Grain Exports and the Causes of China's Great Famine, 1959-1961: County-Level Evidence*

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Abstract

This study quantitatively evaluates the relative importance of different causes of China's Great Famine, especially for the importance of grain exports. We exploit county-level over-time variations in crop specialization patterns to construct Bartik-style measures of export shocks. Using county-level panel data from 1955 to 1963, we regress death rates on the Bartik export measures with county and province-year fixed effects as well as time-varying effects of county-level observables. We use weather shocks to instrument for output and consumption. The regression results suggest that increases in grain exports substantially increase death rates. This effect is larger in counties that are further from railways and with fewer local Chinese Communist Party members. To examine the relative importance of different mechanisms, we also estimate the effects of the procurement policy, the determinants of grain output, and the relationship between death rates and county-level average caloric consumption during the famine period. The counterfactual experiments indicate that the fall in agriculture production, the increase in procurement partly driven by grain exports, and the increasingly progressive and inflexible procurement policy collectively increased the number of excess deaths, where no single factor dominates. In particular, grain exports explain 15 percent of excess deaths, which is one-fourth of the effect of the increase in procurement rates between 1957-1959.

Keywords: famine severity, over-export, county-level data, Bartik-style export shocks, grain procurement, distance to railways, Chinese Communist Party members.

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1 Introduction

China's Great Famine, which raged between 1959 and 1961, caused 16.5-30 million deaths and 30-33 million lost or postponed births. It was the worst famine in human history by population loss. Previous studies suggest that the Great Famine was a consequence of multiple interrelated institutional failures that together led to the collapse of agricultural production and the over-procurement of grains in rural areas (Lin, 1990; Lin and Yang, 2000; Li and Yang, 2005; Meng et al., 2015).

This study contributes to the literature by quantitatively assessing the relative importance of different causes of the Great Famine, including *the export of grains*. Between 1957 and 1959, despite food shortages, the Chinese government increased total grain exports by 2.2 million tons, from 1.9 million to 4.1 million tons (Figure 1). Grain exports were increased to secure foreign currency both to repay loans from the Soviet Union and to import industrial equipment to promote the Great Leap Forward (GLF). As pointed out by Ashton et al. (1984), Johnson (1998), and Riskin (1998), many of the deaths might have been avoided had the government acted swiftly to stop exports and start large-scale imports of grains; the 9.6 million tons of grain exported during the GLF would have met the caloric needs of 16.7-38.9 million people over that three-year period.

What would have happened to the death rates in different regions of China in 1960 had the 2.2 million tons of grains not been procured by the government in 1959 for export? How does the increase in grain exports quantitatively explain the surge in death rates between 1958 and 1960 relative to other factors such as a drop in aggregate food production in 1959? What if the procurement policy had not become more rigid during the GLF period? To answer these questions, we collect *county-level panel* data between 1953 and 1965 on death rates, birth rates, amounts of grain procured, grain output, and weather conditions, as well as county-level cross-sectional data on outputs of different types of grains, crop productivities, distance to railways, and the percentage of the local population who were Chinese Communist Party (CCP) members. Using cross-county over-time variation in death rates, grain output and procurement, and crop compositions, we evaluate the importance of different causes of the Great Famine, especially for grain exports. We use weather shocks as a source of exogenous variation to address the measurement errors and other potential endogeneity issues in output data.

Figure 2 presents a "heat map" of the geographic distribution of changes in death rates between 1957 and 1960. The figure shows substantial variation in excess death rates across different counties during the famine. In the most severely famine-stricken counties, one in five people died in 1960. The spatial pattern of famine severity appears to be systematically related to the pattern of specialization in high-export-exposure crops – rice and soybean. Taking Henan Province as an example, Figure 3 shows that counties with revealed comparative advantage (see equation (19)) in producing rice and soybean tend to experience greater excess mortality during the famine.

We examine how the change in death rates over time is explained by the export shocks using the geographic and temporal variation in the types of crops each county specialized in and the temporal variation in the international relative price of different crops. We present a simple model of inflexible procurement with export shocks, and derive the following model-consistent Bartik-style measure for export shocks:

$$EX_{it} = \sum_k \frac{\hat{Y}^k_{i,t-2}}{\hat{Y}^k_{t-2}} \frac{\hat{X}^k_t}{\hat{Y}_{it}},$$

where the sum is taken across five crop types (rice, soybean, wheat, potato, and others), $\hat{Y}^k_{i,t-2}/\hat{Y}^k_{t-2}$ is a time-varying county i's share of the output of crop k in year $t-2$ that are predicted by weather shocks and crop productivities, and $\hat{X}^k_t$ is China's total export of crop k in year t instrumented by the international price of crop k. Using county-level panel data, we regress death rates on this Bartik measure while controlling for contemporaneous and past output shocks, county and province-year fixed effects, as well as the interaction terms between various observable county-level characteristics and year dummies. The estimated coefficient of the Bartik export shock is large and significantly positive. By interacting the Bartik measure with distance to railways and the relative number of local CCP members, we find that the effect of grain exports on death rates is larger for counties that are further from railways and with smaller shares of local CCP members. The results suggest that provincial governments were able to verify food shortages for counties near railways or with more CCP members, and hence the grain procurement process was more flexible in these regions mitigating the effect of export shocks on death rates.

To quantitatively investigate the mechanism behind the Great Famine, we estimate the following building blocks of our model: (i) the determinants of the procurement policy; (ii) the determinants of grain outputs; and (iii) the county-level relationship between death rates and the average level of caloric consumption during the famine.

We estimate how the procurement policy was determined by export shocks, current output, two-period lagged output at the county level in the GLF and non-GLF periods. We find that retained consumption rates are lower for counties with higher export exposure, and that the procurement policies during the GLF period was much more progressive and inflexible than during the non-GLF period. On the other hand, by estimating how the grain output was determined, we find that a large portion of grain output decline is driven by the reduction in grain-sown areas, while the export expansion during the GLF period was not an important determinant.

We then non-parametrically estimate the relationship between death rates and retained consumption per capita using county-level data, while accounting for possible measurement error of output and procurement by using weather shocks as an exogenous source of consumption variation. The estimate shows that the death rate is a convex decreasing function of the average level of consumption. The gradient is much steeper at the lower end and flattens out as the caloric consumption level gets higher.

Based on the estimated procurement policy, the estimated grain output function, and the estimated relationship between death rate and average level of consumption, we conduct various counterfactual experiments to evaluate the relative importance of different causes of excess deaths in 1960. The results indicate that excess deaths in 1960 would have been (i) lowered by 45% if agriculture production in 1959 had been the same as in 1957, (ii) lowered by 61% if the procurement rate in 1959 had been the same as in 1957, (iii) lowered by 10% if weather conditions in 1959 had been the same as in 1957, (iv) lowered by 27% if the procurement policy in 1959 had been the same as in 1957, and (v) lowered by 15% if grain exports in 1959 had been the same as in 1957. The effect of grain exports on excess deaths is substantial – the effect of grain is quantitatively more important than that of weather shocks, and it explains one-fourth of the effect of the increase in procurement.

We also conduct a counterfactual experiment of *redistributing* export-driven procurements across counties while keeping the aggregate export constant. The result shows that if the export obligations of counties in the bottom quintile of the retained consumption per capita had been lifted and the remaining counties had raised procurement levels to meet the aggregate export requirement, total excess deaths would have declined by 6%. This suggests that the effect of the aggregate exports on mortality would have been much smaller if export crops had been procured more flexibly.

Our study complements previous studies of the causes of China's Great Famine in several ways. First, this study is the first to provide empirical evidence at the micro level showing that the over-exporting of grain is associated with the spatial pattern of famine severity. Second, this study is the first to quantify the relative importance of different causes using the estimated procurement policy, the grain output function, and the estimated relationship between death rates and retained consumption. We find that the fall in agriculture production, the increase in procurement partly driven by grain exports, and the increasingly progressive and inflexible procurement policy collectively increased the number of excess deaths; no single factor can explain all of the excess deaths. Third, unlike previous studies that mainly rely on province-level panel data, we compile a new panel data set on famine severity, grain production, and export exposure together with the distance to railways and CCP membership at the county level.[1] The rich

[1]The studies that use county-level datasets are Bramall (2011), Meng et al. (2015), Chu, Png and Yi (2016), and Kung and Zhou (2017). Bramall (2011) uses county-level data for mortality, output, rainfall, and temperature, but for Sichuan Province only. Meng et al. (2015) provide a county-level analysis to complement their province-level main results, where the county-level famine severity is measured by the relative population size of famine cohorts to that of non-famine cohorts from the 1990 China Population Census. Chu, Png and Yi (2016) also use relative cohort size and investigate the effect of hardship on entrepreneurship. Kung and Zhou (2017) analyze how hometown favoritism by CCP Central Committee members affected famine severity at the prefecture level. They corroborate their prefecture-level findings with a county-level analysis using data from Henan Province. Importantly, none of

cross-county over-time variation in famine severity and crop specialization patterns allows us to identify the relative importance of difference causes of famine, including export shocks and inflexible procurement policies. In contrast, as shown in Appendix B.2, a province-level regression analysis lacks power to identify the effects of export shocks and inflexible procurement policies due to the limited data variation, which underscores the importance of employing the county-level panel data.

Meng et al. (2015) exploit cross-county data and find that agricultural productivity is negatively correlated with survivor birth cohort size. They argue that this negative correlation is driven by the inflexible and progressive procurement policy, and provide empirical evidence on the rigidity of grain procurement using province-level procurement and output data. Relative to their study, our paper makes several new contributions. First, we identify and quantify the effects of export shocks on grain procurement and famine mortality. Second, we analyze how the effect of export shocks as well as the degree of inflexibility in procurement policy at the county level depends on the distance to railways and the political connections as proxied by the CCP membership. Third, Meng et al.'s main regression analysis on the inflexibility of procurement policy is based on the province-level panel data with 19 provinces over the period from 1953 to 1964 without controlling for province fixed effects.[2] In contrast, our county-level panel data allows us to include county fixed effects, province-year fixed effects, and time-varying effects of observable county-level characteristics into the regression specification; hence, we are better equipped to address endogeneity issues arising from both county-level factors as well as time-varying province-level political factors. Fourth, Meng et al. use survivor birth cohort size as a proxy for famine severity; survivor birth cohort size reflects endogenous fertility decisions and fails to capture the mortality rates of the adults and the elderly. In contrast, we collect and employ the county-level panel data on actual mortality rate, which is a more direct measure of famine severity.

Broadly speaking, our study is linked to several strands of research in the trade literature. First, our study relates to the literature examining how political factors affect trade flows, such as Head et al. (2010), Berger et al. (2013), and Fuchs and Klann (2013). It also complements the studies of Acemoglu et al. (2005), Levchenko (2007), and Pascali (2017), who show that gains from international trade depend on institutional quality. Our findings suggest that due to the lack of constraints on executive power, political factors could be dominant determinants of trade flows, leading to unintended and possibly dire consequences. Drawing on the historical setting of China, our empirical analysis complements Pascali's findings of negative gains from trade in countries characterized by an executive power with unlimited authority. In our context, the simultaneous deterioration of multiple institutions during the famine period–the failure of GLF agricultural policies, the distorted information system, the void of market forces, and the more centralized

these studies analyzes how grain exports relate to mortality or the birth cohort size of survivors at the county level.

[2] See Table 7 of Meng et al. (2015)

organizational structure–are necessary conditions for trade to aggravate the famine.

Moreover, our findings contrast with the literature, which finds stabilizing effects of trade on consumption and famine. In particular, Burgess and Donaldson (2010, 2017) show that the railway expansion in colonial India enhanced trade, dampening consumption volatility and hence alleviating the famine induced by bad weather shocks. Ravallion (1987) emphasizes that whether trade has a stabilizing or a destabilizing effect on consumption volatility highly depends on how quickly the domestic price responds to output fluctuations. We argue that in China during the famine, the absence of market forces and a distorted reporting system led to an inability to quickly gather and aggregate information on supply and demand. The extreme sluggishness of price responses resulted in trade having a destabilizing effect. Our study also fits in the rapidly growing literature that uses cross-regional differences in initial production specialization patterns to study the differential effects of trade (or aggregate demand shocks) on local economies (Qian, 2008; Topalova, 2010; Autor et al., 2013; Dube and Vargas, 2013).

The remainder of this paper is organized as follows. Section 2 introduces the background of the Great Famine and the role of international trade. Section 3 describes the dataset. Sections 4 and 5 lays out our theoretical framework and empirical strategy. Section 6 provides empirical evidence demonstrating that the exportation of grains during the famine years aggravated famine severity and that procurement policies became more rigid during the GLF. Section 7 presents our counterfactual experiments and compares the effect of export shocks relative to the effects of other determinants on famine severity. Section 8 concludes.

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 during the 1958-1960 Great Leap Forward

The Communist Party of China (CCP) started collectivization in 1952, in the hope of transforming the Chinese agriculture system from one based on fragmented household farming into a system of large-scale mechanized production. The initial phase of collectivization (1952-1957) was implemented cautiously and smoothly. The production unit was an elementary or advanced cooperative, usually consisting of 20 to 200 households. The 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 the cooperative and each household's income depended on its input of land, capital goods, and labor. In the 1952-1957 period, 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 rural communities, in which approximately 80% of the population lived at the time. Impatient with the lukewarm growth in agricultural output, the central planners decided to aggressively amalgamate rural collectives into massive communes. By the end of 1958, 24,000 communes had been established, with an average size of 5,000 households and 10,000 acres. Compulsory participation in communes became the official policy, and private property rights to land and capital were eliminated. The harvesting and storage of agricultural goods were conducted at the commune level, and private markets for food were virtually eliminated. The peasants no longer received pecuniary rewards for the effort they expended; instead, free food was distributed in communal mess halls. The communal movement was followed by a collapse in agricultural output. The grain output plunged by 15% in 1959, and in 1960 and 1961 reached only about 70% of the 1958 level (Lin, 1990; Lin and Yang, 2000; Li and Yang, 2005; Meng et al., 2015).

