The Causes of China's Great Famine, 1959-1961: County-Level Evidence*

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First Draft: February 23, 2017

Abstract

This paper provides evidence that over-export of grains aggravated the severity of China's Great Famine. We collect the *county-level* information on the death rate, the birth rate, the procurement amount of grains, the output of different types of grains, crop productivity, weather condition, and distance to railroad in 1953-1965. We exploit the county-level variation in the types of crops each county specialized in to construct Bartik style measures for export shocks and regress the death rates on the Bartik measures. The regression result suggests that the effect of grain exports on the excess deaths is substantial, estimated at 12 percent of excess deaths in 1960. We also estimate the determination of procurement policy as well as the causal relationship between the death rates and the consumption per capita at the county-level during the famine period, and conduct counterfactual experiments to quantify the relative importance of different causes of the Great Famine. The counterfactual experiments indicate that that the effect of grain exports explains 10 percent of excess deaths, which amounts to 1/5 of the effect of increase in procurement rate between 1957 and 1959. In addition, 55 and 43 percent of excess deaths were attributed to the surge in procurement rate and the fall of agricultural production, respectively.

*We thank Vanessa Alviarez, Matilde Bombardini, Nicole Fortin, Keith Head, Thomas Lemieux, Kevin Milligan, and Tomasz Swiecki for their comments and suggestions. All errors are on our own.

1 Introduction

During 1959 to 1961, a famine raged across China and resulted in 16.5 to 30 million excess deaths and 30 to 33 million lost or postponed births. In terms of population loss, this famine is the worst famine in human history. The existing literature suggests that the Great Famine is a consequence of multiple interrelated institutional failures, which led to a collapse of agriculture production in 1959 and the over-procurement of grains in rural areas in 1960 (Lin, 1990; Lin and Yang, 2000; Li and Yang, 2005; Meng et al., 2015).

This paper examines one of the underlining causes of the over-procurement of grains: the export of grains. Between 1957 and 1959, despite the shortage of foods, Chinese government increased the total grain exports by a factor of 2 from 1.9 to 4.1 million tons (Figure 1) to secure foreign currencies for repaying foreign loans from the Soviet as well as for importing industrial equipment to promote Great Leap Forward (GLF). As is pointed out by Ashton et al. (1984), Johnson (1998) and Riskin (1998), massive excess death might have been avoided had the government acted swiftly to stop exports and start large-scale imports of grains. In fact, 9.6 million tons of total exported grains during the GLF period are equal to caloric needs of 16.7 to 38.9 million people for three years and, therefore, it is natural to infer that grain exports may be one of the leading causes of over-procurement. There is, however, no existing study that quantitatively assesses the importance of exporting grains in explaining the increase in death rates during the Great Famine.

What would have happened to the death rates across different regions in China in 1960 had there been no increase in export of grains so that 2.2 million tons of grains had not been procured by the government in 1960? How important an increase in grain exports is to quantitatively explain an increase in the death rates between 1957-1960 relative to other factors such as a fall in aggregate food production in 1959? To answer these questions, we collect the *county-level* information on the death rate, the birth rate, the procurement amount of grains, the output of different types of grains, crop productivity, weather condition, and distance to railways in 1953-1965 from various sources, some of which had been classified documents until very recently. Using the cross-county variation in crop compositions together with weather shocks as instrument, we estimate the differential impact of grain exports across counties on the death rates in 1960.

The use of the newly constructed county-level data set is the major thrust of this paper because almost all existing empirical studies on the causes of Great Famine use province-level data.[1] In Figure 2, the cross-county mean of death rates sharply increases during the famine period of 1958-1961; at the same time, the coefficient of variations across counties also increases, indicating the presence of substantial heterogeneity in famine severity across counties. Variance decomposition indicates that the majority of cross-county variations on the changes in death rates from 1957 to 1959 is within province rather than across provinces. Figure 3 presents the "heat map" for geographic distribution of the death rates in China, revealing a substantial variation in death rates across different counties in both 1957 and 1960. The heat map in 1957 is, however, very different from the heat map in 1960 because the county with low death in 1957 often experienced high death in 1960. These facts suggest the importance of investigating county-level data over time.

We take two different approaches to quantify the impact of grain exports on death rates in 1960 and its importance relative to other factors. First, we exploit the county-level variation in the types of crops each county specialized in and construct Bartik style measures for export shocks as $\sum_k \frac{Y^k_{i,57}}{Y^k_{57}} \frac{EX^c_t}{Pop_{it}}$, where the sum is taken across five different crop types (rice, soybean, wheats, potatoes, and others), $\frac{Y^k_{i,57}}{Y^k_{57}}$ is county i's share in output of crop k in 1957, EX^k_t is China's total export of crop k in year t. We regress the death rate on this Bartik measure together with other controls and county-fixed effects using the county-level panel data. We find that the estimated coefficient of this Bartik measure is significantly positive and large in magnitude, indicating the importance of an increase in grain exports to explain the variation in death rates across counties in 1960. Taking the difference in death rates between 1958 and 1960 as the baseline "excess death rates," the estimate indicates that, on average across counties, 12 percent of total excess deaths can be explained by an increase in grain exports between 1957 and 1959.

Second, as a more structural approach, we estimate the determinants of procurement policy as well as the causal relationship between the death rates and the consumption per

[1] The exception is Meng et al. (2015), who also employ county-level analysis to complement their province-level main results.

capita during the famine period.

Motivated by the province-level evidence on the importance of progressive and inflexible procurement policy in Meng et al. (2015), we estimate how the procurement rate is determined by the current output, the two-period lagged output, and distance to railway at the county-level across the GLF period and the non-GLF period. The result indicates that a procurement policy during the GLF period was much more progressive and inflexible than during the non-GLF period. Procurement rate during the GLF period was increasing in two-period lagged output (progressiveness) but was not affected by contemporaneous output (inflexibility), suggesting that any counties that had decreased their outputs relative to two years ago would have been over-procured and in shortage of foods during the GLF period; in contrast, procurement rate during the non-GLF period was found to be more responsive to contemporaneous output than during the GLF period.

When we split the data into counties located nearby railways and those located far away from railways, we find that a procurement policy in counties located nearby railways is more progressive but less inflexible during the famine period than in counties located far away from railways; counties located nearby railways are easier to procure due to low transportation cost, leading to higher degree of progressiveness, while food could be given back in the event of a verified shock to production, where a verification of food shortage would have been easier in counties located nearby railways than in counties located far away from railways.

To investigate how the consumption shortage due to over-procurement led to higher death rates, we non-parametrically estimate the relationship between the death rates and the retained consumption per capita using the county-level data while controlling for possible measurement errors due to mis-reporting of outputs and procurements using weather shocks as a source of exogenous variations. The estimate shows that the death rate is a decreasing function of consumption per capita, where the death rate sharply increases as consumption per capita decreases below 1800 calories.

Based on the estimated procurement policy and the estimated relationship between the death rate and the consumption per capita, we conduct the following counterfactual experiments at each county to quantify the relative importance of different causes of excess deaths in 1960: (i) what if there had been no fall in agriculture production between 1957 and 1959 while keeping the procurement rate as in 1959, (ii) what if there had been no increase in procurement rate between 1957 and 1959, and (iii) what if the procurement rates had been lower because 2.2 million tons of grains had been domestically consumed in rural areas rather than exported to foreign countries.

The counterfactual experiments given the estimated (progressive and inflexible) procurement policy during the famine period indicate that the excess deaths in 1960 would have been: (i) lower by 44 percent if the agriculture production in 1959 had been the same as in 1956, (ii) lower by 57 percent if the procurement rate in 1960 had been the same as in 1957, (iii) lower by 10 percent if the amount of grain exports in 1960 had been the same as in 1957. The result suggests that the effect of grain exports on the excess deaths is substantial, estimated at 10 percent of total excess deaths, explaining nearly one fifth of the effect of increase in procurements.

We also examine the extent to which the progressiveness and inflexibility of procurement policy during the famine period is responsible for the excess deaths by conducting the counterfactual experiment of what if the procurement policy in 1959 had been the same as the procurement policy in 1957. The result shows that the excess deaths in 1960 would have been lower by 28 percent if the procurement policy in 1959 had been the same as in 1957. While the effect of increasingly progressive and inflexible procurement policy is considerable, the change in procurement policies alone cannot explain a large portion of the increase in excess deaths between 1958 and 1960. Similarly, conducting the counterfactual experiment of what would have happened to the death rate in 1958 if the procurement policy in 1957 had been the same as in 1959, we find that the death rate in 1958 would have been higher by 16 percent; the introduction of more progressive and inflexible policy in 1957 would have resulted in substantially higher death rates in 1958 but its severity would have been less than one-sixth of the Great Famine.

Our study complements the literature on the causes of China's Great Famine in several ways. First, this paper is the first in the literature to provide empirical evidence at micro-level to show that over-export of grains is associated with the spatial pattern of famine severity. Second, this paper is also the first in the literature to attempt to quantify the relative importance of different causes using the estimated procurement policy and the estimated relationship between the death rate and the retained consumption; a fall of agriculture production, an increase in procurements, and an increasingly progressive and inflexible procurement policy all contributed to total excess deaths; no single factor can explain all of the excess deaths. Third, unlike the previous studies that mainly rely on province-level panel data, we compile a unique dataset on famine severity, grain production and export exposure at county-level. We conduct our analysis using cross-county within-province variation in order to better account for the unobserved heterogeneity across provinces; controlling for province-level fixed effects is important in this context because many political factors could be operating at the province-level.

The remainder of this paper is organized as follows. Section 2 introduces the background of the Great Famine and the role of international trade while providing the literature reviews. Section 3 describes the dataset. Section 4 presents the spatial distribution of famine severity and underlines the importance of within-province cross-county heterogeneity. Section 5 lays out the theoretical framework and empirical strategy. Section 6 provides empirical evidence that over export of grains during famine years aggravated famine severity and that procurement policies became more rigid during the GLF period. Section 7 presents counterfactual experiments.

2 Background

In this section, we briefly discuss about the background of China's 1959-1961 famine, including rural institutions, the basic facts of this demographic crisis and the role of international trade.

2.1 Rural Institutions

The Communist Party of China (CCP) started collectivization in 1952, in the hope of transforming Chinese agriculture from fragmented household farming into large-scale mechanized production. The initial phase of collectivization (1952-1957) was cautious and smoothed. The production unit was in the form of elementary or advanced cooperative, and usually consisted of 20 to 200 households. Peasants joined the various forms of cooperatives on a voluntary basis and retained the right of withdrawal. Production was planned and organized at the level of cooperative and a household's income depended on their inputs of land, capital goods and labor. In the period 1952-1957, agricultural output grew continuously at an average annual rate of 4.6%. (Lin, 1990; Li and Yang, 2005)

In 1958, the CCP launched the Great Leap Forward movement and adopted radical heavy-industry oriented policies. To achieve the lofty goals set by the GLF, more resources had to be extracted from the vast rural sector which consisted of approximately 80% of the population at the time. Being impatient of the lukewarm growth in agricultural output, the central planner decided to take an aggressive approach and further amalgamate rural collectives into massive communes. By the end of the year, 24,000 communes had been set up, with an average size of 5000 households and 10,000 acres. Compulsory participation in communes became an official policy, and private property rights of lands and capital goods were deprived. Harvest and storage of agricultural goods were conducted at the commune level and private markets for trading foods were virtually eliminated. Peasants no longer received pecuniary rewards for their effort input but instead free foods were supplied in communal mess halls. The communal movement, nevertheless, was followed by the collapse in agricultural outputs. The grain output plunged by 15% in 1959 and reached only about 70% of the 1958 level in 1960 and 1961. (Lin, 1990; Lin and Yang, 2000; Li and Yang, 2005; Meng et al., 2015)

Aside from production, the distribution and consumption of grains were also intensively controlled by the central government. Under an in-kind agricultural tax system, the central planner set a target of grain procurement to meet the needs of planned urban consumption, industrial inputs, reserve requirement and international trade. After harvests, local governments collected grains to fulfill their quota obligations, and peasants kept grains retained after the procurement. This system was progressive and rigid in the sense that local mandatory quotas were set prior to a agricultural season according to the region's past grain output, and might not be adjusted to the actual quantity harvested. To fund the GLF campaign, the government raised the procurement of grains from 46 million tons in 1957 to 52 million tons in 1958, and the total procurement reached 64 million tons in 1959 when the grain output slumped.(Lin and Yang, 2000; Meng et al., 2015)

2.2 The 1959-1961 Great Famine

The Great Famine over 1959-1961 resulted in 16.5 to 30 million excess deaths and 30 to 33 million lost or postponed births.[2] According the official statistics, the national death rate jumped from 11.98 per thousand in 1958 to 25.43 per thousand in 1960 when the famine was most severe. In the meanwhile, birth rate dropped from 29.22 to 20.86 per thousand. Although the famine is a nationwide calamity, there existed considerable differences in famine exposures across regions. For example, while Jiangsu province had an rise in death rate from 9.4 to 18.4 per thousand from 1958 to 1960, its neighbor Anhui province experienced a dramatic increase in death rate from 12.3 to 68.6 per thousand. Moreover, the famine was largely restricted to the rural sector for two reasons. First, the central government gave high priority to urban grain supplies, and hence urban food rations were seldom below the subsistence level. Second, stringent controls over rural-urban migration and even rural-rural migration prohibited starving people from fleeing famine stricken regions. (Lin and Yang, 2000; Meng et al., 2015)

The extant literature on China's Great Famine debate on the primary cause that leads to the nationwide calamity. The first strand of causes are the factors that explained the sudden decline in food-availability. They include factors attributing to the plunge in agricultural output, e.g., a succession of natural disasters (Yao, 1999), forced commualization and removal of exit right (Lin, 1990), diversion of resources from agricultural to heavy industry due to the GLF (Li and Yang, 2005), and also factors causing the waste of food, e.g., consumption inefficiency in commune mess halls Chang and Wen (1998); Yang and Su (1998). The second list of causes focus on the factors resulting in entitlement failures, which include over-procurement of grains from rural sector because of urban-biased food policy (Lin and Yang, 2000), and the rigid and progressive procurement policy that caused over-procurement of grains from regions that suffered larger negative productivity shock (Meng et al., 2015). The literature also point out the macro implications of the surge in net grain export in the period 1958-1960. (Ashton et al., 1984; Johnson, 1998)

For a massive and widespread famine like the one in China during 1959-1961, there could

[2]The estimates of excess deaths and lost/postponed births come from several studies that carefully examine the demographic data, including Coale (1981) Ashton et al. (1984) and Yao (1999) among others.

be a complicated set of factors that interacted and reinforced each other and culminated in a demographic catastrophe. The famine ended in 1962 together with the modification of policies and institutions along multiple dimensions. Extreme policies from the GLF were abandoned. The central government substantially increased grain imports, and transferred a large amount of grains to the rural sector. Rural institutions were altered and resembled those in the pre-GLF years: the role of communes was diminished and production was managed by the elementary or advanced cooperatives; compensation scheme for effort was restored and communal kitchens were abolished; grain procurement rate was reduced and rural trade fairs were reopened. Nevertheless, the grain output in 1962 remained 18.2% lower than the level in 1957, and the pre-famine grain production level was not regained until 1966 (Lin, 1990; Meng et al., 2015).

2.3 The Role of International Trade

China in the 1950s pursued development policies that heavily biased towards industrialization. As a result, the central government harshly squeezed agricultural sector to expedite industrial development and subsidize urbanites (Lin and Yang, 2000). The exports of agricultural goods and grains comprised around 40% and 15% of the total exports before the famine. Hence, to some extent, the country's capacity in obtaining foreign exchange to facilitate industrialization relied on exporting agricultural goods and especially grains. Moreover, since scarce foreign exchange was reserved mainly for importing industrial equipment, China barely import grains until 1961. The zealous industry policies during the GLF further distorted the balance across sectors.

The upper panel of Figure A.1 shows the trade flows between China and the rest of the world. Both export and import increased up to 1959 and China always maintained a trade surplus. The lower panel presents China's exports and imports of grain products.[3] Export of grain products comprised 12.1%-17.6% of the total export over the period of 1955 to 1960. China barely imported grain products until 1961. Moreover, grain exports climbed to its historical height during the onset of famine. The net export of grain products increased from

[3]The trade data is from various volumes of *China Customs Statistics Yearbooks*. The grain products include soybean, rice, wheat, maize, millet, sorghum, barley, buckwheat, beans and flour.

