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

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Abstract

We study the very long-run impacts of fetal malnutrition on children of malnourished mothers. Using data from the China Health and Nutrition Survey, we investigate whether mothers born in the Great Leap Forward Famine transmitted less human capital to their offspring (second generation) at birth and/or choices of less investment in their children's human capital. We find an impact on second-generation wages of all workers and rural workers that is robust to IV estimation. We also estimate a negative impact on hours of work in the total and rural samples, but this estimate is not robust to an IV estimation procedure. We do not find evidence supporting a Trivers-Willard effect (greater negative impact on male offspring than on female offspring) on our sample, although a larger sample (not reported) yields evidence supporting the Trivers-Willard hypothesis.

Key Words: Malnutrition, Health, Labor Market Outcomes, 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 can be obtained.

We suggest two potential propagation paths for first-generation malnutrition shocks to impact the second generation: First, a child of a famine-born mother may biologically inherit the mother's relatively weak physical conditions through imperfect genes[1] (direct channel). Epidemiological studies suggest that "adverse *in utero* experiences may permanently affect maternal growth and development, altering her 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). Thus, pre-birth and early-life malnutrition may adversely affect a woman's reproductive capacity. Second, mothers born around famine tend to have low social and economic status (SES) and this in turn may lead to low human capital development among their children (indirect channel). The failure of scheduled brain and body development in early life is likely to adversely affect the lifetime accumulation of a mother's human capital, because the cost of acquiring additional units is a decreasing function of the stock, beginning in the prenatal period. Schooling, income, marriage partners, and others are likely to be negatively

[1] Almond et al.(2008a) hypothesize that since women are born with all ova, if those ova are somehow affected by fetal malnutrition shock, the negative impacts of mothers could be transmitted to their children.

impacted (Victoria, et al. 2008). Thus, first-generation mothers are likely to have less capacity to invest in the human capital of their children, the second generation.[2]

Using data from a number of major famines,[3] researchers have found various long-run adverse effects of malnutrition *in utero* or in infancy on first-generation adult outcomes. These include physical impacts such as heart diseases, stunted height, mental problems such as schizophrenia, and economic outcomes, e.g., house size, household income, and related variables (Fung, 2009; Yamauchi, 2008; Almond et al., 2008a, 2008b; Chen and Zhou, 2007; Roseboom et al., 2001; Behrman et al., 2004; Barker, 1992; Shi, 2008; Meng and Qian, 2009; Luo et al., 2006; Mu and Zhang, 2008). However, there has been little research about second-generation impacts of famine[4]; Almond, et al. (2008) find an increase in the ratio of female children among second-generation births, which they attribute to the Trivers-Willard hypothesis and Fung and Ha (2009) find negative outcomes on height, age, and years of schooling between 0-18 years old offspring.

We examine mothers' fetal malnutrition effects on the high school entrance decision and labor market outcomes of their young adult or teenage offspring. High-school entrance is a good way to test education outcomes in our sample. The sample has a large number of individuals younger than 16 years old. Elementary and lower middle-school education is mandatory, but upper middle-school (high school) education is not. Thus we can focus in the critical decision whether or not to attend high school. This choice, along with subsequent labor-market outcomes provides an important means of testing the significance of mother's fetal malnutrition shock on the development of human capital in her offspring.

We use provincial death rates by year as a measure of famine intensity. We use household-level cross-sectional data to study second-generation high school decisions and labor market outcomes. We estimate our models for samples that combine urban and rural observations and for rural observations separately. In addition to OLS we use 2SLS estimation to deal with measurement errors and possible omitted- variable bias. We find negative impacts of the GLF famine on wages and work hours. The estimated famine impact on wages is robust to 2SLS

[2] Almond et al. (2008a) call these second-generation effects "echo effects."

[3] 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).

[4] There are some studies on birth outcomes and physical growth (Fung, 2009; Gorgens, Meng, and Vaithiannathan, 2007; Currie and Moretti, 2005, etc.).

estimation and to dividing the sample into rural and urban observations. The estimated impact on work hours is not robust to 2SLS estimation, but it is stronger among rural residents than urban residents. We find no evidence supporting the hypotheses that there are negative second-generation famine effects on schooling or work status. We find no evidence that the second-generation famine effects are indirect, that is operating through famine-induced lower schooling of mothers. We note that, using a larger sample encompassing a wider range of mothers' birth years, we find evidence supporting the Trivers-Willard hypothesis (Trivers and Willard, 1973) on for the variables we study in the second generation. We find, in the larger sample, that famine impacts male offspring high school entrance and current work status more than females. This evidence is not robust to reducing the sample to a somewhat narrower range of mothers' birth years and is not reported in this paper.

The rest of the article is organized as follows. The next section briefly provides the historical background of the China Famine and reviews literature related to the impact of the famine on first-generation human capital and labor market outcomes; section 3 presents our methodology; 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. Historical Background of the China Famine and Related Literature

In 1958, Mao Zedong initiated an ambitious but reckless economic and social experiment, the Great Leap Forward movement (GLF), 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 interacting with other poorly designed government policies that included excessive grain procurement which in turn was encouraged by local 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 had large regional variation (figure 5).

Moreover, urban bias on the part of the Communist regime meant that urban residents were suffered much less, because they had preferential access to food supplies (Lin and Yang, 2000). Not only did death rates surge, but also fertility rates collapsed, with the number of total births per woman falling from 5.6 births per women before the famine to 3.06 in 1961 (Peng, 1987).

After realizing the severity of the famine, the Communist party dropped its audacious and radical policies in January 1962. Agricultural output started to rebound and grain imports increased; equally or more importantly, grain procurement was reduced. Death rates dropped quickly (Figure 1) and so did birth rates rebound, although in a more complex fashion. 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).