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

2.2 The 1959-1961 Great Famine

The Great Famine (1959-1961) resulted in 16.5 to 30 million excess deaths and 30 to 33 million lost or postponed births.[3] According to 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. Over the same period, the birth rate dropped from 29.22 to 20.86 per thousand. Although the famine was a nationwide calamity, there was considerable differences in famine exposure across regions. For example, although the death rate in Jiangsu Province rose from 9.4 to 18.4 per thousand between 1958 and 1960, its neighbor, Anhui Province, experienced a dramatic increase in death rates from 12.3 to 68.6 per thousand over the same period. Moreover, the famine was largely

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

restricted to rural areas 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).[4]

The extant literature on China's Great Famine debate on the primary cause that leads to the nationwide calamity. The first strand of research focuses on the factors that caused the sudden decline in food-availability, including the factors leading to the plunge in agricultural output, e.g., a succession of natural disasters (Yao, 1999), forced communalization and the removal of the right to exit the commune (Lin, 1990), diversion of resources from agricultural to heavy industry to support the GLF (Li and Yang, 2005), and other factors causing food to be wasted, such as consumption inefficiency in commune mess halls (Chang and Wen, 1998; Yang and Su, 1998). The second strand of research focuses on the factors that led to entitlement failures, including the over-procurement of grain from rural areas because of an urban-biased food policy (Lin and Yang, 2000), information distortion inside the government (Fan, Xiong and Zhou, 2016), and the rigid and progressive procurement policy that caused the over-procurement of grain from regions that suffered larger negative productivity shocks (Meng et al., 2015). Previous studies have also noted the macro implications of the surge in net grain exports in the 1958-1960 period (Ashton et al., 1984; Johnson, 1998).

Massive and widespread famines like the one in China during the 1959-1961 period are caused by a complicated set of factors that interact and reinforce each other, until they culminate in a demographic catastrophe. The famine ended in 1962, at the same time as there were modifications to policies and institutions along multiple dimensions. The extreme policies related to the GLF were abandoned. The central government substantially increased grain imports, and transferred a large amount of grain to rural areas. Rural institutions were altered so that they resembled the institutions that existed in the pre-GLF period: the role of communes was diminished and production was managed by elementary or advanced cooperatives; compensation schemes for effort were restored and communal kitchens were abolished; grain procurement rates were reduced; and rural trade fairs were reopened. Nevertheless, the grain output in 1962 remained 18.2% lower than 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

In the 1950s, China pursued development policies that were heavily biased towards industrialization. The agricultural sector was harshly squeezed to expedite industrial development and subsidize urbanites (Lin and Yang, 2000). The exports of agricultural goods and grain comprised

[4] We assess the quantitative importance of cross-county migration in section 3.1.

around 40% and 15% of total exports, respectively, before the famine. Hence, to some extent, the country's ability to obtain foreign currency to facilitate industrialization relied on the export of agricultural goods, especially grain. Moreover, as scarce foreign currency was mainly reserved for imported industrial equipment, China imported very little grain until 1961. The hardline industry policies during the GLF further distorted the balance between sectors.

The upper panel of Figure A.1 shows the flow of trade between China and the rest of the world. Both exports and imports increased between 1955 and 1959, and China maintained a trade surplus. The lower panel presents China's exports and imports of grain products.[5] The export of grain products comprised 12.1%-17.6% of total exports over the 1955 to 1960 period. China imported very few grain products before 1961. Moreover, grain exports climbed to historic levels during the onset of the famine. The net export of grain products grew from 0.64 billion RMB (1.92 million tons) in 1957 to 0.91 billion RMB (2.62 million tons) in 1958, 1.32 billion RMB (4.05 million tons) in 1959, and 0.84 billion RMB (2.77 million tons) in 1960. In 1961, China changed from being a net exporter to a net importer of grains, with net imports amounting to 0.62 billion RMB (4.4 million tons). Over the 1962 to 1966 period, China remained a net importer of grain products (Lin and Yang, 2000).

The rapid deterioration in China's relationship with the USSR after 1959 contributed to the rise in grain exports during the famine years, even though the leadership knew that some people were starving (Riskin, 1998; Yao, 1999). The Sino-Soviet political tensions escalated in June 1960 when the USSR withdrew its economic advisers and specialists from China. The CCP Politburo immediately decided to accelerate repayment of the Soviet loan, changing the repayment period from 16 years to 5 years. The accumulated debt to the USSR at that time around 1.5 billion RMB, which was approximately 14 times the size of the trade surplus in 1958. To meet the repayment timeline, a "trade group" was set up to restrict imports and to oversee the collection of commodities for export (Garver, 2016).[6]

Net grain exports over the 1958 to 1960 period totaled around 9.6 million tons. Meng et al. (2015) estimate that one kilogram of grain contains 3,587 calories and that the average daily caloric need is 804 to 1,871 calories.[7] Given these estimates, the net grain exports during the 1958 to 1960

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

[6]This "trade group" was led by high-ranking officials including the Premier Zhou Enlai and 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 was aware of the lack of food and the hardship caused by increasing grain exports, but Mao claimed, "The Yan'an period was hard too, but eating pepper didn't 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).

[7]As detailed in Meng et al. (2015), daily caloric need is calculated based on the caloric requirements by age and sex recommended by the United States Department of Agriculture (USDA) and the demographic structure of China given in the 1953 Population Census. The authors show that, on average, in China during the 1950s, 1,871 calories were needed per person-day for heavy labor and normal child development, and an individual needed, on average, 804 per day to stay alive.

period would have provided 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 lack of food, China substantially increased its grain imports, resulting in a net grain of 4.4 million tons, which provided the caloric needs of 23.2 to 53.9 million person-years. As has been pointed out by Ashton et al. (1984), Johnson (1998), and Riskin (1998), a huge number of excess deaths could have been avoided had the government acted swiftly to stop exports and start large-scale importation of grain.

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

The increase in rice and soybean exports relative to wheat exports is also aligned with the changes in relative prices over the period. As shown in Panel A of Figure A.10, the export price of rice was higher than that of wheat throughout the 1955-1960 period. The price of rice relative to wheat surged in 1958 and remained higher than the pre-1958 level in 1959 and 1960. We also find a similar evolution in the relative prices of soybean to wheat. Panel B displays the export price of rice from Thailand relative to that of wheat from the US over the same period; the pattern resembles that in Panel A, which demonstrates that the changes in relative price were not a feature unique to exports from China, but were rather driven by international demand and supply forces. Panel C shows that in the US, the domestic price of rice and soybean increased relative to that of wheat over this period. Lastly, Panel D finds a dip of world relative output of rice to wheat in 1958, which mirrors the peak of the international relative price. All of these findings suggest that to meet the lofty industrialization targets and repay external debts, the central government chose to expand the exports of crops that had increasing relative prices.

3 Data

This section describes the data sources and key measurements adopted in the empirical analysis. More details about the dataset and the summary statistics can be found in Appendix A.

3.1 Demographic Data

We collected county-level panel data on population, number of births and number of deaths for 1,803 *rural* counties.[8] The death rate is constructed as the ratio of the number of deaths to the total population and converted to per mil value (i.e., deaths per thousand). The birth rate is constructed in a similar way. The data are mainly collected from the population statistical books published by the provincial Statistics Bureaus in the 1980s. For most counties, the sample period for the panel data is from 1955 to 1965. (To assess total population, we collect data back to 1953.) More details about the data sources are given in Table A.1.[9]

To the best of our knowledge, our study is the first to compile and use county-level panel data on mortality and fertility to study China's Great Famine. In Appendix A.1.1, we show that when aggregated up to the provincial level, our mortality rates are consistent with the province-level data used by previous studies. As reported in Table 1, the cross-county average death rate is 20.59 (per thousand) in the famine years, which is 8.8 higher than the rate in the non-famine years. Similarly, the average birth rate drops to 20.19 (per thousand) in the famine years, from 35.74 in the non-famine years. Taking the 1957 death and birth rates as the baseline mortality and fertility levels, we find that the Great Famine resulted in 15.74 million excess deaths and 18.59 million lost/postponed births in our sample counties during the 1959 to 1961 period.

Figure 2 shows the changes in mortality rates between 1957 and 1960 for the rural counties in our sample. The counties are outlined in grey lines and provinces are outlined in black lines. There is substantial spatial variation in famine severity over the period. Appendix A.1.2 shows that mortality during the famine was highly concentrated: the top 10th percentile of counties account for 52% of the total excess deaths. In Appendix A.1.3, we show that cross-county variation in death rates and birth rates increased substantially during the famine period, in tandem with a surge in mortality and a dip in fertility. More importantly, we find that the within-province variation in famine severity dominates the between-province variation. These findings indicate the importance of investigating the county-level data, in particular the determinants that affect the spatial pattern of famine severity across counties.

[8] These counties are located in 23 provinces, including Anhui, Fujian, Gansu, Guangdong, Guangxi, Guizhou, Heibei, Heilongjiang, Henan, Hubei, Hunan, Jiangsu, Jiangxi, Jilin, Liaoning, Shandong, Shanxi, Shannxi, Sichuan, Yunnan and Zhejiang. Note that the counties that belong to present day provinces Tianjin, Hainan and Chongqing used to belong to Hebei, Guangdong and Sichuan, respectively. We exclude counties in two province-level municipalities, Beijing and Shanghai, where the urban sector dominated, and three autonomous regions, Inner Mongolia, Tibet, and Xinjiang, where people faced different economic policies for historical and political reasons. The number of rural counties varies from 16 in Ningxia (the smallest province in terms of both population and area) to 185 in Sichuan (the largest province in terms of both population and area).

[9] Data for counties in the provinces Anhui and Shannxi are collected from complementary sources. For counties in Anhui, the data are obtained from the Chronicles of Anhui Province, which only cover 1957, 1960, 1962, and 1965. The population statistical book for Shannxi does not contain county-level data on mortality or fertility. Subject to data availability, we collect the data on number of deaths and births for a sample of counties in Shannxi from various volumes of the Local Chronicles.

Although the existing literature argues that cross-region migration was stringently controlled during the famine period (Lin and Yang, 2000; Meng et al., 2015), one may still concern that selective migration may bias our estimates. To alleviate the concern, we assess the quantitative importance of cross-region migration by comparing the actual population with the predicted population, the latter of which is constructed according to: $\widehat{Pop}_{it} = Pop_{it-1} + NumBirth_{it-1} - NumDeath_{it-1}$, where Pop_{it-1}, $NumBirth_{it-1}$ and $NumDeath_{it-1}$ are population, number of deaths and number of births in the previous year. The logarithms of actual and predicted population have a correlation above 0.98 in famine years. In Appendix Table A.3, we relate the prediction error $\ln \widehat{Pop}_{it} - \ln Pop_{it}$ to $DeathRate_{it-1}$, distance to railway $DistRail$, and their interaction term. All estimated coefficients are statistically indifferent from zero, which indicates that cross-county migration is not correlated with famine severity nor proximity to railway networks. We take these findings as supporting evidence that famine-driven cross-region migration is unlikely to be an important confounding factor in our empirical analysis.

3.2 Procurement and Output Data

We compile county-level panel data on grain procurement, sown area, and output from various sources. The majority of the data are from numerous volumes of the county-level Local Chronicles (county gazetteers).[10] We supplement these data with information collected from various statistical books published by provincial Statistics Bureaus and data published by the Ministry of Agriculture of China (MOA).[11] Similar to our demographic data, the sample is restricted to rural counties and covers the 1953 to 1965 period. The details on the data sources are provided in Table A.4. The unbalanced panel includes data on output for 1,677 counties, on sown area for 1,348 counties, and on procurement for 1,405 counties. Appendix A.2 shows that reporting status does not correlate with famine severity, which alleviates the concern that only certain types of counties report output and procurement data. Table 1 shows that the cross-county average per capita grain output, retain rate, and sown area were significantly lower in the GLF period than in the non-GLF period. As a result, the average retained consumption per person-day declined to 1.77 $kCal$ in the GLF period from 2.11 $kCal$ in the non-GLF period.

[10]Local Chronicles contain historical and current information about the nature, society, economy, culture, and politics of a locality. After the upheaval of the Cultural Revolution, the Chinese government continued the age-old tradition of compiling local gazetteers. A collection of Local Chronicles, published in the early 1990s, records the dramatic social changes that occurred between the Republic Era (the 1920s) and the late 1980s. The information and data in the Local Chronicles are sourced from official archives and from the local communities. The Local Chronicles are described in more detail in Xue (2010). 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 reforms and grain outputs across counties.

[11]See http://202.127.42.157/moazzys/nongqingxm.aspx. The MOA reports data on grain output for around 20 counties in each province.

It is possible that the output and procurement data from the GLF period are not fully reliable. The sources of data used in our study may help to alleviate this concern for the following reasons. First, as discussed in Ashton et al. (1984) and Meng et al. (2015), the data released in the post-Mao reform era have been carefully corrected to address potential reporting errors from the Mao-years. Second, as the purpose of compiling county chronicles is to accurately record local history rather than to report to the upper levels of government, the local historians responsible for collecting and compiling the data have relatively little incentive to manipulate the data (Almond, Li and Zhang, 2013). Despite these considerations, we also use data on weather shocks to strip out classical measurement errors in the output and consumption data.

3.3 Data on Regional Agricultural Production

Our empirical analysis also requires county-level data on crop specialization patterns. 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.[12] These data reflect the agriculture production across Chinese counties before the GLF and were only made available to the public recently. Therefore, we consider it unlikely that the data in this source were 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).[13] The grid-level estimates are interpolated from an average of 20 weather stations, corrected 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 from the grids that overlap the county's territory. Then, for each county-year observation, we construct variables of average temperature and precipitation for the spring (February, March and April) and summer (May, June and July) seasons that year.

3.5 Other Data

The data on the productivity of different crops are from the Food and Agriculture Organization (FAO)'s *Global Agro-Ecological Zones (GAEZ) V3.0* database, which provides high resolution

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

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

information on potential yields of different crops under various technologies at the 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, wheat, potato, and other main staple crops at the county-level by computing the average potential yields of the grids that fall within the countys boundary.[14]

The map of China's railroad network in 1957 is obtained from the US Central Intelligence Agency (CIA). We digitize the scanned map, as displayed in Figure A.9. Rail transport was the dominant mode of freight transport in the famine era. According to National Bureau of Statistics China, more than 75% of the total freight transport during the 1958 to 1961 period was by rail.[15] Moreover, due to the weight of grain, it is more likely to be transported by rail (Donaldson, 2016). We also view the distance to railways as a proxy for the extent of information friction, as collecting information on realized outputs and famine severity is more costly in remote regions.

We also collect from the Local Chronicles the county-level data on the number of local Chinese Communist Party (CCP) members in each county in 1956.[16] The data cover 1,450 rural counties. Table 1 shows that, on average, 1.57 percentage of the population had CCP membership in the pre-GLF period. The organizational presence of the party also displays substantial regional variation, with a standard deviation of 1 percentage point.

4 A Simple Model of Procurement and Export

To organize our thinking on different causes of the Great Famine, we develop a simple model of central planning in which procurement is partly pegged to export needs and is inflexible to realized contemporaneous output level. The model also sheds light on how crop-specific export shocks trickle down to different rural counties depending on regional comparative advantage and past weather conditions, and hence guides our empirical analysis.

In the following discussion, the upper case letters denote aggregate variables and lower case letters represent per-capita variables. We use the "hat" notation to represent the central planner's target level of different variables.

