Waterville, Maine: Department of Economics Bowdoin College.

Connelly, Rachel, Roberts, Kenneth, Zheng, Zhenzhen, 2010b. "The Settlement of Rural Migrants in Urban China—Some of China's Migrants Are Not "Floating" Anymore." Working Paper. Waterville, Maine: Department of Economics Bowdoin College

Currie, Janet, Moretti, Enrico. 2007. "Biology as Destiny? Short and Long-Run Determinants of Intergenerational Transmission of Birth Weight." *Journal of Labor Economics* 25(2)

Currie, Janet, Stabile, Mark, Manivong, Phongsack, and Roos, Leslie L., 2010. "Child Health and Young Adult Outcomes." *The Journal of Human Resources* 45, 516-548.

Drake, A. J. and Walker, B. R. 2004. "The Intergenerational Effects of Fetal Programming: Non-genomic Mechanisms for the Inheritance of Low Birth Weight and Cardiovascular Risk." *Journal of Endocrinology* 180:1-16

Deng, Quheng, Gustafsson, 2006. China's Lesser Known Migrants. IZA Discussion Paper No. 2152. http://www.econstor.eu/dspace/bitstream/10419/33872/1/512890544.pdf

Emanuel, Irvin, Kimpo, Christy, and Moceri Victoria. 2004. "The Association of Maternal Growth and Socio-economic Measures with Birth Weight in Four Ethnic Groups." *International Journal of Epidemiology* 33:1236-1242

Fung, Winnie. 2009. "Early Childhood Malnutrition and Adult Obesity: Evidence from the 1959-961 China Famine." Ph.D. diss., Havard University

Fung, Winnie and Ha, Wei. 2009. "Intergenerational Effects of the 1959-61 China Famine." In *Risk, Shocks and Human Development: On the Brink*. eds. Fuentes-Nieva and Seck. Palgrave-Macmillan: London.

Gørgens, Tue, Xin Meng, and Rhema Vaithianathan. 2007. "Stunting and Selection Effects of Famine: A Case Study of the Great Chinese Famine." IZA Discussion Paper No. 2543

Handa, Sudhanshu and Peterman, Amber, 2007. "Child Health and School Enrollment." *The Journal of Human Resources* 42, 863-880.

Lin, Justin W. and Yang, Dennis T. 1998. "On the Causes of China's Great Leap Forward and the China Famine." *China Economic Review* 9: 125-140.

Lin, Justin W., and Yang, Dennis T. 2000. "Food Availability, Entitlements and the Chinese Famine of 1959-6." *The Economic Journal* 110(460):136-158

Li, Wei, and Yang, Dennis T. 2005. "The Great Leap Forward: Anatomy of a Central Planning Disaster.", *Journal of Political Economy* 113(4)

Liu A., Zhao L., Yu D., and Yu, W. 2008. "Study on malnutrition status and changing trend of children under 5 years old in China." Working Paper, Institute for Nutrition and Food Safety, Chinese Center for Disease Control and Prevention.

Lumey, L. H. and Stein, A. D. 1997. "In Utero Exposure to Famine and Subsequent Fertility: The Dutch Famine Birth Cohort Study." *American Journal of Public Health* 87(12):1962-1966

Lumey, L. H. and Stein, A. D. 2000. "The Relationship between Maternal and Offspring Birth Weights After Maternal Prenatal Famine Exposure: the Dutch Famine Birth Cohort Study." *Human Biology*. 72(4):641-54

Luo, Z., Mu, R., and Zhang, X. 2006. "Gender Difference in the Long-Term Impact of Famine." *Review of Agricultural Economics* 28(3):296-304.

Meng Xin and Nancy Qian, 2009. "The Long Term Consequences of Famine on Survivors: Evidence from a Unique Natural Experiment using China's Great Famine." NBER Working paper No. 14917

Meng Xin, Qian, Nancy and Yard Pierre. 2010. "The Institutional Causes of China's Great Famine, 1959-61." NBER Working paper No. 16361

Mu, Ren, and Zhang, X., 2008. "Famine and Overweight in China." IFPRI Discussion Paper 00760

Oreopoulos, Philip, Stabile, Mark, Walid, Randy, and Roos, Leslie L. 2008. Short-, Medium-, and Long-term Consequences of Poor Infant Health: An Analysis Using Siblings and Twins. The Journal of Human Resources 43, 88-138.