Famine Literature Review 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 predetermined *in utero.* A small, but growing, body of literature treats the effects of fetal malnutrition on economic and social outcomes. Since it is impossible, if not, unethical to experiment on human populations, researchers generally rely on historic famines such as the Dutch Famine of the second World War, the China Famine, and others.

A number of researchers have found that famine-related malnutrition experience *in utero* or infancy has long-term negative effects on economic, social and health outcomes among those who directly suffered *in utero* and/or early childhood malnutrition--the first generation. Almond et al. (2008a) use data from the 1% sample of 2000 China Population Census 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 from the same 2000 China Population Census data and provide some suggestive evidence for negative fertility selection after the China famine. 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 have lower height, labor supply, earnings, and other characteristics associated with their human capital. With the same data, Fung (2009) also 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) argue that those who experienced the Dutch Famine *in utero* exhibited a 2-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.

Although they do not directly use a famine as a quasi-natural experiment a few studies examine whether a mother's early-life malnutrition (or low birth weight as a proxy for early-life nutritional status) affects her children's outcomes, e.g., birth weight, height, cardiovascular diseases, test score, and others (Emanuel et al., 2004; Drake and Walker, 2004; Currie and Moretti, 2007). In particular, Drake and Walker (2004) argue that adverse fetal environments such as malnutrition may harm maternal development and this in turn affects her fetus by permanently changing maternal metabolism. Figure 2 provides a graphical illustration of the propagation mechanism of intrauterine growth shock from a mother to her child.

There are two studies of second-generation effects of early-life maternal malnutrition using the China famine as a quasi-natural experiment (Almond et al., 2008a; Fung and Ha, 2009). 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 Trivers-Willard hypothesis 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 et al., 2008a). Fung and Ha (2009) study the second generation effects of early-life maternal malnutrition using the China famine as a quasi-natural experiment and find adverse outcomes of individuals whose mothers are born during the famine. They investigate height-for-age, weight-for-age, and years of schooling for the second generation of famine-born cohorts. However, their samples are obtained by pooling three CHNS waves which include the same individuals interviewed in three different years, and they treat these repeated observations as though they were different individuals observed in the same year. Thus, many of their data points do not provide independent information, and this

complication affects the reliability of their regression results. Another problem with Fung and Hua (2009) is that they use the 1989, 1991, and 1993 CHNS waves in which the offspring of famine-born cohorts are very young. Despite their restriction of the sample to those who are 6-18 years old, using years of schooling to test for education outcomes is problematic, because schooling through lower middle school (junior high school) is mandatory while senior high school education is not. Our paper is similar to Fung and Ha (2009) in that we examine the second-generation effects of maternal malnutrition but it differs in that we focus on discretionary schooling and labor market outcomes.

3. Methodology

Our basic strategy is to use provincial weighted excess death rates as a measure of famine intensity in regression analysis of four human-capital outcomes in the second generation: (i) high-school entrance; (ii) working hours; (iii) wage rates; and (iv) current work status.

Our major hypothesis is that the net impact of mother's *in-utero* famine experience on each of these outcomes is negative. We also attempt to separate the impact coming through the effect of famine on the human capital of mothers as reflected in mothers' schooling from a direct impact on the development of human capital in the second generation, holding constant mothers' characteristics.

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

$$Y_{ijkl} = \beta \mathrm{WEDR}_{jkl} + \theta X_i + \alpha_l + \varepsilon_{ijkl} \qquad 1$$

where

- Y_{ijkl} is a second-generation individual i's variable of interest such as education attainment or labor market outcome;
- 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*,province *l* and month *k*;
- X_i is a vector of control variables including age, urban dummy, and gender dummy of person *i*

- α_l is a province fixed effect; and ε_{ijkl} is individual *i*'s i.i.d. error term.

The variable WEDR is the best approximation available to us for the availability of nutrition to our sample of mothers. It is calculated as the difference between the annual provincial death rate from which is subtracted the mean provincial death rate between 1956-1958 following Chen and Zhou (2007). In Figure 1, we see that death rates are quite stable before 1958, and they abruptly surge during the China Famine of 1959-1961. The 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 (assuming a 9-month gestation period).

We use provincial fixed effects to control for time-invariant differences in unobservables across provinces. Standard errors are clustered at the province level. Summary statistics of the variables used in regression are presented in Table 1.

Econometric Challenges We discuss error-in-variables (EIV) and omitted-variables biases (OVB) that may affect our estimation results. In general all of the errors and omissions discussed below bias our estimation results against rejecting the null. Thus, we regard our estimates as defining lower bounds of the true famine impacts.

1. The weighted excess date rate WEDR is taken as a proxy for famine intensity affecting each first-generation mother. However, since this variable is province-specific, it probably underestimates famine intensity in rural areas while overestimating those in urban areas. Another issue is that we implicitly assume mother's province of birth is the same as the province where she lives. Given the strict regulations population movements that prevailed in China during the GLF period (and are still in effect albeit much more relaxed today) we believe that this assumption is reasonable. Fung (2009) shows that 2.9% of rural households and 7.3% of the spouses are migrants in her sample, and of those who migrated, about 77% of migrants ended up in Heilongjiang province. We have performed a robustness check by dropping Heilongjiang from our sample. The results are by and large similar. The biases arriving from EIV for WEDR are to reduce the likelihood of rejecting the null hypothesis of no effect on human-capital outcomes among the second generation.