[14] We use data on potential yields under low-level input technology, i.e., production is based on rain-fed irritation, low-levels of mechanization, and the use of fertilizers and chemicals for pest and disease control. We believe that this most accurately describes the technologies used by Chinese farmers in the 1950s and early 1960s.

[15] These data are from *60 Years of New China Statistical Book*.

[16] We use the 1957 data for a few counties with missing data for 1956.

4.1 Aggregate Output, Procurement, Consumption and Export

We assume that the central planner would like to achieve a target of per-capita consumption of crop k, denoted by $\hat{c}_t^k$. The aggregate planned rural consumption of crop k is then determined by $\hat{C}_t^k = \hat{c}_t^k N_t$, where N_t denotes rural population in year t. Due to information frictions, the central planner could not fully observe contemporaneous output. Instead, he makes a forecast on year t's aggregate output based on the output two years ago and the planned growth rate ζ_t^k as:[17]

$$\hat{Y}_t^k = (1 + \zeta_t^k) Y_{t-2}^k,$$

where $\hat{Y}_t^k$ denotes the planned aggregate output of crop k in period t.

Given the planned aggregate output and the planned rural consumption, the central government decides the aggregate procurement of crop k, denoted by P_t^k as:

$$P_t^k = \hat{Y}_t^k - \hat{C}_t^k = (1 + \zeta_t^k) Y_{t-2}^k - \hat{c}_t^k N_t. \tag{1}$$

Under compulsory procurement in (1), the actual rural consumption C_t^k is determined as:

$$C_t^k = Y_t^k - P_t^k = Y_t^k - \left((1 + \zeta_t^k) Y_{t-2}^k - \hat{c}_t^k N_t\right). \tag{2}$$

The actual per capital consumption of crop k is then given by:

$$c_t^k = y_t^k - p_t^k = \hat{c}_t^k + y_t^k - (1 + \zeta_t^k) y_{t-2}^k. \tag{3}$$

This equation highlights that the actual consumption per capita, c_t^k, becomes lower than its target, $\hat{c}_t^k$, when the realized output y_t^k does not meet the planned output $(1 + \zeta_t^k) y_{t-2}^k$, leading to the over-procurement.

The parameter ζ_t^k in (1) represents the "target" output growth rate of crop k over two years. The value of ζ_t^k partly reflects optimism over the productivity growth as well as the necessity for raising procurement due to increasing demand for export as well as urban/industrial consumption. Reflecting the inflexible procurement during the GLF period, ζ_t^k is pegged so that the aggregate

[17] Due to Chinas massive geographic size, poor communication and transportation infrastructure, and the inherent mistrust between the governments at different levels, we think the problem of information frictions could be prevalent in the 1950s and 1960s. Anecdotal evidence suggests that it often took more than twelve months for the government to accurately account for production (Walker, 1965: p. 82). Therefore, in the theoretical framework and the baseline empirical analysis, we follow Meng et al.(2015) and assume that output forecast and procurement decision are based on two-year lagged output. In section 6.4, we provide robust checks for this timing assumption.

procurement meets the demand for the urban/industrial consumption and export as

$$P_t^k = \underbrace{(1+\zeta_t^k)Y_{t-2}^k - \hat{C}_t^k}_{\text{supply through procurement}} = \underbrace{D_t^k + X_t^k}_{\text{demand}}, \tag{4}$$

where D_t^k and X_t^k denote the urban/industrial consumption and the export to foreign countries, respectively.

For simplicity, we assume the population stays constant over time, i.e., $N_t = N$ for all t. Then, combining $Y_{t-2}^k = C_{t-2}^k + P_{t-2}^k$ with (4), we have

$$\zeta_t^k = \frac{(\hat{C}_t^k - C_{t-2}^k) + (P_t^k - P_{t-2}^k)}{Y_{t-2}^k} = \frac{(\hat{C}_t^k - C_{t-2}^k) + (D_t^k - D_{t-2}^k) + (X_t^k - X_{t-2}^k)}{Y_{t-2}^k}. \tag{5}$$

Therefore, the target output growth rate ζ_t^k increases as $X_t^k - X_{t-2}^k$ increases, i.e., current year's export demand increases relative to that of two years ago.

4.2 County-level Output, Procurement, Consumption and Export

For brevity, we assume that the central government directly decides how much to procure from each rural county.[18] The central government allocates the procurement quota across different counties analogously to (1) as

$$P_t^k = \sum_i P_{it}^k \quad \text{with} \quad P_{it}^k = (1+\zeta_t^k)Y_{it-2}^k - \hat{c}_t^k N_{it}, \tag{6}$$

where P_{it}^k is the procurement quota of crop k for county i. Under this procurement quota, the central government intends to assure that every county i achieves the same level of per-capita consumption, i.e., $\hat{c}_t = \sum_k \hat{c}_t^k$.

Then, similarly to the derivation of (3), the actual per-capita consumption of crop k in county i is given by $c_{it}^k = \hat{c}_t^k + y_{it}^k - (1+\zeta_t^k)y_{i,t-2}^k$, and summing this equation across k, the actual per-capita consumption $c_{it} = \sum_k c_{it}^k$ is determined as

$$\underbrace{c_{it}}_{\text{actual}} = \underbrace{\hat{c}_t}_{\text{target}} + \underbrace{y_{it} - \sum_k (1+\zeta_t^k) y_{i,t-2}^k}_{\text{output gap}}, \tag{7}$$

[18] In reality, the central government makes decisions on the procurement quota across different provinces and, then, each provincial government makes the decision on how much to procure across different prefectures, which in turn determine the quota for each rural county. Extending our model to incorporate provinces and prefectures by introducing the procurement quota at province/prefecture level similarly to (6) is straightforward. Our model can be also extended to allow target per-capita consumptions across different crops to be county-specific and depend on the county's comparative advantage in producing different crops so that the county-level procurement quota is non-negative.

where $y_{it} = \sum_k y_{it}^k$ denotes per-capita output.

Therefore, the actual per capita consumption c_{it} becomes lower than its target $\hat{c}_t$ when the realized output falls short of the planned per-capita output, leading to a negative "output gap." In view of (5) and (7), an increase in aggregate export of crop k results in an increase in required procurement of crop k by increasing ζ_t^k, and makes it difficult to meet the planned output of crop k. This "export-driven" procurement shock has differential impacts across different counties, depending on y_{it-2}^k which reflects a county's comparative advantages as well as past weather conditions. In particular, an increase in export of crop k may have a large negative impact on the actual per-capita consumption for counties that have comparative advantage in crop k and experienced a good weather shock for crop k two years ago.

4.3 Empirical Specification

The Appendix B.1 shows that, when $\hat{C}_t^k / Y_{t-2}^k$ is approximately constant across all k and is equal to κ_t, the equation (7) with (5) can be approximated via log-linearlization as

$$\ln c_{it} = (1 - \kappa_t + \ln \hat{c}_t) + \kappa_t(\ln y_{it} - \ln y_{it-2}) - \underbrace{\sum_k \frac{Y_{i,t-2}^k}{Y_{t-2}^k} \frac{X_t^k}{Y_{it}}}_{EX_{it}} - \underbrace{\sum_k \frac{Y_{i,t-2}^k}{Y_{t-2}^k} \frac{D_t^k}{Y_{it}}}_{DomProc_{it}} + \varepsilon_{it}, \tag{8}$$

where ε_{it} contains approximation errors. Equation (8) motivates our regression specification (15)-(16) in Section 6.1, where $1 - \kappa_t + \ln c_t$ is controlled by the province-year fixed effects while we specify the coefficient of $\ln y_{it}$ and $\ln y_{it-2}$ to be different between the GLF period and the non-GLF period.[19]

As is suggested by the model, a county's exposure to grain exports is captured by a Bartik-style measure:

$$EX_{it} = \sum_k \frac{Y_{it-2}^k}{Y_{t-2}^k} \frac{X_t^k}{Y_{it}} . \tag{9}$$

More specifically, the export of crop k is apportioned to county i according to its share in national production of the crop in two-year lagged period. This apportioned export is then normalized by the total grain output of the county, Y_{it}. By construction, EX_{it} captures share of procurement in total output attributable to the need of exports. A county is more exposed to export demand shock of crop k if it was more specialized in crop k or received favourable whether shocks to crop k in the two-year lagged period. Similar interpretation applies to domestic procurement shock $DomProc_{it}$.

[19] The left panel of Figure A.11 provides a snapshot of the data, by plotting $\ln c_{it}$ against $\ln y_{it} - \ln y_{it-2}$ for 1957 and 1959. We find supporting evidence for equation (8). Moreover, we detect a steeper negative slope for 1959, which again suggests the procurement policies became less flexible during the GLF period.

5 Empirical Strategy and Measures

The section describes the empirical strategy to address potential measurement errors in the grain output data, and the procedure to construct the county-level export shock in equation (8).

5.1 Grain Outputs and Weather Shocks

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

$$\ln y_{it}^k = \theta_0^k + \theta_1^k \psi_i^k + \sum_{\ell} \theta_2^{k\ell} z_{it}^{\ell} + \tilde{v}_{it}^k \,, \tag{10}$$

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

Due to the lack of data on output and labor input by crop, we aggregate equation (10) using different crops' output share in 1957 ($s_i^k = Y_{i,57}^k / Y_{i,57}.$) as weights and link each county's aggregate grain output to its productivity and realized weather conditions:[20]

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

where $v_{it} = \sum_k s_i^k \tilde{v}_{it}^k$. We replace time-invariant 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:

$$\ln y_{it} = \sum_{\ell} \sum_k \theta_2^{k\ell} (s_i^k z_{it}^{\ell}) + \phi_i + \gamma_{pt} + v_{it}, \tag{11}$$

where γ_{pt} is the province×year dummy that captures the province-specific policy shocks. With the rich fixed effect structure, the identification of $\theta_2^{k\ell}$ comes from the time variation of weather conditions within a county. The component $\widetilde{\ln y}_{it} = \sum_{\ell} \sum_k \hat{\theta}_2^{k\ell} (s_i^k z_{it}^{\ell})$ captures the effect of weather on grain output; henceforth, we refer to it as "weather index" or "weather shock." As discussed in the following sections, we employ weather shocks as instruments to purge potential measurement errors in output and consumption data.

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

5.2 Measurement of Export Shocks

Guided by the theoretical framework discussed in section 4, a county's exposure to grain exports is captured by the following Bartik-style measure:

$$EX_{it} = \sum_k \frac{Y^k_{it-2}}{Y^k_{t-2}} \frac{X^k_t}{Y_{it}} \times 100 \ . \tag{12}$$

For presentation purpose, we scale the measure by 100. By construction, EX_{it} captures share of procurement in total output (in percentage point) attributable to the need of exports.

Empirically, we modify the baseline measure (12) to address data limitation issues and endogeneity concerns related to each component of the measure (12), i.e., Y^k_{it-2}/Y^k_{t-2}, X^k_t and Y_{it}. The steps are discussed as follows.

5.2.1 Output Shares in the Two-Year Lagged Period

Since we only have county-level information of output by crop in 1957, we need to impute the crop-specific output shares in the two-year lagged period, Y_{it-2}/Y^k_{t-2}. We proceed as follows. First, using the estimated effects of different weather shocks ($\theta^{k\ell}_2$) and fixed effects from regression (11), we derive the "residual" output by crop in 1957 according to:

$$\hat{\xi}^k_{i,57} = \ln y^k_{i,57} - \sum_\ell \sum_k \hat{\theta}^{k\ell}_2 z^\ell_{i,57} - \hat{\gamma}_{p,57}.$$

We then relate $\hat{\xi}^k_{i,57}$ to the underlying productivity of producing crop:

$$\hat{\xi}^k_{i,57} = \theta_0 + \theta^k_1 \psi^k_i + \tilde{v}^k_{i,57}$$

and obtain the estimates of $\hat{\theta}^k_1$. Together with the estimates of $\theta^{k\ell}_2$ and γ_{pt}, we can predict yearly per-capita output by county and by crop in the following way:

$$\ln \hat{y}^k_{it} = \hat{\theta}^k_1 \psi^k_i + \sum_\ell \sum_k \hat{\theta}^{k\ell}_2 z^\ell_{it} + \hat{\gamma}_{pt}.$$

Lastly, we derive the aggregate output according to $\hat{Y}^k_{it} = N_{it} \exp(\ln \hat{y}^k_{it})$ where N_{it} denotes the start-of-period population, and obtain two-period lag output share $\hat{Y}^k_{it-2}/\sum_i \hat{Y}^k_{it-2}$.

Note that the variation of the imputed output share in two-year lagged period stems from two sources – the cross-county difference in suitability of cultivating different crops and short-run fluctuations in weather conditions within a county. In other words, due to the procurement rigidity, a county may have larger exposure to an increasing export of crop k due to two reasons.

First, *ceteris paribus*, it has a comparative advantage in producing crop k. Second, the county experienced favourable weather shocks that increased the yields of crop k in two-year lagged period. As discussed below, our panel regression analysis controls for county-fixed effects, province-year fixed effects, and the interactions between various observed county characteristics and year dummies; suitability of cultivating different crops and time-varying weather shocks are likely to be exogenous once conditioned on unobserved permanent county characteristics, time-varying provincial factors, and time-varying factors of a rich set of observed county characteristics.

5.2.2 Export Demand Shock at the National Level

The total export at the national level X_t^k embodies both supply shocks in China and demand shocks from the rest of world. To the extent that that each county is too small to affect the outcomes at the national level, it is plausible that changes in X_t^k are exogenous from the perspective of a county. Therefore, in principle, the effect of EX_{it} on county-level procurments and death rates can be identified using county-level variations in crop shares when the underlying variations in predicted crop-shares are exogenous and the change in crop-specific procurement at the national level is mainly driven by the export shock.[21]

However, one may have a concern that crop-specific export shocks at the national level could be driven by spatially correlated supply shocks within a larger region that are also associated with endogenous determinants of famine severity.[22] To address this concern, we use the information of international prices to extract the changes in export exposure that is due to exogenous shift in external demand by estimating the following equation:

$$\ln X_t^k = \eta_0 + \eta_1 \ln P_t^k + \phi_k + \gamma_t + \varepsilon_{kt} \ , \tag{13}$$

where P_t^k is the export price of crop k in year t, and ϕ_k and γ_t are crop and time fixed effects, respectively. In column (1) of Table 2, we employ the data of the period 1953 to 1965 and find that the elasticity of exports to price is 2.59 with a p-value of 1.84. We then use the exponent of the fitted value $\widehat{X}_t^k$ to capture the exogenous component of exports at the national level.

Our estimation strategy relies on the assumption that the changes in prices of different crops were driven by international demand and supply forces which are exogenous of domestic shocks in China. In spite of its sheer population size, China might not have strong market power in international market of grains – its contribution to world grain export was on average 2% over period 1953 to 1965.[23] However, there remain two threats to the exogeneity assumption of international

[21] See Goldsmith-Pinkham, Sorkin and Swift (2018) for related arguments.