Peng, Xizhe. 1987. "Demographic consequences of the Great Leap Forward in China's Provinces." *Population and Development Review*, 13(4): 639-70.

Roseboom, Tessa J., Meulen, Jan H.P., Ravelli, Anita C.J., Osmond, Clive,Barker, David J.P., and Bleker, Otto P. 2001. "Effects of Prenatal Exposure to the Dutch Famine on Adult Disease in Later Life: An Overview." *Twins Research* 4(5):293-298.

Sen, Amartya, 1981a. Poverty and Famines: An Essay on Entitledments and Deprivation. Oxford: Clarendon Press.

Sen, Amartya. 1981b. "Ingredients of Famine Analysis: Availability and Entitlements." *Quarterly Journal of Economics* 95, 433-464.

Shi, Xinzheng. 2008. "Famine, Fertility, and Fortune in China" Ph.D. diss., University of Michigan

Shonkoff, J. P., and Phillips, D. 2000. *From Neurons to Neighborhoods: The Science of Early Child Development.* National Academies Press, Washington DC

Steckel, Richard, H. 1995. "Stature and the Standard of Living." *Journal of Economic Literature* 33(4):1903-1940

Strauss, John, and Thomas, D. 1998. “Health, Nutrition, and Economic Development.” *Journal of Economic Literature* 36(2):766-817

Susser E, Lin, S. P. 1992. “Schizophrenia After Prenatal Exposure to the Dutch Hunger Winter of 1944-1945.” *Arch Gen Psychiatry* 49:983-988.

Trivers, Robert, and Willard, Rob E. 1973. “Natural Selection and the Ability to Vary the Sex Ratio of Offspring.” *Science* 179

United Nations, 2009. *The Millennium Development Goals Report 2009*. The United Nations Department of Economic and Social Affairs

Victoria, C.G., Adair, L., Fall, C., Hallal, P. C., Martorell, R., Richter, L. and Sachdev, H. S. 2008. “Maternal and Child Undernutrition: Consequences for Adult Health and Human Capital.” *The Lancet* 17:23-40

Wooldridge, Jeffrey M. 2002. *Econometric Analysis of Cross Section and Panel Data*, Cambridge, MA: MIT Press.

Yamauchi, Futoshi. 2008. “Early Childhood Nutrition, Schooling and Sibling Inequality in a Dynamic Context: Evidence from South Africa” *Economic Development and Cultural Change* 56(3)

Yang, Dennis Tao, and Cai Fang. 2003. *How Far Across the River?: Chinese Policy Reform at the Millennium*, Stanford University Press

Table 1 Provincial death rates 1954-1966 (number of deaths per 1,000)