2. Our sample size is inherently small, and this can increase estimated standard errors.

Again, our results are biased toward failing to reject the null when it is false. During the period of the China Famine, not only did the death rate surge, but also the birth rate dropped significantly[5] (Ashton et al., 1984). Thus, the sample size of the first generation of the China Famine is relatively smaller than would be implied simply by the time span covered. Moreover, since the offspring of the famine cohort were born mostly in 1980s and 1990s, many of the second generation are still in school and not yet in the labor force.[6] The small-sample problem is exacerbated for the wage variables, because individuals living in rural areas and working on farms are unlikely to report a market wage.

We have chosen our dependent variables with an eye toward reducing small- sample problems. Thus for schooling, we examine decisions to enter high school, but not college. High school education is not mandatory in China and its enrollment rate was still low during the time period covered[7]. For labor market outcomes, we exclude observations that are still attending school and when studying working hours we delete observations for which there is no reported wage.

3. We do not have data on measures of income of the first-generation mothers' parents. This omission is also likely to bias our results against rejecting the null of no famine impact, because it is reasonable to assume that those who were born during the China GLF famine are more likely to have parents of higher socioeconomic status and thus have selectively better innate traits[8]. During 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 child-bearing generation. A major systematic source of error is due to the urban bias of policies in the Mao era. We introduce a dummy variable for rural residence to correct for this possible source of omitted-variable bias, and we also estimate separate regressions for rural and urban residents.

In an attempt to reduce the severity of measurement error and unobserved heterogeneity

[5] The number of live births per thousand dropped from 34 (in 1957) to 18 (in 1961) during the China famine (Lin and Yang, 2000).

[6] Since next rounds of the survey are expected to be collected in 2009 and 2011, the small sample problem will be eased. When the 2009 survey is available, the effective sample size for labor market outcomes will be more than double.

[7] In our sample, 56% entered high school.

[8] Shi (2008) studied fertility selection around the China Famine period. He found a positive selection among famine-born cohorts, i.e., holding other things constant, famine-born cohorts have better innate than others.

not corrected by provincial fixed effects, we adopt an instrumental variables technique for the variable WEDR. To instrument for weighted provincial death rates, we use several variables used in Li and Yang (2005), which include measures of grain procurement, communal dining participation, fertilizer use, weather index, acreage with grain sown, the percent of grain-sown land with irrigation[9] [10]. These variables, all pertaining to a period well before the birth dates of our second-generation sample, are very unlikely to be correlated with residuals of the second-generation human-capital and labor market outcome regressions. Moreover, the first-stage estimates shown in table 6 provide strong evidence that the instruments can "explain" the GLF famine.[11]

4. Data and Sample Selection

Most of our data come from the China Health and Nutrition Survey (hereafter CHNS)[12]. It has been co-conducted by the Carolina Population Center at the University of North Carolina, Chapel Hill and the National Institute of Nutrition and Food Safety at the Chinese Center for Disease Control and Prevention since 1989. Seven waves are available as of 2009 and additional waves are to be collected in 2009 and 2011. The data is collected by a multi-stage, random cluster process in each province. The CHNS covers about 4400 households and approximately 19000 individuals in 9 provinces (Guiangxi, Guizhou, Heilongjiang, Henan, Hubei, Hunan, Jiangsu, Liaoning, and Shandong) as illustrated in Figure 3.[13] These nine provinces widely differ in economy, geography and other characteristics. The CHNS includes a broad range of questions

[9] We are grateful to Dennis Tao Yang and Wei Li for generously providing their data for these IVs. These variables are originally employed in their article to explain causes of the China famine and are recorded by province and year. Since the unit of observation of weighted excess date rates is year, month, and province of mother's birth, we weighted the instrumental variables in the same way we weighted excess death rates.

[10] Meng and Qian (2009), using a different data set also used county-level grain productivity (per capita area suitable for cultivating rice and wheat, and per capita area of rice and wheat sown) to instrument for famine intensity.

[11] We use these instruments to so we conduct 2SLS estimation of regressions with both binanry and continuous dependent variables. 2SLS estimation for binary variables requires that we rely on a linear probability model instead of a preferred binary choice model such as probit or logit. If we conduct conditional maximum likelihood estimation of binary choice model (e.g., probit) with an endogenous explanatory variable, we have to impose strong distributive assumptions about the relationship between a binary variable and an endogenous variable and the test statistics do not support them so we decide to employ 2SLS estimation (Wooldrige, 2002). Another advantage of 2SLS estimation is that it allows us to easily examine weak instruments and exogeneity of instrumental variables by an over-identifying test (Cameron and Trivedi, 2009).

[12] Further information can be found at http://www.cpc.unc.edu/projects/china

[13] Liaoning province was dropped in 1997 and returned in 2000, and Heilongjiang was newly added in 1997.

on health, nutrition intake and many social and economic characteristics. This rich set of information on individuals and households makes it an excellent micro-level dataset for examining the long-run consequences of maternal malnutrition. It has served as the basis for several studies of the long-term first-generation impacts of the China Famine (Chen & Zhou, 2007; Meng and Qian, 2009; Fung, 2009; Gorgens et al., 2005; Luo et al., 2006, and others).

We use the 2006 Survey which includes 11,742 individuals (9788 adults and 1954 children) in order to obtain adult children or late teen children of famine-born cohorts (the second generation of the China famine). Our sample consists of offspring whose mothers born between 1954 and 1967 which is the same time span used by following Chen and Zhou (2007)[14]. Within this group there is a subsample of 145 mothers who experienced the famine *in utero* or in early childhood (0-2 years old) among 495 mothers[15]. The distribution of mothers by birth year is in Figure 4A. We restrict the sample first to offspring whose biological mother's date of birth information is available and second to those who were 16 years old or older as of 2006. The final sample size of the second generation is 639 and the distribution of second generation (children) by mother's birth year is shown in Figure 4b.