[22] Province-year fixed effects partly account for such omitted factors, but cannot fully address the concern.

[23] We calculate the China's share of world grain export using information from two resources: *The State of Food and Agriculture* by FAO, and *Historical Materials of Food Issues in Contemporaneous China* published by Ministry of Commerce of China. We omit soybean from the calculation due to the lack of information on world total export

prices. First, the dramatic export expansion during the GLF period (1958-60) and the export contraction in the last year of famine (1961) could affect the international prices. In particular, we find that China's share of world export increased to 5.2% in 1959. Second, China could have a comparative advantage in some crops and play a larger role in these markets. In the following, we assess the likelihood that the baseline result may be biased by China's potential influences on international prices.

Table A.5 in appendix report China's share in world total export of different crops. We find that China was an important rice exporter whose export supply could reversely affect international prices, leading to a downward bias of estimated export supply elasticity. To address this concern, in column (2) of Table 2, we drop rice from regression (13). The estimated elasticity is somewhat larger, but it is statistically indifferent from the baseline estimate. Column (3) extends the sample period to 1986. The export supply elasticity is more precisely estimated but resembles the baseline results. The regression in column (4) excludes the period 1958-61 to alleviate the concern that the dramatic changes in export supply during the GLF and famine periods could affect international prices. Column (5) further drops rice. The result remains robust. Lastly, in column (6), we exclude the crop-year observations with export supply surges or declines by more than 2% of the world export and find a statistically similar result. We take these findings as supporting evidence that the estimated export supply elasticity is unlikely to be severely biased by China's market power in the international grain market. We construct the export shock using the baseline estimate in column (1) and assure that the regression results are robust to alternative measures of export shock constructed from other estimates of supply elasticity.

5.2.3 Contemporaneous Output

The contemporaneous output Y_{it} in the denominator of equation (12) may also be correlated with unobserved county-specific shocks that affect famine severity. To allay the concern, we replace Y_{it} by the predicted aggregate output from equation (11), i.e., $\hat{Y}_{it} = N_{it} \exp(\ln \hat{y}_{it})$, to construct the export shock. The variation of the predicted output mainly arises from weather shocks and county-specific and time-invariant factors.[24]

5.2.4 Refined Measure of Export Shocks

Replacing the components in equation (12) by their exogenous counterparts, we refine the export shock as follows:

$$EX_{it} = \sum_k \left(\frac{\widehat{Y}^k_{it-2}}{\sum_i \widehat{Y}^k_{it-2}} \right) \frac{\widehat{X}^k_t}{\hat{Y}_{it}} \times 100. \tag{14}$$

during the period 1953-1965.

[24]Alternatively, we may construct $\hat{Y}_{it}$ as $\hat{Y}_{it} = \sum_k \hat{Y}^k_{it}$. In the unreported results, we find that baseline results are robust to the alternative measure of export shock that is constructed using this alternative $\hat{Y}_{it}$.

By construction, EX_{it} in (14) measures county i's procurement as a share of total output (in percentage point) in year t due to export demand that is driven by changes in international prices.[25]

The variation in the export shock defined in equation (14) stems from two sources. The first source of variation is from the cross-county differences in crop specialization pattern in two-year lagged period. Importantly, the the imputed lagged output shares reflect slowly evolving regional comparative advantage in cultivating different crops and within-county year-to-year fluctuations in weather conditions, which are deemed to be exogenous with respect to local economic and political conditions in GLF period after controlling for county fixed effects and province-year fixed effects. The second is time variation arising from crop-specific external demand shocks induced by changes in international relative prices. Our identification strategy relies on the interaction of these two sources of variation, which is plausibly exogenous conditional on a rich set of controls and fixed effects.

Crop suitability and weather shocks may directly affect the procurement beyond its effect on county-level export shocks. To address this concern, our panel regression analysis includes county fixed effects which control for time-invariant unobserved country characteristics (e.g., the local cadres ability and connections, regional weather patterns, local culture of a region, disease environment, altitude, and latitude) that are correlated with crop specialization pattern and affect grain procurement and mortality independently. In addition, we control for province-year fixed effects, which flexibly account for time-varying aggregate shocks at the province level (e.g., GLF policies that differed across provinces, characteristics and career concerns of the provincial leaders, etc.). Conceptually, the strategy is similar to difference-in-differences estimation strategy, where we compare counties (within a province) specializing in producing different crops with various changes in international relative prices.

Given the set of fixed effects that flexibly control for all time-invariant county factors and time-varying shocks at the province level, the primary remaining concern could be the possibility that lagged crop specialization patterns are systematically correlated with unobserved county-specific characteristics that have time-varying effects on grain procurement, mortality, and fertility. To mitigate such concerns, we collect a variety of county characteristics ranging from agricultural productivity, geo-climatic conditions, remoteness, to local political factors. By interacting these factors with year dummies, we control for their time-varying effects which may be correlated with county-level export shocks. We find that export remains to exert similar effects conditional on these county-specific time-varying controls. We also demonstrate that grain procurement and famine severity are uncorrelated with future export shocks, which allays the concerns that our

[25] 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). Given the similar caloric content of different crops, we believe that the measure X_{it} captures the caloric loss due to export shocks.

results are driven by county-specific pre-determined trends that are correlated with lagged crop specialization patterns.

6 Empirical Results from Panel Regression Analysis

This section reports our main empirical results based on panel regression analysis. We start by examining the effects of grain export shocks on consumption/procurement, mortality and fertility in subsection 6.1. Subsection 6.2 shows that the procurement policies became more rigid during the GLF period, and more so in the counties further away from the railway networks. Subsection 6.3 investigates the determinants of grain outputs. Subsection 6.4 demonstrates the robustness of our main findings to many additional specifications and alternative measures.

Throughout the empirical analysis, we make the timing assumption as illustrated in Figure 4. Export shocks influence procurement intensity in year t. Moreover, the procurement intensity is determined before the output is realized, and may not be adjustable to contemporaneous production when the procurement policies are rigid. The procurement intensity and realized output in year t together determine retained consumption that are used to support life for a large part of the the following year $t+1$. Based on this timeline, procurement intensity and retained consumption are related to export exposure in the contemporaneous period t. The mortality and fertility in year $t+1$ are affected by export shock in year t. Following the literature, we define GLF period as 1958-1960. The politico-economic shocks during the GLF affected the severity of the Great Famine during 1959-1961.

6.1 Effects of Export Shocks

As discussed in Section 4, we consider the export shock as shifting retained consumption, and hence impacting mortality and birth. Extending the model (8), the regression specification is as follows:

$$\begin{aligned}\ln c_{it} = {} & \beta_x EX_{it} + \sum_{\tau} (\beta_1^{\tau} - 1)\mathbf{1}(t \in \tau) \times \ln y_{it} + \sum_{\tau} \beta_2^{\tau}\mathbf{1}(t \in \tau) \times \ln y_{it-2} \\ & + g(\hat{v}_{it}) + g(\hat{v}_{it-2}) + \phi_i + \gamma_{pt} + \lambda_i' \kappa_t + \varepsilon_{it},\end{aligned} \tag{15}$$

or, equivalently,

$$\begin{aligned}\ln \underbrace{r_{it}}_{c_{it}/y_{it}} = {} & \beta_x EX_{it} + \sum_{\tau} \beta_1^{\tau}\mathbf{1}(t \in \tau) \times \ln y_{it} + \sum_{\tau} \beta_2^{\tau}\mathbf{1}(t \in \tau) \times \ln y_{it-2} \\ & + g(\hat{v}_{it}) + g(\hat{v}_{it-2}) + \phi_i + \gamma_{pt} + \lambda_i' \kappa_t + \varepsilon_{it},\end{aligned} \tag{16}$$

where $\ln r_{it}$ and $\ln c_{it}$ are the logarithm of retain rate and consumption per capita of county i in year t, respectively; EX_{it} is defined as in (14); $\mathbf{1}(t \in \tau)$ is an indicator variable that equals 1 if year t belongs to period $\tau \in \{GLF, NonGLF\}$, where the GLF period is 1958-1960 and the $NonGLF$ period is 1953-1957 and 1961-1964; ϕ_i and γ_{pt} denote county and province-year fixed effects, respectively, while $\lambda_i'\kappa_t$ represents the interactions of observed county characteristics and year dummies. By including ϕ_i, γ_{pt}, and $\lambda_i'\kappa_t$, we flexibly account for any time-invariant county-specific determinants of grain procurement, time-varying policy shocks at the provincial level, as well as time-varying effects of observed county characteristics.

While output data from post-Mao reform era have been corrected to address potential reporting errors from the Mao-years (Ashton et al., 1984; Meng et al., 2015), one may concern that there remain measurement errors due to misreporting in the output data, and misreporting may be caused by time-varying unobserved factors that affect procurement. Furthermore, there may be unobserved time-varying output shocks that are correlated with procurement. We use the control functions to address these concerns by including $g(\hat{v}_{it}) = \sum_\tau \beta_3^\tau \mathbf{1}(t \in \tau) \times \hat{v}_{it}$ and $g(\hat{v}_{it-2}) = \sum_\tau \beta_4^\tau \mathbf{1}(t \in \tau) \times \hat{v}_{it-2}$ as additional controls in (16), where $\hat{v}_{it}$ is the residual from regression (11) and $\hat{v}_{it-2}$ is the corresponding two-period lagged value. As long as weather shocks are exogenous to procurement conditional on county fixed effects, province-year fixed effects, and time-varying effects of observed county characteristics, we may consistently estimate β_1^τ and β_2^τ by control function approach while the estimated coefficients β_3^τ and β_4^τ represent the extent to which time-varying measurement errors and unobserved output shocks affect procurement.[26]

In column (1) of Table 3 Panel A, we find that counties that were more exposed to grain exports had, on average, lower retain rates. Column (2) further explores how the effect of export shocks varies by distance to railway networks and by the organizational presence of the CCP. In particular, the variable $CCP\ Member$ measures the proportion of the population who had CCP membership in 1956 at the county level in percentage points, and it is demeaned from the cross-county average. $DistRail$ measures the nearest distance to the railway networks, and it is also demeaned from the cross-county average. The estimated coefficient of EX_{it}, therefore, still captures the average effect of export, and it resembles the baseline estimate in column (1). In addition, consistent with the observation that distance to railways relates to transportation costs, the estimated coefficient of $EX_{it} \times DistRail$ is positive, albeit statistically insignificant. We also find that the negative effect of export shocks on the retain rate is weaker in counties with higher party membership, although the estimate is statistically insignificant. In columns (3) and (4), we split counties into "Near" and "Far" groups based on whether their distance to railway networks is below or above the median distance. The estimated effect of export shock is smaller for the Far group than for the Near group, although the difference is not statistically significant.

[26] Table A.6 reports the estimates of the control functions $g(\hat{v}_{it})$ and $g(\hat{v}_{it-2})$.

Panel B investigates the reduced-form relation between mortality and export exposure. Consistent with the findings in Panel A, a higher export exposure raises the death rate. This result is robust across various specifications. In addition, as shown in column (2), the effect of export shocks on death rates was larger in counties farther away from railways or with fewer CCP members. We find that a percentage point increase in export shock raises death rate by 0.21 per thousand more for a county at the 75th percentile of $DistRail$ than a county at the 25th percentile.[27] A percentage point increase in export shock induces death rate by 0.34 per thousand more for a county at the 25th percentile of $CCP\ Member$ relative to a county at the 75th percentile.[28] Panel C repeats the regressions but uses birth rate as the outcome variable. The results mirror those of the death rate.

Comparing results in column (2) across Panels A and B, we find that although the counties further away from railways incurred less export-induced procurement plausibly due to higher transportation costs, they experienced more severe famine attributable export expansion. These results suggest that upper level governments were less able to verify food shortage in remote counties and/or it was logistically costlier to transport relief grains to these regions. We also find that a higher presence of CCP mitigate the effects of export on both grain procurement and famine severity. This finding indicates that Chinese party-state displayed systematic favoritism by extracting fewer resources from counties with more party members, and/or by transferring more food to these counties to relieve famine.[29]

Using the county-level panel data in Henan and Hubei provinces for which the grain resale data is available, column (1) of Table 4 provides suggestive evidence that the Chinese party-state gave back more food to counties with more party members in the event of export-induced over-procurement.[30] These results are largely consistent with Kung and Zhou (2017), who find that the famine was less severe in the hometowns of Central Committee (CC) members. This resale channel reinforces the procurement channel in affecting the effect of grain export on famine severity. In addition, albeit statistically insignificant, the negative coefficient of the interaction term $EX_t \times DistRail$ indicates that remote counties receive fewer relief grain in the event of food shortage. Columns (2) and (3) repeat the regressions in column (2) of Table 3 for these two provinces and find largely consistent results.

The exogeneity of the Bartik-style measures relies on the identification assumptions that (i)

[27] The interquartile range of distance to railways is 0.11 thousand kilometers.

[28] The interquartile range of percentage of people with CCP membership is 0.77%.

[29] We also estimate the specification of column (4) of Table 3 using a dummy variable for hometowns of CC members of the 8th Congress (which is used in Kung and Zhou (2017)) in place of the proportion of the population who had CCP membership, and find that the coefficient of the interaction between CC members and export is insignificant. One possible reason for this finding is that the variation of the number of CC members is small; there are only 88 counties with CC members among 1803 counties in our sample.

[30] As discussed in footnote 17, procurement usually occurred after the autumn harvest in October or November. Hence, post-procurement redistribution (or resale) could take place in the following year. In light of this timeline, column (2) investigates the effect of exports on grain resale in period $t + 1$.

other time-varying, county-specific determinants of the outcome variable are uncorrelated with lagged crop specialization patterns, and (ii) other crop-specific domestic demand or supply shocks at the national level are uncorrelated with the external export demand shock. A potential concern regarding assumption (i) is that lagged output shares, which are partly determined by cross-county difference in suitability of cultivating different crops, could be correlated with other county-specific characteristics, for example, local cadres' political connections and incentives, climate, geographies, and population density. To the extent that these variables are correlated with lagged crop specialization patterns and have time-varying effects on procurement and mortality, our baseline estimates would be biased. To alleviate the concern, columns (5)-(8) of Table 3 augment the baseline specification with interaction variables of county-specific characteristics and year dummies, which flexibly control for their time-varying effects. These characteristics include population density, average agricultural productivity, distance to railway networks, distance to the provincial capital, terrain ruggedness, average spring temperature and precipitation, average summer temperature and precipitation, whether the county is the home town of a CCP Central Committee member of the 8th Congress, and the percentage of population with CCP membership in 1956.[31] The estimated effects of export shock on retain rate and death rate remain very similar to the baseline findings.