Province	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966
Beijing	8.6	9.5	7.7	8.2	8.1	9.7	9.1	10.8	8.8	8.1	8.3	6.8	7.2
Tianjin	9.3	9.9	8.8	9.4	8.7	9.9	10.3	9.9	7.4	7.3	7.8	6.2	6.9
Hebei	12.1	11.6	11.3	11.3	10.9	12.3	15.8	13.6	9.1	11.2	10.9	8.7	8.7
Shanxi	14.7	12.9	11.6	12.7	11.7	12.8	14.2	12.2	11.3	11.4	14	10.4	10.3
Neimonggu	20.9	11.4	7.9	10.5	7.9	11	9.4	8.8	9	8.5	11.8	9.3	8.1
Liaoning	8.6	9.4	6.6	9.4	8.8	11.8	11.5	17.5	8.5	7.9	9.3	7.1	6.2
Jilin	10.4	9.9	7.5	9.1	9.1	13.4	10.1	12.1	10	9.4	12.6	9.7	8.6
Heilongjiang	11.1	11.3	10.1	10.5	9.2	12.8	10.5	11.1	8.6	8.6	11.5	8	7.4
Shanghai	7.1	8.2	6.6	6.1	6.2	7.8	6.9	7.7	7.2	7	6.1	5.7	5.3
Jiangsu	12.2	11.8	13	10.3	9.4	14.6	18.4	13.4	10.4	9	10.1	9.5	8.1
Zhejiang	13.4	12.6	9.5	9.3	9.2	10.8	11.9	9.8	8.6	7.9	7.9	8.1	7.1
Anhui	16.6	11.8	14.3	9.1	12.4	16.7	68.6	8.1	8.2	7.9	8.6	7.2	7.1
Fujian	10.9	10.4	10.2	9.8	9.4	12.5	20.7	16	11.7	9.3	8.7	7.9	7.7
Jiangxi	14.2	16.2	12.5	11.5	11.3	13	16.1	11.5	11	9.8	10.9	9.4	8.5
Shandong	11.7	13.7	12.1	12.1	12.8	18.2	23.6	18.4	12.4	11.8	12	10.2	9.9
Henan	13.3	11.8	14	11.8	12.7	14.1	39.6	10.2	8	9.4	10.6	8.5	8.2
Hubei	15.9	11.6	10.8	9.6	9.6	14.5	21.2	9.1	8.8	9.8	10.9	10	9.7
Hunan	17.5	16.4	11.5	10.4	11.7	13	29.4	17.5	10.2	10.3	12.9	11.2	10.2
Guangdong	11.2	10.6	11.1	8.4	9.2	11.1	15.2	10.8	9.4	7.6	8.3	6.8	6.4
Guangxi	15.2	14.6	12.5	12.4	11.7	17.5	29.5	19.5	10.3	10.1	10.6	9	7.5
Sichuan	8.4	9.2	10.4	12.1	25.2	47	54	29.4	14.6	12.8	13.9	11.5	10.8
Guizhou	12.2	16.2	13	12.4	15.3	20.3	52.3	23.3	11.6	17.1	20.7	15.2	13.5
Yunnan	16.7	13.7	15.2	16.3	21.6	18	26.3	11.8	10.9	14.1	15.2	13	10.8
Shannxi	11	10.5	9.9	10.3	11	12.7	12.3	8.8	9.4	10.6	15.6	13	12.9
Gansu	11.6	11.9	10.8	11.3	21.1	17.4	41.3	11.5	8.3	10.4	15.6	12.3	11.5
Qinghai	13.3	14.6	9.4	10.4	13	16.6	40.7	11.7	5.4	8.4	15.5	9.1	9.7
Ningxia	13.1	10.2	10.6	11.1	15	15.8	13.9	10.7	8.5	10.2	13.4	9.3	9.4
Xinjiang	16.8	14.4	14.2	14	13	18.8	15.7	11.7	9.7	9.4	16.4	11.1	9.4
Nation	12.8	12	10.8	10.7	12	15.1	23.2	13.1	9.5	9.8	11.8	9.4	8.8

Source: Shi (2008)

Table 2a Sample Statistics (junior secondary school)

Offspring Characteristics Age 13-15 in 2000									
Mother's Birth Year	Rural					Urban			
	Mean WEDR/1000	Females (19,774)		Males(21,441)		Females (3,691)		Males (4,140)	
		Mothers Born %	Entered J. HS %	Mothers Born %	Entered J. HS %	Mothers Born %	Entered J. HS %	Mothers Born %	Entered J. HS %
1954	1.01	3.48	70.1	3.61	74.6	2.95	95.4	3.26	91.9
1955	0.48	4.31	67.9	4.66	72.2	2.90	94.3	3.77	91.7
1956	0.06	5.12	70.7	5.54	71.4	4.06	93.3	4.37	94.5
1957	-0.46	6.07	69.8	6.17	74.0	5.58	93.2	6.64	91.2
1958	0.27	6.23	68.4	6.46	74.2	6.77	91.6	6.47	94.4
1959	3.10	5.37	69.0	5.45	74.8	7.40	94.9	6.62	92.0
1960	9.26	6.54	69.7	6.75	72.5	9.16	94.7	9.52	94.7
1961	6.77	6.92	67.7	6.77	72.7	8.91	91.8	8.67	93.3
1962	-0.29	13.49	70.5	13.52	74.7	15.98	94.1	15.34	92.9
1963	-1.66	15.99	72.0	15.52	75.5	17.04	92.2	16.76	91.6
1964	-0.65	11.47	68.8	11.03	70.8	9.35	91.6	9.90	91.7
1965	-1.26	9.27	66.7	8.75	68.3	6.39	88.1	6.06	87.3
1966	-2.51	5.70	62.6	5.76	64.2	3.49	84.5	2.61	84.2
Total or Mean	-1.24	100	69.2	100	72.6	100	92.5	100	92.2