5. Estimation Results

Our estimation results are reported in tables 2 through 5. We first show OLS and then report IV results.[16] Table 2 presents our probit and OLS regression estimates for high-school entrance, working hours, and wage rate, and labor force participation reported in columns (1) through (4), respectively. The 2SLS estimation results are reported in table 3; and results for the rural subsample are reported in table 4 (probit and OLS) and table 5 (2SLS)[17]. All equations were estimated including a variable representing mother's schooling and without the mother's schooling variable. Our estimation results are not substantially different when mother's

[14] Our results are quantitatively robust in general if we include birth cohorts before 1954 or after 1967.

[15] The number of children per biological mother is about 1.29

[16] The first-stage estimation results are shown in table 6. The instrumental variables used are individually significant and are jointly significant to explain famine intensity and are orthogonal to residuals in the second stage regression according to over-identifying test statistics. See detailed explanation of the instrumental variables in Li and Yang (2005)

[17] Acknowledging that 2SLS is not ideal for estimating a binary choice model, we also conduct conditional MLE as a robustness check as discussed in Section III, using the Stata® command *ivprobit*. The Wald test statistic suggests that the result is not precise but the signs of coefficients are the same and their significance and magnitudes are generally robust.

schooling is included, and regressions of mother's schooling showed no significant impact of WEDR on mothers' educational attainment. The negligible estimated impact of the GLF famine on mothers' schooling is rather surprising and warrants further investigation. Almond et al. (2008a) find that first-generation impacts include a higher rate of illiteracy and lower probability of marriage. We conjecture that since our sample is biased toward married women with children, the impact of the famine on their human capital is attenuated.

The estimated impact of WEDR on high-school entrance is not statistically significant at conventional levels regardless of estimation technique and sample. The estimation results for work hours are shown in column (2). If maternal famine experience hampers the development of various dimensions of health capital, it is probable that those who suffered from the famine would reduce their working hours, *cet. par*.(Strauss and Thomas, 1998).[18][19] The dependent variable is average working hours per day of survey respondents as of 2006, and we restrict the sample to those who report positive working hours. About half of people report 8 working hours per day. The OLS estimation results for work hours imply a negative and statistically significant impact on work hours in the full sample and a larger impact in the rural sample. While the sign of the estimated impact on work hours is also negative in 2SLS estimation, the magnitudes are smaller, and the estimated coefficients are imprecise. An indication of the magnitude of the second-generation impact on work hours can be obtained by multiplying the estimated regression coefficients by one standard deviation of WEDR. This exercise implies that a one standard deviation increase in the weighted excess death rate reduces mean weekly work hours in the full second-generation sample by 0.21 hours and by about 0.33 hours in the rural sample, using the OLS estimates. The 2SLS impacts are proportionately smaller.

The estimated famine impact on second-generation wages is negative, sizeable, and significant in both samples and is very robust to 2SLS estimation (column (3)). A one standard deviation increase in WEDR reduces wages by about 10% in the full sample and by about the

[18] Chen and Zhou (2008) find that the famine experience negatively affects labor supply in terms of annual total working hours for people born in 1959-1962 although only the cohort born in 1959 has a 5% level statistical significance.

[19] Strictly speaking, if reduced human capital simply results in a lower wage, and if leisure is a normal commodity and highly income elastic, then the affected individual may work more. However, if the health impediment results in conditions that are not offset by lower wages and/or results in intermittent or permanent incapacity to work, then the individual is likely to work less even if the "normal" labor supply of hours is "backward bending."

same amount in the rural sample when the OLS coefficients are used.[20] The 2SLS estimates are twice as large.

Tests of the hypothesis that mother's famine experience negatively affects children's current work status are shown in column (4) of tables 2 through 5. The dependent variable is dummy variable for whether a survey respondent was working or not at the time of interview. We restrict the sample to those who are out of school in order to exclude individuals who are not working due to school enrollment. The estimation results show no significant impact in OLS estimation in either the total or rural samples and, curiously, a positive and significant impact in the total sample when 2SLS estimation is employed.Evidently, reduced second-generation human capital does not sufficient to preclude working.

6. Concluding Remarks

The China Famine, a tragic event in the world history, provides an opportunity to examine the link between malnutrition and social, economic, and the health outcomes of those who experience malnutrition in early life and of their progeny. Social scientists have found that the effects of early life malnutrition are durable, widespread, and last through adult life 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 first-generation mothers. Our estimation results using data from the 2006 cross-section of the China Health and Nutrition Survey show that there are indeed identifiable second-generation effects of prenatal malnutrion. They appear as reduced working hours and lower wages. The impact on wages is particularly large and significant, and it is robust to IV estimation. Confining the sample to rural residents strengthens the effects of fetal malnutrition on wages and working hours, which is consistent with rural areas' being more severely affected by famine-induced nutritional deficiencies.

These results support the existence of an important multiplier of policies that support the nutrition of pregnant women and infants in any country where nutritional deficiencies remain. Indeed, China has recently taken steps to improve the nutritional status of children. The National Program of Action for Child Development in China aims to reduce the number of malnourished

[20] Only 47% of the rural sample reports a wage.

children under age 5 by a 25% in 2010. 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. If individual nations and international agencies 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. Even the outcomes we have identified to not capture the likely full and, long-term effects that last into the second generation. 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 ages of the second generation. Impacts on the development of chronic physical and mental illnesses in the second generation remain to be identified.

