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The long-term health and economic consequences of the 1959–1961 famine in China

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Abstract

This paper, using a difference-in-differences method, tries to quantify the long-term effects of China's 1959–1961 famine on the health and economic status of the survivors. We find that the great famine caused serious health and economic consequences for the survivors, especially for those in early childhood during the famine. Our estimates show that on average, in the absence of the famine, individuals of the 1959 birth cohort would have otherwise grown 3.03 cm taller in adulthood. The famine also greatly impacted the labor supply and earnings of the survivors with famine exposure during their early childhood.

JEL classification: I12; J13

Keywords: Famine; Health; Difference-in-differences estimator; China

1. Introduction

China's 1959–1961 famine stands out as the worst in human history: there were about 15–30 million excess deaths and about 30 million lost or postponed births.[1] The startling severity of this famine of modern times has provoked persistent efforts in understanding this unprecedented

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[1] Although no one doubts the enormity of the famine, there is no general consensus regarding the estimate of lost population during the famine (see Ravallion, 1997). The estimates vary from an upper bound of 30 million excess deaths (Ashton et al., 1984) to a lower bound of 15 million (Riskin, 1990). Some authors suggest an estimate of 18–23 million extra deaths (Peng, 1987; Chang and Wen, 1997; Yao, 1999). In contrast, estimates of lost births are very similar, around 30 million (Ashton et al., 1984; Yao, 1999).

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catastrophe and quantifying its devastating effects. Many previous studies have explored in great detail the causes of the famine and its impact on mortality and childbearing behavior (Ashton et al., 1984; Peng, 1987; Lin, 1990; Lin and Yang, 2000; An et al., 2001). Nevertheless, very few studies have touched on the long-term health and economic consequences for the survivors of the great famine, and little is known about the magnitude of these consequences.

The 1959–1961 famine created a large undernourished population during the three-year period. Malnutrition and exposure to famine-related diseases adversely affected the health of the survivors. In particular, it may have had adverse consequences for children who were conceived or born during the famine. There is a large body of evidence in population health literature showing that exposure to malnutrition or other adverse environments in the fetal period and early childhood exerts significant lasting effects on health, well-being and competence (Barker, 1989, 1992; Hertzman and Wiens, 1996; Hertzman and Power, 2003; Heymann et al., 2005). Economists have also increasingly recognized the vital role of health status as a dimension of human capital in economic development.[2] In particular, recent research provides strong evidence on the long-term effects of childhood health and economic circumstances on adult health, employment and socioeconomic status (SES) (Case et al., 2005). Combining these findings from different disciplines suggests that negative health consequences in early life may translate into negative economic outcomes in adulthood. From this perspective, it is both interesting and important to understand to what extent the 1959–1961 famine exerted sustained health and economic effects on a large surviving population, mostly in rural areas.

A rigorous and systematic analysis of the long-term impact of the famine, however, is hindered by a number of problems. The first is limitations of data, such as the lack of data tracking individual characteristics of the population during and after the famine. Collection of data during the famine would have been virtually impossible. A more realistic source of data comes from surveys sampling the population exposed to, and surviving the famine. But even if we have such a dataset, identifying the effects directly caused by the famine is still very challenging. An analysis based upon a sample of the surviving population may potentially suffer from a sample selection problem if the childbearing decisions during the famine respond to the famine and systematically correlate with the heterogeneity across individuals, such as socioeconomic status. If fertility was more responsive among those families with higher SES, then more children may have been born into poor or less healthy families. This selection effect will cause a spurious correlation between exposure to famine and its effect on health and economic outcomes. Leaving aside this sample selection bias, we also encounter the problem of how to build a causal relationship between famine and its long-term effects when many other unobserved characteristics may confound our inference.

Existing literature on the sustained effects of famine has not satisfactorily addressed the issues of sample selection and causal inference. One of the main approaches adopted in current literature to estimate the effects of famine, relies on variations in exposure to famine across cohorts.[3] A key

[2] See Strauss and Thomas (1998) for a comprehensive survey on the linkage between health and economic outcomes.

[3] Stein et al. (1975) used vital registration records to compare age-specific mortality rates for different cohorts, and found a sustained effect of the Dutch 1944–1945 famine on the mortality of those infants whose late gestation period coincided with the famine. Razzaque et al. (1990) estimated the long-term effects of the Bangladesh famine of 1974–1975 by examining three separate cohorts: famine-born, famine-conceived, and non-famine. Using the non-famine born cohort as the reference group, they showed evidence of higher mortality in famine-born and conceived cohorts. Using a similar approach, Roseboom et al. (2001) and Roseboom et al. (2003) found that prenatal exposure to maternal starvation in the Dutch 1944–1945 famine had lasting effects on health in adult life. Also see Hart (1993) and Lindstrom and Berhanu (1999) for a similar study of the impact of famine on nutrition, marital fertility, infant mortality, wage income and migration behavior.

idea behind this approach is that individuals born after a famine will not be affected by it, while those who are born during the famine may be affected differently from those conceived during the famine. Therefore, this source of variation across birth cohorts can be used to identify the effects of famine. But this approach may suffer from the possibility of confounding the effects of famine with intrinsic cohort effects. In other words, the observed difference in demographic effects (e.g., mortality rate) across birth cohorts may be a reflection of general cohort effects even without exposure to the famine.[4] Unless we can control the same set of cohorts in some regions not exposed to famine, it is hard to attribute these observed effects directly to famine.

In this paper, we are interested in identifying the long-term causal effects of the 1959–1961 famine on the health and economic outcomes of survivors. In particular, using a cross section sample of Chinese rural people born between 1954 and 1967, we try to estimate precisely to what extent the attained height of rural cohorts in adulthood was reduced by the exposure to famine in their early childhood, and how the resulting adverse health consequences impaired their labor supply behavior and family income. To our knowledge it is the first attempt to present the estimates of long-term effects of the 1959–1961 famine in the literature.

We find strong evidence that the great famine in 1959–1961 caused serious health and economic consequences for the survivors, especially for those who were in early periods of life during the famine. Our estimates show that on average, in the absence of the famine, individuals born in 1959 would have otherwise grown 3.03 cm taller. Quantile regressions present some evidence that the height reduction appears to be larger for the individuals with shorter heights. The famine also greatly impacted the labor supply and earnings of the survivors with famine exposure during their early childhood.

China's 1959–1961 famine provides a unique case for studying the long-term effects of famine in general. The uniqueness of this famine not only lies in its long time span,[5] unprecedented severity and scope of incidence, but also in its substantial variation across regions. The effects of famine were much more devastating in rural areas than in urban areas. Exposure to famine also varied greatly across provinces due to the variance in population density, exposure to bad weather and provincial response to food shortage, among many other contributing factors. Regional disparity in famine severity, combined with variations in health consequences across cohorts commonly exploited in the literature, provides us with a crucial source of exogenous variation to identify the causal effects of famine. A major innovation of this paper is to combine the variations of famine effects across regions and cohorts to construct a difference-in-difference (DID) estimator.[6] More specifically, we will introduce a key variable—the interaction terms between dummy variables indicating the birth cohorts and excess death rates of 1960 in the region where the cohorts were born to capture the causal effects of the famine on this particular cohort. Here, excess death rate of a region is a proxy for the severity of the famine.

China's institutional context during the famine period greatly alleviates a host of potential concerns surrounding the legitimacy of our DID estimation. As discussed above, sample selection problems constitute a serious challenge to any attempt to identify the causality between famine and its outcomes. However, China's rural situation in 1959–1961 considerably mitigates the potential

[4] Razzaque et al. (1990) noted that the excess mortality for famine-born cohorts identified by Stein et al. (1975) was actually a general cohort effect also observed in control regions without exposure to the famine.