Notes:

1. WEDR is for rural male sample

Table 2b Sample Statistics

Offspring Characteristics Age 16-18 in 2000									
Mother's Birth Year		Rural				Urban			
	Mean WEDR/1000	Females (12,180)		Males(14,253)		Females (3,373)		Males (3804)	
		Mothers Born %	Entered S. HS %	Mothers Born %	Entered S. HS %	Mothers Born %	Entered S. HS %	Mothers Born %	Entered S. HS %
1954	1.40	7.84	14.2	7.79	17.5	7.56	79.2	7.52	73.6
1955	0.81	9.49	13.5	9.89	17.0	10.52	82.3	10.36	78.7
1956	0.16	10.25	15.4	10.59	19.9	13.25	77.1	12.88	74.9
1957	-0.43	11.67	16.2	12.38	20.5	16.99	78.2	16.64	77.7
1958	0.18	11.81	16.1	11.42	18.9	15.48	77.1	16.11	73.2
1959	2.75	9.24	17.4	8.98	19.8	10.91	75.9	10.75	69.3
1960	8.46	9.42	15.8	8.97	18.1	8.89	70.2	9.36	63.6
1961	7.28	6.88	14.2	6.84	18.9	4.18	66.2	4.50	56.8
1962	-0.38	10.04	13.9	10.13	15.8	6.34	62.8	6.02	59.4
1963	-1.72	7.66	9.5	7.30	13.4	3.47	54.3	3.34	59.2
1964	-0.68	3.46	7.7	3.42	12.5	1.39	45.7	1.63	43.9
1965	-0.97	1.55	8.5	1.67	8.9	0.71	39.1	0.71	34.8
1966	-2.12	0.70	4.9	0.62	9.1	0.3	40.0	0.18	42.9
Total or Mean		100	14.4	100	17.7	100	74.2	100	70.7

1. WEDR is for rural male sample

Table 3a

Dependent Variable Junior Secondary school Entrance

Females Age 13-15 in 2000 Mothers born 1954-1966 (age 34-46 in 2000)

Youngest possible age of mother at birth of child 19 years; oldest possible 33 years

Regressors	Rural								Urban	
	1	2	3	4	5	6	7	8	9	10
	Probit	Probit	Probit	Probit	Probit	Probit	Probit	2S Probit	Probit	Probit
WEDR *In utero*	-8.84 (-1.78) [-3.03] {-0.016}	-7.68 (-2.13) [-2.61] {-0.014}	-6.58 (-2.94) [-2.21] {-0.012}			-8.71 (-4.54) [-2.89] {--0.015}	-9.00 (-1.84) [-3.09] {-0.017}	-31.92 (-1.96) [-13.38] {-0.071}	12.19 (1.90) [1.26] {0.007}	8.98 (1.33) [0.90] {.0055}
WEDR. Birth Year+1				-5.70 (-3.01) [-1.96] {-0.010}						
WEDR Birth Year+2					-6.18 (-2.97) [-2.11] {-0.012}					
WEDR0*WEDR2*1000						-0.13 (-1.09) [-0.045] {--0.0019}				
Mother Born in Different Province (Migrant)							-0.29 (-0.08)			-.072 (-0.37)
Migrant*WEDR Moth. Birth Year							23.18 (1.50)			225.8 (2.66)
Mother's School Years			0.096 (15.51) [0.032] {0.089}} {{-0.002}}[vii]							
Housetype 2		-0.19 (-3.60)	-.0.17 (-3.30)							
Housetype 3		-0.46 (-7.31)	-0.36 (-5.78)							
Housetype 4		-0.42 (-6.47)	-0.35 (-5.47)							
House Area		0.0058 (8.08)	0.0051 (7.51)							
# Offspring		-0.15 (-5.98)	-0.15 (-6.28)							
Constant	0.19 (2.85)	0.66 (6.92)	0.84 (7.71)	0.18 (2.82)	0.18 (2.79)	0.19 (2.83)	0.20 (3.04)	0.32 (2.38)	2.63 (12.7)	2.61 (12.11)
R-sq. (pseudo R-sq probit)	0.084	0.12	0.14	0.083	0.083	0.084	0.084		0.13	0.14
N	19,774	19,472	19.472	19,774	19,774	19,774	19,774	19,337	3,917	3,917
P-value of Wald test statistic of exogeneity of instrments								0.15		