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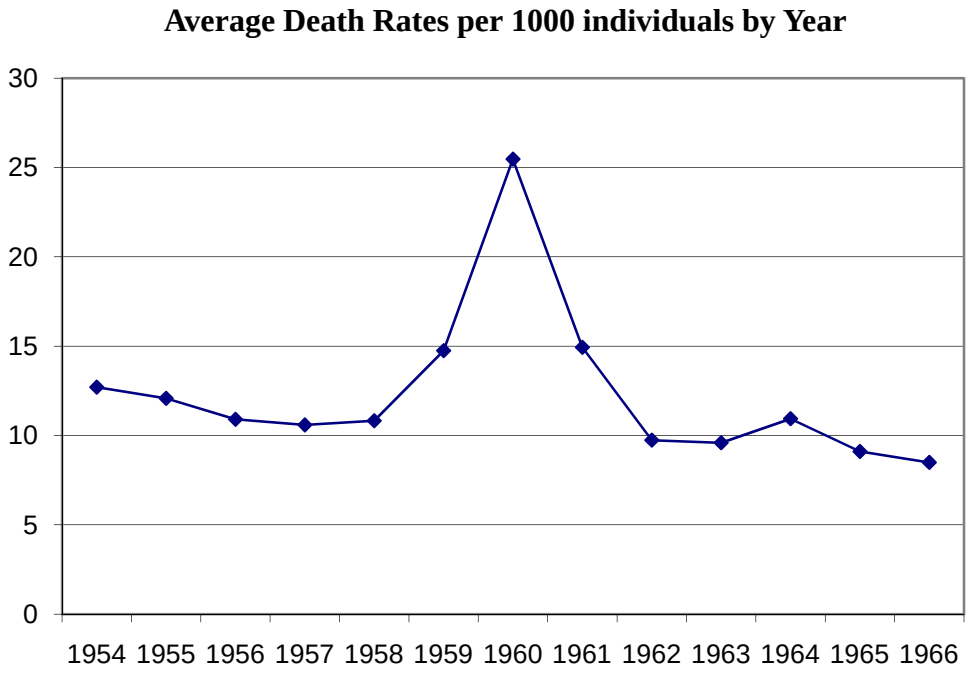
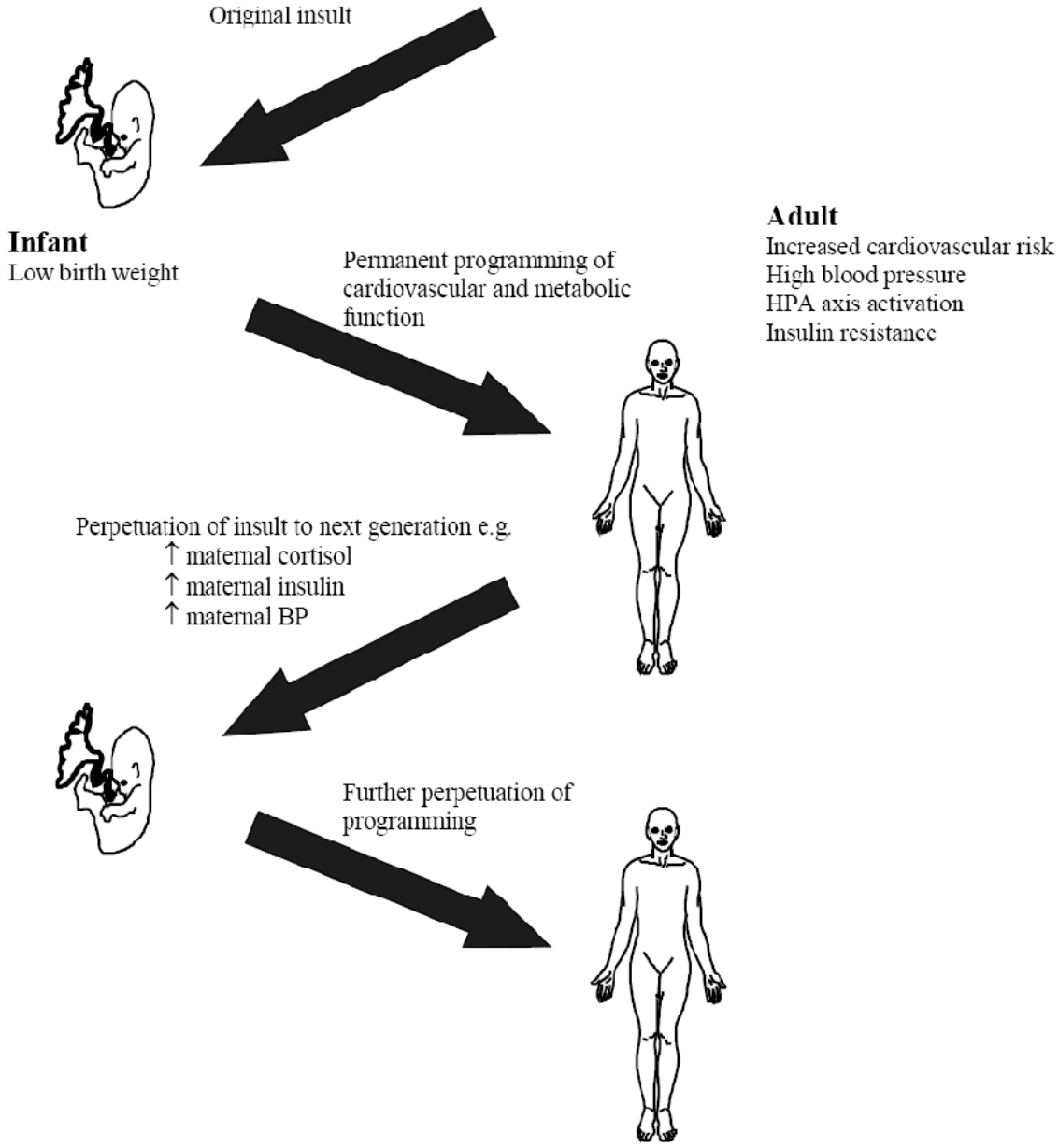
Figure 1: the average death rates per 1000 individuals by year from 1954 to 1966 of all survey participating