[5] The Dutch 1944–1945 famine and Bangladesh 1974–1975 famine lasted only around one year.

[6] Similar strategies are used in the evaluation of the causal effects of social programs. For instance, Duflo (2001) relies on the variations across regions and cohorts to develop a difference-in-difference estimator to identify the effect of the school construction program on education.

selection into childbearing by social-economic status of parents. Following a series of political movements commencing in 1949, such as Land Reform, Agricultural Collectivization and the Great Leap Forward movement, there was no private ownership of land and other production tools and vehicles, and the virtual equalization of SES within and across communes occurred. In addition, China's residence registration system, which aimed at restricting migration and relocation, helps establish a very high correlation, especially in rural areas, between the region of birth and growing-up and the region of residence at the time of survey (1991). The strict prohibition of migration from rural areas during the famine period also limits the potential selection through migration.[7]

This paper contributes to our better understanding of the long-term effects of the worst famine in history. Evaluating the long-term effects of famine in the long run has traditionally been the sphere of medical researchers, demographers and historians and has received scant attention in economics literature. In this study, we try to conduct a serious econometric analysis and obtain more reliable estimates of the causal effects of famine. In many ways, our study also addresses the broader questions of how events in early life affect long-term health and economic outcomes and of how adverse health effects in early life affect labor supply and income in later periods. The research conducted in this paper closely relates to a burgeoning literature on the linkage between health, labor market outcomes and economic development (Strauss and Thomas, 1998). Fogel (1992, 1994) has convincingly established the relationship between aggregate movements in adult height and long-term changes in standard of living. Some other studies have devoted efforts to identifying the effects of health on wages and labor supply at an individual level (Strauss, 1986; Schultz and Tansel, 1997; Thomas and Strauss, 1997). In this paper, we offer indirect and supportive evidence on the linkage between health and labor market outcomes activated through the effects of famine.

The remainder of this paper is organized as follows. In Section 2 we briefly introduce the 1959–1961 Chinese famine. In Section 3 we describe the data. Section 4 discusses the identification strategy used to evaluate the effect of the famine on height and economic outcomes. Section 5 presents regression results on the sustained effect of the famine on the height, labor supply and income of survivors. Section 6 discusses the validity of the DID estimator and the fitness of OLS. Section 7 briefly concludes this research.

2. The 1959–1961 famine in China

China initiated an agricultural collectivization program in the early 1950s. After several waves of accelerated and sweeping collectivization, a nationwide "Great Leap Forward" movement began in 1958. All rural households were organized into many thousands of People's communes. In the following three years (1959–1961), agricultural production dropped sharply and the great famine ensued. The 1959–1961 famine was caused by a host of interrelated factors, such as bad weather, excessive procurement by the state, delayed response to the food shortage, weakened production incentives due to the sweeping collectivization program in 1958, and resource diversion as a result of massive industrialization (Eckstein, 1966; Ashton et al., 1984; Peng, 1987; Lin, 1990; Lin and Yang, 2000; An et al., 2001). Despite the debate on major sources of the 1959–1961 famine, no one will deny that the sudden, sharp drop in grain production in 1959–1961 was

[7] See Strauss and Thomas (1998) for more discussions on selective migration and its impact on the estimation of causal effect of health on wages.

directly responsible for the great famine. Prior to the 1959–1961 famine, China's grain output experienced steady growth and reached a peak of 200 million tons in 1958. In 1959, grain output dropped sharply by 15%, and in the following two years, the output continued to decline, only reaching about 70% of the 1958 record level (State Statistical Bureau, 1990). The declining trend in grain production came to a halt in 1962, and only by 1966 had total grain production recovered to the 1958 output level.

The prolonged and nationwide famine caused an unprecedented number of deaths. The estimated daily per capita availability of food energy during 1959–61 decreased considerably, falling well below average food energy requirements (about 2100 calories). The worst case occurred in 1960, with only 1500 calories (Ashton et al., 1984). As a result, national death rates were 14, 25, and 14 per thousand for the years of 1959, 1960, and 1961, respectively while the average death rate for 1956–1958 was only about 11 per thousand. Fertility rates also dropped sharply in the years 1959–1961. According to Peng (1987), total fertility up to age 39 was about 5.6 births per woman in pre-famine years, but this rate dropped to its lowest level, 3.06, in 1961. Some estimates show that the famine led to 23–30 million excess deaths and 30 million lost births (Ashton et al., 1984; Peng, 1987). The severity of the 1959–1961 famine went unnoticed outside of China until the release of demographic data by the Chinese government in the early 1980s.

Although almost every region was affected by the famine, the effect of the famine demonstrated considerable regional disparities. For example, food availability was much worse in rural areas than urban areas, due to the state's preferential treatment towards urban residents through grain rationing and the maintenance of state-controlled stockpiles. Exposure to the famine varied greatly across provinces because of the variances in the proportion of rural population, population density, exposure to natural disaster, and provincial response to food shortage. During the famine period, the inter-provincial shipment of grain encountered general resistance from well-supplied provinces, while the degree of resistance and the willingness to under-report grain production exhibited significant differences (Ashton et al., 1984; Lin and Yang, 2000).

The variation in the degree of famine can be measured by the disparity in regional excess mortality, which is defined as the deaths exceeding those that would have occurred under prevailing normal conditions. We calculate excess death rate as the difference between death rate in the famine year and average death rate during 1956–1958. Table 1 presents the death rates from 1956 to 1964 as well as excess mortality during the famine period for eight provinces. The death rates were relatively stable prior to 1959 for each province, but during 1959–1961, death rates rose sharply and were on average significantly higher than the years before and after the famine. The variations in excess death rates across regions were also relatively large, particularly in 1960, the worst year of the famine. In 1960, the excess death rates ranged from 4 per thousand in Liaoning to 35.4 per thousand in Guizhou. By contrast, the death rate in the periods 1956–1958 and 1962–1964 essentially remained at the normal level, and its variation across regions was also small.

3. Data

The individual-level data used in this study are drawn from the China Health and Nutrition Surveys (CHNS). These surveys were conducted by the Carolina Population Center at the University of North Carolina, Chapel Hill, The Institute of Nutrition and Food Hygiene, and the Chinese Academy of Preventive Medicine. The data can be found on the web site: http://www.cpc.unc.edu/projects/china. The data on excess death rates during the famine period 1959–1961 are adapted from Lin and Yang (2000).

Table 1
Death rates in the sampled provinces: unit 0.1%

Provinces	1956	1957	1958	1959	1960	1961	1962	1963	1964
Panel A: Death rates in the sampled provinces: 1956–1964									
Liaoning	6.6	9.4	6.6	11.8	11.5	17.5	8.5	7.9	9.3
Jiangsu	13	10.3	9.4	14.6	18.4	13.4	10.4	9	10.1
Shandong	12.1	12.1	12.8	18.2	23.6	18.4	12.4	11.8	12
Henan	14	11.8	12.7	14.1	39.6	10.2	8	9.4	10.6
Hubei	10.8	9.6	9.6	14.5	21.2	9.1	8.8	9.8	10.9
Hunan	11.5	10.4	11.7	13	29.4	17.5	10.2	10.3	12.9
Guangxi	12.5	12.4	11.7	17.5	29.5	19.5	10.3	10.1	10.6
Guizhou	7.5	8.8	13.7	16.2	45.4	17.7	10.4	9.4	10.5
Nation	11.4	10.8	12.0	14.6	25.4	14.2	10.0	10.0	11.5
Panel B: Excess death rates in the: sampled provinces: 1959–1961									
Liaoning				4.3	4.0	9.97			
Jiangsu				3.7	7.5	2.5			
Shandong				5.9	11.3	6.07			
Henan				1.3	26.8	−2.63			
Hubei				4.5	11.2	−0.9			
Hunan				1.8	18.2	6.3			
Guangxi				5.3	17.3	7.3			
Guizhou				6.2	35.4	7.7			
Average for sampled provinces				4.1	16.4	4.5			
Nationwide average				3.7	14.4	3.2			

Source: Panel A is adapted from Lin and Yang (2000), Table 3, P147. Excess death rates in Panel B are calculated as the difference between death rates in the famine year and the average of death rates in 1956–1958.