Table 3b

Dependent Variable Junior Secondary school Entrance
Males Age 13-15 in 2000 Mothers born 1954-1966 (age 34-46 in 2000)
Youngest possible age of mother at birth of child 19 years; oldest possible 33 years

Regressors	Rural								Urban	
	1	2	3	4	5	6	7	8	9	10
	Probit	Probit	Probit	Probit	Probit	Probit	Probit	2S Probit	Probit	Probit
WEDR. *In utero*	-9.28 (-3.59) [-2.93] {-0.016}	-8.02 (-2.66) [-2.49] {-0.014}	-7.81 (-2.52) [-2.42] {-0.012}			-9.54 (-6.38) [-3.02] {-0.016}	-9.24 (2.78) [-2.92] {-0.015}	-36.75 (-2.10) [-17.5] {-.096}	5.57 (0.74) [0.66] {0.003}	4.92 (0.61) [0.58] {0.003}
WEDR Birth Year+1				-4.44 (-1.43) [-1.40] {-0.0075}						
WEDR Birth Year+2					4.28 (1.91) [1.35] {0.0076}					
WEDR0*WEDR2*1000						0.54 (4.39) [0.17] {0.0073}				
Mother Born in Different Province (Migrant)							-0.33 (-2.95)			-0.02 (-0.12)
Migrant*WEDR Moth. Birth Year							-14.9 (-0.5)			12.48 (0.5)
Mother's School Years			0.075 (11.65) [0.023] {0.064} {{-0.0009}}							
Housetype 2		-0.19 (-4.25)	-0.17 (-4.01)							
Housetype 3		-0.49 (-7.42)	-0.41 (-6.70)							
Housetype 4		-0.39 (-4.93)	-0.33 (-5.20)							
House Area		0.0036 (4.63)	0.0031 (4.30)							
# Offspring		-0.180 (-7.18)	-0.17 (-7.00)							
Constant	0.42 (6.32)	1.78 (12.94)	1.78 (11.06)	0.41 (6.33)	0.40 (6.17)	0.42 (6.34)	0.43 (6.41)	0.93 (5.83)	0.69 (4.57)	0.70 (4.57)
R-sq. (pseudo R-sq probit)	0.11	0.14	0.16	0.11	0.11	0.11	0.11		0.10	0.10
N	21,441	21,111	21,111	21,441	21,441	21,441	21,441	20,986	4,329	4,329
P-value of Wald test statistic of exogeneity of instrments								0.11		

Table 3c

Dependent Variable Senior Secondary school Entrance
Females Age 16-18 in 2000 Mothers born 1954-1966 (age 34-46 in 2000)
Youngest possible age of mother at birth of child 16 years; oldest possible 30 years