0.64 billion RMB (1.92 milliion tons) in 1957 to 0.91 billion RMB (2.62 million tons) in 1958, to 1.32 billion RMB (4.05 million tons) in 1959, and to 0.84 billion RMB (2.77 million tons) in 1960. In 1961, China switched from a net exporter to a net importer of grains with net imports amounting to 0.62 billion RMB (4.4 million tons). Over the period 1962 to 1966, China remained as a grain net importer of grain products (Lin and Yang, 2000).

The rapid deterioration of relationship with the USSR since 1959 partially contributed to the rise of grain exports in famine years while the leadership knew that some of its people were starving (Riskin, 1998; Yao, 1999). The sino-soviet political tension escalated in June 1960 when the USSR withdrew its economic advisers and specialists working in China then. The CCP Politburo immediately decided to accelerate the repayment of Soviet loan from 16 years to 5 years. The accumulated debt owning to the USSR amounted to around 1.5 billion RMB then, which was approximately 14 times as large as the trade surplus in 1958. To meet the repayment timeline, a "trade group" was set up to restrict imports and oversee the collection of commodities for export (Garver, 2016).[4]

Net grain exports over the period of 1958 to 1960 totaled around 9.6 million tons. Meng et al. (2015) estimate that one kilogram of grains contains 3,587 calories and daily average caloric need is 804 to 1,871.[5] Combined with these estimates, the net grain exports during 1958 to 1960 translates into energy that would suffice the caloric needs of 16.7 to 38.9 million people for three years. These estimates are commensurate with the total population loss during the Great Famine. In 1961, pressured by the food deficiency, China substantially increased grain imports, resulting in a net grain imports of 4.4 million tons which provided 23.2 to 53.9 million person-year caloric needs. As is also pointed out by Ashton et al. (1984), Johnson (1998) and Riskin (1998), massive excess death could have been avoided had the

[4]This "trade group" was led by high-ranking officials including the premier Zhou Enlai, the vice premiers Li Fuchun and Li Xiannian (See the CPC Central Committee emergency notification of the campaign for commodity procurement and export. http://cpc.people.com.cn/GB/64184/64186/66667/4493401.html). The leadership were aware of the food deficiency and hardship of increasing grain exports, but Mao claimed "The Yan'an period was hard too, but eating pepper didnt kill anybody. Our situation now is much better than then. We must tighten our belts and struggle to pay off the debt within five years." (Garver, 2016).

[5]As is detailed in Meng et al. (2015), the daily caloric need is calculated based on caloric requirements by age and sex recommended by the United States Department of Agriculture (USDA) and the demographic structure in China from the 1953 Population Census. The authors show that for China as a whole in the 1950s, 1871 calories were needed per person-day on average for heavy labor and normal child development. Also, on average, an individual only needed 804 per day to stay alive.

government acted swiftly to stop exports and start large-scale imports of grains.

The aggregate data veil the composition of types of grain crops that were actually exported and the changes in composition over time. Figure 1 shows that soybean and rice are the two most important export goods, which together made up 81% to 95% of total grain exports across years. More importantly, different crops had different exposures to export shock. Relative to the period 1955-1957, the exports of rice and soybean expanded respectively by 6.4 and 2.03 million tons in 1958-1960. The exports of wheat, maize and other grain products increased slightly by 0.99, 0.72 and 0.06 million tones, respectively. In the empirical analysis, we study the cross-county variation in export shocks that stems from regional differences in crop specialization pattern.

The increase in rice and soybean exports relative to wheat exports is also aligned with the changes in relative prices over the period. As is shown in Panel A of Figure A.4, the export price of rice was higher than that of wheat through out the period 1955-1960. The relative price surged in 1958 and remained higher than the pre-1958 level in 1969 and 1960. We also find a similar evolution of relative price of soybean to wheat. Panel B displays the export price of rice from Thailand relative to that of wheat from the US over years. This time series resembles that in Panel A, which ensures that the evolution of relative price was not a feature unique to exports from China, but rather driven by international demand and supply forces. Lastly, Panel C shows that the domestic price of rice and soybean increases relative to that of wheat over time in the US. All these findings suggest that in need of meeting the lofty industrialization targets and repaying external debts, the central government chose to expand exports of crops with increasing relative price.

3 Data

This section describe our dataset that is complied from different sources. More details about the data sources and summary statistics can be found in Appendix A.

3.1 Demographic Data

We collected the county-level data on population, population by gender, number of births and number of deaths for 23 provinces in China, which comprises around 95.4% of China's population in 1953. Death rate is constructed as the ratio of number of deaths to population and converted to per mil value (i.e., deaths per thousand). Birth rate is constructed in a similar way. There were 28 province-level divisions in China during the period of 1950s and 1960s. (The present day provinces Hainan and Chongqing used to belong to provinces Guangdong and Sichuan, respectively. The present day province-level municipality Tianjin belonged to province Hebei.) We exclude two province-level municipalities, Beijing and Shanghai, where there were few rural counties, and three autonomous regions, Inner Mongolia, Tibet and Xinjiang, where people faced different economic policies due to historical and political reasons.[6]

The data are mainly collected from population statistical books published by provincial Statistics Bureaus in the 1980s. The sample is restricted to rural counties. For most provinces, the sample period spans from 1955 to 1965. (For population, we collected data back to 1953.) The number of rural counties varies from 16 in Ningxia province (the smallest province in terms of both population and area) to 185 in Sichuan (the largest province in terms of both population and area). In total, there are 1803 rural counties in our sample. More details about the data sources are listed in Table A.1.[7]

To the best of our knowledge, our paper is the first to compile and use the county-level information on mortality and fertility to study China's Great Famine. In Appendix A.1.1, we show that when aggregating up to the province level, the mortality rates align with the province-level data employed by the existing studies. Taking the 1957 death and birth rates as the counterfactual mortality and fertility levels, we find that the Great Famine resulted in

[6]The overlap of provinces between our sample and Meng, et al. (2015) include Anhui, Fujian, Guangdong, Heibei, Heilongjiang, Henan, Hubei, Hunan, Jiangsu, Jiangxi, Jilin, Liaoning, Shandong, Shanxi, Shannxi and Zhejiang.

[7]Data for provinces Anhui and Shannxi are collected from complementary sources. For counties in Anhui, the data are obtained from Chronicles of Anhui Province, which only cover the years 1957, 60, 62 and 65. The population statistical book for Shannxi does not contain the county-level information on mortality or fertility. Subject to the data availability, we collect the data of number of deaths or births for a sample of counties in Shannxi from various volumes of Local Chronicles.

15.74 million excess deaths and 18.59 million loss/postponed births in our sample counties during the period of 1959 to 1961. In addition, as is shown in Appendix A.1.2, the famine had a pattern of high concentration in mortality, with the top 10th percentile of counties accounted for 52% of the total excess deaths.

3.2 Procurement and Output Data

We compile a county-level panel data on grain procurement and output from various sources. The majority of the data is from numerous volumes of the county-level Local Chronicles (county gazetteers), which contain historical and current materials on nature, society, economy, culture and politics in a locality. After the upheaval of the Cultural Revolution, Chinese government continued the age-old tradition of the compilation of local gazetteers. A volume of Local Chronicles were published in the early 1990s, recording the dramatic social changes that had occurred between the Republic Era (the 1920s) and the late 1980s. The materials and data in Local Chronicles are sourced from official archives and raw materials from the local communities. More details about Local Chronicles are described in Xue (2010).[8] We supplement this data with information collected from various statistical books published by provincial Statistics Bureaus and output data from Ministry of Agriculture of China (MOA)[9]. Similar to our demographic data, the sample is restricted to rural counties and covers the period of 1953 to 1965. The details about data sources are provided in Table A.3. The unbalanced panel covers 1648 counties for output and 1400 counties for procurement. Appendix A.2.1 shows that the reporting status is uncorrelated with the famine severity. It alleviates the concern that counties self-selected into reporting output and procurement data.

One may worry that the output and procurement data during the GLF period may not be fully reliable. The sources of data employed in our study may help alleviate the concern due to the following reasons. First, as is discussed in Ashton et al. (1984) and Meng

[8]This archival data has been used in recent studies. For example, Chen, Li and Meng (2013) collect data on the year in which ultrasound machines were introduced in different counties. Almond, Li and Zhang (2013) collect data on the timing of land reform and grain outputs across counties.

[9]See http://202.127.42.157/moazzys/nongqingxm.aspx. For each province, the MOA report data on grain output for around 20 counties.

et al. (2015), the data released in the post-Mao reform era have been carefully corrected to address potential reporting errors from Mao-years. Second, because the purpose of compiling county chronicles is to accurately record local history rather than to report to the upper level government, local historians responsible for data collection and compilation have relatively little incentive to manipulate the data (Almond, Li and Zhang, 2013). Despite of all these considerations, we will use data on weather shocks to strip out any potential measurement errors in the output data.

3.3 Data on Agricultural Production and Export Exposure

Our empirical analysis also requires the county-level data on crop specialization pattern. To obtain these variables, we use the recently declassified data from *County Statistics on Cultivated Area and Output of Different Crops (1957)*, which is published by the Chinese Ministry of Agriculture.[10] These data reflect the agriculture production across Chinese counties before the GLF and was made available to public only recently. Therefore we consider that it is less likely to have been misreported by the famine-era government.

3.4 Weather Data

The historical weather data are taken from *Terrestrial Air Temperature and Precipitation: Monthly and Annual Time Series (1950-1996), Version 1.01*, which provides monthly averages of temperature and precipitation at 0.5×0.5 degree grid level (approximately 56 km$\times$56 km at the equator).[11] The grid-level estimates are interpolated from an average of 20 weather stations, with correction for elevation. The grid data are mapped to counties. Specifically, for each county-year-month observation, we calculate the average temperature and precipitation using the data of grids that overlap with the county territory. Then, for each county-year observation, we construct variables of average temperature and precipitation in spring (February, March and April) and in summer (May, June and July).

[10] To the best of our knowledge, this statistical book is the only available source that provides data on agricultural production at county level by crop before the GLF.

[11] This dataset has been used in several recent studies, including Dell *et al.* (2012) and Meng et al. (2015).

3.5 Other Data

The data on productivity of cultivating different crops are from the Food and Agriculture Organization (FAO)'s *Global Agro-Ecological Zones (GAEZ) V3.0* database, which provides high resolution information on potential yields of different crops under various technologies at 5×5 arc-minute grid level (approximately 9.25 km×9.25 km at the equator). The potential yields are estimated using agronomic models and based on climate conditions, soil type, elevation and topography. Unlike directly observed yields, the potential yields at a given location are a function of local biophysical conditions, and hence they are plausibly exogenous to other economic activities. We construct the potential yields of rice, soybean and wheat at county-level, by computing the average potential yields of grids that fall within the county boundary.[12]

The map of historical railroad network in 1957 China is obtained from the US Central Intelligence Agency (CIA). We digitize the scanned map as displayed in Figure

4 Cross-County Variation in Famine Severity

Panel A of Figure 2 shows the cross-county average of mortality rate and its coefficient of variation (cv). We find that, accompanied with the surge in death rate, the variation also increased substantially during the famine period. Panel B corresponds to the time series for birth rate, and finds that the cross county variation in birth rate peaked in the famine period in contrast with the dip of the average. The findings suggest there existed considerable variation in famine severity across China.

Figure 3 shows the 1957 and 1960 mortality rate for rural counties in our sample. The changes in death rate between 1957 and 1960 are presented in Figure A.6. Counties are outlined in grey lines and provinces are outlined in black lines. There exist considerable differences in spatial distributions between non-famine and famine years. More importantly,

[12] We use data on potential yields under low-level input technology, i.e., production is based on rain-fed irritation, low-level of mechanization, utilization of fertilizer and chemicals for pest and disease control. We consider that the low-level input technology better describes the technologies used by Chinese farmers in the 1950s and early 1960s. The potential yield of rice is taken as the maximum value of the potential yields of wetland rice and dryland rice.

the cross-county variation in famine severity is substantial, even within a province.

We further decompose the variation of mortality rate into the within-province and between-province components:

$$CV^2 = \frac{\frac{1}{N}\sum_i (DR_i - \overline{DR})^2}{\overline{DR}^2} = \underbrace{\frac{\frac{1}{N}\sum_p \sum_{i\in p} (DR_i - \overline{DR}_p)^2}{\overline{DR}^2}}_{Within-Province\ Component} + \underbrace{\frac{\sum_p \frac{N_p}{N} (\overline{DR}_p - \overline{DR})^2}{\overline{DR}^2}}_{Between-Province\ Component}$$

where DR_i denotes the mortality rate in county i in a specific year. $\overline{DR}_p$ is the average mortality rate of province p and $\overline{DR}$ is the national average mortality rate. Panel A of Figure 4 shows the results for the variation decomposition by year. We find that the within-county component contributes more to the overall variation over the sample period. In addition, both between and within component surged in the famine period. Panel B conducts the analogous analysis for birth rate. We find a similar pattern that within component is always larger than the between component, and both of them increased over the famine period.

Figure 5 provides another snapshot of the data. It shows that the correlation of death and birth rates changed from positive in 1957 to negative in 1960. The purple dots are the counties that had death rate above median and birth rate below median in 1960. These were the counties that experienced more severe famine, but they were more or less randomly distributed in the distribution of 1957.

These findings suggest the importance of investigating the county-level data and in particular the determinants that affected the spatial pattern of famine severity across counties.

5 Theoretical Framework and Empirical Strategy

In this section, we lay out the theoretical framework that sheds lights on different causes of the Great Famine. The framework also guides our empirical strategy and quantitative analysis.

5.1 Procurement Policies, Retain Rate and Calorie Consumption

Consider the following model of procurement. The government determines the procurement rate so that the county i will receive the average per capita consumption $\bar{c}_{it}$. If the government had known the county i's output and population, then the procurement rate r_{it} would have been determined as

$$\bar{c}_{it} = c_{it} = r_{it} y_{it},$$

where c_{it} and y_{it} are the per capita consumption and per capita output, respectively. The retain rate denoted by $r_{it} = \frac{Y_{it} - P_{it}}{Y_{it}} = C_{it}/Y_{it}$ represents the fraction of output retained by the county. In this case, the target consumption $\bar{c}_{it}$ equals actual consumption c_{it}.

However, procurement policies could be rigid in the sense that the government partially relies on the past output to determine target consumption. That is,

$$\bar{c}_{it} = r_{it} y_{it}^{1-\rho} y_{it-2}^{\rho},$$

where the parameter ρ captures the rigidity of the procurement policies. Assuming the target consumption depends on observable county-specific characteristics x_{it} and unobserved shock ε_{it}, i.e., $\bar{c}_{it} = \bar{c}_{it}(x_{it}, \varepsilon_{it})$, we arrive at the following specification:

$$\begin{aligned} \ln r_{it} &= \ln \bar{c}_{it} - (1-\rho) \ln y_{it} - \rho \ln y_{it-2} \\ &= \beta_1 \ln y_{it} + \beta_2 \ln y_{it-2} + x_{it}' \beta_x + \varepsilon_{it}, \end{aligned} \tag{1}$$

where β_1 and β_2 measures the elasticity of retain rate to the current and past outputs, which could depend on some observables like distance railways. The elasticities could also be different in the GLF period from those in Non-GLF period. In our framework, export shock (EX_{it}) is a component of the vector x_{it} and hence a shifter for retain rate.

Figure 6 follows the specification (1) and shows the partial regression plots of procurement rate against past output ($\ln y_{t-2}$) and current output ($\ln y_t$) for years 1957 and 1959.[13] In both years, procurement rate is positively associated with the past output. The positive correlation is stronger in 1959, suggesting the procurement policies became more rigid. In

[13] We employ the fact that when r_{it} is small $p_{it} \approx -\ln(1 - r_{it})$, where p_{it} denotes the procurement rate.

addition, we find that the procurement is uncorrelated with current output in 1957 and the correlation became slightly negative in 1959.

Under the rigid procurement policies, the actual consumption could deviate from the target level, and their relation is given by

$$c_{it} = \left(\frac{y_{it}}{y_{it-2}}\right)^{\rho} \times \bar{c}_{it}. \tag{2}$$

It suggest that in counties that experienced a decline in outputs relative to two years ago, the actual consumption would be lower than the target level. The responsiveness of consumption to output shock depends on the rigidity of the procurement policies, which is captured by ρ. The left panel of Figure 7 provides a snapshot of the data, by plotting $\ln c_{it}$ against $\ln y_{t-2} - \ln y_t$ for 1957 and 1959. We find supporting evidence for equation (2). Moreover, we detect a steeper negative slope for 1959, which again suggests the procurement policies became less flexible during the GLF period.