The CHNS was designed to examine the effects of health, nutrition, and family planning policies in China. The survey focuses on issues related to social economic change in China and the effect that these changes have on the health and nutritional status of its population. The survey collects detailed information about households and individual economic, demographic and social characteristics, community organizations, individual food consumption, nutrition intake and health status. There have so far been five waves of panel surveys conducted in 1989, 1991, 1993, 1997, and 2000, respectively. The 1989 survey included 3,795 households and, in 1991 and 1993, 3616 and 3441 households respectively, participated in the survey. In 1989, health and nutritional data was collected only from preschoolers and adults aged 20–45. The 1989 survey covered 15,917 individuals. All individuals in each household were surveyed in 1991 and 1993 for all data, although some households were lost from the data due to their migration to other communities.

The CHNS data cover eight provinces—Guangxi, Guizhou, Henan, Hunan, Jiangsu, Liaoning and Shandong that vary substantially in geography, economic development, public resources, and health indicators. In terms of living standards, Jiangsu, Liaoning and Shandong are among the richest provinces, Henan and Hunan among the middle, and Guangxi and Guizhou are among the poorest. Geographically, Jiangsu, Liaoning, Shandong and Guangxi are coastal regions while the other provinces are inland regions. A multistage, random cluster process was used to draw the sample survey in each of the provinces. In 1989–1993, there were the 190 primary sampling units, which consisted of 32 urban neighborhoods, 30 suburban neighborhoods, 32 towns and 96 suburbs.[8] In 1997, the survey designers dropped Liaoning province and added a new province (Heilongjiang). Liaoning province returned to the survey in 2000.

In this study we will mainly focus on a sub-sample of adult residents in rural areas who were born in a range of years before and after the famine period because rural residents were affected by the famine much more severely than urban residents. Urban samples will be considered only as a reference group. These birth cohorts include those affected by the famine and those who were not. As will be discussed below, varied exposure to the famine across cohorts constitutes an important source of identification in our empirical analysis.

Since our analysis mainly relies on the variations in exposure to famine both in regions and cohorts, the best we can utilize is a cross-sectional dataset. Given the availability of five cross-sectional datasets, which cover the absolute majority of the same individuals in different survey years, the choice of one particular survey year as the focus of the analysis is somewhat arbitrary. This paper will focus on the 1991 survey data since they provide us with the largest number of effective observations. Summary statistics of the key variables used in our analysis are given in Table 3.

4. Econometric issues

The study of long-term effects of famine on the health and economic status of survivors faces the challenge of how to build a causal link between famine and its effects. One of the main approaches to tackling the problem of causality is to seek a natural experiment, which creates exogenous variation in the exposure to the famine. In this paper we make use of two crucial sources of variation in the exposure to famine, namely, variations in effects of famine across cohorts and regions to construct a difference-in-differences estimator. In examining the effects of famine on health consequences, we will focus on the height of the survivors. We choose height as health indicator for three reasons: firstly, it constitutes an important aspect of health status of the individual; secondly, evidence shows that malnutrition in early life may have a sustained effect on ultimate height (see discussion below); and lastly, it is available in the dataset and easy to measure.

One of the crucial sources of variation exploited in this study is the effect of famine on the long-term growth potential of different cohorts during and after the famine. A person's height would not be affected by the famine if he or she was born after the famine period. Similarly, people who were over age 18 years during the famine had already attained their adult height. But for the cohorts that were in gestation up to 18 years of age in 1961, there is a high probability that their attained height could have been affected by the famine, although the effects might be very different. The population health literature presents strong evidence on long-term health effects of several crucial developmental periods, especially the fetal and infant periods. Under nutrition in early life may permanently alter the body's structure, physiology and metabolism, and thereby increase the susceptibility to disease in adult life (Barker, 1989, 1992).

Based on existing research published in population health literature, we can test one hypothesis that exposure to famine during the prenatal and early periods of childhood will exert larger effects than at other subsequent periods. As a result, this study will concentrate on one set of birth cohorts, namely those individuals who were born between 1959 and 1962. Given the fact that the famine exerted an influence mainly on residents born between 1959 and 1962, we restrict the sample of birth cohorts to five years before and after the famine period. As a result, the control group is

[8] In the context of China, suburban areas are usually treated as rural areas in terms of administration.

Table 2
The frequency of various birth cohorts in the sample

Birth cohorts	Rural sample		Urban sample	
	Frequency	Percent	Frequency	Percent
1954	159	8.14	69	7.27
1955	153	7.89	83	8.96
1956	161	8.29	80	8.43
1957	150	7.68	72	7.69
1958	152	7.83	58	6.11
1959	120	6.14	51	5.37
1960	105	5.43	62	6.53
1961	66	3.43	45	4.74
1962	140	7.17	62	6.53
1963	189	9.68	103	11.06
1964	160	8.24	80	8.43
1965	149	7.63	68	7.17
1966	133	6.81	71	7.48
1967	109	5.63	40	4.21
Total	1953	100	949	100

made up of those individuals who were born after the famine (i.e., from 1963 to 1969), and those born between 1954 and 1958.[9]

The frequency of birth cohorts in the rural and urban samples is illustrated in Table 2. In the rural sample, we observe a continuing decline in the number of observations for the birth cohorts 1959, 1960 and 1961, and then a strong rebound in the years 1962 and 1963. The most dramatic drop in observations occurred between 1960 and 1961 when the three-year famine got the worst in 1960. These dramatic changes surrounding the famine years exactly mirror general patterns in birth and death rates in China in the same period. According to a statistical report cited in Lin and Yang (2000),[10] China's death rate hit the record high in 1960 while the birth rate reached the record low in 1961. Peng (1987) mentioned that total fertility up to age 39 was about 5.6 births per woman prior to the famine, but this rate dropped to its lowest level, 3.06 in 1961. Subsequently, there was a dramatic rebound (over 100%) in birth rate between 1961 and 1962 as a response to improved situations in food supply. This implies that the dramatically changing patterns observed in our sample are not due to sampling errors. By contrast, urban residents suffered much less than their rural counterparts, and as a result, birth cohorts in the urban sample do not exhibit such dramatic changes as in the rural sample, although we also see a marked reduction in observations between 1960 and 1961.

The disparity in the effects of the famine across regions is another important component that we use to identify the long-term effects of the famine. As documented in Section 2, the severity of the 1959–1961 famine varied across regions. The excess death rate in Guizhou in 1960 was 36 per thousand, but only 4 per thousand in Liaoning province. Fig. 1 illustrates considerable variation in excess death rates across regions in our sample. The variation in severity of the famine would also have created different effects on the height attainment of affected individuals.

Using variations across both regions and birth cohorts in the exposure to famine to estimate the long-term effect of the famine raises several methodological concerns. First, our research

[9] Our empirical results remain qualitatively similar if we include more birth cohorts prior to 1954 or after 1967.

[10] Fig. 1 in Lin and Yang (2000, p. 142) depicts the birth rate and death rate in China from 1949 to 1989, using the data source published by the China State Statistical Bureau (1990).