Regarding the assumption (ii), by instrumenting exports of different crops with their international prices, we potentially purge the confounding effects of supply shocks.[32] However, one may still concern that if the crops that experienced larger increase in international prices were also the ones that had larger increases in procurement for domestic purposes, we may overstate the effect of exports. As shown in columns (2)-(5) of Table A.7, however, changes in domestic procurement are uncorrelated with changes in log prices nor changes in the constructed export shocks $\widehat{X}_t^k$, suggesting that our baseline results are unlikely to be confounded by correlated export and domestic procurement shocks. In Table A.8, we control of the Bartik-style measure of procurement for domestic purposes $DomProc_{it} = \sum_k \left(\frac{\widehat{Y}_{it-2}^k}{\sum_i \widehat{Y}_{it-2}^k} \right) \frac{D_t^k}{\widehat{Y}_{it}} \times 100$, where D_t^k denotes the amount of procurement of crop k for domestic purposes in year t. The estimated effect of grain export remain similar to the baseline findings, which further alleviates the concern about the confounding effects introduced by domestic procurement.[33]

[31] We construct index of terrain ruggedness following Nunn and Puga (2012).

[32] As is discussed in subsection 5.2.2, China's share in world grain export is 2% in our sample period. Admittedly, the surge in grain export from China during the GLF period, especially for rice, might alter the supply in the international market. To alleviate the concern, we re-estimate supply elasticities excluding rice and GLF period. In subsection 6.4, we show that our results remain robust to alternative measures of export shocks which are constructed with alternative estimates of supply elasticities.

[33] We also find that an increase in domestic procurement raises mortality rate and lowers fertility rate. For retain rate, the estimated effect of domestic procurement is statistically insignificant. This finding should *not* be taken as a rejection of the mechanism emphasizing the role of domestic procurement. Instead, it is likely due to the lack of cross-crop variation in changes of domestic procurement. Figure A.12 shows that unlike export, domestic procurement of different crops are more in tandem with each other, resulting in a lower variation of $DomProc_{it}$

6.1.1 Discussion: The Magnitude of the Effect of Export Shock on Famine Severity

Although we postpone the formal quantitative analysis of export effects to section 7, it is worthwhile to pause and gauge the magnitude of the effects of export shocks. The baseline estimate in panel B column (1) of Table 3 implies that an increase in export shock by one standard deviation over the period of 1957 to 1959 induces an increase in mortality rate by 2.11 per thousand, which amount to 9.5% of the standard deviation of the increase in mortality rate over 1958 to 1960.[34]

Figure 5 shows the share of grain export in total output, total grain consumption, and rural grain consumption over time;[35] the share of grain export in output peaked in 1959 and but only amounted to 2.8%. So why did grain export has a disproportionally large effect on famine severity in rural regions (where our sample covers)? There are at least three possible reasons.

First, grain export may have a disproportional effect on rural consumption relative to urban consumption and industrial inputs during the GLF period; in fact, the share of grain export in rural grain consumption surged by 3.2 percentage points from 1.7% in 1957 to 4.9% in 1959, which is disproportinally larger than the increase in its share in total grain consumption. Furthermore, export-driven procurement is less flexible than procurement for urban consumption because redistributing back grains to rural counties in the event of food shortage is not possible once the grains are exported overseas. Second, the relation between caloric consumption and mortality is highly nonlinear. Given the widespread food shortage in rural regions during the famine period, a further reduction in rural consumption by 3.2 percentage points could have a disproportional effect on mortality. Third, there was an uneven distribution of grain export across counties. Together with (i) the regional differences in degree of food deficiency due to other political-economic factors, and (ii) nonlinear effect of caloric consumption and mortality, the effect of grain export could be disproportionally large in the regions where the gradient of mortality to caloric consumption is steep. In particular, in section 7, we find the excess deaths induced by grain export could have been lowed by 5.8% if the burden of export-driven procurement had been reallocated from the famine stricken counties to the rest of the country.[36]

6.2 Changes in Procurement Policies in the GLF Period

Table 3 also provides county-level evidence for inflexible and progressive procurement policies in the GLF period. Column (1) of Panel A finds that in the GLF period, the elasticity of the retain rate to contemporaneous output diminished and became statistically insignificant. In contrast,

than that of Ex_{it} – the coefficients of variation are 0.54 and 1.51 for $DomProc_{it}$ and Ex_{it}, respectively.

[34] Over the period of 1957 to 1959, the standard deviation of the increase in export is 3.97 percentage point. Over the period 1958 to 1960, the standard deviation of the increase in death rate is 22.19 per thousand.

[35] The data on urban and rural consumption of grains are obtained from *Nongye Jingji Ziliao, 1949-1983* published by the Ministry of Agriculture.

[36] See section 7 and row (A.10) in Table 8.

past output gains a larger weight in determining the retain rate during the GLF period. These results indicate that the procurement policies became more rigid during the GLF period.

Columns (3) and (4) of Panel A examine the heterogeneity in procurement policies across counties with different distance to railways. For the Near group, although the effect of current output diminished during the GLF period, its effect remained negative and significant. In contrast, for the Far group, the retain rate solely depended on past output in the GLF period. The coefficient of $GLF \times \ln y_{t-2}$ is smaller in magnitude for the Near group than for the Far group, suggesting that procurement was less reliant on past output in counties closer to railways. In addition, we find that procurement policies were more progressive for counties near railways, in the sense that the coefficient of $NonGLF \times \ln y_t$ was larger in magnitude for the Near group. These findings suggest that the rigidity of procurement policies was more pronounced in counties further away from the railway network but, given the same output level, counties located near railways had higher procurement due to lower transportation costs. Columns (5)-(8) repeat the regressions but include a rich set of time-varying county controls. The results remain similar.

Panel B repeats the regressions using the death rate in year $t+1$ as the outcome variable. In the GLF period, the mortality rate was higher when there was a positive output shock in the two-year lagged period. A higher realized contemporaneous output helped to alleviate the famine. Moreover, as shown in columns (3) and (4), current and past output shocks had greater effects on death rates in counties that were further away from railways. These findings echo those in Panel A. Panel C reports the regression results when birth rate is the outcome variable. The findings mirror those for the death rate.

We also augment the regression model by allowing the elasticities of the retain rate to contemporaneous and past outputs to vary across years. The left panel of Figure A.13 shows the coefficient β_1^τ and β_2^τ which map out the evolution of procurement policies over time. We find that procurement policies became less responsive to current output and more influenced by past output after 1958. The elasticities revert back to their pre-GLF level after 1960. The right panel repeats the analysis, but uses the death rate as the dependent variable. The patterns of this estimates mirror the counterparts in the left panel.

6.3 Determinants of Grain Output

This section investigates the determinants of the slump in grain output during the GLF period by estimating the following equation:

$$\ln y_{it} = \theta_x EX_{it} + \theta_{\text{area}} Area_{it} + \sum_{\ell} \sum_{k} \theta^{k\ell} s_i^k z_{it}^{\ell} + \phi_i + \gamma_{pt} + u_{it} \ , \tag{17}$$

where EX_{it} is the export shock in (18) and $Area_{it}$ denotes the logarithm of per capita grain sown area.

As reported in column (1) of Table 5, the estimated elasticity of output per capita to sown area is 0.62 and highly significant. The average per capita grain sown area decreased dramatically from 0.573 to 0.488 acres between 1957 and 1959. Our estimate suggests that this reduction in agricultural input led to a decrease in grain output of 0.05 log points. Column (2) shows that the estimated elasticities of grain output to sown area are statistically similar in the GLF and non-GLF periods while column (3) suggests that the decline in output during the GLF period did not systematically vary with distance to railways or the number of CCP members.

In column (4), we study the effect of export shocks on grain output. Export shock has small an insignificant effects on output, which suggests that export expansion during the GLF period mainly affect retained consumption and hence famine severity through the channel of procurement. Column (5) shows that the effect of export shocks on output does not vary along the dimensions of distance to railways or CCP membership.

In columns (6), we replace the province×year fixed effects with year fixed effects and investigate the effects of the province-level GLF intensity on grain output. This exercise tests the consistency of our county-level findings with the findings of previous studies based on province-level data.[37] Column (7) shows that after controlling for county-level variables, log per capita sown area, and export exposure, the variables that proxy for province-level GLF intensity have no significant effect on grain output.

6.4 Robustness

6.4.1 Alternative Measures of Outcome Variables

Table 6 evaluates the robustness of our results to alternative measures of food availability and famine severity. Guided by the model discussed in section 4, we use log retain rate as the outcome variable in the baseline analysis.[38] To assure that our results are not driven by the log transformation, column (1) replaces the outcome variable by retain rate. Column (2) estimates equation (15)

[37] Following Li and Yang (2005) and Meng et al. (2015), we use steel output per capita as a proxy for the intensity of the GLF in an area. We find that the estimated coefficient of steel production (measured by kilograms per capita) is negative but 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, we investigate whether counties in the provinces that had relatively late "liberations" by the CCP experienced a larger decline in grain output. The estimated coefficient of the interaction term is negative and significant at the 10% level. Following Kung and Lin (2003) and Meng et al. (2015), column (6) also presents the intensity of the 1957 anti-rightest movement (measured by the number of persons purged per million) as a proxy for the political zealousness of provincial governments. We find that the 1957 political purge had an insignificant effect on grain output during the GLF period.

[38] In addition, working with logarithms also provides convenience for decomposing the reduction in retained consumption into the increase in procurement and the decline in output. (Note that $\ln c_{it} = \ln r_{it} + \ln y_{it}$.)

and finds that an increase in export exposure reduces retained consumption.[39] The results of both specifications are consistent with our baseline findings. Columns (3) and (4) take log death rate and log birth rate as the outcome variable, respectively. A larger export shock has a significantly positive (negative) effect on log death (birth) rate, which alleviates the concern that the baseline results could be driven by outliers.

Following Meng et al. (2015), as shown in column (5), we use the birth cohort sizes of survivors observed in the 1990 China Population Census as a proxy for famine severity at the county level. Figure A.14 correlates the change in death (birth) rate between 1957 and 1960 with the relative population size of the famine cohort.[40] Relative cohort size is negatively correlated with changes in death rates but fails to capture the large surge in mortality. However, it clearly mirrors the changes in fertility. Given the close association between birth cohort sizes and birth rates, it is unsurprising that the results from using the log population size of a cohort born in year t+1 as the outcome variable agrees with the results obtained using birth rates, as shown in Panel C of Table 3.

6.4.2 Alternative Measures of Export Shocks

As is discussed in section 5.2.2, the surge in rice export from China during the GLF period may shift supply in the world market and confound the external demand shocks. To allay this concern, we reconstruct the Bartik export shock using the supply elasticity reported in column (2) of Table 2 which is obtained from regression (13) excluding rice. As is reported in column (1) or Table 7, we obtain similar estimates using this alternative export shocks. In the unreported results, we assure that baseline results are robust to alternative measures of export shocks that are constructed from different supply elasticities reported in columns (3)-(6) in Table 2.

As another robustness check, we use start-of-period population to normalize the apportioned export and modify the baseline measure in the following way:

$$EX_{it} = \sum_k \left(\frac{\widehat{Y^k_{it-2}}}{Y^k_{t-2}} \right) \frac{\hat{X}^k_t}{N_{it}}, \tag{18}$$

By construction, it captures the per capita reduction in food availability in kilograms due to export growth that is driven by changes in international prices. As is shown in column (2) of Table 7, the results are insensitive to this alternative measure.

[39] Note that the regression with $\ln c_{it}$ as outcome variable is the same as the one with $\ln r_{it}$ — except that the coefficients associated with $\ln y_{it}$ would be adjusted by +1.

[40] As discussed in Meng et al. (2015), the birth cohort size of survivors cannot capture the mortality rates of the elderly and the functional form of the relationship between mortality rate and survivor birth cohort size is not known. For the counties in our sample, the correlation between birth rate and relative cohort size is 0.63 and the correlation between death rate and relative cohort size is -0.34.

6.4.3 Different Lag Structure of Output Shocks

Our baseline analysis follows Meng et al. (2015) and includes two-period lagged output to capture the procurement rigidity. To assess the robustness of the results to alternative lag structure, column (3) of Table 7 replaces $\ln y_{i,t-2}$ by $\ln y_{i,t-1}$. Our main findings remain. First, the estimated coefficient of export shock resembles the baseline estimate. Second, the procurement policy is progressive and became more rigid in GLF period. In the GLF period, the elasticity of the retain rate to contemporaneous output diminished and became statistically insignificant, while one-period lagged output gains a larger weight in determining the retain rate. Column (4) conducts a horse race between one- and two-period lagged output shocks. We find that conditional on $\ln y_{i,t-2}$, estimated effect of $\ln y_{i,t-1}$ becomes smaller and statistically insignificant in both GLF and non-GLF periods.

6.4.4 Revealed Comparative Advantage

To corroborate the effect of export shocks on famine severity using alternative measures of export exposure, we construct a measure of revealed comparative advantage (RCA) as follows:

$$RCA_i^k = \frac{Y_{i,57}^k}{\sum_i Y_{i,57}^k} \bigg/ \frac{\sum_k Y_{i,57}^k}{\sum_i \sum_k Y_{i,57}^k} . \tag{19}$$

The numerator of the RCA measure is county i's share of the national output of crop k. The denominator is county i's share of the national output of all crops. If the RCA measure is above one, then the county captures a greater share of national outputs in crop k than it does on average, which reflects that the county has a comparative advantage in producing crop k. This measure shares a similar spirit with Balassa's (1965) measure of RCA.

Using the constructed RCA measure, we test the hypothesis that counties with a comparative advantage in producing high-export-exposure crops (rice and soybean) experienced a larger decline in retain rate than other counties by estimating:

$$\begin{aligned} \ln RetainRate_{it} =& \alpha_1 GLF \times RCA_i^{r,s} + \alpha_2 GLF \times \bar{\psi}_i + \sum_\tau \beta_1^\tau \mathbf{1}(t \in \tau) \times \ln y_{it} \\ &+ \sum_\tau \beta_2^\tau \mathbf{1}(t \in \tau) \times \ln y_{it-2} + g(\hat{v}_{it}) + g(\hat{v}_{it-2}) + \phi_i + \gamma_{pt} + \varepsilon_{it}, \end{aligned} \tag{20}$$

where $RCA_i^{r,s}$ is the average RCA of rice and soybean. $\bar{\psi}_i$ denotes the average productivity of county i, which captures the effect of an absolute advantage.[41] As in equation (16), $g(\hat{v}_{it})$ and $g(\hat{v}_{it-2})$ are control functions while ϕ_i and γ_{pt} are county and province×year fixed effects,

[41] $\bar{\psi}_i$ is the average productivity of rice, soybean, wheat, potato, and other main staple crops (barley, maize, and sorghum).

respectively.