5.2 Outputs, Consumption, Mortality and Birth

We link the death rate in period $t+1$ to retained consumption in period t in the following non-parametric way:

$$DR_{it+1} = f(c_{it}) + x'_{it}\gamma_{\lambda} + u_{it}, \tag{3}$$

where $f(\cdot)$ is a non-parametric function of retained caloric consumption.[14] Equation (3) relaxes the linearity assumption adopted in the existing literature. As is shown in the following sections, the relation between mortality and consumption displays strong non-linearity, which has important implications when we quantify the effects of different underlying shocks.

As $\ln c_{it} = \ln r_{it} + \ln y_{it}$, we may also investigate the reduced-form relation between mortality, output and export shocks by estimating the following specification:

$$DR_{it+1} \propto \gamma_1 \ln y_{it} + \gamma_2 \ln y_{it-2} + x'_{it}\gamma_{\lambda} + u_{it}.$$

[14]The timing assumption is based on the calendar of procurement and agricultural production. Procurement occurred after autumn harvest in Oct/Nov. The retained consumption was to support life for many months of the following year. (Meng et al., 2015)

The analysis for birth is analogous to mortality.

5.3 Grain Outputs and Weather Shocks

Consider the following specification of output per capita for crop k in county i in year t:

$$\ln y_{it}^k = \theta_0^k + \theta_1^k \psi_i^k + \sum_{\ell} \theta_2^{k\ell} z_{it}^{\ell} + \nu_{it}^k \,, \tag{4}$$

where $y_{it}^k = Y_{it}^k / L_{it}^k$ is per capita output of crop k in county i and year t, ψ_i^k is the productivity of cultivating crop k, and z_{it}^{ℓ}'s denote different weather conditions including spring/summer temperature, spring/summer precipitation, their squared terms and interaction terms.

Due to the lack of data on output and labor input by crop, we aggregate equation (4) using different crops' output share in 1957 ($s_i^k = Y_{i,57}^k / Y_{i,57}.$) as weights and link the a county's aggregate grain output to its productivity and realized weather conditions:[15]

$$\ln y_{it} = \sum_k \theta_0^k s_i^k + \sum_k \theta_1^k (s_i^k \psi_i^k) + \sum_{\ell} \sum_k \theta_2^{k\ell} (s_i^k z_{it}^{\ell}) + \tilde{\nu}_{it},$$

where $\tilde{\nu}_{it} = \sum_k s_i^k \nu_{it}^k$. We replace components $\sum_{k=1} \theta_0^k s_i^k + \sum_{k=1} \theta_1^k (s_i^k \psi_i^k)$ by county fixed effects ϕ_i and estimate the following output specification:

$$\ln y_{it} = \sum_{\ell} \sum_k \theta_2^{k\ell} (s_i^k z_{it}^{\ell}) + \phi_i + \gamma_{pt} + \tilde{\nu}_{it}, \tag{5}$$

where γ_{pt} is the province×year dummy that capture the province specific policy shocks. The component $\widetilde{\ln y_{it}} = \sum_{\ell} \sum_k \hat{\theta}_2^{k\ell} (s_i^k z_{it}^{\ell})$ capture the effect of weather on grain output, and we will refer it as "weather index" or "weather shock" henceforth.

[15] The aggregation relies on the assumption that allocation of workers is proportional to output so that $s_i^k = Y_{it}^k / Y_{it} == L_{i,57}^k / L_{i,57}$.

6 Empirical Results

6.1 Non-Parametric Relation Between Mortality and Calorie Intake

To investigate the relation between death rate and caloric consumption, we estimate the following semi-parametric model:

$$DR_{i,60} = f(\ln(c_{i,59})) + \gamma_p + \varepsilon_i \ , \tag{6}$$

where $c_{i,59}$ is the caloric content of the retained grains in 1959, i.e., $y_{i,59} - p_{i,59}$, and γ_p denotes the province fixed effects. We only use the 1959 consumption data and 1960 death data to estimate equation (6). This is because the famine was most severe in 1960 and the caloric content of retained grain in 1959 was more likely to reflect the actual level of calorie supply.[16] To further address the potential problem of measurement errors, we adopt the control function approach as is described below.

We first estimate the following model linking the caloric consumption to weather shocks and underlying productivity levels:

$$\ln c_{i,59} = \kappa_1 \ln \tilde{y}_{i,59} + \kappa_2 \ln \tilde{y}_{i,57} + \lambda_i' \kappa_3 + \gamma_p + \nu_i \ , \tag{7}$$

where $\ln \tilde{y}_{i,59} = \sum_\ell \sum_k \hat{\theta}_2^{k\ell}(s_i^k x_{i,59}^\ell)$ is the summary index of weather shocks that is derived from regression (5) and $\ln \tilde{y}_{i,57}$ is the corresponding value for 1957. The vector λ_i contains productivity of cultivating different crops and the average weather conditions over 1953 and 1965. We obtain the residuals $\hat{v}_i$ from equation (7) and estimate the following model:

$$DR_{i,60} = f(\ln(c_{i,59})) + g(\hat{v}_i) + \gamma_p + \varepsilon_i \ , \tag{8}$$

[16] The amount of retained grains in 1958 is likely to understate the true amount of food available in 1959, as the inventory of foods might not be completely exhausted at the start of the famine. In the last year of famine (i.e., 1961) relief plans stepped in. Without detailed data on grain relief, the calorie supply could be imprecisely measured.

where $g(\hat{v}_i)$ is a cubic function of $\hat{v}_i$.

The estimated non-parametric functions $\hat{f}(\ln(c_{i,59}))$ of model (6) and model (8) are presented by the green curve and the blue curve in Figure 8, respectively. The two reference lines corresponding the two thresholds, i.e., logarithms of 900 and 1800 calories per person-day. We find that death rate decreases monotonically with caloric consumption. The gradient is steeper at the lower end and flattens out when consumption level is sufficiently high. In addition, we find that estimated function of model (8) has a steeper slope than that of model (6), which suggests that the data on caloric consumption are subject to measurement errors.

We estimate the relation between birth rate and caloric consumption analogously. The result is presented in Figure 9. We detect a steeper positive relation between birth rate and caloric consumption from the control function approach.

6.2 Effects of Output Shocks

In this subsection, we provide county-level evidence on inflexible and progressive procurement policies in the GLF period by investigating the following relationship:

$$\ln RetainRate_{it} = \sum_{\tau} \beta_1^{\tau} \mathbf{1}(t \in \tau) \times \ln y_{it} + \sum_{\tau} \beta_2^{\tau} \mathbf{1}(t \in \tau) \times \ln y_{it-2} + \lambda_i' \beta_3 + \gamma_{pt} + \varepsilon_{it} \quad (9)$$

where $\ln(RetainRate)_{it}$ is the log retain rate of county i in year t; $\mathbf{1}(t \in \tau)$ is an indicator variable that equals to 1 if year t belongs to period $\tau \in \{GLF, NonGLF\}$; the vector λ_i contains county-specific controls; γ_{pt} denotes province×year dummies that capture policy shocks at the province level.

The regression result for the baseline specification is reported in column (1) of Table 1 Panel A. Column (2) augments the model with county fixed effects. Different specifications give a robust finding that in the GLF period, the elasticity of retain rate to contemporaneous output became statistically insignificant and small in magnitude. In contrast, past output gained a larger weight in determining retain rate during the GLF period. The results indicate that the procurement policies became more rigid during the GLF period. In addition, we find that procurement is progressive in the sense that retain rate decreased with current output in the non-GLF period and two-year lagged output in the GLF period.

In column (3), we use the control function to the address the concern that the output data may be subject to measurement errors which bias the estimates. More specifically, we extend the model (9) to:

$$\ln RetainRate_{it} = \sum_{\tau} \beta_1^{\tau} \mathbf{1}(t \in \tau) \times \ln y_{it} + \sum_{\tau} \beta_2^{\tau} \mathbf{1}(t \in \tau) \times \ln y_{it-2}$$
$$+ g(\hat{v}_{it}) + g(\hat{v}_{it-2}) + \phi_i + \gamma_{pt} + \varepsilon_{it}$$

where $g(\hat{v}_{it}) = \sum_{\tau} \beta_4^{\tau} \mathbf{1}(t \in \tau) \times \hat{\nu}_{it}$ and $g(\hat{v}_{it-2}) = \sum_{\tau} \beta_5^{\tau} \mathbf{1}(t \in \tau) \times \hat{\nu}_{it-2}$. $\hat{v}_{it}$ is obtained from regression (5) and $\hat{v}_{it-2}$ is the corresponding two-period lagged value. Consistent with the baseline findings, column (3) shows that the procurement became more rigid during the GLF period. The effect of current output dwindled in the GLF period when the past output became a significant determinant.

In columns (4) and (5), we split counties into "Near" and "Far" groups based on whether their distance to railroad is below or above the median distance. We find that the rigidity of procurement policies is more pronounced in the counties that are further away from the railway network. For the Near group, while the effect of current output diminished during the GLF period, its effect remained negatively significant. In contrast, for the Far group, the retain rate solely depended on the past output in the GLF period. It is also worth noting that, the coefficient of $GLF \times \ln y_{t-2}$ is smaller in magnitude for the Near group than that of the Far group, suggesting that procurement was less reliant on past output for the counties closer to railways. We also find that the procurement policies were more progressive for the Near group. These findings suggest that on the one hand, given the same output level counties located near to railways were more liable to higher procurement due to low transportation cost. On the other hand, a verification of food deficiency would have been easier for counties located nearby railways which help lessen the rigidity of procurement.

Panel B repeats the regressions but replaces the outcome variable by death rate in year $t + 1$. In the GLF period, the mortality rate is higher when it received a positive output shock in the two-year lagged period. A higher realized contemporaneous output helped alleviating the famine. Moreover, as is shown in columns (4) and (5), the current and past output shocks have larger effect in magnitude on death rate for counties that were further away from railways. These finding echo those in Panel A, suggesting that procurement policies were rigid in the GLF period and more so in the remote regions. Panel C reports the regression results when birth rate is the outcome variable. The findings mirror those for the death rate.

6.3 Effects of Export Shocks

In this section, we employ the cross-crop differences in export expansion and cross-county variation in crop specialization pattern to study the effect of export expansion on famine severity. In particular, we use the data on regional output share in 1957 and construct a Bartik-style index to measure a county's exposure to grain exports, that is:

$$Export_{it} = \sum_k \frac{Y_{i,57}^k}{Y_{57}^k} \frac{Export_t^k}{Pop_{it}}.$$

Specifically, the national export of crop k, $Export_t^k$, is apportioned to county i according to its share in national output $\frac{Y_{i,57}^k}{Y_{57}^k}$ in 1957. Then, this imputed regional export is normalized by the local population Pop_{it}. By construction, $Export_{it}$ captures the per capita reduction in food availability in kilogram due to export growth.[17] Over the period of 1957 and 1959, export increased by 5.1 kilogram per capita. There existed substantial cross-county variation with the standard deviation equaling 3.1.

As is discussed in section 5, we consider the export shock as a shifter of retained consumption, and hence mortality and birth. The empirical model we estimate is:

$$\ln RetainRate_{it} = \alpha Export_{it} + \sum_\tau \beta_1^\tau \mathbf{1}(t \in \tau) \times \ln y_{it} + \sum_\tau \beta_2^\tau \mathbf{1}(t \in \tau) \times \ln y_{it-2}$$
$$+ g(\hat{v}_{it}) + g(\hat{v}_{it-2}) + \lambda_i' \beta_3 + \gamma_{pt} + \varepsilon_{it}.$$

The baseline regression result is presented column (1) of Table 2 Panel A. Column (2) extend the model by including county fixed effect, and hence the identification comes from

[17] According to FAO (2003), the caloric contents per gram of rice, soybean, wheat, potato and other grains are similar (4.12-4.16 for rice, 4.07 for soybean, 3.78-4.12 for wheat and 4.03 for potatoes). Because of the similar caloric content of different crops, we consider the measure $Export_{it}$ well captures the caloric loss due to export shocks.

within-county variation in export exposure. We find that counties that were more exposed grain exports had lower retain rate on average, and the finding is robust across different specifications.

Column (3) include the interaction terms of export exposure with current and past outputs. The coefficient of $Export_t \times \ln y_t$ is marginally insignificant, with p-value 0.12. It provides suggestive evidence that conditional on export exposure, the counties that experienced a positive contemporaneous output shock were able to retain more foods. Column (4) further introduces the interaction term of export exposure and distance to railway.[18] Consistent with the prior that distance to railways increases transportation costs, we find that conditional on export exposure, the counties further away from railways had higher retain rate.

Columns (5) and (6) investigate the effect of export shocks separately for the Near and Far groups. For the counties closer to railways, the current and past shocks do not change the gradient of retain rate-export relation. In contrast, for the counties further away from railways, a positive contemporaneous output shock mitigated the adverse effect of export growth. This could be due to the higher transportation costs or more stagnant information flow in the remote counties.

Panel B investigates the reduced form relation between mortality and export exposure. Resonating with the findings in Panel A, a higher export exposure raised the death rate. The result is robust across various specifications and different samples. In addition, we find that conditional on export exposure, a higher current output lowered the death rate while a higher past output increased it. The pattern is more pronounced in the Far distance group. The findings again suggest that the procurement policies were rigid. In column (4), we find that conditional on export exposure, the counties further away from railways had a higher death rate on average. This result suggests that certain characteristics in the remote areas like poorer infrastructure may aggravate famine severity. Panel C repeats the regressions but replaces the outcome variable by birth rate, and most of the results mirror those of the

[18]Rail transport was the dominant mode of freight transport in the famine era. According to National Bureau of Statistics China, rail transport comprised more than 75% of the total freight transport during 1958 to 1961. (*60 Years of New China Statistical Book*) Moreover, because of the weight of grains, their transport could largely rely on railroad. (Donaldson , 2016)

death rate.

6.4 Robustness

Table 4 evaluates the robustness of our results to alternative measures of procurement, food availability and famine severity. Panel A replaces the outcome variable by procurement rate and obtains consistent results: procurement policies became more inflexible in the GLF period and more so in the counties that are further away from the railways. A larger export exposure raises the procurement rate while the effect is marginally insignificant with p-value 0.15. Panel B uses the log calorie supply as dependent variable and our baseline findings retain.

Following Meng et al. (2015), we use the birth cohort sizes of survivors observed in the 1990 China Population Census to proxy for famine severity at the county level. Figure A.7 correlates the change in death (birth) rate over 1957 and 1960 with the relative population size of famine cohort. On the one hand, the relative cohort size is negatively correlated with the change in death rate while fails to capture the observations with a large surge of mortality. On the other hand, it is more closely associated with the change in fertility. Table 4 Panel C replaces dependent variable by the log population size of cohort born in year $t+1$.[19] Column (9) shows that during the GLF period, a higher contemporaneous output level alleviated the famine and hence increased the cohort size, while a higher past output had an opposite effect. Again, the effect is stronger in the more remote counties. We also find that export shock has a significant negative effect on cohort size. Panel D reports the results for the natural population growth rate defined as the difference between birth and death rates. Our results are robust to this alternative measure.

[19]Figure A.8 decompose the normalized log cohort size into the between and within-province components. Consistent with the findings in Figure A.2, a majority of the spatial variation in famine severity stems from the within-province component.

6.5 The Province-Level Determinants of Outputs

This section investigates the province-level determinants of the slump in grain output during the GLF period with the following specification:

$$\ln y_{it} = \mathbf{w_{pt}}\theta + \sum_{\ell}\sum_{k}\theta^{k\ell}s_i^k z_{it}^{\ell} + \phi_i + \gamma_t + u_{it} \ , \tag{10}$$

where the vector $\mathbf{w_{pt}}$ contains different proxies of the province-level GLF intensity. We cluster the standard errors at province-year level.

Due to the data limitation, we are not able to study the role of county-level GLF policy shocks. Nevertheless, regression (10) is informative for two reasons. First, it provides a test of consistency of our county-level findings with the extant literature that employ the province-level data. Second, it allows the evaluation of the impact of GLF policies on the famine severity. The counterfactual exercises will be explained at length in Section 7.