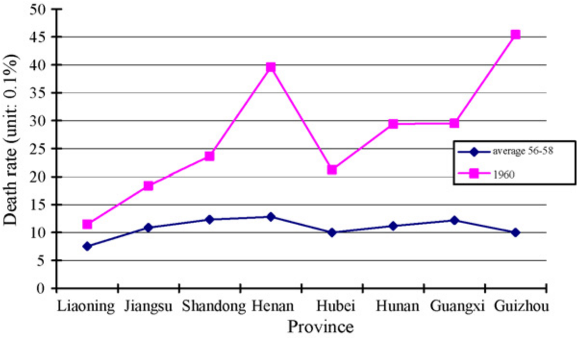

Fig. 1. Death rates in the sampled provinces.

program implicitly assumes that the region of birth must be highly correlated with the region of growing-up and of residence at the time of survey. This assumption needs to be justified before any analysis is conducted.

Before the 1990s, there were severe restrictions on migration and relocation in China. The restriction on regional mobility was made possible by a residence registration system, which was called the "*Hukou*" (residence booklet) system. Migration in the planned economy needed to be approved by authorities on a case-by-case basis. Rural residents faced even more severe restrictions on migration across localities. While migration based on individual free choice was prohibited before 1978, government-planned migration still occurred even during the most restrictive periods of China's centrally planned economy (Liang and White, 1996). However, there is evidence suggesting that the magnitude of these policy-driven migrations before 1978 was very small relative to the population at risk.[11] In our study, we will focus on rural samples because the correlation between region of birth and region of current residence is presumably high during the period covered by the study.[12]

Second, although there was a strict restriction on regional mobility in China, the great famine in 1959–1961 could have potentially caused widespread panic and an exodus of the population, as observed during famines in other countries. In fact, even when a number of the population died of starvation, large scale migration did not occur during the famine period. This is because all rural residents were organized into hundreds of thousands of People's communes that were managed in a quasi-military fashion and migration was completely monitored and prohibited. Anecdotal stories reveal that the cadres of People's communes appealed to village militiamen to confine hungry villagers within village boundaries, and any attempt to flee would invite harsh punishment.[13]

Third, since fertility may have responded to the famine, the identifying regional variation may not be exogenous. As the famine lasted nearly three years, childbearing fell substantially, as documented by several researchers (Ashton et al., 1984; Peng, 1987). Our sample also demonstrates such a marked fall in childbearing (see Table 2). The number of sampled individuals born during

[11] According to Liang and White's (1996) study of China's migration patterns based on China's 1% population survey in 1987, interprovincial migrants only accounted for 0.3–0.7% of the population at risk during the period 1959–1963.

[12] Our focus on rural samples is also based on the fact that rural areas were much more seriously exposed to famine than urban areas.

[13] Lin and Yang (2000, footnote 23, p. 145) mentioned an anecdotal story that a senior official from the Food and Agricultural Organization of the United Nations travelled around China for two weeks in 1960 without noticing the usual signs he observed in the incidence of famine in other countries.

the famine period exhibits a noticeable decline compared to those born before and after the famine, especially in rural areas. The sharpest fall occurred in the 1961 cohort, both in rural and urban areas. If this reduction in births was highly correlated with socioeconomic status (SES), then a problem of selection bias would occur. For example, if fertility was more responsive among those of relatively "high" SES, then more children may have been born into poor or less healthy parents during the famine, and this would cause a spurious correlation between exposure to famine and its effects on height and economic status.

We argue that given the rural situation in 1959–1961 in China, the problem of selection into childbearing during the famine will not be a serious concern if we mainly focus on rural samples. A crucial institutional fact we should keep in mind is that after Land Reform in 1952, Agricultural Collectivization in 1953–1956, and the Leap Forward Movement in 1958, landlords and rich peasants totally disappeared in rural areas. Especially in 1958, every peasant was organized into People's communes where property rights to land, cattle, agricultural vehicles, and other production tools were all owned by the communes, and no private ownership was allowed. Absurdly, villagers were even mandated to eat three meals a day in commune kitchens without paying bills, and the People's communes supplied all the food. Equality was expanded as far as to food consumption within the village. As a result of these institutional changes with the ultimate goal of eliminating private ownership and income inequality, a high degree of equalization of socioeconomic status across peasants in rural areas had emerged after 1958, and to a lesser extent in urban areas. The drastic change in income distribution in rural areas did not occur until the introduction of the household responsibility system in late 1979 in which the land was subcontracted to rural households. In this sense, the selection into childbearing by SES during the famine due to the differences in wealth or property between families would be considerably mitigated in the rural sample.

However, the selection into childbearing could still occur by other means, such as the health of parents. If more healthy parents tend to have fewer children, then more children in poor health could have been born. It is difficult to determine exactly the extent that this possibility became a reality during the famine, but it seems to us that if health was indeed a factor in selection, the opposite case might be more likely. This is because the deeply rooted Chinese culture of "more children, more happiness" encourages more births whenever possible. The strong desire for childbearing is constrained only by income and health conditions. This is especially true in rural areas. Therefore, if more healthy parents tend to bear a child, then this selection effect may cause under-estimation of the effect of famine.[14] In other words, our estimates may only provide a lower-bound estimation of long-term effects of the famine.

5. The long-term effect of the famine: basic results

5.1. The effects on height

We first quantify the lasting effects of the famine on attained height of the survivors by estimating the following equation:

$$H_{ijk} = C + \beta_k + \sum_{k=1954}^{1962} \gamma_k(\mathrm{edr}_j \times \mathrm{birth}_{ik}) + \delta \mathrm{edr}_j + \varepsilon_{ijk} \tag{1}$$

[14] We will discuss this selection problem in more detail in the next section.

where H_{ijk} is attained height (measured in centimeters) by maturity or in 1991 for individual i, born in region j, in cohort k. β_k are the cohort fixed effects, and edr_j are the excess death rate of region j in 1960, the worst year of the famine. We use excess death rate as a proxy of the severity of the famine. The excess death rate in 1960 is calculated as the gap between the death rate in 1960 and the average death rate in the three years before 1959. birth_{ik} is a dummy variable indicating whether individual i was born in the year k. Note that $k = 1962$ refers to a birth cohort in gestation in 1961 and born in 1962. We include this birth cohort because, as discussed in the previous section, the exposure to famine during the fetal period may exert significant effects on body composition and growth after birth, including height attainment.

The coefficient of the interaction between the excess death rate and birth cohort dummy variables measures the causal effect of the famine on height attainment. We expect that the magnitude of these estimated coefficients varies with birth cohorts. More specifically, we expect a larger impact of the famine on the relatively young birth cohorts, especially those who were in gestation and early childhood during the famine. The total sample includes those individuals born between 1954 and 1962 as the treatment group, and individuals born between 1963 and 1967, which are treated as the control group. In total, this sample covers 1,946 complete observations. In order to account for the potential correlation of observations within the same cluster, we will report standard errors clustered at provincial levels.

Columns (1)–(4) of Table 4 present the regression results estimating the long-term effect of famine on attained height. Note that the dummy variables for birth cohorts from 1954 to 1962 are controlled in the regressions in Table 4, but their coefficients are not reported due to space limitations. We mainly report the coefficients of interaction terms between excess death rate and birth cohorts, which, as discussed above, measure the estimated effects of the famine on height attainment. Column (1) of Table 4 reports regression results estimating Eq. (1) using the rural sample. It is clear that most famine-affected birth cohorts have shorter height than the counterfactual case that the famine had not occurred, which is reflected in the negative coefficients of the interaction terms. This implies that the famine generally caused adverse impacts on the growth of the survivors. Among the cohorts with adverse effects of famine, those birth cohorts of 1959, 1960, and 1962 have more severe and also statistically significant effects.