The regression results are reported in column (5) in Panel A of Table 7. The estimated coefficient for $GLF \times RCA_i^{r,s}$ is negative and statistically significant, indicating that during the GLF period the retain rate decreased more in counties that had a comparative advantage in producing rice and soybean relative to other crops. Column (5) Panel B uses death rates as the outcome variable. We find that during the GLF period, death rates increased faster in counties with a comparative advantage in rice and soybean. In addition, higher absolute advantage tended to alleviate the famine.

In columns (6), we use an alternative measure of comparative advantage by replacing $RCA_i^{r,s}$ with the average productivity of rice and soybean, that is, $\psi_i^{r,s}$. We find that, conditional on the absolute advantage, counties with a higher productivity in rice and soybean experienced, on average, a greater reduction in retain rate and a faster increase in mortality during the GLF period. These findings are consistent with those in columns (5).

6.4.5 Procurement Rigidity: Control Function v.s. IV Approach

In column (7) of Table 7, we verify that our results are robust to IV estimation. Specifically, instead of including control functions $g(\hat{\nu}_{it})$ and $g(\hat{\nu}_{it-2})$, we instrument $\sum_\tau \beta_1^\tau \mathbf{1}(t \in \tau) \times \ln y_{it}$ and $\sum_\tau \beta_2^\tau \mathbf{1}(t \in \tau) \times \ln y_{it-2}$ with $\sum_\tau \beta_1^\tau \mathbf{1}(t \in \tau) \times \widetilde{\ln y_{it}}$ and $\sum_\tau \beta_2^\tau \mathbf{1}(t \in \tau) \times \widetilde{\ln y_{it-2}}$, where $\widetilde{\ln y_{it}}$ and $\widetilde{\ln y_{it-2}}$ are the exogenous weather shocks constructed in section 5.1. The estimated effects of output shocks on retain rate and mortality remain similar.

6.4.6 Placebo Tests: Effects of Past and Future Export Shocks

Column (1) of Table 8 relates the retain rates in 1962-1965 to the export shocks in 1958-1961. We find that the four-year lagged export shock has no effect on the retain rate. Columns (3) and (5) repeat the analysis, but replace the outcome variable with death rates and birth rates, respectively. Reassuringly, we find that neither mortality nor fertility is affected by past export shocks.

Column (2) regresses retain rates from 1954-1957 on future export shocks (1958-1961), and finds that export shock in four-year lead period has small and insignificant effects on retain rate. Similarly, in columns (4) and (6), we find that future export shocks have insignificant effects on death and birth rates. These findings suggest that counties hit by larger export shocks in the future period were not already experiencing relatively faster reductions in retain rate, or increases in death rates, or declines in birth rates.

6.4.7 Heterogeneous Effects of Export Shocks: Alternative Measures of Remoteness and Provincial Characteristics

In this section, we adopt different measures of remoteness to demonstrate the robustness of the heterogeneous effects of export shocks. First, following Nunn and Puga (2012), we construct a terrain ruggedness index (TRI) for each county. We argue that counties with high TRI values are more likely to be in remote areas where transportation and information costs are higher. Second, we use the distance to the provincial capital as a measure of the distance to economic and political centers. Third, as different measures of remoteness are positively correlated with each other, we extract the principal component of distance to railways, distance to provincial capital, and TRI, and take it as an alternative measure of remoteness.[42] We repeat the regression in column (2) of Table 3 using these alternative measures. Results for log retain rate and for death rates are reported in columns (1)-(3) and (4)-(6) of Table 9, respectively. Again, we obtain results that are consistent with the baseline findings.

7 Counterfactual Simulation

In this section, we undertake a set of counterfactual experiments to infer the roles of different underlying shocks in shaping famine severity. We study the response of mortality in 1960 when different economic conditions in 1959 (the peak of GLF) revert to their 1957 levels (the pre-GLF period).[43] Recall that retained consumption is determined as follows:

$$c_{it} = r_{it} \times y_{it} \quad \text{with} \tag{21}$$

$$r_{it} = r\big(y_{it}, y_{it-2}, EX_{it}, \boldsymbol{\beta_t}\big) \quad \text{and} \quad y_{it} = y\big(\boldsymbol{z^{\ell}_{it}}, Area_{it}\big),$$

where, as in equation (16), the retain rate $r_{it} = c_{it}/y_{it}$ is a function of contemporaneous and past output, export shocks, and period-specific procurement policies which is captured by $\boldsymbol{\beta_t}$; output per capita y_{it} depends on weather conditions and per capita grain sown area as specified in equation (17). Log-linearizing equation (21), we decompose the change in retained consumption in 1959, and consequently the change in mortality in 1960, into the components contributed by procurement shocks (r_{it}) and output shocks (y_{it}). Then, we assess the quantitative importance of the different underlying factors that determine procurement and output. We also quantify the effect of the unequal distribution of food in rural areas.

We adopt two procedures to obtain the change in excess deaths under different counterfactual

[42] The correlation between TRI and distance to railways is 0.47. The correlation between distance to a provincial capital and distance to railways is 0.58.

[43] As our dataset is unbalanced, the exercises are restricted to the subsample of counties for which information on output and procurement are available for both 1957 and 1959. This subsample consists of 760 counties.

scenarios. The first is a "structural" approach. In this approach, we compute counterfactual value of per capita calorie intake based on (21) and, then, substitute counterfactual per capita calorie intake into the estimated non-parametric relation between mortality and per capita calorie intake to compute counterfactual death rates. The second approach is a reduced-form approach, which directly uses the estimated reduced-form relation between death rates and underlying shocks in Panel B of Table 3. The two procedures should yield similar findings if the underlying shocks affect mortality only through changes in caloric supply.

In the following subsections, we first estimate the nonparametric relation between mortality and per capita calorie intake, and use the estimated non-parametric function to quantify the effect of different underlying shocks and the unequal distribution of food 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 or postponed births.

7.1 Non-Parametric Relation Between Mortality and Per Capita Calorie Intake at the County Level

To investigate the county-level relation between death rates and the average level of caloric consumption, we estimate the following semi-parametric model:

$$DR_{i,60} = f(\ln(c_{i,59})) + \gamma_p + \varepsilon_i \ , \tag{22}$$

where $c_{i,59}$ is the caloric content of retained grain in 1959, i.e., $r_{i,59} \times y_{i,59}$, and γ_p denotes province fixed effects. We use only the 1959 consumption data and 1960 mortality data to estimate equation (22) because the famine was most severe in 1960 and the caloric content of retained grain in 1959 is more likely to reflect the actual level of calories available.[44] To further address the potential problem of measurement error, we adopt the control function approach as described below.

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

$$\ln c_{i,59} = \kappa_1 \widetilde{\ln y}_{i,59} + \kappa_2 \widetilde{\ln y}_{i,57} + \kappa_3 \hat{\phi}_i + \gamma_p + e_i \ , \tag{23}$$

where $\widetilde{\ln y}_{i,59} = \sum_\ell \sum_k \hat{\theta}_2^{k\ell}(s_i^k z_{i,59}^\ell)$ is the summary index of weather shocks derived from the panel data regression (11), and $\widetilde{\ln y}_{i,57}$ is the corresponding value for 1957. $\hat{\phi}_i$ is the estimated county-

[44] The amount of retained grain in 1958 is likely to understate the true amount of food available in 1959, as the inventory might not have been completely exhausted at the start of the famine. Similarly, the actual level of calorie supply in 1961 may not be fully reflected in the retained grain in 1960, as relief plans were implemented in the last year of famine (i.e., 1961) and no detailed data on grain relief are available. The measurement errors associated with inventory and grain relief could be systematically correlated with famine severity, and may not be fully addressed by our control function or IV strategy.

fixed effect from panel data regression (11) which summarizes the county-specific time-invariant characteristics that affect grain supply. We obtain the residuals $\hat{e}_i$ from equation (23) and estimate the following semiparametric model:[45]

$$DR_{i,60} = f(\ln(c_{i,59})) + g(\hat{e}_i) + \varsigma\hat{\phi}_i + \gamma_p + \varepsilon_i \ , \tag{24}$$

where $g(\hat{e}_i)$ is a cubic function of $\hat{e}_i$. By controlling for the residuals from (23) as well as the county fixed effect $\hat{\phi}_i$ from grain output regression (11), the function $f(\ln(c_{i,59}))$ in Model (24) is estimated using the variation in consumption that is attributable to weather shocks.

The estimated non-parametric functions $\hat{f}(\ln(c_{i,59}))$ of Models (22) and (24) are presented as the green and blue curves, respectively, in Figure 6. The two reference lines correspond to the logarithms of 900 and 1,800 calories per person-day. We find that the death rate decreases monotonically with caloric consumption. The gradient is steeper at the lower end and flattens out when the consumption level is sufficiently high. In addition, we find that the estimated function of Model (24) has a steeper slope than that of Model (22), suggesting that the data on caloric consumption are subject to measurement error. The slope of the estimated function remains negative even above 1,800 calories per person-day. We interpret this as evidence that food is distributed unequally within a county – when food is distributed unequally, some individuals may die of food shortage even when the average level of consumption is moderately high within a county; as the average level of consumption rises, however, unequal food distribution becomes less important, leading to the negative slope beyond 1,800 calories per person-day.[46]

We estimate the relation between birth rates and caloric consumption analogously. The results are presented in Figure 7. We detect a steeper positive relation between birth rates and caloric consumption using the control function approach.

7.2 Counterfactuals Based on Nonparametric Function

Before delving into different counterfactual scenarios, we first look at the data on excess death rates in the subsample of counties for which we have information on caloric consumption. As reported in row (A1) of Table 10, the death rate was on average 14.66 (per thousand) higher in 1960 than in 1958. Cross-county variation in this increase is considerable, with a standard deviation of 23.19. These excess death rates translate into a total number of excess deaths of

[45] The semiparametric model (24) is estimated using the approach proposed by Robinson (1988). More details are given in Appendix B.3. We also estimated (24) by specifying $g(\hat{e}_i)$ using a B-Spline instead of a cubic function and found that the estimated function $f(\ln(c_{i,59}))$ was similar.

[46] Figure A.16 shows that the squares of the estimated residuals in Model (24) have a downward relationship with the average level of consumption. In Appendix B.4, we argue that this heteroskedasticity is consistent with cross-county heterogeneity in within-county food distribution.

4,053,054.[47] This number serves as a benchmark for the following counterfactual exercises.

7.2.1 Quantitative Importance of Different Underlying Shocks

Our first question is how many deaths could have been avoided had the caloric consumption in 1959 been the same as 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 deaths. Based on the estimated non-parametric function, we calculate the change in death rate for each county as follows:

$$DeathRate_{i,60} - DeathRate_{i,60}^{CF} = \hat{f}(\ln(c_{i,59})) - \hat{f}(\ln(c_{i,57})) \ .$$

In row (A2) of Table 10, we find that the average death rate would have been 13.9 (per thousand) lower in this counterfactual scenario. The implied aggregated number of excess deaths is 3,766,056, which is 92.92% of the actual number of excess deaths. Therefore, almost all excess deaths can be explained by the lower caloric consumption. The remaining deaths may reflect other factors affecting mortality during the chaotic GLF period.

In the second counterfactual exercise, we adjust the output level in 1959 to be the same as in 1957, but keep the retain rate as in 1959. The implied change in death rate is constructed as follows:

$$DeathRate_{i,60} - DeathRate_{i,60}^{CF} = \hat{f}(\ln(c_{i,59})) - \hat{f}(\ln(c_{i,59}^{CF})) \ ,$$

where $c_{i,59}^{CF} = r_{i,59} y_{i,57}$. Row (A3) shows that if output had not declined in 1959, the average death rate would have been 6 (per thousand) lower and 1,820,674 deaths could have been avoided, which is 44.92% of the actual excess deaths.

Rows (A3.a) and (A3.b) show different determinants of output decline. Row (A3.a) demonstrates the role of resource diversion in the GLF period. Based on the estimates in column (1) of Table 5, we construct a counterfactual consumption level in 1959 by assuming that the per capita grain sown area is the same as in 1957. We find that in the absence of resource diversion, the number of excess deaths would have been 36.42% lower. In row (A3.b), we consider the counterfactual scenario of no weather shocks in 1959. Without weather shocks, the number of excess deaths would have been 9.94% lower.

In row (A4), we consider the scenario in which the retain rate in 1959 reverts to its 1957 level, but the output level remains at its actual 1959 level. In this setting, the death rate and the total number of excess death would have been 9.66 (per thousand) and 2,458,859 lower, respectively. The

[47] The total number of excess deaths is calculated as follows:

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

.

decrease in the number of excess deaths is 60.67% of the actual amount. Note that the combined effect of output and procurement shocks is larger than that of consumption shocks (105.59% versus 92.92%) due to the non-linear relation between mortality and caloric consumption.

In row (A5), we quantify the effect of export expansion on excess deaths. Specifically, we consider the counterfactual scenario where the export exposure in 1959 had been the same as that in 1957. Using the estimates in column (1) of Panel A in Table 3, we calculate the counterfactual changes in the grain retain rate and the implied changes in caloric consumption. Then, we translate the implied changes in caloric consumption to counterfactual changes in deaths using the estimated non-parametric function given in Figure 6. In the absence of export expansion, retained consumption would have been higher and the number of excess deaths would have been 14.92% lower.

Next, we ask the following question: how would the number of deaths change if the procurement policies had been 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 output with their non-GLF counterparts. Using the estimated elasticities in column (1) Panel A of Table 3 and estimated non-parametric function $f(\cdot)$, we simulate the counterfactual changes in retained consumption and hence changes in mortality. Row (A6) shows that more rigid procurement policies in the GLF period contributed 26.86% of the excess deaths.[48] In row (A7), we also consider an alternative counterfactual experiment in which the procurement policies in 1957 are the same as in the GLF period. The counterfactual change in the death rate is then $DeathRate_{58}^{CF} - DeathRate_{58}$. In this scenario, the average death rate would have been 2.24 (per thousand) higher in 1958, less than one sixth of the actual increase in death rate between 1958 and 1960. This finding indicates that the fact that procurement policies became more progressive and inflexible over the GLF period cannot alone explain a large portion of the excess deaths between 1958 and 1960. Furthermore, the differences between (A6) and (A7) suggest that the inflexible and progressive procurement policies had a larger impact when accompanied by a widespread, large decline in output.

7.2.2 Quantitative Importance of Consumption Inequality

What would have happened if the available food had been equally distributed across the counties? In row (A8), we equalize the average level of consumption across counties, while keeping the aggregate consumption and the within-county inequality constant.[49] In this scenario, the total excess deaths would have been 35.24% lower. For the counterfactual experiment presented in

[48]This result is largely consistent with the results in Meng et al. (2015). Using the province-level observations of mortality and production over time, Meng et al. (2015) find that "the inflexible and progressive procurement policy contributed to 32–43% of total famine mortality."