Column (1) in Table 3 finds that grain output per capita is associated with resource allocations at the province-level. A county had a higher output level on average when the provincial government allotted more land to grain production. Following Li and Yang (2005) and Meng et al. (2015), column (2) add steel output per capita as a proxy for the GLF zealousness. We find that the estimated coefficient of steel production is negative albeit statistically insignificant. Kung and Lin (2003) show that provinces that were liberated after the national liberation date were more likely to adopt aggressive GLF policies. Based on this argument, in columns (3) we investigate whether counties in the provinces that had late "liberation" by CCP experienced a larger decline in grain output. The estimated coefficient of the interaction term is negatively significant at 10% level. Following Kung and Lin (2003) and Meng et al. (2015), column (4) employs the intensity of the 1957 anti-rightest movement (measured by the number of persons purged per million) to proxy for the political zealousness of a province. We find that the 1957 political purge has a negative but insignificant effect on grain output during the GLF period. Column (5) includes all the proxies of GLF intensity into one regression and finds that only per capita sown area has a statistically significant effect on output. Lastly, in column (6) we include province×year dummies which capture all the policy shocks at the province level. The R-squared increases slightly from 0.729 to 0.777.

In sum, consistent with the existing literature we find that GLF policies have significant effect on grain output level. Moreover, the extent of resource diversion from agricultural sector is likely to summarize the policy shocks. To gauge the magnitude of the provincial policy shocks, we consider two provinces, Henan and Shanxi at the 25th and 75th percentiles of change in sown area per capita over 1957 and 1959. (The declines in per capita sown area were 0.206 and 0.154 log point for Henan and Shanxi, respectively.) According to the estimates in column (1) of Table 3, counties in Henan had 0.028 log point larger decline in per capita output than Shanxi.

7 Counterfactual Simulation

In this section, we undertake a set of counterfactual experiments aimed at inferring the roles of different underlying shocks in shaping the famine severity. To do so we study the responses of mortality in 1960 when different economic conditions in 1959 revert to their 1957 levels.[20] Recall that the retained consumption is determined by:

$$c_{it} = r_{it}\big(y_{it}, y_{it-2}, EX_{it}, \boldsymbol{\beta_t}\big) y_{it}\big(\boldsymbol{z_{it}^{\ell}}, w_{pt}\big), \tag{11}$$

where the retain rate is a function of contemporaneous and past outputs, export shock, and procurement policies that is captured by $\boldsymbol{\beta_t}$; the per capita output depends on weather conditions and province-level policy shocks. Based on equation (11), we decompose the change in retained consumption in 1959 and consequently the change in mortality in 1960 into the components contributed by procurement shock and output shock. We also quantify the effects of different underlying factors in determining procurement and output.

We adopt two alternative procedures to obtain the change in excess deaths under different counterfactual scenarios. The first is a more "structural" approach. In particular, counterfactual change in death rate is computed based on the counterfactual change in caloric supply

[20] As our data is unbalanced, the exercises are restricted to a subsample of counties for which information on output and procurement are available in both 1957 and 1959. The subsample consists of 755 counties.

and the estimated non-parametric relation between mortality and calorie intake. The second approach uses the reduced-form relation between death rate and different underlying shocks. The two procedures may yield similar findings if the underlying shocks affect mortality only through altering caloric supply.

In the following subsections, we first use the estimated non-parametric function to quantify the effect of different underlying shocks on excess mortality. We then compare the results to those obtained from the reduced-form pass-through. Lastly, we conduct an analogous analysis for lost/postponed births.

7.1 Counterfactuals Based on Nonparametric Function

Before delving into different counterfactual scenarios, we first look into the data of excess death rate for the sample of counties with information on caloric consumption. As is reported in row (A1) of Table 5, the death rate in 1960 was on average 14.7 (per thousand) higher than that in 1958. The cross-county variation is considerable with a standard deviation of 23.25. The excess death rates translates into a total number of excess deaths that amounts to 4,068,519.[21] This number serves as a benchmark for the following counterfactual exercises.

Our first question is how many deaths could have avoided had the caloric consumption in 1959 was the same as that in 1957. If food deficiency was the only cause of the famine, one would expect this number to be very close to the actual number of excess death. Based on the estimated non-parametric function, we calculate the change in death rate for each county according to

$$\Delta \widetilde{DeathRate}_i = \hat{f}(\ln(c_{i,59})) - \hat{f}(\ln(c_{i,57})) \ .$$

We find that the average death rate would have been 13.2 (per thousand) lower in this counterfactual scenario. The implied aggregated number of excess deaths is 3,634,159, which is 89.3% of the actual number of excess deaths. There are at least two reasons why the counterfactual excess death is lower than the actual one. First, our analysis only considers

[21]The total number of excess deaths is calculated according to:

$$TotalExcessDeaths_{60} = \sum_i DeltaDeathRate_{i,60-58} \times Pop_{i,60}$$

the relation between death rate and average level of caloric consumption. The within-county inequality in food availability may result in extra deaths. Due to the data constraint, this channel is ignored in our study. Second, during the chaotic GLF period, there could be other factors affecting mortality.

In the second counterfactual exercise, we adjust the output level in 1959 to be the same as that in 1957 while keeping retain rate as in 1959 in equation (11). The implied change in death rate is constructed according to

$$\Delta \widetilde{DeathRate}_i = \hat{f}(\ln(c_{i,59})) - \hat{f}(\ln(\tilde{c}_{i,59})) \ ,$$

where $\tilde{c}_{i,59} = r_{i,59} y_{i,57}$. Row (A3) shows that if the output had not declined in 1959, the average death rate would have been 5.9 (per thousand) lower and 1,747,629 deaths could have been avoided which is 43% of the actual excess deaths.

Rows (A3.a) and (A3.b) explore different determinants in output decline. In particular, row (A3.a) examine the role of resource diversion in the GLF period. Based on the estimates in column (1) of Table 3, we construct the counterfactual consumption level in 1959, assuming the province-level per capita grain sown area to be the same as 1957. We find that in the absence of resource diversion, the number of excess deaths could have been 1,080,047 lower, around 26.6% of the total excess deaths. In row (A3.b), we consider the counterfactual scenario of no weather shocks in 1959. Without the weather shocks, the number of excess deaths will 248,489 lower, which is 6.1% of the overall excess deaths.

Following the similar procedure, row (A4) considers the case that the procurement in 1959 remained the same as that in 1957. We find that in this counterfactual setting, the death rate and the total number of excess death would have been 8.9 (per thousand) and 2,310,339 lower, respectively. The decrease in number of excess deaths amounts to 56.8% of the actual amount. It is worth noting that the combined individual effects of output shocks and procurement shocks is larger than that of the consumption shocks (100.7% versus 89.3%) due to the non-linear relation between the mortality and caloric consumption.

In row (A5), we quantify the effect of export expansion on excess deaths in 1959. To be precise, we apportion the increase in export of different crops back to each county according to its output share in 1957. Hence, the counterfactural consumption in 1959 is raised by $\sum_k \frac{Y^k_{i,57}}{Y^k_{57}} \frac{Export^k_{59} - Export^k_{57}}{Pop_{i,59}}$. In the absence of export expansion, the average death rate would have decreased by 1.51 (per thousand). As a result, the number of excess deaths would have reduced by 422,361, which is 10.4% of the actual excess deaths. Next, row (A6) introduces the heterogeneous effects of export shock on excess deaths. More specifically, we construct the counterfactual change in retain rate based on the estimates in column (4) of Panel A in Table 2, and compute the resulting change in consumption. We find that 7.2% of excess deaths could be attributed to export expansion, which is somewhat smaller than that in row (A5).

Then we ask the following question: how would the number of deaths change if the procurement policies were more flexible. To answer this question, we proceed in two steps. First, we replace the GLF period's elasticities of retain rate to contemporaneous and past outputs by their non-GLF counterparts. Based on the estimates in column (3) of Panel A in Table 1, we calculate the changes in grain retained rate. Second, we translate the implied changes in caloric consumption to counterfactual change in deaths using the estimated non-parametric function in Figure 8. Row (A7) shows that the rigid procurement policies in the GLF period contributed to 28.1% of the excess deaths. Row (A8) considers an alternative counterfactual experiment in which the procurement policies in 1957 had been the same as the GLF period. The counterfactual change in death rate over 1958 to 1960 is then $DeathRate_{60} - \widetilde{DeathRate}_{58}$. The corresponding implied number of excess death accounted for 16.4% of the actual amount, which is about half of that in row (A8). These results indicate that a change in procurement policies between 1957 and 1959 toward more progressive and inflexible policy alone cannot explain the large portion of excess deaths between 1957 and 1960. Furthermore, the difference between (A7) and (A8) suggests that the inflexible and progressive procurement policies matters more when it is accompanied with a widespread large decline in output.

7.2 Counterfactuals Based on Reduced-Form Regressions

In this section, we present the counterfactual change in excess deaths based on the reduced-form relation between death rate and different underlying shocks. Row (A9) and (A12) employ the estimates in Panel A column (3) of Table 1. We find that in absence of output shock between 1957 and 1959, 950,637 deaths would have avoided which accounts for 23.4% of the total excess deaths. Note that the result is not the reduced-form counterpart of that in row (A3). This is because output shocks affect both retained rate and potential food supply, and the reduced-form estimates capture the combined effects. Row (A12) gauges the impact of rigid procurement policies in the GLF period. The reduced-form pass-through implies 9.1% excess deaths could have avoided, which is smaller than the finding in row (A7). In row (A10) and (A11), we quantify the impact of export expansion using respectively the estimates in column (2) and (3) of Table 2 Panel B. We find that 12.3%-12.7% of the excess deaths could be explained by export shocks.

7.3 An Analogous Analysis for Lost/Postponed Births

We conduct an analogous analysis for lost/postponed births in Figure 9 and Panel B of Table 5. We briefly discuss the main findings here. First, the decline in caloric consumption between 1957 and 1959 explains 73% of the total lost/postponed births. Third, the relative importance of different underlying shocks is similar to that in Panel A. For example, the effect of export shock is about one tenth of the effect of caloric consumption shock for both death and birth. Lastly, compared to the approach based on the non-parametric relation, the reduced-form pass-through yields similar estimates for the effects of export shocks.

8 Conclusion

References

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Figure 1: Composition of Grain Exports (1955-1961)

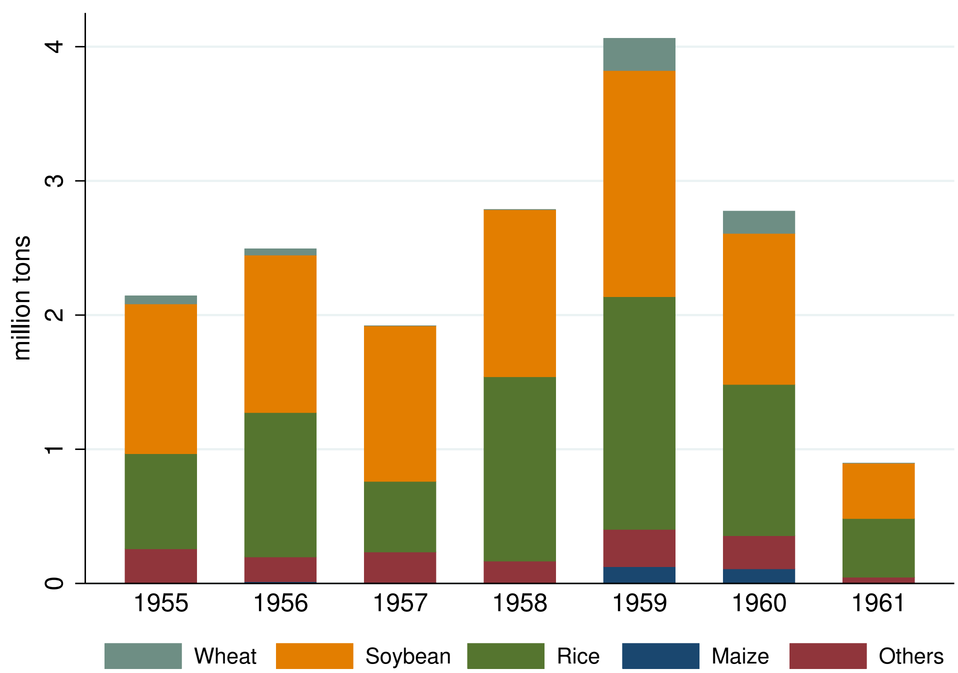


Figure 2: Cross-County Variation in Famine Severity

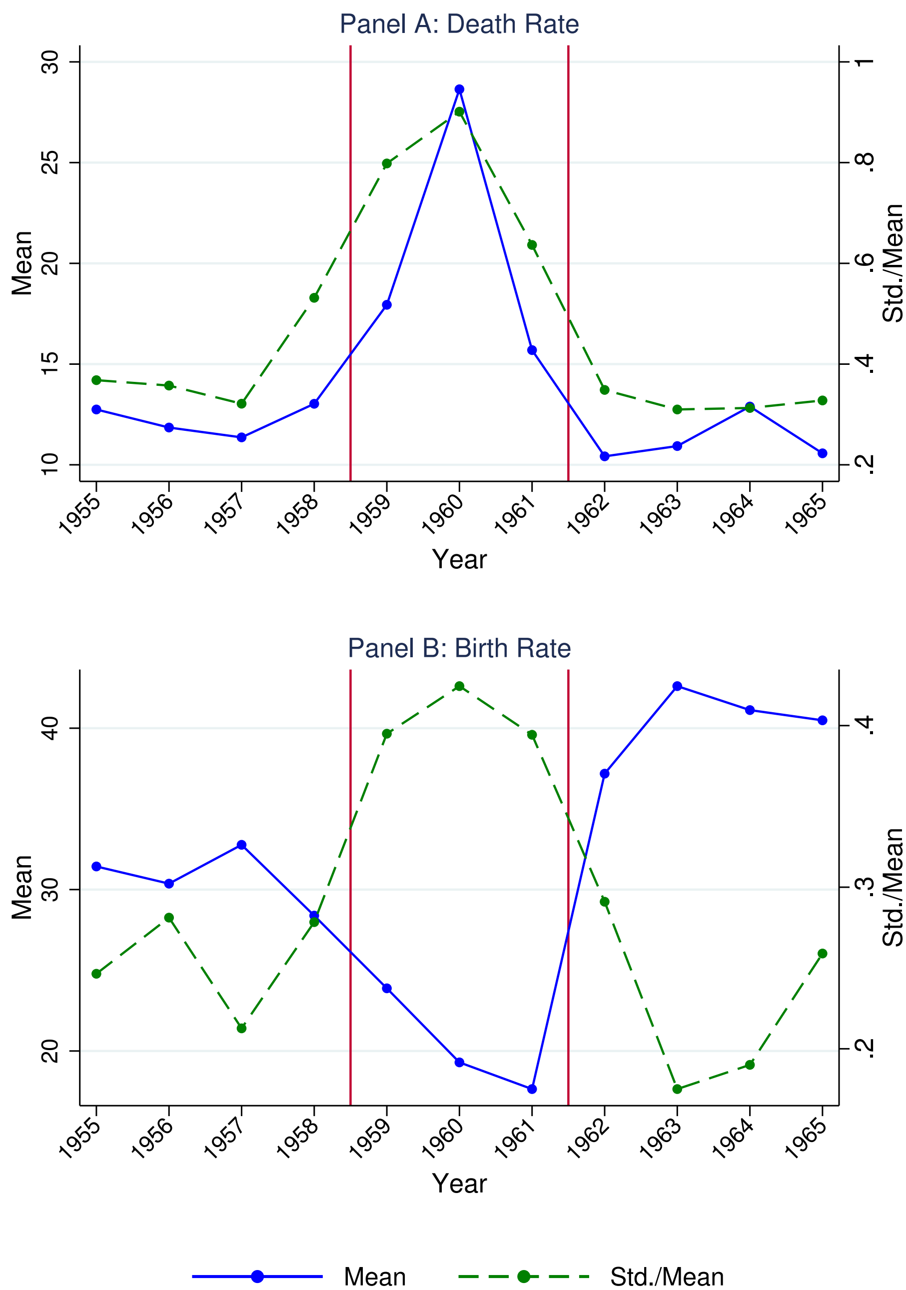
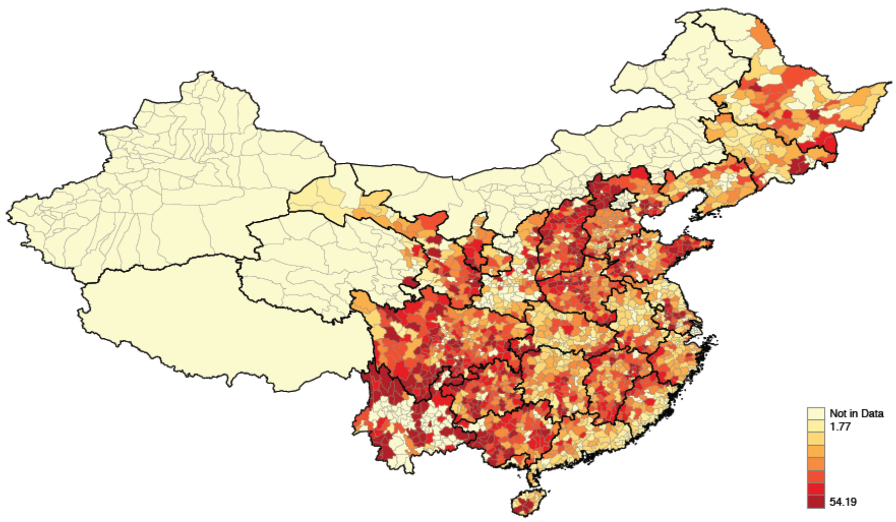
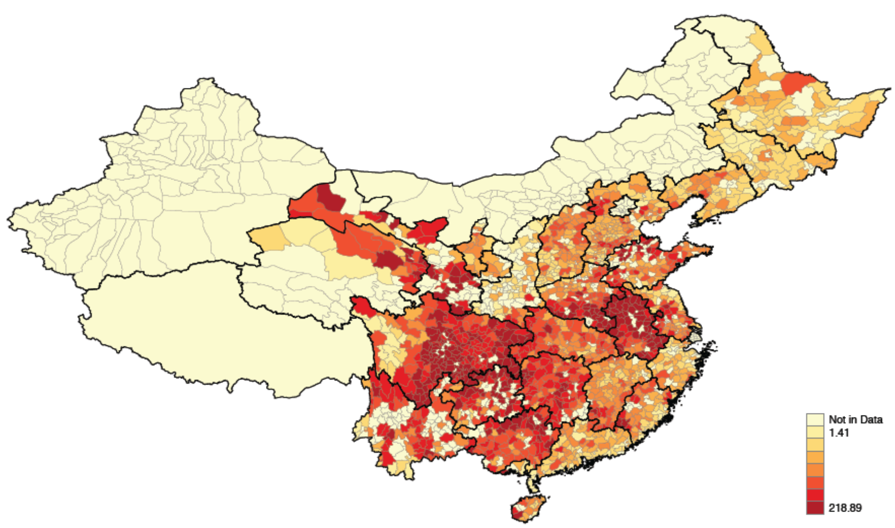