Regressors	Rural							Urban	
	Probit	Probit	Probit	Probit	Probit	Probit	2SProbit	Probit	Probit
WEDR Moth. *In utero*	-3.79 (-2.34) [-0.81] {-0.0045}	-2.92 (-1.05) [-0.61] {-0.0034	-2.27 (-0.81) [-0.45] {-0.0023}			-3.75 (2.32) [-0.80] {.00045}	0.20 (0.01) [0.53] {0.0029}	7.54 (1.80) [2.34] {0.014}	8.76 (1.67) [2.72 {0.016}
WEDR Moth. Birth Year+1				-0.59 (-0.13) [-0.13] {-0.0008}					
WEDR Moth. Birth Year+2					-4.81 (-1.91) [1.04] {-0.0064}				
Mother Born in Different Province (Migrant)						0.12 (0.92)			-0.08 (-0.59)
Migrant*WEDR Moth. Birth Year						-7.05 (-0.38)			-8.16 (-0.42)
Mother's School Years			0.096 (18.36) [0.019] {0.053} {{-0.0012}}						
Housetype 2		-0.30 (-3.70)	-0.29 (-3.54)						
Housetype 3		-0.56 (-5.07)	-0.49 (-4.59)						
Housetype 4		-0.53 (-5.97)	-0.48 (-5.25)						
House Area		0.0048 (8.50)	0.0042 (7.83)						
# Offspring		-0.027 (-1.36)	-0.028 (-1.31)						
Constant	-0.34 (-1.85)	-0.39 (-2.81)	-10.07 (-7.08)	-0.33 (-1.78)	-0.36 (-1.85)	-0.35 (-1.88)	-1.16 (-5.00)	-0.36 (-0.69)	-0.36 (-0.52)
R-sq. (pseudo R-sq probit)	0.05	0.08	0.11	0.05	0.05	0.05		0.08	0.08
N	12,180	12,019	12,019	12,180	12,180	12,180	11,921	3,373	3,373
P-value of Wald test statistic of exogeneity of instrments							0.89		

Table 3d

Dependent Variable Senior Secondary school Entrance
Males Age 16-18 in 2000 Mothers born 1954-1966 (age 34-46 in 2000)
Youngest possible age of mother at birth of child 16 years; oldest possible 30 years

Regressors	Rural							Urban	
	1	2	3	4	5	6	7	8	9
	Probit	Probit	Probit	Probit	Probit	Probit	2S Probit	Probit	Probit
WEDR *In utero*	-3.66 (4.03) [-0.91] {-0.0051}	-3.83 (-0.93) [-0.93] {-0.0052}	-4.19 (-1.01) [-1.00] {-0.0050}			-3.62 (-4.18) [-0.90] {-0.0051}	-5.59 (-0.28) [-1.32] {-0.0074}	6.38 (1.28) [2.15] {0.010}	6.84 (1.33) [2.30] {0.11}
WEDR Birth Year+1				-1.79 (-0.48) [-0.44] {-0.0002}					
WEDR Birth Year+2					-3.65 (-1.01) [-0.92] {-.0052}				
Mother Born in Different Province (Migrant)						0.009 (0.06)			-0.10 (-0.84)
Migrant*WEDR Moth. Birth Year						-2.12 (-0.12)			-9.63 (-0.92)
Mother's School Years			0.065 (10.39) [0.016] {0.045} {{-0.0006}}						
Housetype 2		-0.12 (-1.68)	-0.10 (-1.38)						
Housetype 3		-0.37 (-3.43)	-0.21 (-2.87)						
Housetype 4		-0.29 (-3.87)	-0.25 (-3.15)						
House Area		0.0031 (7.97)	0.0028 (7.76)						
# Offspring		-0.042 (-1.72)	-0.037 (-1.55)						
Constant	-0.11 (-0.88)	-0.0003 (-0.00)	-0.55 (-2.17)	-0.10 (-0.87)	-0.11 (-0.93)	-0.11 (-0.95)	-1.55 (-6.10)	-0.34 (-0.79)	-0.27 ((-1.11)
R-sq. (pseudo R-sq probit)	0.06	0.07	0.086	0.06	0.06	0.06		0.07	0.07
N	14,253	14,038	14,038	14,253	14,253	14,253	13,940	3,804	3,804
P-value of Wald test statistic of exogeneity of instrments							0.93		

Notes to all tables.

i. Marginal probability at mean in brackets. Product of marginal probability at mean and one standard deviation of regressor in braces. Z-statistics in parentheses.

ii.There are 69.2% of the sample of rural females and 92.4% of urban females age 13-15 who have at least one year of junior secondary school.

iv. All estimates include dummy variables for mother's birth province, mother's birth year, and offspring age.

v. All two-stage probit results are based on first-stage regressions using five weather dummies as instrumental variables.

vi. House type refers to the material used to construct the house. In the 2000 China Population Census, there are four categories: 1) steel and concrete, 2) brick and stone, 3) wood, bamboo, and grass, and 4) others. In the regression, the missing category is the first one (steel and concerete).