Interestingly, our results suggest that exposure to famine during early years of childhood gives rise to more devastating long-term effects in later life, which is consistent with general findings in population health literature (e.g., Barker, 1989, 1992; Heymann et al., 2005). The birth cohorts of 1962, and 1960 and 1959 have the largest coefficients in absolute value, and all are significant at the 5% level. The estimated coefficient on the interaction term between excess death rate and 1959 birth cohort is −0.185, which means that this cohort lost nearly 0.19 cm in attained height if excess death rate increases by one per thousand people in the region where this cohort were born. The average excess death rate for the sample provinces was about 16.4 per thousand in 1960. Therefore, on average, individuals born in 1959 would otherwise have grown 3.03 cm taller in the absence of the famine. Likewise, individuals born in the years 1960 and 1962 would have a 3 cm and 2.94 cm increase in height attainment, respectively if the famine had not occurred. The most striking result is that those who were still in gestation in the year 1961 also suffered very severely from the famine, closely similar to the 1960 cohort (the coefficient is −0.179). These economically important results demonstrate large and devastating effects of the great famine, which occurred 30 years ago, on the surviving population. They also lend strong support to the notion that exposure to adverse health shocks in early childhood as well as in the prenatal period translates into serious health consequences in adulthood.

The famine lasted from 1959 to 1961, but peaked in 1960, as shown by the death rates across provinces in Table 1. In view of this fact, one would expect that the largest effect on height reduction should appear in 1960. However, our estimated results show that the 1959 birth cohort suffered most severely, followed by the individuals born in 1960 and 1962, although the differences between them seem to be very small. The possible reason why the 1959 birth cohort suffered most severely from the famine is that the famine started in 1959 so the individuals born in 1959 had the longest duration of exposure (at least two full years just after birth) to the famine. The exposure duration also explains the diminishing effects in the years 1960 and 1962.

The only exception is the 1961 cohort whose interaction coefficient is positive, although statistically insignificant. As previously noted, due to the famine peaking in 1960, there was a dramatic, nationwide slump in birth rate in 1961. In our rural sample, the cohort size shrinks from 105 to 66 between 1960 and 1961. When food supply becomes critical, the selection into childbearing caused by the famine may prevail, namely, only the strongest babies (in the prenatal period) with normal heights or greater, surviving the year 1960—the worst year of the famine, while the weakest babies perished. In other words, the selection effect occurs through the health of parents, which, as previously discussed, is very likely to happen. This is because in the era of the Great Leap Forward, China's rural households were virtually economically equal but health conditions were not necessarily so uniform. The time-honored tradition of having more children would drive rural people to attempt childbearing even under very unfavorable conditions. While the selection of strong offspring is expected to exist during the whole famine period, the effect should be the greatest in 1961 since the food supply conditions in the previous year were the worst.

The stark contrast between urban and rural residents in their exposure to famine provides a good opportunity for a check on the robustness of our basic results obtained above. Urban residents suffered much less from the famine, due to the state's preferential policy towards the urban population, and furthermore, they tended to be more mobile than rural residents. Therefore, a weaker effect of famine is expected to appear in the urban sample. To check whether this expectation is valid, we rerun the regression using the urban sample, and the results are presented in Table A1 in Appendix A. Overall, there is no systematic pattern in the effects of famine on height, and we indeed find a much weaker effect of famine on urban residents than on rural residents, especially for the birth cohorts of 1959, 1961 and 1962 with negative interaction coefficients. In the urban sample, only the interaction coefficient of year 1962 is statistically significant. These findings are consistent with the population literature on the largest effect of negative environments in early life, or alternatively consistent with the mobility hypothesis: Very young birth cohorts were more likely to be living in their region of birth while older ones are less likely so.

5.2. The effects on labor supply

We have estimated the impact on height of the famine of 1959–1961 in the section above. The reduction in attained height, however, only reflects a part of the effects of famine on the survivors. A large body of literature has established that health will be rewarded in the labor market, particularly in developing countries (Haddad and Bouis, 1991; Strauss and Thomas, 1997, 1998). In light of this literature, it is very interesting to examine how the great famine affected the labor market consequences (labor supply and income) of the survivors whose health and development were adversely impacted.

It is worth noting that in addition to height the famine affected many other attributes of survivors, such as mental or cognitive development and physical strength, and even some non-health factors. The latter are all rewarded in the workforce but are only imperfectly correlated with attained height.

Our data do not permit us to measure these health dimensions other than height, so it is impossible for us to explore the specific mechanisms by which the famine affected the labor market outcomes. Despite these limitations, we can still obtain the total effect of famine on the economic outcomes of survivors by estimating its reduced-form effect. In other words, we can run a series of reduced-form regression models with economic measures as the outcome and the same set of covariates as in the height equations. If we believe the famine altered long-term economic status mainly through height and other dimensions of health capital, then we should see some strong negative effects of famine as shown in the height equations, although a perfect match in coefficient patterns between the height equation and labor supply or income equation may not be observed due to the multiplicity of ways in which the economic outcomes are affected by the famine.

Let us first estimate the potential effects of the famine on labor supply behavior of the survivors. Labor supply can be measured by annual total working hours for each individual in the sample. Total working hours typically consist of time spent on farming, home gardening, raising livestock, fishing, as well as time spent on non-agrarian uses, such as working in town and village enterprises. More specifically, we estimate the following labor supply equation using the log of annual total working hours as the dependent variable:

$$\log L_{ijk} = C + \beta_k + \sum_{k=1954}^{1962} \gamma_k(\mathrm{edr}_j \times \mathrm{birth}_{ik}) + \delta\mathrm{edr}_j + X\lambda + \varepsilon_{ijk} \tag{2}$$

where $\log L_{ijk}$ represents the log of total working hours in 1991 of the individual i, born in region j, in cohort k. Note that in our sample, each individual has a positive number of working hours in the whole year of 1991. Thus, our sample does not suffer from the problems of data censoring. As discussed above, the estimated coefficients, γ_k, represent the reduced-form effect of famine on labor supply of the survivors in rural areas. In contrast to Eqs. (1) and (2) adds a new set of control variables which capture the individual's personal characteristics affecting labor supply, denoted by X. They include years of schooling, age, age squared, a gender dummy variable, family size, employment status, thirteen occupation dummy variables, and four marriage status dummy variables.[15] The summary statistics of these control variables are given in Table 3.

The second column of Table 4 reports the OLS regression results estimating Eq. (2). Despite the fact that a number of birth cohorts do not yield expected effects of famine, we can still see a similar pattern of the effects of famine as shown in the height equation. Most importantly, the results show that the famine affected the 1959 and 1960 birth cohorts most severely: the total labor supply of the 1959 cohorts was reduced by approximately 1.7%, if the excess death rate in the region increased by 1 person per thousand people. For the 1960 birth cohort, the reduction in labor supply is even larger—2.1%. These two marginal effects are statistically significant at the 5% and 10% levels, respectively. Column (2) also suggests that the working hours of birth cohorts 1961 and 1962 were negatively affected by the famine, although the effects are not significant at conventional levels. These findings indicate that exposure to the famine in early life may cause lasting effects on labor supply behavior.

How is the effect of famine on labor supply related to its effect on health? Our data cannot explicitly establish the link between these two effects given the multiple linkages connecting famine, health and labor supply. Nevertheless, a comparison of the results in column (1) and

[15] Thirteen occupation dummy variables capture fourteen occupations, ranging from administrator, office staff to farmer/hunter/fisherman. Marriage status is characterized by five categories: (1) never married; (2) married; (3) divorced; (4) widowed; and (5) separated.