Figure 3: The Number of Deaths per 1000 Population in 1957 and 1960



(a) The number of deaths per 1000 population in 1957



(b) The number of deaths per 1000 population in 1960

Figure 4: Decomposition of Within- versus Between-Province Variation

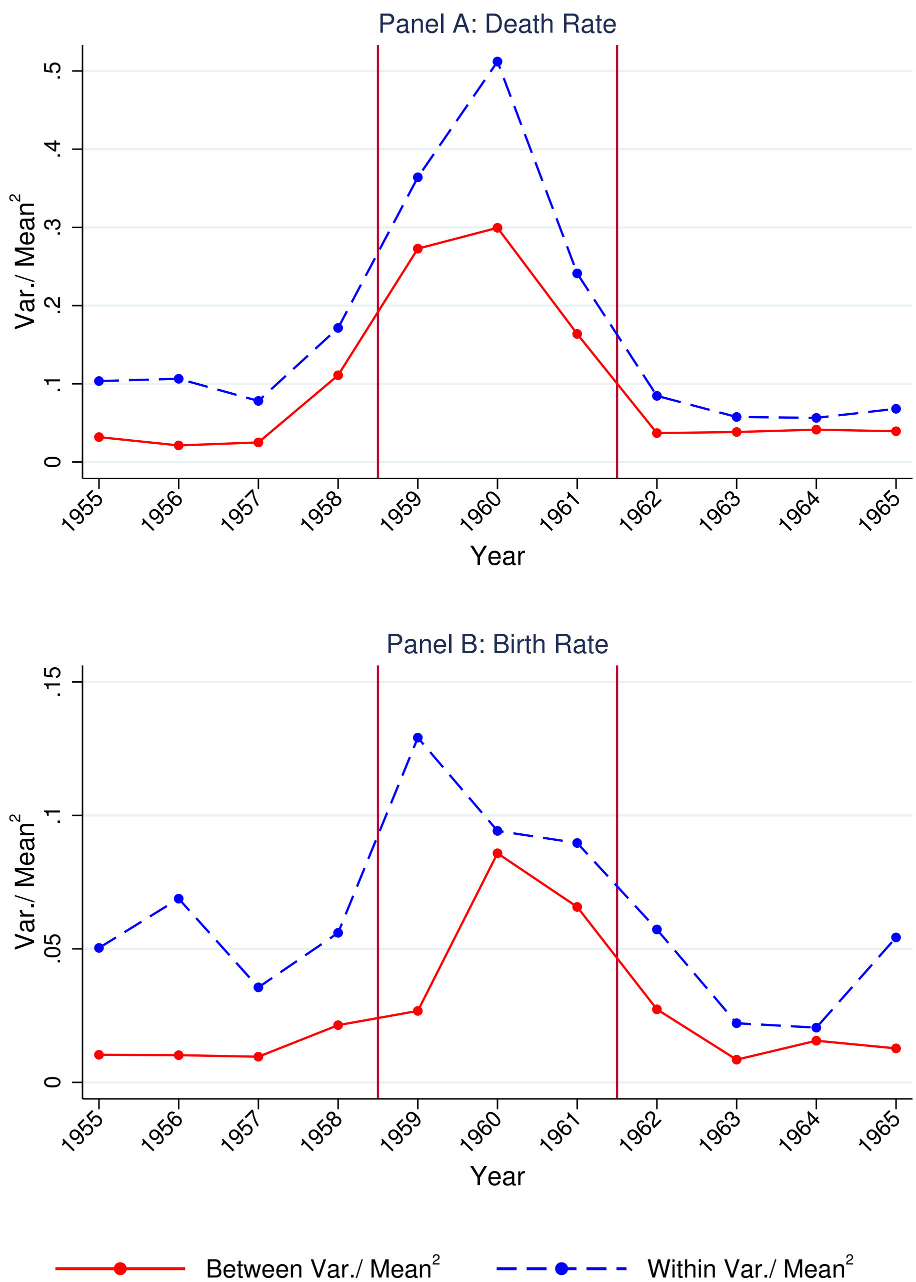


Figure 5: Correlation between Changes in Mortality and Birth Rates

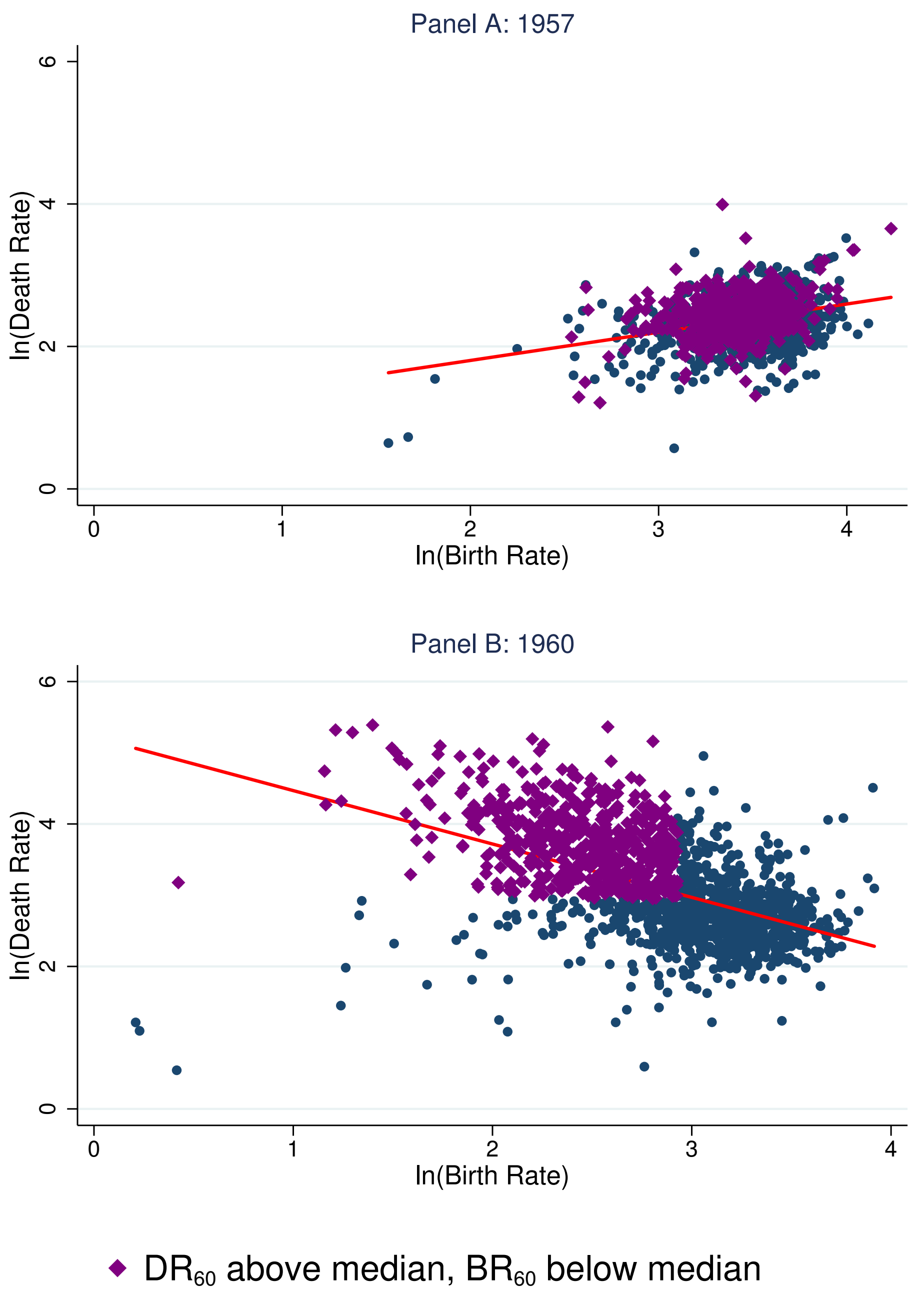
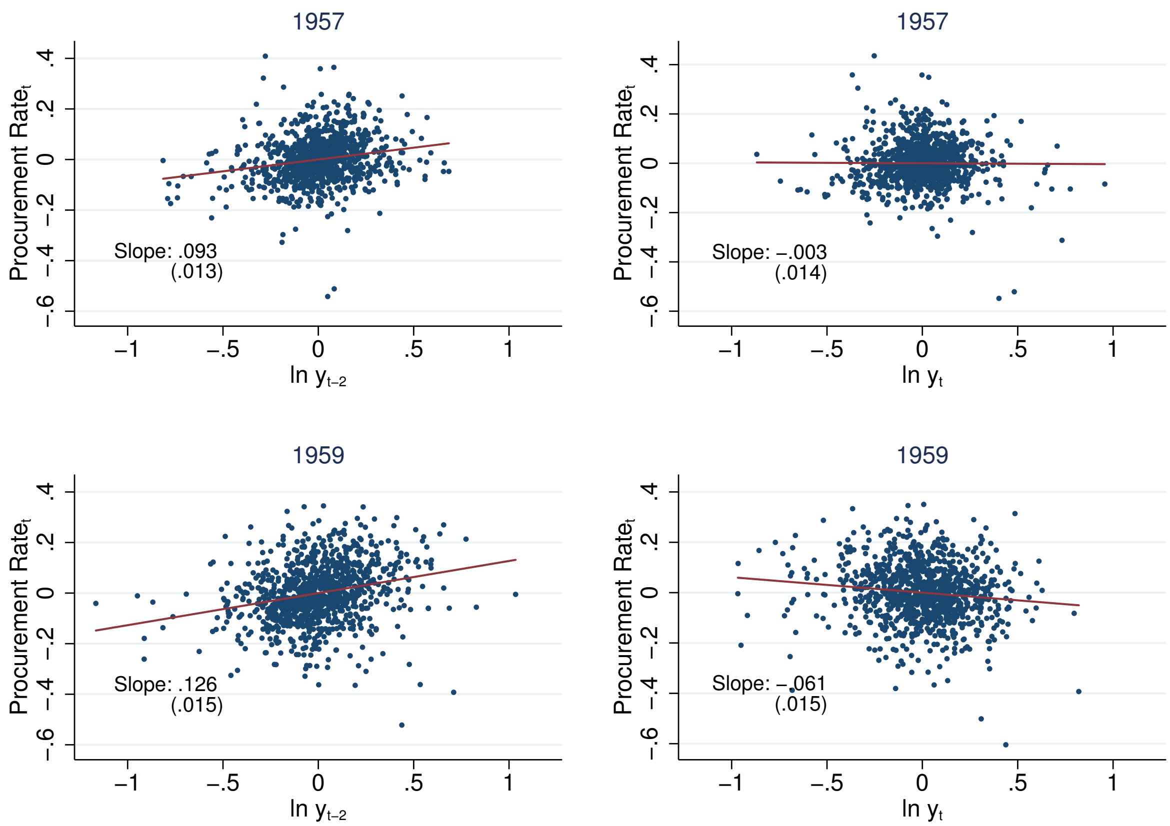
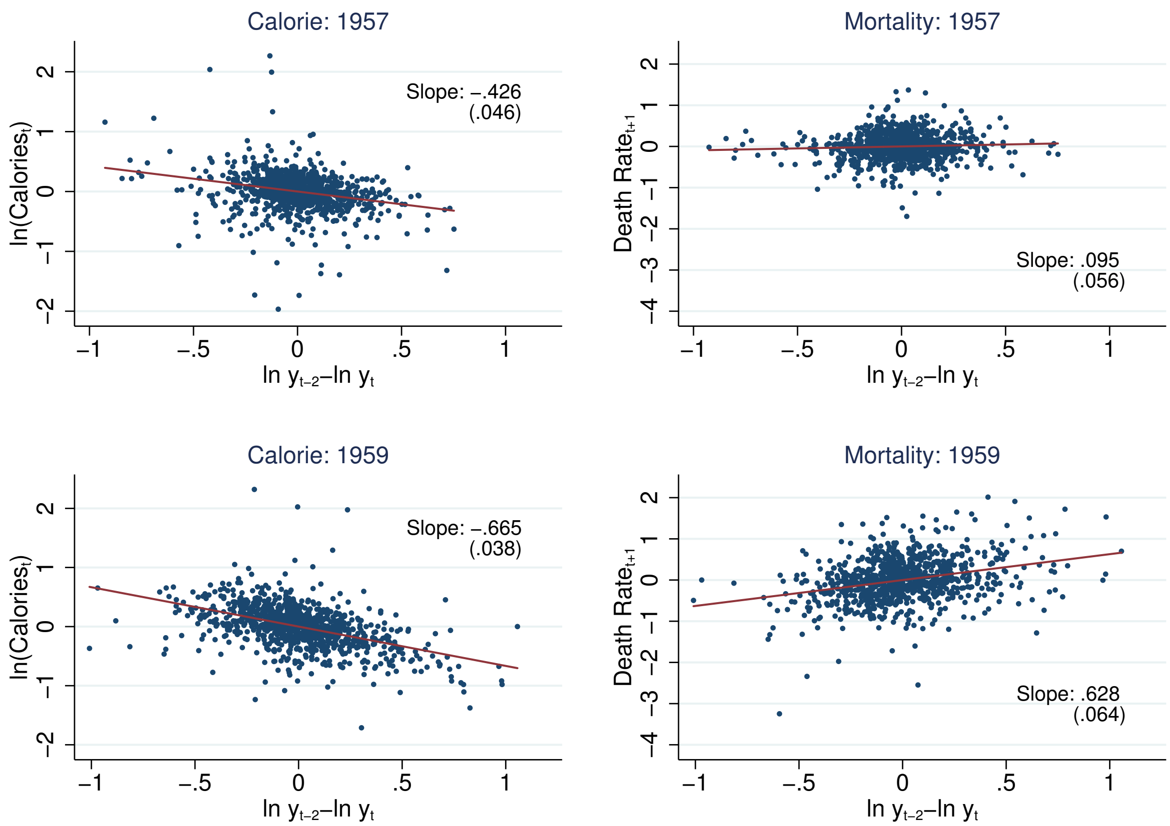


Figure 6: Correlation between Procurement Rate and Outputs



Note: The figures present the partial regression plots of the empirical model: $ProcRate_{it} = \beta_1 \ln y_{it} + \beta_2 \ln y_{it-2} + \gamma_p + \varepsilon_{it}$, where γ_p denotes the province dummy. The upper panel shows the result for year 1957, and the lower panel corresponds to year 1959.