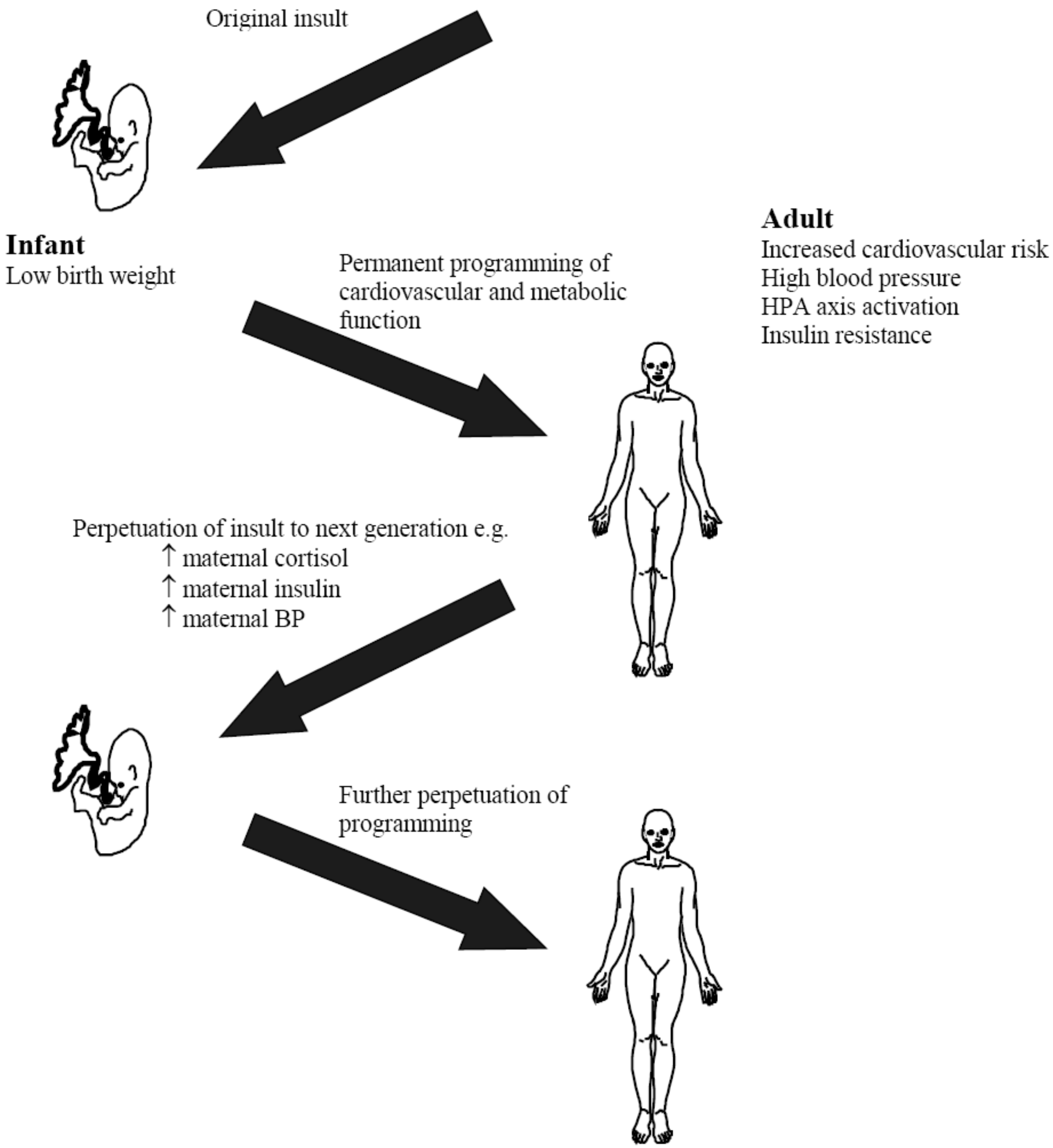
vii. The number in double braces is the impact of one standard deviation of WEDR on the additional schooling of a mother multiplied by the marginal probability at mean WEDR of the impact of mother's schooling years.