Source: Author's calculation using data adapted from Ling and Yang (2000)

Figure 2: Second-Generation Effects of Fetal Programming



Source: Drake and Walker (2004)

Figure 3: CHNS Survey Map

Figure 4A: Distribution of Birth Year of Mothers

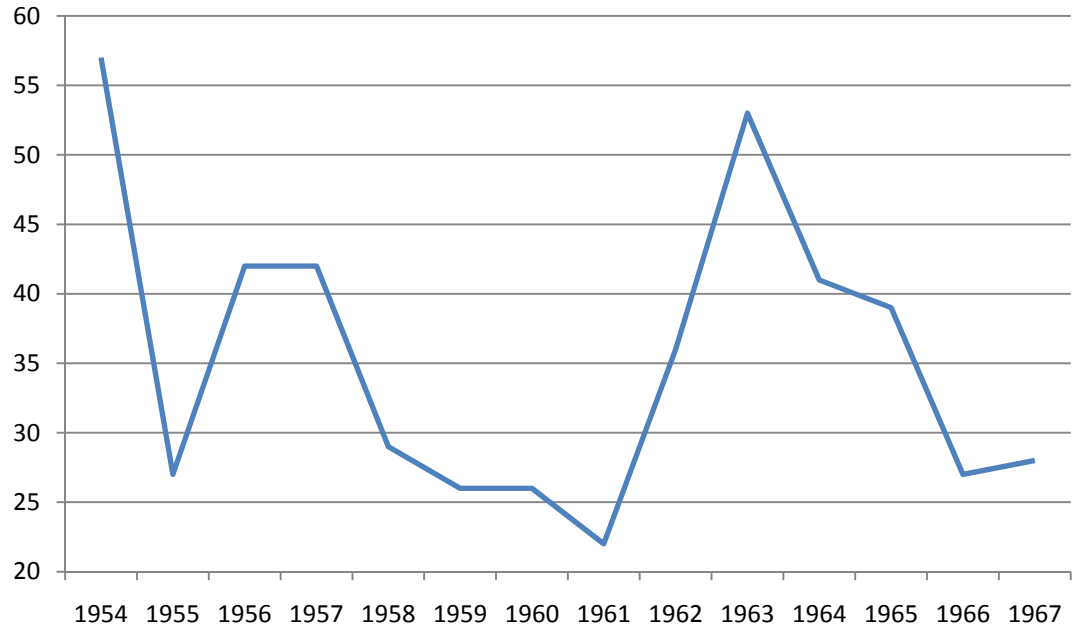


Figure 4B: Distribution of Children by Birth Year of Mothers

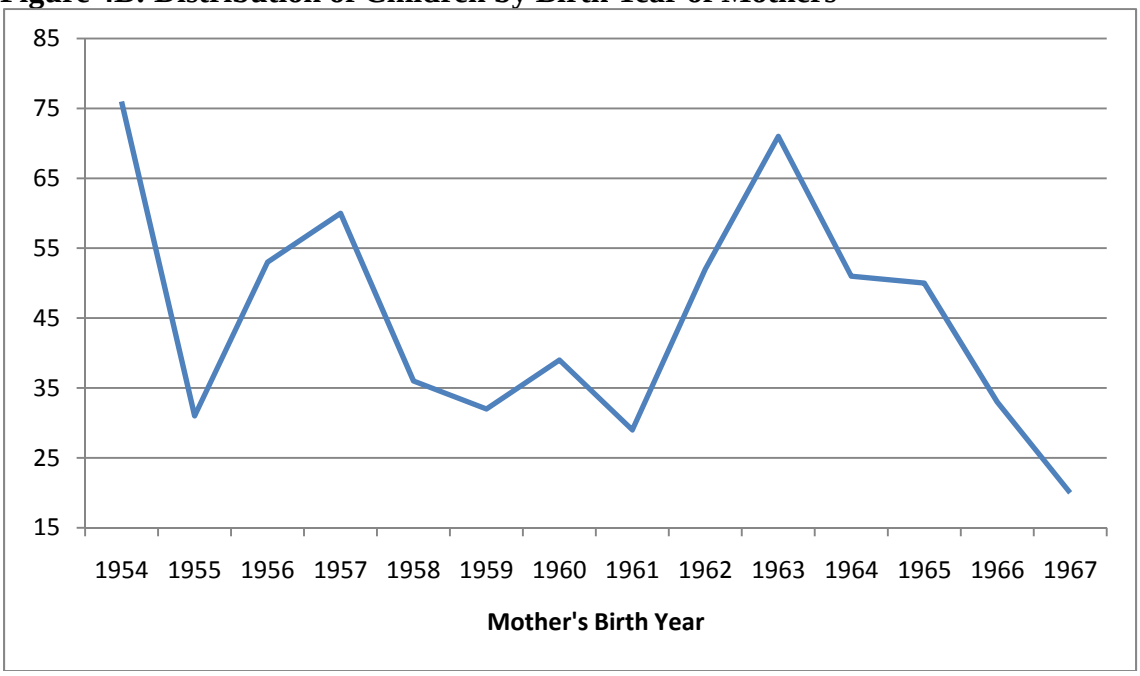
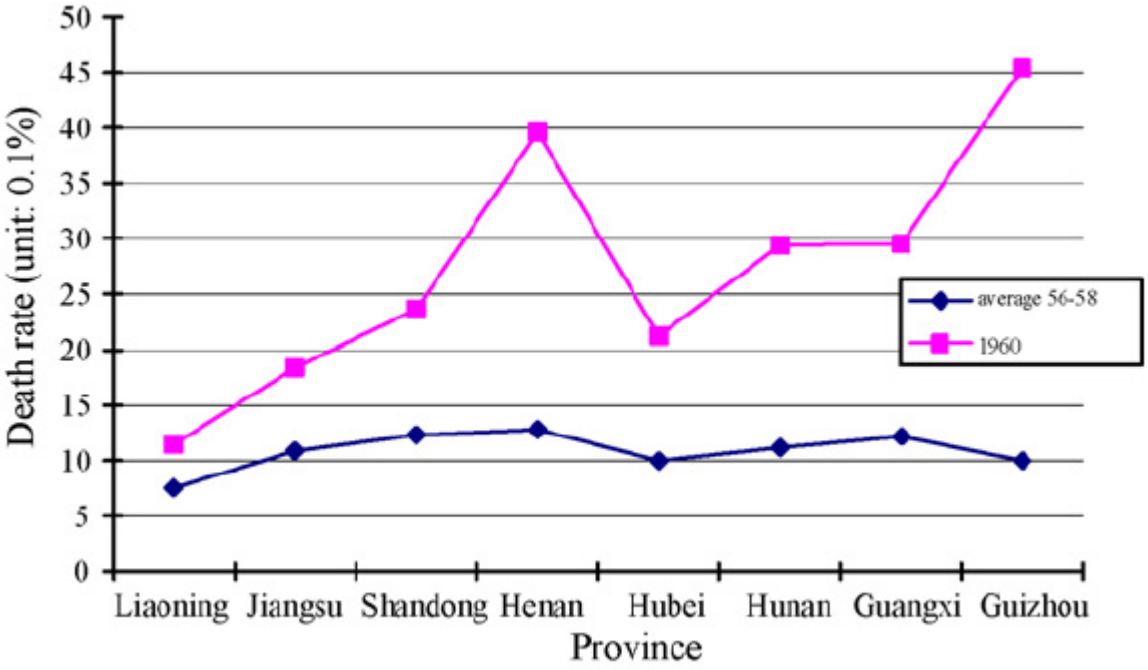