Figure 7: Correlations between Calorie, Death Rate and Output Shocks



Note: The figures present the partial regression plots of the empirical models: $\ln c_{it} = \beta(\ln y_{it-2} - \ln y_{it}) + \gamma_p + \varepsilon_{it}$ and $\ln DR_{it} = \beta(\ln y_{it-2} - \ln y_{it}) + \gamma_p + \varepsilon_{it}$, where γ_p denotes the province dummy. The upper panel shows the result for year 1957, and the lower panel corresponds to year 1959.

Figure 8: Semi-parametric Regression: Death Rate and Log Caloric Consumption

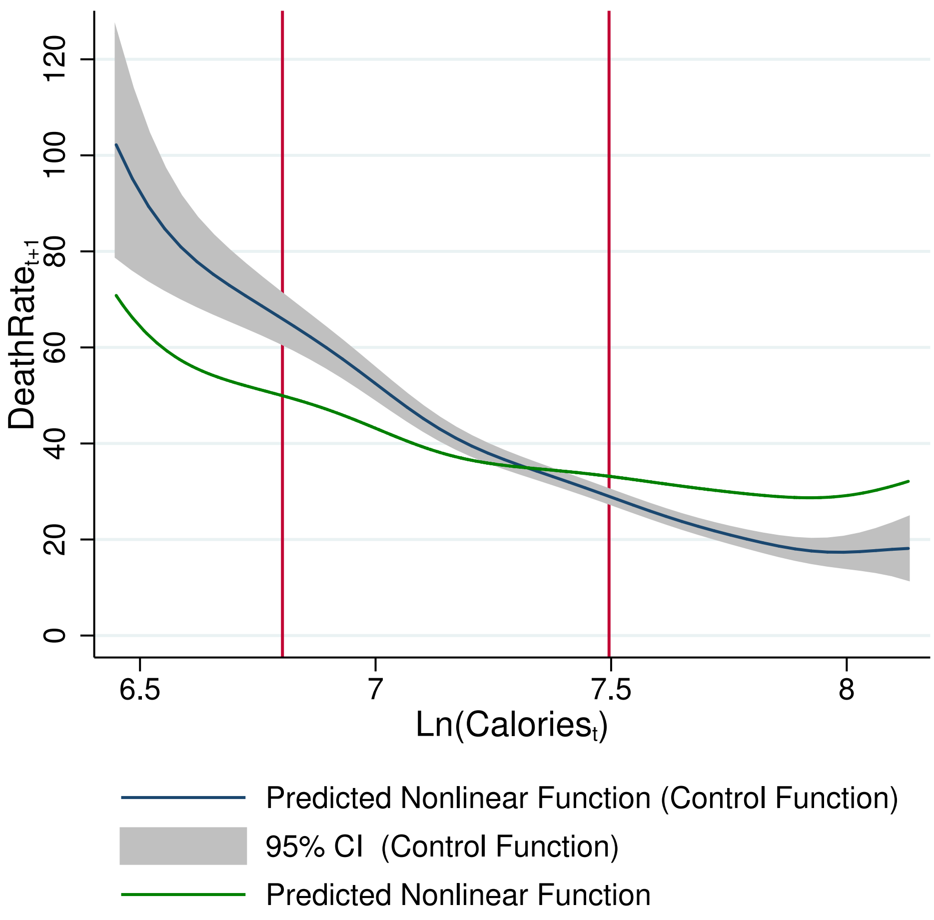


Figure 9: Semi-parametric Regression: Birth Rate and Log Caloric Consumption

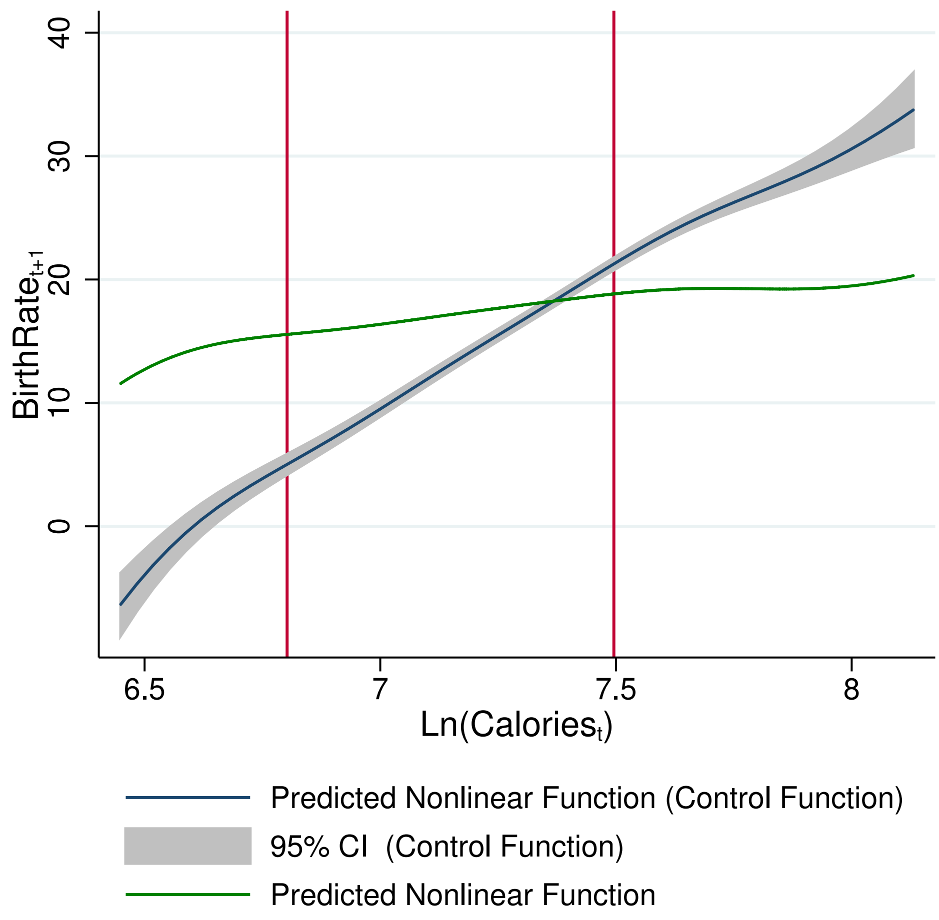


Table 1: Procurement, Comtemporaneous and Past Outputs

	All	All	All	Near	Far
	(1)	(2)	(3)	(4)	(5)
Panel A: Dependent Variable $\ln RetainRate_t$					
GLF$\times \ln y_t$	-0.002	0.001	-0.055	-0.126**	0.000
	(0.017)	(0.013)	(0.040)	(0.057)	(0.061)
GLF$\times \ln y_{t-2}$	-0.079***	-0.054***	-0.127***	-0.094*	-0.147***
	(0.017)	(0.013)	(0.038)	(0.053)	(0.055)
Non-GLF$\times \ln y_t$	-0.065***	-0.045***	-0.166***	-0.202***	-0.114***
	(0.008)	(0.008)	(0.022)	(0.031)	(0.031)
Non-GLF$\times \ln y_{t-2}$	-0.021***	-0.010**	-0.002	-0.003	-0.011
	(0.006)	(0.005)	(0.019)	(0.028)	(0.025)
N	10,258	10,258	9,625	4,985	4,710
R^2	0.503	0.795	0.798	0.812	0.792
Panel B: Dependent Variable $DeathRate_{t+1}$					
GLF$\times \ln y_t$	-8.941***	-7.773***	-24.189***	-15.083***	-32.856***
	(1.411)	(1.352)	(4.529)	(4.803)	(8.782)
GLF$\times \ln y_{t-2}$	9.698***	9.422***	29.982***	20.539***	38.239***
	(1.302)	(1.204)	(5.612)	(6.337)	(9.629)
Non-GLF$\times \ln y_t$	-0.229	-0.001	4.210***	2.731*	3.896*
	(0.181)	(0.320)	(1.296)	(1.617)	(2.321)
Non-GLF$\times \ln y_{t-2}$	0.236	0.963***	2.089*	1.683	2.412
	(0.152)	(0.274)	(1.168)	(1.135)	(2.003)
N	12,352	12,352	11,636	6,038	5,598
R^2	0.533	0.620	0.640	0.691	0.643
Panel C: Dependent Variable $BirthRate_{t+1}$					
GLF$\times \ln y_t$	3.563***	4.093***	8.146***	2.405	17.022***
	(0.462)	(0.489)	(1.827)	(2.180)	(3.681)
GLF$\times \ln y_{t-2}$	-2.371***	-2.272***	-2.596	1.448	-8.356**
	(0.429)	(0.474)	(1.918)	(2.348)	(3.698)
Non-GLF$\times \ln y_t$	3.332***	3.976***	8.549***	7.924***	10.411***
	(0.425)	(0.414)	(1.188)	(1.551)	(1.954)
Non-GLF$\times \ln y_{t-2}$	-2.306***	-1.865***	-2.728***	-3.548***	-1.596
	(0.370)	(0.367)	(1.046)	(1.319)	(1.739)
N	12,369	12,369	11,650	6,039	5,611
R^2	0.719	0.795	0.798	0.805	0.804
Province×Year	Y	Y	Y	Y	Y
County		Y	Y	Y	Y
Control function			Y	Y	Y

Notes: Column (1) control for county specific time-invariant characteristics, including suitability of cultivating different crops and average weather conditions. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 2: Export Exposure, Retained Rate, Death and Birth Rates

	All	All	All	All	Near	Far
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Dependent Variable $\ln RetainRate_t$						
$Export_t$	-0.010***	-0.003*	-0.026**	-0.027***	-0.022*	-0.031*
	(0.001)	(0.001)	(0.011)	(0.011)	(0.013)	(0.019)
$Export_t \times \ln y_t$			0.005	0.005	0.000	0.010**
			(0.003)	(0.003)	(0.004)	(0.005)
$Export_t \times \ln y_{t-2}$			-0.001	-0.001	0.003	-0.006
			(0.003)	(0.003)	(0.004)	(0.005)
$Export_t \times DistRail$				0.012*		
				(0.007)		
GLF$\times \ln y_t$	0.057	-0.052	-0.091**	-0.092**	-0.123**	-0.061
	(0.047)	(0.040)	(0.044)	(0.044)	(0.062)	(0.065)
GLF$\times \ln y_{t-2}$	-0.147***	-0.127***	-0.108**	-0.109**	-0.122*	-0.091
	(0.046)	(0.037)	(0.046)	(0.046)	(0.062)	(0.070)
Non-GLF$\times \ln y_t$	-0.147***	-0.167***	-0.183***	-0.185***	-0.203***	-0.145***
	(0.018)	(0.022)	(0.024)	(0.024)	(0.034)	(0.033)
Non-GLF$\times \ln y_{t-2}$	0.045**	-0.003	-0.001	-0.001	-0.019	0.010
	(0.017)	(0.018)	(0.023)	(0.023)	(0.034)	(0.034)
N	9,695	9,695	9,695	9,695	4,985	4,710
R^2	0.526	0.798	0.799	0.799	0.813	0.794
Panel B: Dependent Variable $DeathRate_{t+1}$						
$Export_t$	0.270***	0.381***	2.341***	2.121***	1.596**	4.373***
	(0.055)	(0.091)	(0.754)	(0.750)	(0.776)	(1.251)
$Export_t \times \ln y_t$			-0.804***	-0.784***	-0.549*	-1.585***
			(0.264)	(0.263)	(0.316)	(0.490)
$Export_t \times \ln y_{t-2}$			0.494**	0.497**	0.347	0.959**
			(0.217)	(0.218)	(0.266)	(0.440)
$Export_t \times DistRail$				1.529**		
				(0.756)		
GLF$\times \ln y_t$	-27.392***	-24.741***	-18.822***	-19.016***	-10.927***	-24.833***
	(5.231)	(4.517)	(3.951)	(3.955)	(3.319)	(7.967)
GLF$\times \ln y_{t-2}$	26.024***	30.065***	24.760***	24.586***	16.247***	31.075***
	(5.262)	(5.520)	(4.589)	(4.560)	(4.236)	(8.067)
Non-GLF$\times \ln y_t$	-0.043	4.342***	6.635***	6.441***	4.276**	8.793***
	(0.508)	(1.296)	(1.680)	(1.671)	(2.169)	(2.822)
Non-GLF$\times \ln y_{t-2}$	-0.238	2.313**	0.476	0.345	0.493	-0.606
	(0.454)	(1.172)	(1.267)	(1.261)	(1.344)	(2.206)
N	11,636	11,636	11,636	11,636	6,038	5,598
R^2	0.559	0.641	0.644	0.644	0.695	0.649

Table 2 (Cont.): Export Exposure, Retained Rate, Death and Birth Rates

	All (1)	All (2)	All (3)	All (4)	Near (5)	Far (6)
Panel C: Dependent Variable $BirthRate_{t+1}$						
$Export_t$	-0.074**	-0.127***	-0.598*	-0.496	-0.462	-0.897
	(0.030)	(0.046)	(0.351)	(0.347)	(0.389)	(0.681)
$Export_t \times \ln y_t$			-0.004	-0.013	0.003	0.124
			(0.098)	(0.098)	(0.110)	(0.204)
$Export_t \times \ln y_{t-2}$			0.082	0.080	0.055	0.002
			(0.104)	(0.104)	(0.109)	(0.230)
$Export_t \times DistRail$				-0.714**		
				(0.327)		
GLF$\times \ln y_t$	3.110**	8.329***	8.291***	8.381***	2.535	16.275***
	(1.531)	(1.819)	(1.927)	(1.923)	(2.276)	(3.756)
GLF$\times \ln y_{t-2}$	-2.441	-2.623	-3.177	-3.096	1.084	-8.243**
	(1.521)	(1.896)	(2.099)	(2.092)	(2.413)	(4.018)
Non-GLF$\times \ln y_t$	7.732***	8.506***	8.483***	8.574***	7.941***	9.869***
	(0.821)	(1.184)	(1.214)	(1.213)	(1.610)	(1.979)
Non-GLF$\times \ln y_{t-2}$	-7.021***	-2.803***	-3.183***	-3.122***	-3.919***	-1.731
	(0.812)	(1.046)	(1.144)	(1.142)	(1.424)	(1.951)
N	11,650	11,650	11,650	11,650	6,039	5,611
R^2	0.730	0.798	0.799	0.799	0.805	0.805
Province×Year	Y	Y	Y	Y	Y	Y
County		Y	Y	Y	Y	Y
Control function	Y	Y	Y	Y	Y	Y

Notes: Column (1) control for county specific time-invariant characteristics, including suitability of cultivating different crops and average weather conditions. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 3: Province-Level Determinants of County-Level Grain Output

	(1)	(2)	(3)	(4)	(5)	(6)
ln Per Capita Sown Area	0.529***				0.516***	
	(0.092)				(0.091)	
Per Capita Steel Output		-0.000			-0.001	
		(0.001)			(0.001)	
GLF× Late Liberation			-0.062*		-0.055	
			(0.035)		(0.035)	
GLF× Intensity of the 1957				-0.209	0.130	
Anti-Rightest Movement				(0.642)	(0.647)	
County	Y	Y	Y	Y	Y	Y
Year	Y	Y	Y	Y	Y	
Province×Year						Y
N	15,840	15,840	15,840	15,840	15,840	15,840
R^2	0.729	0.723	0.724	0.723	0.729	0.777

Notes: Standard errors are clustered at the province×year level. *** p<0.01, ** p<0.05, * p<0.1