Table 3
Summary statistics

	N	Mean	S.D.	Min.	Max.
Attained height (cm)	1953	160.344	7.934	123	185
Excess death rate (0.1%)	1953	15.314	9.552	4	35.4
Log of annual total working hours	1899	6.001	0.849	0	7.598
Log of gardening hours	1899	2.019	2.211	0	6.735
Log of farming hours	1899	3.762	2.544	0	6.830
Log of agrarian income	1666	5.632	1.075	0.470	8.316
Log of farming income	1084	5.230	1.220	−1.163	7.813
Log of gardening income	1353	4.709	1.137	0.827	8.316
Years of schooling	1953	7.035	3.595	0	18
Gender (male = 1 female = 2)	1953	1.535	0.499	1	2
Age	1953	30.681	4.103	24	37
Family size	1951	4.320	1.357	2	12
Employment status (employed = 1, otherwiae 0)	1948	0.965	0.184	0	1
Log of house space per capita	1946	4.233	0.565	2.303	6.109

column (2) provides interesting hints about the linkage. We have previously found in column (1) of Table 4 that the 1959 and 1960 birth cohorts were the two cohorts that suffered the largest reduction in attained height. A similar pattern emerges in labor supply reduction: the 1959 and 1960 birth cohorts experienced the largest reduction in working hours. Furthermore, prenatal exposure to the famine negatively affected both health and labor supply. These similarities provide some evidence for the hypothesis that the effects of famine on labor supply may be mediated through its effect on health (proxied by attained height). We notice that the match in coefficient patterns in years 1959–1962 between the height equation and labor supply equations is not perfect. For example, the relative magnitudes in the interaction coefficient between 1959 and 1960 are reversed from column (1)–(2), and the signs of the coefficients in year 1961 are not the same. A possible interpretation for these inconsistencies is that attained height may not be perfectly correlated with other dimensions of health status.

In order to determine the robustness of the basic results, we use another measure of labor supply, i.e., annual working hours in home gardening, which constitutes only a part of total labor supply (approximately 12% in our sample). The choice of home gardening as our second measure of labor supply needs some explanation. Home gardening is an activity of Chinese peasants who work on private plots; small pieces of land near their place of residence.[16] Peasants plant vegetables and fruit on private plots mainly for supplementary cash income. They carry out home gardening usually in their leisure time after a day of intensive work in the farm, but this does not mean that home gardening is a form of relaxation. It can be very demanding of physical strength and skill. Given the supplementary nature of gardening activity, we expect that home gardening will be much more responsive at the margins to the health and strength of the farmer. Therefore, gardening working hours provides us an additional source of identification of the causal effect of famine on labor supply.

[16] The origin of private plots can be dated back to the early 1960s, immediately after the 1959–1961 famine. As a response to the food shortage in the famine period, a small area of private land was allotted to each rural household in 1963 to allow some supplementary sources of living, such as the planting of vegetables and fruit. Peasants had no legal, but *de facto* entitlements to private plots.

Table 4
The long term effects of the famine on height, labor supply and income

	Dependent variable						
	Attained height (cm) (1)	Log of annual total working hours (2)	Log of gardening hours (Tobit model) (3)	Log of annual per capita agrarian income (4)	Log of farming income (5)	Log of gardening income (6)	Log of house space per capita (7)
Excess death rate in 1960 (EDR)	−0.219 (0.018)***	0.012 (0.001)***	0.069 (0.015)***	0.001 (0.004)	−0.010 (0.006)	−0.002 (0.005)	−0.002 (0.003)
EDR × birth54	−0.093 (0.086)	0.009 (0.006)	−0.008 (0.031)	−0.004 (0.008)	−0.003 (0.012)	−0.001 (0.011)	−0.004 (0.003)
EDR × birth55	−0.099 (0.044)*	0.009 (0.001)***	−0.023 (0.031)	0.004 (0.007)	−0.004 (0.012)	0.001 (0.011)	−0.004 (0.003)
EDR × birth56	0.118 (0.061)*	0.010 (0.006)	−0.033 (0.033)	0.000 (0.013)	−0.016 (0.013)	0.005 (0.011)	−0.005 (0.005)
EDR × birth57	−0.141 (0.044)**	0.005 (0.003)	−0.025 (0.031)	−0.004 (0.009)	−0.011 (0.013)	0.006 (0.011)	−0.000 (0.004)
EDR × Birth58	0.047 (0.053)	0.010 (0.003)**	0.016 (0.034)	0.003 (0.009)	−0.005 (0.014)	0.007 (0.012)	−0.009 (0.004)*
EDR × birth59	−0.185 (0.053)**	−0.017 (0.006)**	−0.109 (0.040)***	−0.020 (0.009)*	−0.010 (0.016)	−0.024 (0.014)*	−0.010 (0.004)**
EDR × birth60	−0.183 (0.048)***	−0.021 (0.011)*	−0.122 (0.046)***	0.002 (0.006)	−0.043 (0.018)**	−0.002 (0.016)	0.003 (0.004)
EDR × birth61	0.036 (0.054)	−0.007 (0.005)	−0.024 (0.046)	0.022 (0.014)	0.025 (0.018)	0.018 (0.017)	0.001 (0.004)
EDR × birth62	−0.179 (0.051)**	−0.006 (0.004)	−0.011 (0.042)	−0.015 (0.013)	−0.024 (0.017)	−0.003 (0.015)	0.001 (0.007)
Constant	164.71 (0.415)***	24.60 (19.08)	−76.408 (57.160)	12.47 (25.04)	37.741 (23.104)	−2.878 (19.805)	5.008 (0.337)***
Observations	1946	1871	1871	1630	1068	1322	1874
R-squared	0.11	0.14		0.10			0.47

Note: Standard errors clustered at provincial level are reported in parentheses. The regressions in columns (2)–(7) include years of schooling, age, age squared, gender, family size, employment status, thirteen occupation dummy variables, four marriage status dummy variables, excess death rate, and birth cohort dummies. The significance levels of 1%, 5%, and 10% are denoted by ***, **, and * respectively.

Using the log of home gardening hours as the dependent variable has its problem: there is a positive measure of individuals (approximately one third) in the whole sample collapsing at zero value. The data-censoring problem justifies the use of a Tobit model. Regression results are reported in the third column of Table 4. Again, we find the most significant and largest effect of famine on labor supply in home gardening for the 1959 and 1960 cohorts. The negative effects are also identified for cohorts 1961 and 1962, though are not significant at conventional levels. These coefficient patterns seem qualitatively similar to the findings in total working hours regression.

However, there are some interesting differences. Comparing the magnitudes of the effect of famine between column (2) and (3) of Table 4, we find that the marginal effects of famine are much larger for home gardening than for total working hours. For example, the marginal effect of famine for cohort 1959 on labor supply in home gardening is approximately 11% if the excess death rate increases by 1 per thousand people, more than six times of marginal effect on total labor supply. This result exactly confirms our expectation that the response of labor supply in home gardening is much more elastic to the condition of health than that of labor supply in other more "essential" activities, such as farming. So this evidence further increases our confidence that we are identifying the causal effects of famine on health and economic consequences.

5.3. *The effect on income*

To precisely measure the income for an individual in rural areas is somewhat difficult, mainly due to the fact that family members commonly work together on their allotted farmland and individual contributions to the family income might be indistinguishable. In addition, the majority of rural peasants were self-employed, and only very few of them earned wages in township-village enterprises. As an alternative, we use three measures of per capita family income to proxy an individual's annual income. The first is log of annual per capita agrarian income, the second, log of annual per capita farming income, and the third, log of annual per capita home gardening income. All these income measures are closely related to the physical strength and health of the individual.