Figure 5: Death Rates of Sampled Provinces



Source: Chen and Yuyu (2007)

Table 1A: Descriptive Statistics (Mother's years of birth: 1954-1967)

	Obs.	Mean	Standard Deviation	Max	Min
Presently working (1 if working, 0 otherwise)	517	0.56	0.50	1	0
Average working hours per day (for whose work hour is positive)	277	7.77	2.18	13	1
Weighted excess date rates by Mother's Year of Birth, Month of Birth, and Province	639	0.39	4.20	23.57	-6.20
High school entrance rate	639	0.56	0.50	1	0
Age	639	20.51	3.50	32	16
Urban dummy (1 if urban, 0 if rural)	639	0.43	0.50	1	0
Gender (1 if men, 0 if women)	639	0.62	0.49	1	0

Table 1B: Descriptive Statistics by Mother's Birth Year

	Mother's Birth Year								
	1954-1958 (before the famine)			1959-1961 (during the famine)			1962-1967 (after the famine)		
	Obs.	Mean	Standard Deviation	Obs.	Mean	Standard Deviation	Obs.	Mean	Standard Deviation
Weighted excess date rates by Mother's Year of Birth, Month of Birth, and Province	256	0.63	2.45	97	5.33	5.47	286	-1.49	3.48
High school entrance rate	256	0.59	0.49	97	0.57	0.50	286	0.54	0.50
Average working hours per day (for whose work hour is positive)	150	7.98	2.05	48	7.73	1.97	79	7.37	2.48
Log Wage	89	6.87	0.42	27	6.34	0.49	36	6.70	0.67
Presently working (1 if working, 0 otherwise)	232	0.67	0.47	85	0.59	0.50	200	0.43	0.50
Age	256	22.81	3.61	97	20.69	2.65	286	18.39	2.00
Urban dummy (1 if urban, 0 if rural)	256	0.47	0.50	97	0.43	0.50	286	0.40	0.49
Gender (1 if men, 0 if women)	256	0.63	0.49	97	0.60	0.49	286	0.63	0.48

Table2: The Probit and OLS estimates of the Effects of the China GLF Famine

	Dependent Variable			
	High School Entrance	Working Hours	Log Wage	Labor Force Participation
Unit	1 if entered; 0 otherwise	Hours	Logarithm of Yuan	1 if working; 0 otherwise
	(1) Probit	(2) OLS	(3) OLS	(4) Probit
Weighted excess date rates of Mother	**-0.018**	**-0.050****	**-0.024****	**0.002**
	(0.012)	**(0.018)**	**(0.010)**	**(0.019)**
Gender dummy	-0.339***	-0.194	0.127	-0.090
	(0.119)	(0.310)	(0.089)	(0.196)
Urban dummy	0.826***	0.721	0.176*	-0.218*
	(0.148)	(0.497)	(0.097)	(0.114)
Age	0.004	0.079*	0.044***	0.100***
	(0.022)	(0.043)	(0.014)	(0.029)
Constant	0.069	6.843***	5.618***	-1.775***
	(0.387)	(0.924)	(0.269)	(0.577)
Province Fixed Effects	Y	Y	Y	Y
(pseudo) R^2	0.12	0.12	0.26	0.07
Observations	639	277	152	432
		(for those who report positive working hours)	(for those who report wages)	(for those who are currently out of school)

Robust standard errors are reported in parentheses and are clustered at the province level