[49]In this scenario, the county-level average of consumption is equalized across counties, but there remains inequality within each county.

row (A9), we equally distribute consumption across counties within a province, while keeping the province-level consumption level unchanged; removing the within-province consumption inequality lowers the total excess deaths by 28.19%. These findings are consistent with Meng et al. (2015), who find that unequal food distribution was one of the main contributors to the severity of the Great Famine. Moreover, we show that within-province inequality could be a more important factor than between-province inequality, which aligns with our variation decomposition analysis in Appendix A.1.3.

We also quantitatively assess how the distribution of export-driven procurement affected the severity of the famine. We consider a counterfactual scenario in which the central planners could identify the famine-stricken counties (i.e., counties in the bottom quintile of pre-export consumption per capita) and reduce their export obligations.[50] The planners could then procure the aggregate export from the remaining counties based on their consumption share. The results given in row (A10) show that had this reallocation of exports occurred, the total excess deaths would have been 5.82% lower. In row (A11), we conduct an analogous experiment at the provincial level and find that the within-province redistribution of exports would have lowered the total excess deaths by 5.56%. These findings suggest that the adverse effects of exports on famine would have been greatly mitigated if export procurement had been more progressive at the contemporaneous consumption level. They also echo the discussions in section 6.1.1 on the magnitude of the export effects on famine severity: in the famine ridden regions where the gradient of mortality to caloric consumption is steep, further grain procurement due to export needs could have disproportionally large effects on famine severity.

7.2.3 Robustness

In Appendices B.5 and B.6, we adopt alternative approaches to estimate the relationship between mortality and calorie intake, and simulate the changes in deaths under different counterfactual scenarios. Specifically, we use the control function estimates and IV estimates of the spline regressions given in Table A.10. We find that the quantitative effects of different underlying shocks closely align with the baseline results given in Table 10.

7.3 Counterfactual Changes in Mortality and County Characteristics

In this section, we link the changes in mortality of the various counterfactual scenarios, $DeathRate_{i,60} - DeathRate^{CF}_{i,60}$, to different observable county characteristics including i) whether the county is located near a railway (Near vs. Far), ii) whether the county has a comparative advantage in high-export-exposure crops (High vs. Low), iii) whether the county has a high percentage of CCP

[50]The average retained consumption per capita was 975 Cal. for these counties.

members (High vs. Low), and iv) whether the county experienced good weather shocks in 1957 (Bad vs. Good).[51]

Figure 8 shows the distributions of the counterfactual changes in the death rate if export exposure in 1959 had been the same as in 1957. The figures are generated based on the counterfactual experiment presented in row (A.5.b) of Table 10. We report the p-value of the Kolmogorov-Smirnov equality-of-distributions test in the upper-right corner of each figure. As expected, the distribution of the high-export-exposure group first-order stochastically dominates (FOSD) that of the low-export-exposure group, and the distribution of the group near to railways FOSD that of the group far away from railways. In addition, we find that the distribution of the good-past-weather group FOSD that of the bad-past-weather group. These patterns suggest that counties specializing in high-export-exposure crops, near to railways, or experiencing good past weather shocks were likely to suffer more from over procurement due to export expansion. These results are consistent with our reduced-form regression findings. The Kolmogorov-Smirnov test fails to reject the equality of the distributions of low-CCP-members and high-CCP-members groups.[52]

Figure 9 illustrates the scenario where the output in 1957 had remained the same as in 1959, repeating the exercise in Figure 8. We find the distribution of the far-from-railway group FOSD that of the near-to-railway group, partly because procurement policies were more rigid in remote regions, and as a result output shocks had, on average, larger effects on consumption and mortality. The distribution of the low-CCP-members group FOSD that of the high-CCP-members group, perhaps because procurement policies were more rigid in counties with low party presence.[53] The distribution of the good-past-weather group FOSD that of the bad-past-weather group. This finding is mechanical, as in this counterfactual scenario the increase in output is larger, on average, for the good-past-weather group. Lastly, the distributions of the high- and low-export-exposure groups are statistically equal.

Next, we consider the counterfactual scenario in which the retain rate in 1959 is the same as in 1957. The distributions of changes in death rate are presented in Figure 10. The distribution of the near-to-railway group FOSD that of the far-from-railway group, suggesting that counties nearer

[51] i) Counties are classified into "Near" and "Far" groups based on whether their distance to a railroad is below or above the median distance. ii) Counties are classified into "High" and "Low" groups based on whether the average RCA of rice and soybean is above or below the median value. iii) Counties are classified into "High" and "Low" groups depending on whether the percentage of the population with CCP membership is above or below the median value. iv) Counties are classified into "Good" and "Bad" groups depending on whether the deviation of the weather index in 1957 from the historical average (i.e., $\widetilde{\ln y_{i,57}} - \frac{1}{12}\sum_{t=53}^{64} \widetilde{\ln y_{it}}$) is above or below the median.

[52] It is worth noting that for distance to railways and organizational presence of CCP, the heterogeneous effects detected by the counterfactual simulation are different from the reduced-form results in Panel B of Table 3. This is because the quantitative exercises in Figure 8 isolate the mechanism of procurement and hence emphasize on how the strength of this mechanism varies by remoteness and CCP membership. The reduced form estimates, however, capture the combined channels of procurement and information frictions.

[53] As reported in column (2) of Table 5, the decline in output in the GLF period is not systematically correlated with $CCP\ Member$. Therefore, the detected difference in the distributions is unlikely to be the result of differential output declines in the high-CCP-members group and low-CCP-members group.

railways are more likely to be over-procured due to lower transportation costs. The distribution of the low-export-exposure group is more skewed to the right than the high-export-exposure group, in contrast to the finding in figure 8. This result implies that export shocks may affect consumption and mortality independently of the procurement for domestic distributional purposes. In addition, the distribution of the high-CCP-members group is more skewed to the right than that of the low-CCP-members group. The distributions of the good-past-weather group and the bad-past-weather group are statistically equal.[54]

Finally, Figure 11 reports the results for the counterfactual scenario in which procurement policies in 1959 are less rigid. The distribution of the far-from-railway group is more skewed to the right. As expected, the distribution of the low-CCP-members group FOSD that of the high-CCP-members group, and the distribution of good-past-weather group FOSD that of the bad-past-weather group. There are no statistical differences between the distributions of the high- and low-export-exposure groups.

7.4 Counterfactuals Based on Reduced-Form Regressions

In this section, we present the counterfactual changes in excess deaths based on the reduced-form relations between death rates and underlying shocks. The analysis presented in row (A12) uses the estimates in column (1) of Table 3 Panel B. We find that in the absence of any output shocks between 1957 and 1959, 1,126,522 deaths would have been avoided, which amounts to 27.79% of the total excess deaths. Note that this result is not the reduced-form counterpart of that in row (A3), as output shocks affect both the retain rate and potential food supply and the reduced-form estimates capture the combined effect. As shown in row (A13), we quantify the impact of export expansion using the estimate in column (1) of Table 3 Panel B. We find that 17.6% of the excess deaths can be explained by export shocks. The estimated effect of export shocks obtained from the reduced-form pass-through approach is similar to that based on the non-parametric relation (i.e., row (A5)).

7.5 An Analogous Analysis for Lost/Postponed Births

We conduct an analogous analysis for lost/postponed births; the results are presented in Figure 7 and Panel B of Table 10. We briefly discuss the main findings here. First, the decline in caloric consumption between 1957 and 1959 explains 66.46% of the total lost/postponed births. Second,

[54] A good 1957 weather shock decreases the retain rate in 1957, as the retain rate is negatively linked to contemporaneous output in the non-GLF period (Table 3). However, a good 1957 weather shock also reduces the retain rate in 1959, due to the rigidity of the procurement policies in the GLF period. These two counteracting forces affect the counterfactual changes in the retain rate, i.e., $r_{i,57} - r_{i,59}$. The opposite is the case for a bad 1957 weather shock. In Figure 10, we cannot detect the differences between the distributions of the good- and bad-past-weather groups, probably because $r_{i,57}$ is also affected by 1957 weather conditions.

the relative importance of different underlying shocks is similar to those given in Panel A. For example, the effect of export shocks is about one seventh of the effect of caloric consumption shocks for both death and birth rates. Compared to the approach based on the non-parametric relation, the reduced-form pass-through approach yields similar estimates for the effect of export shocks.

We find that calorie intake has lower explanatory power for fertility than for mortality, perhaps because other factors independently affected fertility during the famine period. For example, the zealous devotion to labor-intensive GLF projects could have led to spousal separations and the postponement of marriages. In addition, fertility could have been strategically postponed during this turbulent period. These factors make birth rate a less ideal proxy for famine severity than death rate. As relative cohort size is more closely correlated with birth rate than mortality rate (Figure A.14), it may also be a noisier proxy for famine severity than death rate.

8 Conclusion

It is often said that all famines are man-made, and the China's Great Famine is not an exception. Given that the China's Great Famine is the worst famine in human history by population loss, it is imperative to understand the mechanism behind the Great Famine, to learn from it, and hopefully to prevent us from repeating the similar tragedy in future. The previous studies point out that the Great Famine was a consequence of multiple institutional failures that led to the fall in grain production and the over-procurement of grains in rural areas but, due to the data limitation, no existing study provides quantitative evaluation of the relative importance of different mechanisms, especially for the importance of exporting grains. Using newly collected county-level panel data, this study quantifies the relative importance of different causes of the Great Famine, paying particular attention to the role of grain exports.

We find that the collapse of grain production, the over-procurement partly driven by grain exports, and the increasingly rigid procurement policy were collectively responsible for the Great Famine, where no single factor dominates quantitatively. In particular, we find that increases in grain exports were responsible for 15-18% of the excess deaths between 1958 and 1960, and that 61% and 45% of the excess deaths can be attributed to the surge in the procurement rate and the fall in agricultural production, respectively. Therefore, one fourth of the effect of the increase in procurement on excess deaths is attributable to an increase in grain exports.

It is important to emphasize that we quantify the effect of grain exports in our counterfactual experiments under a *ceteris paribus* assumption. Most importantly, we hold the inflexible procurement policy – the key institutional feature identified by Meng et al. (2015) – as constant. If the procurement policy had been flexible and the government had been able to collect information and respond to food shortages quickly, then the effect of grain exports would have been smaller. In fact, we find that the effect of exports on death rates is smaller for counties located closer to railways and counties with more CCP members, where verification of food shortages was presumably easier, suggesting that the degree of flexibility moderates the effect of grain exports on famine. Our counterfactual experiment of redistributing export-driven procurement across counties also indicates that the impact of grain exports on mortality would have been much smaller even when the aggregate export had been kept constant if grains had been flexibly procured from counties with relatively food abundance. In this sense, the inflexibility of the procurement policy was a necessary condition for grain exports to have had such a large impact on mortality.

Exporting grains during a famine is not a feature unique to China's Great Famine. There have been several "export-driven famines," including the Irish great famine between 1845 and 1852, various famines in India between 1860 and 1910, the Bengal famine of 1943, and the Soviet-Ukraine famine of 1932-33 (Woodham-Smith, 1964; Sen, 1981; Ghose, 1982; Ravallion, 1987; Davies and Wheatcroft, 2004; Wemheuer, 2015). In particular, during the Soviet-Ukraine famine of 1932-1933, the government compulsorily procured grains from rural areas, exporting 1.6 million tons of grains to cope with foreign debts, under a centrally planned economy with agricultural collectivization (Davies and Wheatcroft, 2004). These grain exports could have fed all of the victims of the famine (Wemheuer, 2015). The good harvest of 1930 was partly responsible for the decision to export substantial amounts of grain in 1931 and 1932 (Davies and Wheatcroft, 2004). Given the striking similarity between the Soviet-Ukraine famine and China's Great Famine, this study is useful for better understanding the causes of the Soviet-Ukraine famine.

More broadly, this study provides insight into the importance of institutional quality and political factors in determining the consequences of international trade. Under a centrally planned economy in which information about demand and supply is not quickly aggregated and transmitted upwards and in which bureaucrats and farmers do not have proper incentives to correctly report production, international trade may have severe consequences. China's Great Famine is an extreme example of how the gains of international trade can be negative when the pattern of trade and allocation of resources are determined by political factors under an inflexible institution.

References

Acemoglu, Daron, Simon Johnson, James Robinson. 2005. “The Rise of Europe: Atlantic Trade, Institutional Change, and Economic Growth.” *American Economic Review* 95(3): 546-579.

Almond, Douglas, Hongbin Li, and Shuang Zhang. 2013. “Land Reform and Sex Selection in China.” NBER Working Paper.

Ashton, Basil, Kenneth Hill, Alan Piazza and Robin Zeitz. 1984. “Famine in China, 1958-61.” *Population and Development Review* 10(4): 613-645.

Autor, David H., David Dorn, and Gordon H. Hanson. 2013. “The China Syndrome: Local Labor Market Effects of Import Competition in the United States.” *America Economic Review* 103(6): 2121-2168.

Balassa, Bella. 1965. “Trade Liberalization and ‘Revealed’ Comparative Advantage.” *The Manchester School of Economics and Social Studies* 32(2): 99-123.

Berger, Daniel, William Easterly, Nathan Nunn and Shanker Satyanath. 2013. “Commercial Imperialism? Political Influence and Trade During the Cold War.” *American Economic Review* 103(2): 863-895.

Bramall, Chris. 2011. “Agency and Famine in China’s Sichuan Province, 1958-1962.” *China Quarterly* 208: 990-1008.

Burgess, Robin, and Dave Donaldson. 2010. “Mitigate the Effects of Weather Shocks? Evidence from India’s Famine Era.” *American Economic Review* 100(2): 449-453.

Burgess, Robin, and Dave Donaldson. 2017. “Railroads and the Demise of Famine in Colonial India.” Working Paper.

Chang, Gene Hsin, and Guanzhong James Wen. 1998. “Food Availability versus Consumption Efficiency: Causes of the Chinese Famine.” *China Economic Review* 9(2): 157-166.

Chen, Yuyu, Hongbin Li and Lingsheng Meng. 2013. “Prenatal Sex Selection and Missing Girls in China.” *The Journal of Human Resources* 48(1): 36-70.

Chen, Shuo, and James Kai-sing Kung. 2011. “The Tragedy of the Nomenklatura: Career Incentives and Political Radicalism during China’s Great Leap Famine.” *American Political Science Review* 105(1): 27-45.

Chu, Junhong, Ivan Png, and Junjian Yi. 2016. “Entrepreneurship and the School of Hard Knocks: Evidence from China?s Great Famine.” Working Paper.