Columns (4)–(6) in Table 4 report OLS regression results estimating the sustained effect of famine on the income of the famine survivors.[17] Column (4) uses log of annual per capita agrarian income as the dependent variable. Two birth cohorts—1959 and 1962, are affected most severely by the exposure to the famine, and their coefficients are −0.020 and −0.015, respectively. The former is significant at the 10% level. This means that for the 1959 cohort, the annual per capita agrarian income decreases by approximately 2% if the excess death rate in the region of birth increases by 1 person per thousand. Using the log of annual per capita farming income as the dependent variable we obtain a slightly different result. Now the most severely affected cohort is the 1960 cohort, whose estimated coefficient is −0.043, which is significant at 5% level. For the 1962 cohort, the effect of famine becomes slightly more serious on per capita farming income than on per capita agrarian income, as shown by the difference between its coefficients in column (4) and (5). Column (6) reports the results using the log of annual per capita home gardening income as the dependent variable. The results show that 1959 birth cohort suffered a relatively large and significant reduction in home gardening income due to the exposure to the famine.

[17] There is a positive measure of zero values on all three per capita income measures. Since all these income measures are only available at household level and individual contributions are indistinguishable, a Tobit model may not apply here due to the lack of detailed information on an individual's participation in various income-generating activities. Therefore, we only report OLS regression results.

Annual income may vary from year to year, so annual income proxies as a measure of long-term earnings are subject to volatility. A good indicator to reflect long-term earnings is the value of assets. Our dataset includes detailed information on the quantities of durable consumer goods (such as a refrigerator), house space, etc. for each household. However, we do not know the prices at which these durable goods were purchased and what their resale values are, so we face a problem of aggregation if we want to construct the value of assets held by each household. As a compromise, we choose the house space per capita as an alternative measure of household wealth for the following reasons: (a) House property is generally thought to be the most valuable asset for rural households in China, and as a matter of routine each household desires to build a large house whenever possible; (b) the space of a house can be comparable to a large extent across households in small rural localities sharing similar tastes for construction style and building materials. The major problem with this new measure lies in its lack of information on house quality. The regression results using the log of house space per capita as dependent variable are reported in column (7) in Table 4. It is shown that in terms of the reduction in house space, cohort 1959 suffered most severely from the famine and the effect is significant at the 5% level.

The precision of the estimates obtained from income and wealth equations may be contaminated by measurement errors when per capita household income or wealth are used to measure individual earnings. In addition, lack of information on an individual's participation in various income-generating activities prevents the application of the Tobit model to deal with a positive measure of zero values of dependent variables. These data limitations probably explain why the consistency of the results between income equations and height equation appears less satisfactory than that between labor supply equations and height equation. Despite these potential problems, regression results from income and wealth equations still provide certain support to the general finding that adverse events in early life tend to have a large and sustained effect on earnings in later life.

6. Specification tests

6.1. Test of the assumption of difference-in-differences estimation

We rely on a difference-in-differences method to identify the causal effects of the famine on health and socioeconomic status of the survivors. In order for the DID estimator to remain free from bias, changes in the excess death rate should not be systematically related to other omitted factors that also affect height. To check this, we use a sub-sample of individuals who were born between 1963 and 1966, i.e., in the aftermath of the famine. Since none of these birth cohorts were ever directly exposed to the famine, we expect that the great famine would not produce any negative effects on them. Using the cohorts of 1967 as the control group,[18] the regressions reported in Table 5 examine whether the famine affected birth cohorts of 1963–1966 who were not exposed to the famine. As clearly shown, no matter which dependent variable is employed, the effects of the famine for these cohorts either have the wrong sign, or do not have any statistical significance. This experiment strongly suggests that our DID estimator works quite well in this case.

6.2. Quantile regressions

Is the OLS regression a good fit for our estimation? Since the great famine is likely to have different effects on survivors, one may raise the question concerning whether the OLS regression

[18] This cut-off age is somewhat arbitrary, but we alternated different cut-off cohorts and obtained similar results.

Table 5
The test of the assumption of difference-in-differences estimation

	Attained height	Log of total working hours	Log of gardening hours	Log of annual agrarian income per capita	Log of farming income	Log of gardening income
Excess death rate in 1960 (EDR)	−0.281 (0.056)***	0.004 (0.009)	0.052 (0.022)**	0.011 (0.011)	−0.012 (0.015)	−0.010 (0.013)
EDR × birth1963	0.077 (0.070)	0.009 (0.011)	−0.030 (0.027)	−0.004 (0.014)	0.004 (0.019)	0.001 (0.016)
EDR × birth1964	0.027 (0.068)	0.010 (0.011)	−0.009 (0.027)	−0.016 (0.013)	−0.005 (0.018)	0.003 (0.015)
EDR × birth1965	0.110 (0.070)	0.006 (0.011)	−0.016 (0.027)	−0.015 (0.013)	−0.001 (0.018)	−0.004 (0.016)
EDR × birth1966	0.069 (0.070)	0.002 (0.011)	0.011 (0.027)	−0.001 (0.014)	0.019 (0.019)	−0.006 (0.016)
Constant	181.599 (1.328)***	5.963 (0.210)***	−0.894 (0.516)*	5.654 (0.265)***	5.923 (0.384)***	4.818 (0.314)***
Observations	742	711	711	621	424	499
R-squared	0.54	0.05	0.17	0.08	0.12	0.10

Note: Standard errors clustered at provincial level are reported in parentheses. The dummy variables for various birth cohorts and excess death rate are controlled in the regression. The significance levels of 1%, 5%, and 10% are denoted by ***, **, and * respectively.

is the best fit for our study. This is especially so for height regressions. Given the same exposure to the famine, we would expect a larger effect on individuals with shorter heights, but not those with normal heights. In order to uncover a finer grained effect of famine, we alternatively adopt quantile regression estimation. Table 6 presents the quantile regression results estimating the effects of famine on height.

For an illustration of the difference between ordinary least squares and quantile regression estimates, we pick the effects of famine on birth cohorts 1959 and 1960 as an example. The details can be found in Fig. 2, which plots nine distinctive quantile regression estimates for two birth cohorts, with the quantile scale ranging from 0.1 to 0.9 as the solid curves with filled dots. Each of the plots has a horizontal quantile, and the vertical scale represents the effect of famine on height. In each panel, the two dotted curves represent a 95% point wise confidence band for the quantile regression estimates. The solid line with filled dots in each panel indicates the OLS estimate of the conditional mean effect, and the two dashed lines represent the 95% confidence intervals for the OLS estimate.