Table 4: Robustness – Different Outcome Variables

Dep Var.	Panel A: $ProcurementRate_t$				Panel B: $\ln Calorie_t$			
	All	Near	Far	All	All	Near	Far	All
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
GLF$\times \ln y_t$	0.049**	0.088***	0.017	0.048**	0.945***	0.874***	1.000***	0.947***
	(0.024)	(0.033)	(0.038)	(0.024)	(0.040)	(0.057)	(0.061)	(0.040)
GLF$\times \ln y_{t-2}$	0.066***	0.044	0.080**	0.067***	-0.127***	-0.094*	-0.147***	-0.128***
	(0.022)	(0.030)	(0.034)	(0.022)	(0.038)	(0.053)	(0.055)	(0.037)
Non-GLF$\times \ln y_t$	0.126***	0.150***	0.089***	0.127***	0.834***	0.798***	0.886***	0.832***
	(0.014)	(0.021)	(0.021)	(0.014)	(0.022)	(0.031)	(0.031)	(0.022)
Non-GLF$\times \ln y_{t-2}$	-0.008	-0.014	0.004	-0.007	-0.002	-0.003	-0.011	-0.004
	(0.013)	(0.019)	(0.017)	(0.013)	(0.019)	(0.028)	(0.025)	(0.018)
$Export_t$				0.001				-0.003**
				(0.001)				(0.001)
$Export_t \times DistRail$				-0.006				0.013*
				(0.004)				(0.007)
N	9,695	4,985	4,710	9,695	9,695	4,985	4,710	9,695
R^2	0.813	0.824	0.810	0.814	0.960	0.957	0.967	0.960

Table 4 (Cont.): Robustness – Different Outcome Variables

Dep Var.	Panel C: $\ln CohortSize_{t+1}$				Panel D: $PopGrowthRate_{t+1}$			
	All	Near	Far	All	All	Near	Far	All
	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
GLF$\times \ln y_t$	0.280***	0.148	0.449***	0.291***	32.327***	17.497***	49.942***	33.164***
	(0.092)	(0.105)	(0.168)	(0.092)	(5.434)	(6.023)	(10.414)	(5.405)
GLF$\times \ln y_{t-2}$	-0.192**	0.028	-0.392**	-0.193**	-32.530***	-19.075**	-46.579***	-32.405***
	(0.092)	(0.108)	(0.157)	(0.091)	(6.650)	(7.818)	(11.384)	(6.500)
Non-GLF$\times \ln y_t$	0.116**	0.170***	0.098	0.114**	4.325**	5.199**	6.492**	4.323**
	(0.048)	(0.064)	(0.077)	(0.048)	(1.803)	(2.328)	(3.144)	(1.789)
Non-GLF$\times \ln y_{t-2}$	-0.051	0.001	-0.059	-0.053	-4.814***	-5.213***	-4.021	-4.937***
	(0.041)	(0.056)	(0.067)	(0.041)	(1.562)	(1.728)	(2.649)	(1.552)
$Export_t$				-0.006***				-0.393***
				(0.002)				(0.112)
$Export_t \times DistRail$				-0.012				-2.027**
				(0.020)				(0.805)
N	11,658	5,967	5,691	11,658	11,634	6,036	5,598	11,634
R^2	0.942	0.942	0.945	0.942	0.774	0.808	0.774	0.775
Province$\times$Year	Y	Y	Y	Y	Y	Y	Y	Y
County	Y	Y	Y	Y	Y	Y	Y	Y
Control function	Y	Y	Y	Y	Y	Y	Y	Y

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 5: Counterfactural Exercises

Panel A: Change in Deaths	$\Delta DeathRate$ mean	std	implied number of excess deaths	% of actual excess deaths
(A1) From Data: $DeathRate_{60} - DeathRate_{58}$	14.71	23.24	4068518.50	100
Approach 1: Based on the Non-Parametric Function				
(A2) Caloric consumption in 1959 same as 1957	13.16	15.64	3634158.50	89.32
(A3) Output in 1959 same as 1957	5.87	12.36	1789700.50	43.99
(A3.a) Agricultural Inputs in 1959 same as 1957	3.89	2.61	1080046.50	26.55
(A3.b) No weather shocks in 1959	0.32	4.88	248488.84	6.11
(A4) Procurement Rate in 1959 same as 1957	8.90	10.26	2310339.00	56.79
(A5) Export exposure in 1959 same as 1957	1.51	1.68	422360.47	10.38
(A6) Export exposure in 1959 same as 1957: Hetero.	1.04	0.99	291855.16	7.17
(A7) Procurement Policies in 1959 same as Non-GLF period	4.12	3.17	1141869.62	28.07
(A8) Procurement Policies in 1957 same as GLF period	2.54	1.50	646145.69	16.44
Approach 2: Based on Reduced-Form Regressions				
(A9) Output in 1959 same as 1957	3.15	6.08	950633.69	23.37
(A10) Export exposure in 1959 same as 1957	1.91	1.05	501306.56	12.32
(A11) Export exposure in 1959 same as 1957: Hetero.	1.81	1.65	516377.59	12.69
(A12) Procurement Policies in 1959 same as Non-GLF period	0.83	7.09	370098.97	9.10

Panel B: Change in Births	$\Delta BirthRate$ mean	std	implied number of lost births	% of actual lost births
(B1) From Data: $BirthRate_{58} - BirthRate_{60}$	9.51	9.88	2754116.75	100
Approach 1: Based on the Non-Parametric Function				
(B2) Caloric consumption in 1959 same as 1957	7.45	7.16	2011462.75	73.03
(B3) Output in 1959 same as 1957	2.96	5.70	895058.06	32.50
(B3.a) Agricultural Inputs in 1959 same as 1957	2.01	0.72	545310.75	19.80
(B3.b) No weather shocks in 1959	0.13	2.36	127162.13	4.62
(B4) Procurement Rate in 1959 same as 1957	44.69	4.01	1179195.62	42.82
(B5) Export exposure in 1959 same as 1957	0.71	0.46	194447.83	7.06
(B6) Export exposure in 1959 same as 1957: Hetero.	0.51	0.31	140864.91	5.11
(B7) Procurement Policies in 1959 same as Non-GLF period	2.08	0.85	561223.44	20.38
(A8) Procurement Policies in 1957 same as GLF period	1.68	0.65	418042.69	16.21
Approach 2: Based on Reduced-Form Regressions				
(B9) Output in 1959 same as 1957	1.06	2.05	320146.38	11.62
(B10) Export exposure in 1959 same as 1957	0.63	0.35	166653.50	6.05
(B11) Export exposure in 1959 same as 1957: Hetero.	0.84	0.48	216317.45	7.85
(B12) Procurement Policies in 1959 same as Non-GLF period	1.48	0.11	382903.22	13.90

Notes: The implied number of excess deaths is the sum of excess deaths of 755 counties with data on caloric consumption in both 1957 and 1959.

Appendix

A Data Appendix

A.1 Demographic Data

A.1.1 Consistency of the County-Level Data with Other Data Sources

To examine the reliaility of this new dataset, we cross-check with the province-level data employed by Lin and Yang (2000) and Meng et al. (2015).[22] Figure A.2 plots the province-level death rates aggregated from our county-level data against the existing provincial-level data. The scatter points cluster along the 45 degree line and there is no pattern that our data systematically over or under report death rates. (The correlation coefficient of the two series is 0.991.) This result is expected, as both our data and the data employed by the existing studies come from China's Statistics Bureaus.

A.1.2 Excess Deaths and Loss/Postponed Births During the Great Famine

We calculate the number of excess deaths and loss/postponed births during the Great Famine as follows. For each county, we take the 1957 death/birth rate as the benchmark death/birth rates (which would have been the 1959-1961 death/birth rate without famine) and compute the difference between the 1957 death/birth rate and the 1959-1961 death birth rate for each county, i.e., $\Delta DeathRate_{it,57}$ and $\Delta BirthRate_{it,57}$. Then the excess deaths and loss/postponed births during the are given by:

$$TotalExcessDeaths = \sum_{t=59,60,61} \sum_{i} (\Delta DeathRate_{it,57} \times Pop_{it})$$

$$TotalLossBirths = \sum_{t=59,60,61} \sum_{i} (\Delta BirthRate_{it,57} \times Pop_{it})$$

The total excess deaths is 15.74 million and the total loss/postponed births is 18.59 million. These numbers amount to 0.03 and 0.035 of the total 1957 population in sample. (The total

[22]Both studies use the data from statistical yearbooks from the National Statistics Bureau (NBS).

excess deaths as a share of national population is 0.024 and the total loss births as a share of national population is 0.029.)

A.2 Output and Procurement Data

A.2.1 Selection Issue

A potential concern is that counties self-select into reporting procurement and output data. In particular, one may worry that counties that experienced more severe famine because of over-procurement may avoid reporting their data. To investigate this possibility, we divide counties into two groups: (i) counties with complete data on retained rate over the sample period, and (ii) counties with incomplete data. Panel A of Figure A.3 plots the average death rate across years by county group. The two series closely track with each other in non-famine years. In 1959, the counties with incomplete data on retained rate had an higher average death rate. However, in 1960 the pattern reversed. Panel B presents the corresponding plot for birth rate. For most of the years, there is no significant difference between the groups. The findings in Figure A.3 suggest that our data are unlikely to be subject to severe selective reporting.

Figure A.1: Export and Import (1955-1961)

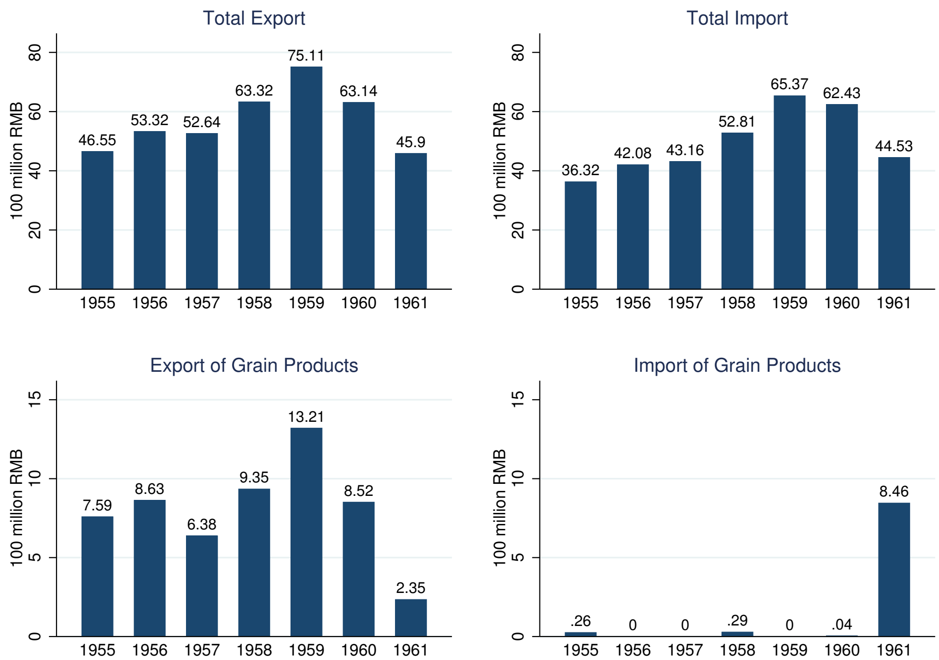
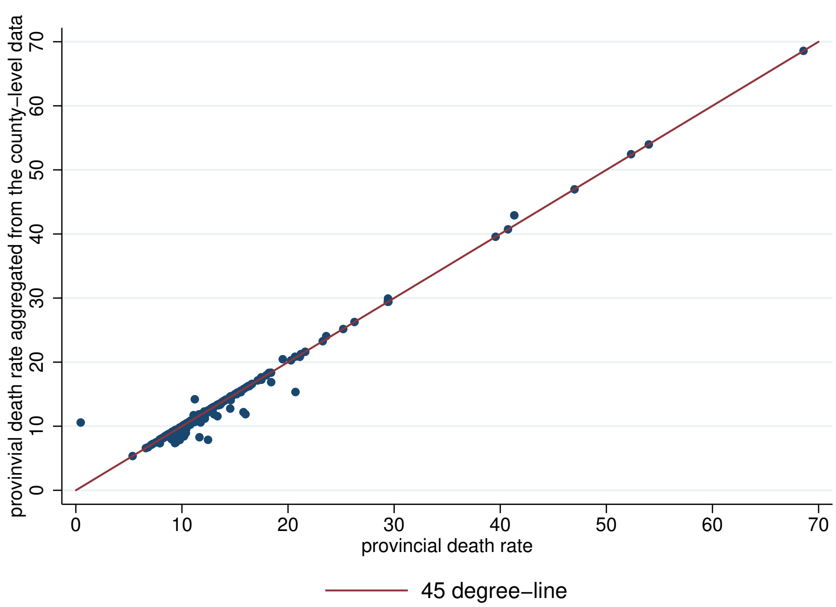


Figure A.2: Comparison of the Province-Level Death Rates from Different Sources



Note: The figure excludes province Shannxi, as we only have data for a sample of counties.