Table 4 First Stage Regressions for WEDR/1000 in Mother's Birth Year, Rural Offspring Age 13-15 in 2000

	Females	Males	
Weather Good	1.31 (10.16	1.23 (9.85)	1.22 (9.68)
Weather Average	1.78 (13.57)	1.79 (14.07)	1.78 (13.97)
Weather Bad	2.41 (18.35)	2.28 (18.27)	2.27 (18.13)
Weather Very Bad	2.33 (16.20)	2.10 (15.13)	2.12 (15.20)
House Type 2			0.22 (1.88)
House Type 3			0.04 (0.22)
House Type 4			0.37 (2.65)
House Area			-0.14 (-1.65)
Number of Children			0.09 (1.92)
Constant	-1.96 (-4.39)	-0.40 (-0.76)	-0.001 (-1.88)
Adj R-sq.	0.41	0.40	0.40

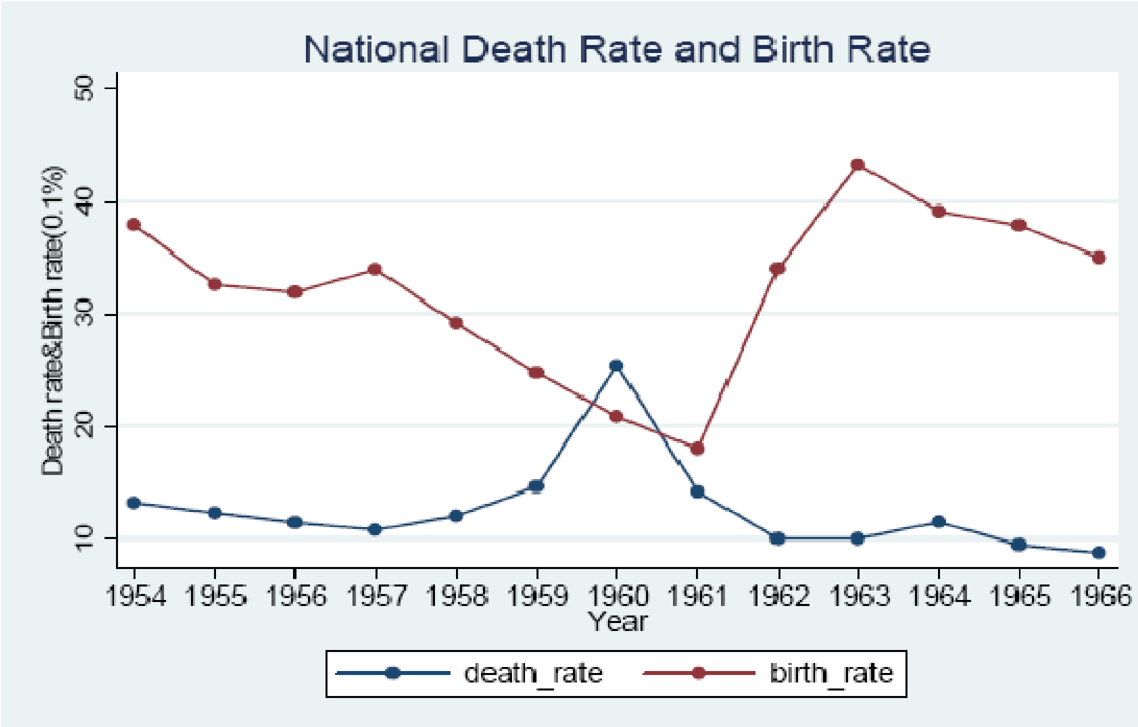
Notes:
1. Sample size is 19,337 for males and 20,896 for females
2. Omitted dummy variables are Weather Very Good and House Type 1 (made of steel and concrete)
3. Each regression includes dummy variables for mother's birth province and mother's birth year.

Figure 1 Second-Generation Effects of Fetal Programming



Source: Drake and Walker (2004)

Figure 2 National death rates and birth rates (unit: 0.1%)



Source: Shi (2008). The statistics are originally from the China National Bureau of Statistics.