Close inspection of the plots in Fig. 2 reveals that if there is any difference between OLS and quantile regression estimates, we can discern a somewhat imperfect pattern in which the effects of famine appear to be larger in the lower quantiles of the distribution (i.e., the individuals

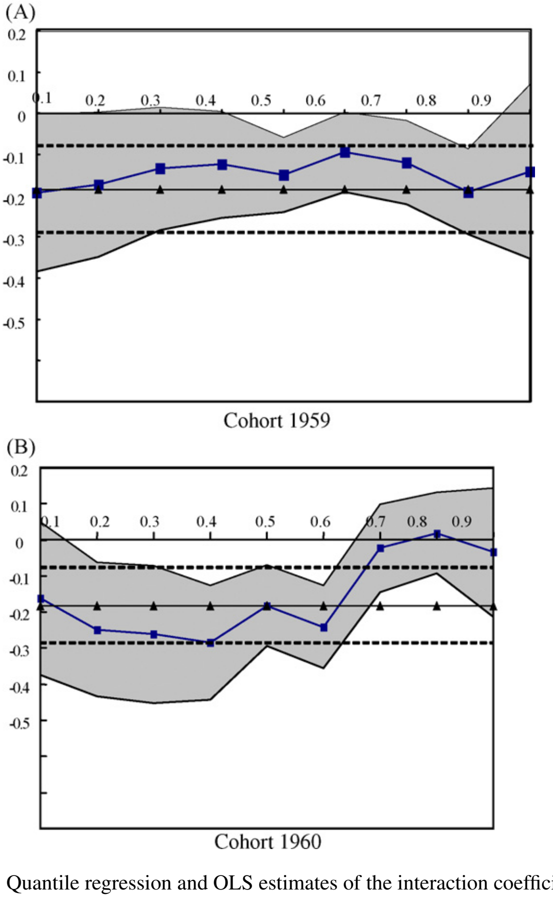

Fig. 2. Quantile regression and OLS estimates of the interaction coefficients.

Table 6
Quantile regression estimating the effect of famine on attained height

Quantile	Dependent variable: attained height (cm)								
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Excess death rate in 1960 (EDR)	−0.239 (0.044)***	−0.271 (0.036)***	−0.232 (0.029)***	−0.252 (0.025)***	−0.239 (0.017)***	−0.239 (0.017)***	−0.217 (0.019)***	−0.185 (0.019)***	−0.202 (0.041)***
EDR × birth54	−0.108 (0.072)	−0.041 (0.072)	−0.098 (0.061)	−0.090 (0.054)*	−0.083 (0.038)**	−0.097 (0.039)**	−0.106 (0.046)**	−0.064 (0.050)	−0.038 (0.110)
EDR × birth55	−0.061 (0.088)	0.007 (0.085)	−0.028 (0.066)	−0.072 (0.057)	−0.039 (0.038)	0.000 (0.039)	−0.063 (0.044)	−0.160 (0.047)***	−0.164 (0.099)*
EDR × birth56	−0.058 (0.085)	0.083 (0.079)	0.032 (0.064)	0.045 (0.057)	0.132 (0.039)***	0.124 (0.040)***	0.106 (0.043)**	0.152 (0.043)***	0.159 (0.102)
EDR × birth57	−0.129 (0.105)	−0.039 (0.078)	−0.091 (0.062)	−0.119 (0.054)**	−0.098 (0.038)***	−0.110 (0.040)***	−0.124 (0.045)***	−0.081 (0.047)*	−0.063 (0.087)
EDR × Birth58	−0.218 (0.097)**	−0.050 (0.087)	−0.126 (0.069)*	−0.060 (0.062)	−0.004 (0.041)	−0.008 (0.042)	0.044 (0.047)	0.056 (0.048)	0.132 (0.098)
EDR × birth59	−0.193 (0.098)**	−0.173 (0.090)*	−0.134 (0.076)*	−0.124 (0.066)*	−0.149 (0.046)***	−0.094 (0.049)*	−0.119 (0.052)**	−0.190 (0.053)***	−0.141 (0.108)
EDR × birth60	−0.162 (0.108)	−0.248 (0.095)***	−0.262 (0.097)***	−0.285 (0.081)***	−0.182 (0.057)***	−0.241 (0.058)***	−0.023 (0.062)	0.019 (0.057)	−0.035 (0.091)
EDR × birth61	0.153 (0.134)	0.172 (0.122)	0.032 (0.093)	0.106 (0.077)	0.118 (0.053)**	0.073 (0.057)	0.049 (0.063)	0.041 (0.064)	0.045 (0.135)
EDR × birth62	−0.180 (0.114)	−0.139 (0.093)	−0.185 (0.079)**	−0.158 (0.071)**	−0.016 (0.047)	−0.033 (0.050)	−0.074 (0.053)	−0.182 (0.053)***	−0.068 (0.104)
Constant	174.060 (1.163)***	177.483 (0.973)***	178.864 (0.786)***	180.712 (0.682)***	181.949 (0.459)***	182.955 (0.475)***	183.893 (0.520)***	185.039 (0.518)***	185.970 (1.103)***
Observations	1946	1946	1946	1946	1946	1946	1946	1946	1946

Note: Standard errors clustered at provincial level are reported in parentheses. All regressions include excess death rate and birth cohort dummies. The significance levels of 1%, 5%, and 10% are denoted by ***, **, and * respectively.

with shorter heights) while the effects appear to be smaller in the upper tails of the distribution. However, we must be aware that for two panels in Fig. 2, this pattern is not consistent and the quantile regression estimates appear to "fluctuate" across different quantiles. Despite some degree of irregularity, quantile regressions still offer us a richer picture of the famine effect across different quantile points of the distribution than least squares regressions.[19]

7. Conclusion

The famine of 1959–1961 in China not only killed over 20 million people, but also dramatically damaged the health of survivors in later life. Using a unique individual level dataset, this paper examines the long-term effects of the famine on the health and economic status of the survivors. While the main approach adopted by many previous studies relies on the variations in exposure to the famine by different cohorts (i.e., famine-born, famine-conceived, and non-famine cohorts), we construct a difference-in-difference estimator by using the variations in exposure to famine both across regions and across cohorts. We find that the great famine in 1959–1961 caused serious health consequences for the survivors, especially for those who were young during the famine. Our estimates show that on average, in the absence of the famine, individuals born in the year 1959 would otherwise have grown significantly taller, worked longer hours and earned much more income. These empirical findings strongly suggest that the great tragedy in 1959–1961 has a considerable sustained welfare impact on the survivors more than 30 years later.

Although it presents some interesting results on the effects of famine, this paper has its potential limitations. Here we emphasize two of them. Firstly, our study relies on a relatively small sample. The data include a sample of nearly 2000 observations from eight provinces and 14 birth cohorts, and consequently there are less than 20 observations across provinces and cohorts. The generality of our estimates of the famine effects remains to be tested upon a large sample. Secondly, the estimates of the effects of famine on labor supply and income are simply derived from a set of reduced-form regressions, leaving unexplored the specific mechanisms through which exposure to famine during early childhood translates into economic outcomes in later life. The existing literature highlights health as the key channel linking famine exposure and economic outcomes. However, the multiplicity of the dimensions in health capital at risk because of famine exposure and with only one dimension (attained height) available for analysis prevents any attempt to open up this black box. In this sense, our empirical analysis only provides some indirect evidence on the potential linkage between health and economic outcomes triggered by the great famine. A detailed exploration of transmission mechanisms from the famine to its effects on labor market outcomes as well as the role of health capital will be an interesting topic for future research.

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[19] We also apply quantile regressions to labor supply and income equations and obtain similar results.

Appendix A

See Table A1.

Table A1
The long-term effect of the famine on attained height: urban sample

	Dependent variable: attained height (cm)
Excess death rate in 1960 (EDR)	−0.273 (0.024)***
EDR × birth54	0.116 (0.066)
EDR × birth55	0.209 (0.078)**
EDR × birth56	−0.039 (0.058)
EDR × birth57	−0.116 (0.078)
EDR × birth58	0.044 (0.048)
EDR × birth59	−0.010 (0.112)
EDR × birth60	0.099 (0.119)
EDR × birth61	−0.098 (0.131)
EDR × birth62	−0.146 (0.060)**
Constant	167.999 (0.491)***
Observations	944
R-squared	0.11

Note: Standard errors clustered at provincial level are reported in parentheses. The dummy variables for various birth cohorts and excess death rate are controlled in the regression. The significance levels of 1 % and 5% are denoted by *** and ** respectively.

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