* Significant at 10%; ** Significant at 5%; *** Significant at 1%

Table3: The 2SLS estimates of the Effects of the China GLF Famine

	Dependent Variable			
	High School Entrance	Working Hours	Log Wage	Labor Force Participation
Unit	1 if entered; 0 otherwise	Hours	Logarithm of Yuan	1 if working; 0 otherwise
	(1) 2SLS	(2) 2SLS	(3) 2SLS	(4) 2SLSt
Weighted excess date rates of Mother	**0.006**	**-0.007**	**-0.048****	**0.016****
	(0.007)	**(0.064)**	**(0.020)**	**(0.007)**
Gender dummy	-0.109**	-0.147	0.084	-0.025
	(0.043)	(0.292)	(0.106)	(0.072)
Urban dummy	0.289***	0.713	0.154	-0.080*
	(0.0515)	(0.500)	(0.097)	(0.038)
Age	-0.002	0.072	0.052***	0.030**
	(0.007)	(0.042)	(0.015)	(0.009)
Constant	0.476**	6.544***	5.725***	-0.171
	(0.161)	(1.179)	(0.261)	(0.151)
Province Fixed Effects	Y	Y	Y	Y
R^2	0.15	0.11	0.24	0.07
Observations	639	277 (for those who report positive working hours)	152 (for those who report wages)	(for those who are currently out of school)

Robust standard errors are reported in parentheses and are clustered at the province level

* significant at 10%; ** significant at 5%; *** significant at 1%

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Table 4: The Probit and OLS estimates of the Effects of the China GLF Famine (Rural Sample)

	Dependent Variable			
	High School Entrance	Working Hours	Log Wage	Labor Force Participation
Unit	1 if entered; 0 otherwise	Hours	Logarithm of Yuan	1 if working; 0 otherwise
	(1) Probit	(2) OLS	(3) OLS	(4) Probit
Weighted excess date rates of Mother	**-0.029**	**-0.085****	**-0.023****	**0.007**
	(0.024)	**(0.026)**	**(0.014)**	**(0.029)**
Gender dummy	-0.434***	-0.589	0.203	-0.132
	(0.124)	(0.372)	(0.126)	(0.229)
Age	-0.002	0.104	0.041**	0.084***
	(0.023)	(0.068)	(0.021)	(0.029)
Constant	0.135	6.530***	5.464***	-1.423***
	(0.462)	(1.317)	(0.375)	(0.626)
Province Fixed Effects	Y	Y	Y	Y
(pseudo) R^2	0.09	0.21	0.37	0.05
Observations	363	180	84	276
		(for those who report positive working hours)	(for those who report wages)	(for those who are currently out of school)

Robust standard errors are reported in parentheses and are clustered at the province level

* Significant at 10%; ** Significant at 5%; *** Significant at 1%

Table 5: The 2SLS estimates of the Effects of the China GLF Famine (Rural Sample)

	Dependent Variable			
	High School Entrance	Working Hours	Log Wage	Labor Force Participation
Unit	1 if entered; 0 otherwise	Hours	Logarithm of Yuan	1 if working; 0 otherwise
	(1) 2SLS	(2) 2SLS	(3) 2SLS	(4) 2SLSt
Weighted excess date rates of Mother	**0.002**	**-0.025**	**-0.042***	**0.016**
	(0.010)	**(0.071)**	**(0.022)**	**(0.009)**
Gender dummy	-0.151***	-0.531	0.155	-0.043
	(0.043)	(0.343)	(0.152)	(0.079)
Age	-0.004	0.097	0.047*	0.025**
	(0.008)	(0.065)	(0.021)	(0.008)
Constant	0.592***	6.574***	5.408***	0.082
	(0.172)	(1.337)	(0.359)	(0.167)
Province Fixed Effects	Y	Y	Y	Y
R^2	0.11	0.11	0.35	0.05
Observations	363	180 (for those who report positive working hours)	84 (for those who report wages)	276 (for those who are currently out of school)

Robust standard errors are reported in parentheses and are clustered at the province level

* significant at 10%; ** significant at 5%; *** significant at 1%

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Table 6: The First Stage Estimates of the Effect of the China Famine Causes on Famine Intensity

Dependent Variable: Weighted excess date rates of Mother	
Instrumental Variables	
Communal Dining Participation Rates of Mother's Birth Year and Province	4.082 (0.757)
Grain Procurement of Mother's Birth Year and Province (in million tons)	-0.010 (0.004)
Acreage Sown with Grain of Mother's Birth Year and Province	-9.447 (1.676)
Percent of Acreage Sown with Grain with Irrigation of Mother's Birth Year and Province	-2.415 (0.467)
Fertilizer Use of Mother's Birth Year and Province (in million tons)	-0.213 (0.128)
Very Good Weather Dummy of Mother's Birth Year and Province	-2.799 (0.606)
Good Weather Dummy of Mother's Birth Year and Province	-2.938 (0.521)
Average Weather Dummy of Mother's Birth Year and Province	-1.672 (0.512)
Bad Weather Dummy of Mother's Birth Year and Province	-1.009 (0.644)
Very Bad Weather Dummy of Mother's Birth Year and Province	(dropped)
Control Variables	
Urban Dummy	-0.174 (0.248)
Gender Dummy	-0.194 (0.251)
Age	0.101 (0.044)
Constant	86.948 (13.785)
Province Fixed Effects	Yes
Joint F-test of IVs (F-statistics / P-value)	26.950 (0.000)
R^2	0.455
Observations	639

Robust standard errors are in parentheses; Instruments are variables in used Li and Yang (2005). See detailed description of variables Li and Yang (2005).
* Significant at 10%; ** Significant at 5%; *** Significant at 1%