Figure A.3: Mean Mortality and Birth Rates by Reporting Status

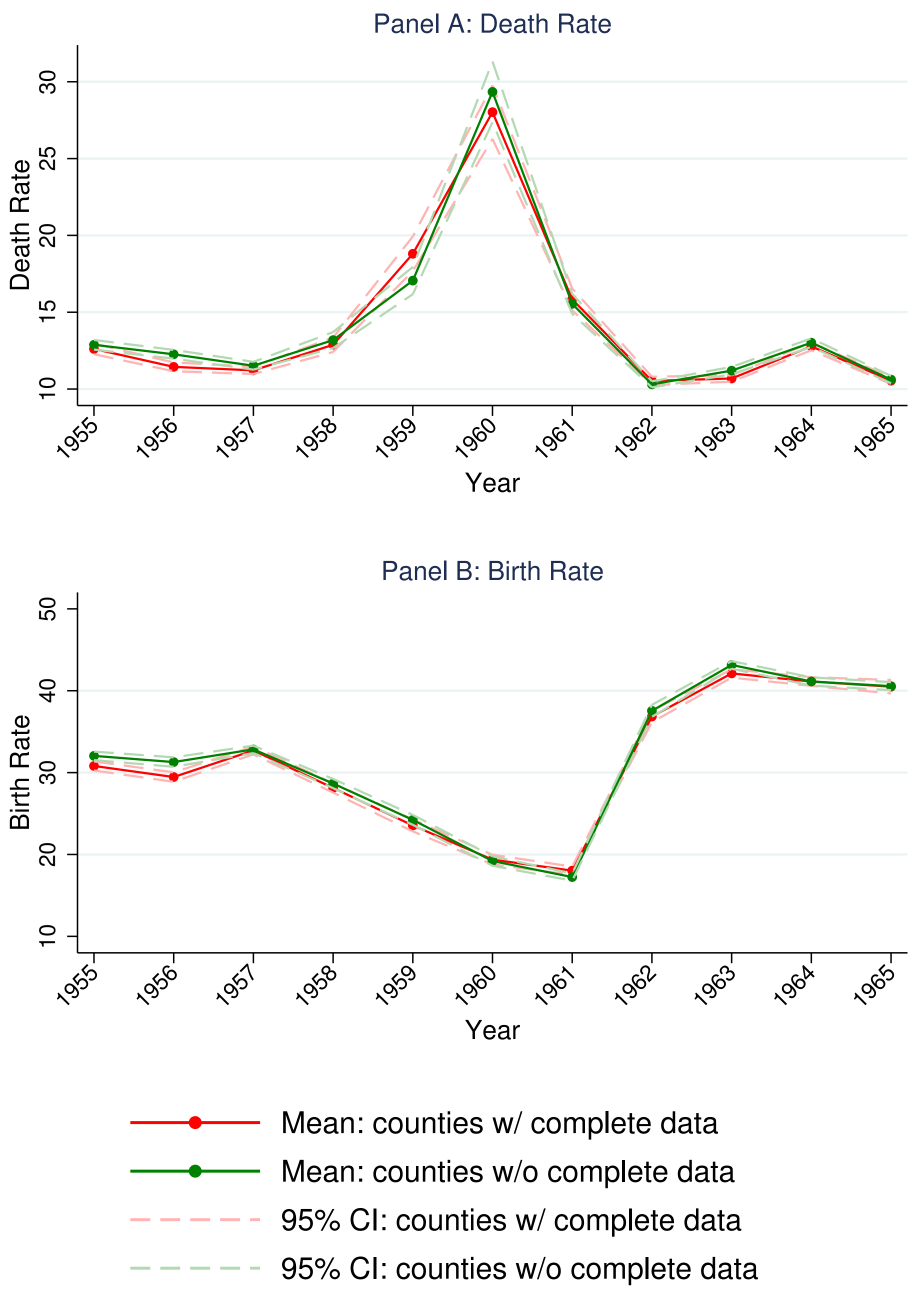


Figure A.4: Relative Price over 1955-1961

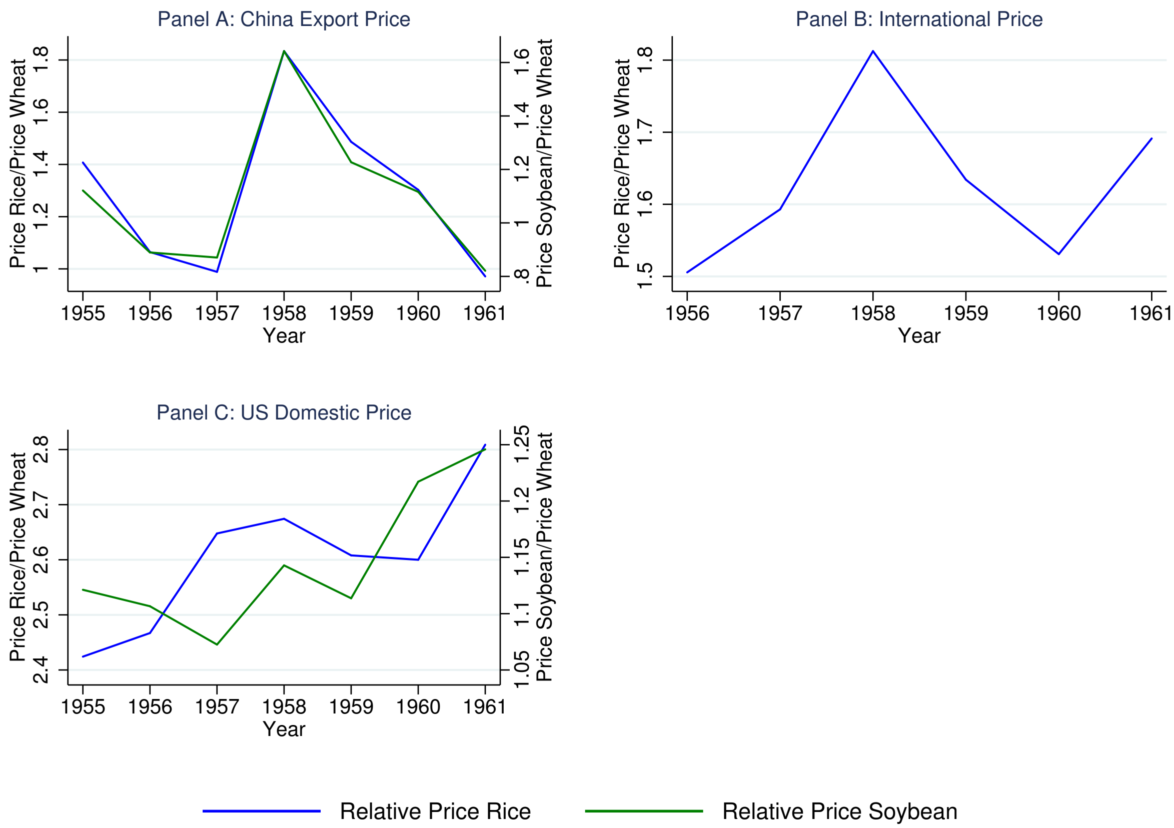


Figure A.5: Railway Network in 1957

Figure A.6: Change in Mortality Rate between 1957 to 1960

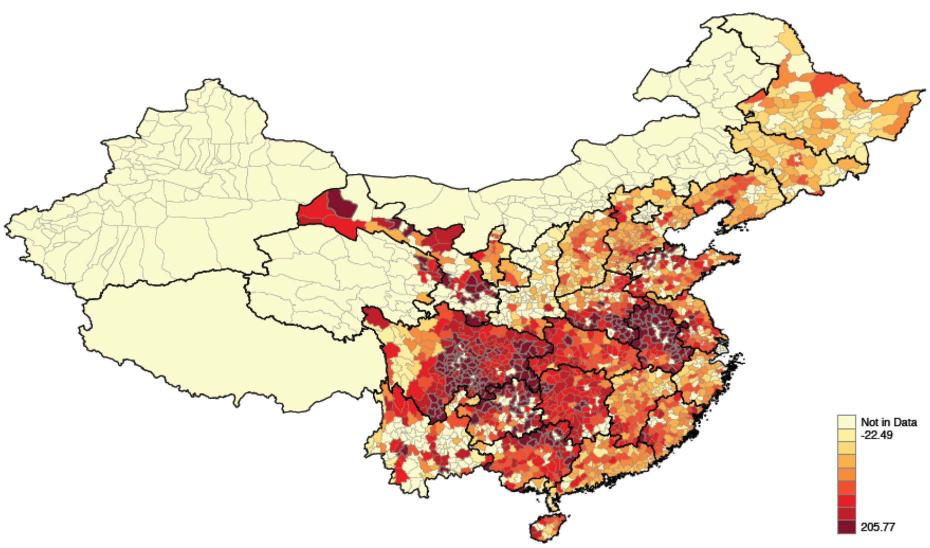
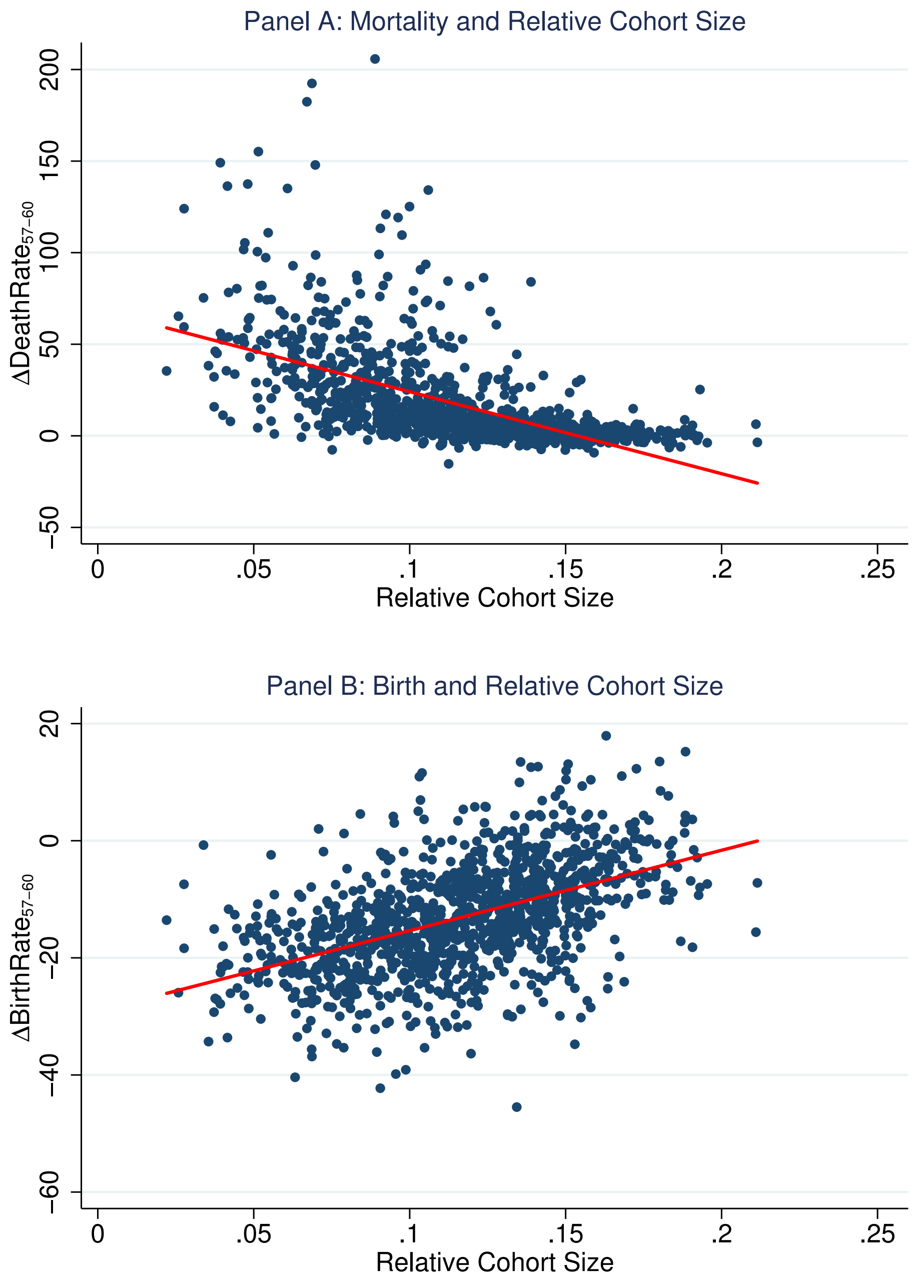
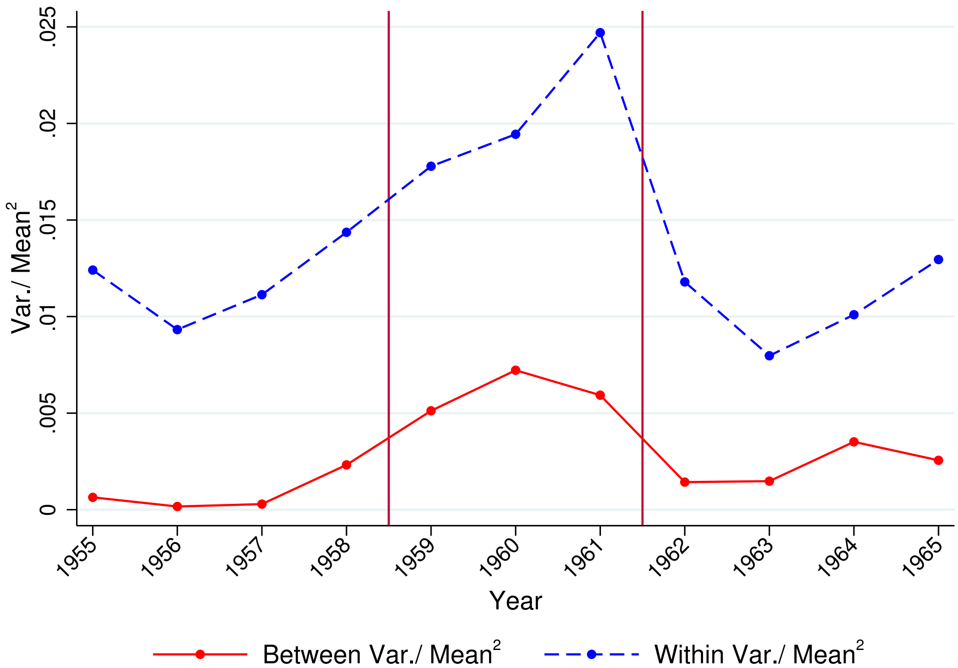


Figure A.7: Correlation of Death and Birth Rates with Relative Cohort Size



Note: The figure correlates the increase in death (birth) rate over 1957 and 1960 with the relative population size of the famine birth cohort. The y-axis is the change in death (birth) rate over 1957 and 1960. The x-axis is the population size of famine birth cohorts (1959-1961) normalized by the total population of cohorts born between 1953-1965 observed from the 1990 China Population Census.

Figure A.8: Decomposition of Within- versus Between-Province Variation – Relative Cohort Size



Note: The figure decomposes the variance of relative cohort size $\frac{\ln CohortSize_{it}}{\sum_{t=1953}^{1965} \ln CohortSize_{it}}$ into the between-province component and between-province component.

Table A.1: Data Sources of Mortality and Birth Rates

Province	Data Source	Period	Number of Counties
Anhui (34)	Chronicles of Anhui Province	1957,60,62, 65	64
Fujian (35)	Fujian Population Statistics: 1949-1988	1955-1965	61
Gansu (62)	Gansu Population Statistics: 1949-1987	1955-65	72
Guangdong (44)	Guangdong Population Statistics: 1949-1985	1955-59, 61-65	99
Guangxi (45)	Guangxi Population Statistics: 1949-1985	1955-65	74
Guizhou (52)	Guizhou Population Statistics: 1949-1984	1955-65	78
Hebei (13)	Hebei Population Statistics: 1949-1984	1955-65	136
Heilongjiang (23)	Heilongjiang Population Statistical Yearbook 1989	19545-65	58
Henan (41)	Henan Population Statistics: 1949-1988	1955-65	109
Hubei (42)	Hubei Population Statistics: 1949-1978	1955-65	72
Hunan (43)	Hunan Population Statistics: 1949-1991	1955-65	85
Jiangsu (32)	Jiangsu Population Statistics	1955-65	61
Jiangxi (36)	Jiangxi Population Statistics: 1949-1985	1955-65	82
Jilin (22)	Jilin Population Statistics: 1949-1984	1955-65	37
Liaoning (21)	Liaoning Population Statistics: 1949-1984	1955-65	44
Ningxia (64)	Ningxia Population Statistics: 1949-1985	1955-65	16
Qinghai (63)	Qinghai Population Statistics: 1949-1985	1955-65	39
Shandong (37)	Shandong Population Statistics: 1949-1984	1955-65	100
Shanxi (14)	Shanxi Population Statistics: 1949-1990	1955-65	94
Shannxi (61)	Various volumes of Local Chronicles and Shannxi Population Statistics: 1949-1990	1955-65	56
Sichuan (51)	Sichuan Population Statistics: 1949-1987	1955-65	185
Yunnan (53)	Yunnan Population Statistics: 1949-1988	1955-65	118
Zhejiang (33)	Zhejiang Population Statistics: 1949-1985	1956-65	63

Note: Province codes are in the parentheses.

Table A.2: Famine Severity and Concentration

Year	Total Excess Death	Total Loss Births	Top 10 percent $\Delta DeathRate_{it,57}$ Excess Deaths	Top 10 percent $\Delta DeathRate_{it,57}$ Share of Total	Bottom 10 percent $\Delta BirthRate_{it,57}$ Loss Births	Bottom 10 percent $\Delta BirthRate_{it,57}$ Share of Total
	(1)	(2)	(3)	(4)	(5)	(6)
1959	3801.372	-4548.173	2318.716	0.610	-1028.363	0.226
1960	9667.090	-6742.743	4634.940	0.479	-1460.015	0.217
1961	2274.805	-7297.030	1266.120	0.557	-1359.642	0.186

1959-61 total excess deaths as a share of 1957 population in sample	1959-61 total excess deaths as a share of 1957 national population	1959-61 total loss births as a share of 1957 population in sample	1959-61 total loss births as a share of 1957 national population
(7)	(8)	(9)	(10)
0.030	0.024	0.035	0.029

Note: The number of deaths and births are in thousands.

Table A.3: Data Sources for Grain Procurement and Output

Province	Data Source
Anhui (34)	Local Chronicles, MOA
Fujian (35)	Local Chronicles, MOA
Gansu (62)	Local Chronicles, MOA
Guangdong (44)	Local Chronicles, MOA
Guangxi (45)	Local Chronicles, MOA
Guizhou (52)	Local Chronicles, MOA
Hebei (13)	Local Chronicles, MOA
Heilongjiang (23)	Local Chronicles, MOA
Henan (41)	Henan Agriculture Statistics: 1949-1979
Hubei (42)	Hubei Economic Statistics: 1949-1978
Hunan (43)	Local Chronicles, MOA
Jiangsu (32)	Local Chronicles, Jiangsu Agriculture Statistics: 1949-1979
Jiangxi (36)	Local Chronicles, MOA
Jilin (22)	Local Chronicles, MOA
Liaoning (21)	Local Chronicles, MOA
Ningxia (64)	Local Chronicles, MOA
Qinghai (63)	Local Chronicles, MOA
Shandong (37)	Local Chronicles, MOA
Shanxi (14)	Local Chronicles, MOA
Sichuan (51)	Local Chronicles, MOA
Yunnan (53)	Local Chronicles, Yunnan Agriculture Statistics: 1949-1979
Zhejiang (33)	Local Chronicles, MOA

Note: Province codes are in the parentheses.