Coale, Ansley J.. 1981. “Population Trends, Population Policy, and Population Studies in China.” *Population and Development Review* 46(1): 1-34.

Davies, R. W., and Wheatcroft, Stephen G. (2004), *The Years of Hunger: Soviet Agriculture, 1931-33.* Palgrave Macmillan.

Dell, Melissa, Benjamin F. Jones, and Benjamin A. Olken. 2012. "Temperature Shocks and Economic Growth: Evidence from the Last Half Century." *American Economic Journal: Macroeconomics* 4(3): 66-95.

Donaldson, Dave. 2016. "Railroad of the Raj: Estimating the Impact of Transportation Infrastructure." *American Economic Review* Forthcoming.

Dube, Oeindrila, and Juan F. Vargas. 2013. "Commodity Price Shocks and Civil Conflict: Evidence from Colombia." *Review of Economic Studies* 80(4): 1384-1421.

Fan, Ziying, Wei Xiong and Li-An Zhou. 2016. "Information Distortion in Hierarchical Organizations: A Study of China's Great Famine." Working Paper.

FAO, Food and Agriculture Organization of the United Nations. 2003. "Food Energy–Methods of Analysis and Conversion Factors." *FAO Food and Nutrition Paper 77.*

Fuchs, Andreas, and Nils-Hendrik Klann. 2013. "Paying a visit: The Dalai Lama effect on international trade." *Journal of International Economics* 91(1): 164-177.

Garver, John W.. 2016. "China's Quest: The History of the Foreign Relations of the People's Republic of China." New York: Oxford University Press.

Ghose, Ajit Kumar. 1982. "Food Supply and Starvation: A Study of Famines with Reference to the Indian Sub-Continent." *Oxford Economic Papers* 34(2): 368-389.

Goldsmith-Pinkham, Paul, Isaac Sorkin, and Henry Swift. 2018. "Bartik Instruments: What, When, Why, and How." NBER Working Paper No. 24408.

Gráda, Ó Cormac. 2007. "Making Famine History." *Journal of Economic Literature* 45(1): 5-38.

Head, Kieth, and Thierry Mayer and John Ries. 2010. "The Erosion of Colonial Trade Linkage after Independence." *Journal of International Economics* 81(1): 1-14.

Johnson, D. Gale. 1998. "China's Great Famine: Introductory Remarks." *China Economic Review* 9(2): 103-109.

Kung, James Kai-sing, and Justin Yifu Lin. 2003. "The Causes of China's Great Leap Famine, 1959-1961." *Economic Development and Cultural Change* 52(1): 51-73.

Kung, James Kai-sing, and Titi Zhou. 2017. "Political Elites and Hometown Favoritism in Famine-stricken China." manuscript, Hong Kong University of Science and Technology.

Levchenko, Andrei A.. 2005. "Institutional Quality and International Trade." *Review of Economic Studies* 74(3): 791-819.

Li, Wei, and Dennis Tao Yang. 2005. "The Great Leap Forward: Anatomy of a Central Planning Disaster." *Journal of Political Economy* 113(4): 840-877.

Lin, Justin Yifu. 1990. "Collectivization in China's Agricultural Crisis in 1959-1961." *Journal of Political Economics* 98(6): 1228-1252.

Lin, Justin Yifu, and Dennis Tao Yang. 1998. "On the Causes of China's Agricultural Crisis and the Great Leap Famine." *China Economic Review* 9(2): 125-140.

Lin, Justin Yifu, and Dennis Tao Yang. 2000. “Food Availability, Entitlements and the Chinese Famine of 1959-61.” *Economic Journal* 110(460): 840-877.

Matsuura, Kenji, and Cort Willmott. 2007. *Terrestrial Air Temperature and Precipitation: Monthly and Annual Time Series: (1950-1996)* Version 1.01. University of Delaware. http://climate.geog.udel.edu/ climate/.

Meng, Xin, Nancy Qian, and Pierre Yared. 2015. “The Institutional Causes of China’s Great Famine, 1959-1961.” *Review of Economic Studies* 82(4): 1568-1611.

Nunn, Nathan, and Diego Puga. 2012. “Ruggedness: The Blessing of Bad Geography in Africa.” *Review of Economics and Statistics* 94(1): 20-36.

Pascali, Luigi. 2017. “The Wind of Change: Maritime Technology, Trade, and Economic Development.” *American Economic Review* Forthcoming.

Palacpac, Adelita C.. 1977. “World Rice Statistics.” The International Rice Research Institute, Department of Agricultural Economics.

Qian, Nancy. 2008. “Missing Women and the Price of Tea in China: The Effect of Sex-Specific Earnings on Sex Imbalance.” *Quarterly Journal of Economics* 123(3): 1251-1285.

Ravallion, Martin. 1987. “Trade and Stabilization: Another Look at British India’s Controversial Foodgrain Exports.” *Exploration in Economic History* 24(4): 354-370.

Riskin, Carl. 1998. “Seven Questions about the Chinese Famine of 1959-61.” *China Economic Review* 9(2): 111-124.

Robinson, Peter M.. 1988. “Root-N-Consistent Semiparametric Regression.” *Econometrica* 56: 931-954.

Sen, Amartya. 1981. “Poverty and Famines: An Essay on Entitlement and Deprivation.” Oxford: Oxford University Press.

Topalova, Petia. 2010. “Factor Immobility and Regional Impacts of Trade Liberalization: Evidence on Poverty from India.” *American Economic Journal: Applied Economics* 2(4): 1-41.

Xue, Susan. 2010. “New Local Gazetteers from China.” *Collection Building* 29(3): 110-118.

Walker, Kenneth R.. 1965. “Planning in Chinese Agriculture: Socialisation and the Private Sector,1956-1962.” Psychology Press.

Wemheuer, Felix. 2015. “Famine Politics in Maoist China and the Soviet Union.” New Haven: Yale University Press.

Woodham-Smith, Cecil. 1964. “The Great Hunger: Ireland, 1845-49.” London: Hamilton.

Yang, Dali Li., and Fubing Su. 1998. “The Politics of Famine and Reform in Rural China.” *China Economic Review* 9(2): 111-124.

Yao, Shujie. 1999. “A Note on the Causal Factors of China’s Famine in 1959-1961.” *The Journal of Political Economy* 107(6): 1365-1369.

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

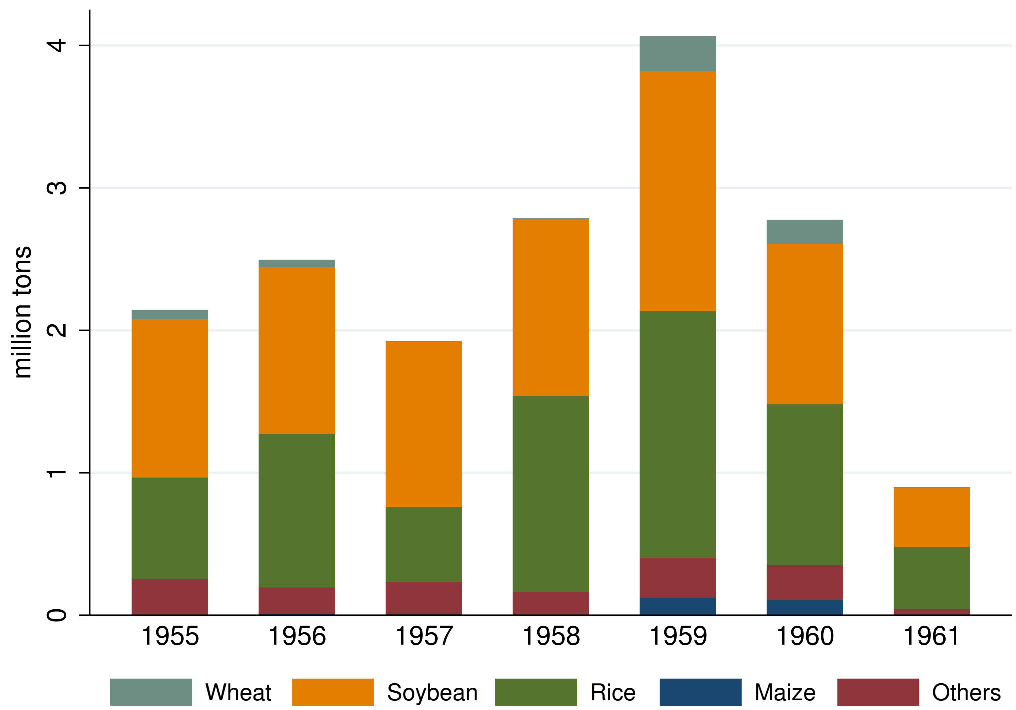


Figure 2: Change in # of Deaths per 1000 Pop. between 1957 and 1960

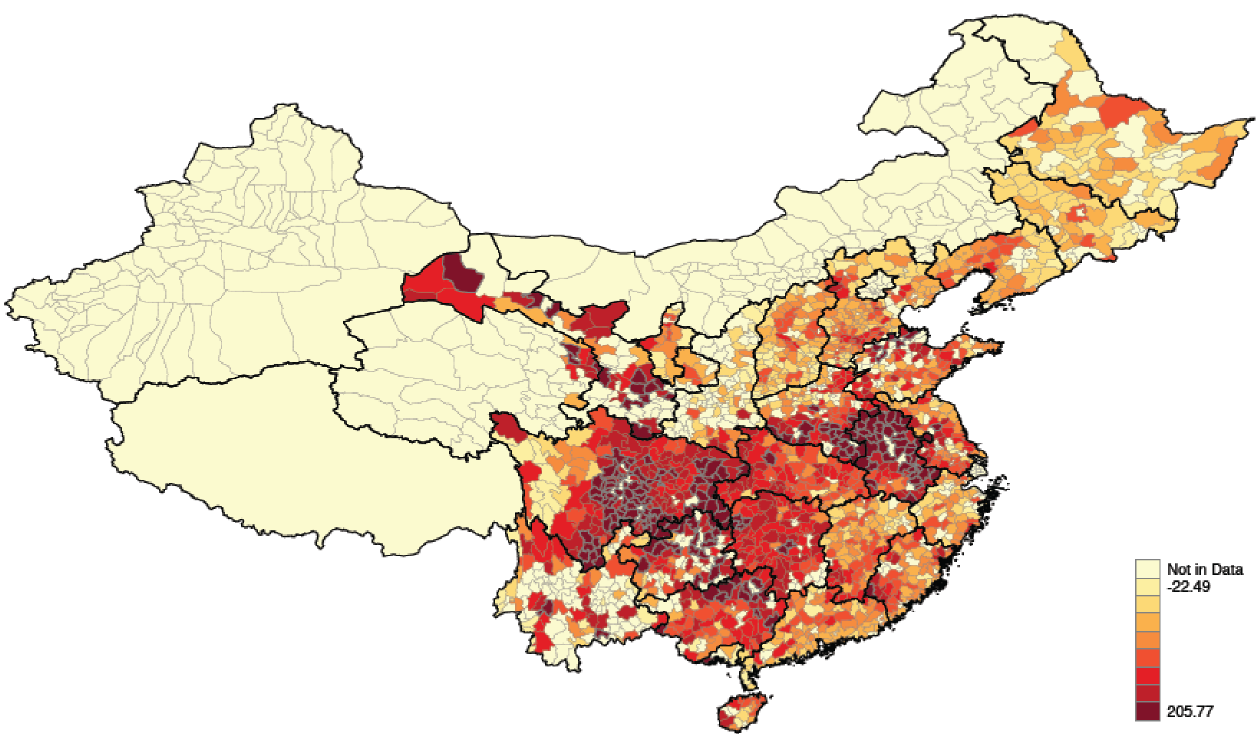
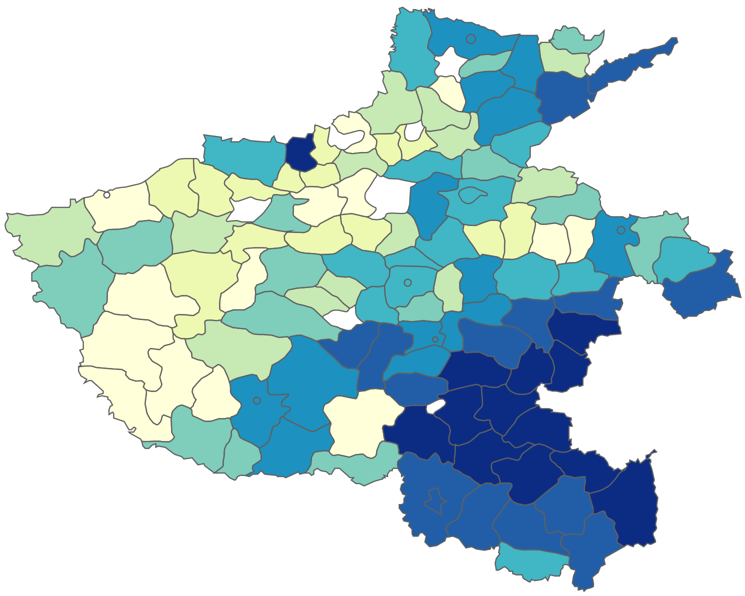
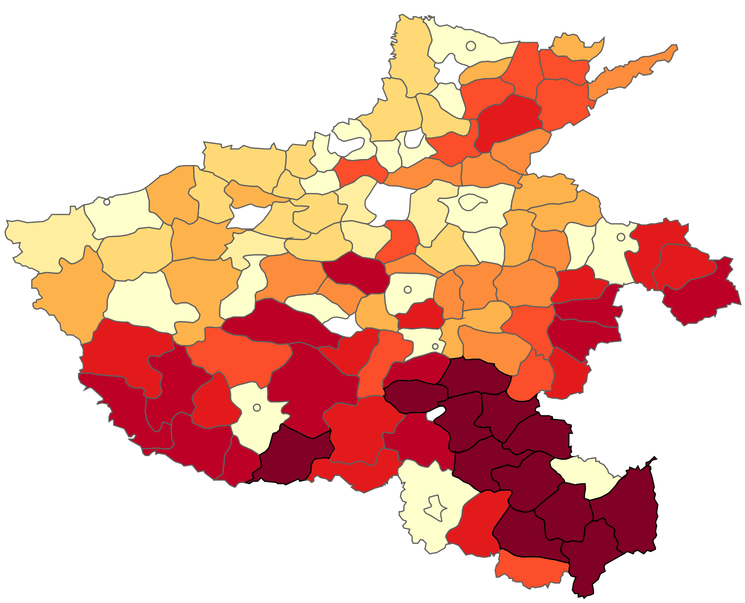


Figure 3: Crop specialization and excess mortality in Henan province



(a) RCA in Rice and Soybean



(b) Change in # of Deaths per 1000 Pop. between 1957 and 1960

Figure 4: Timing Assumption

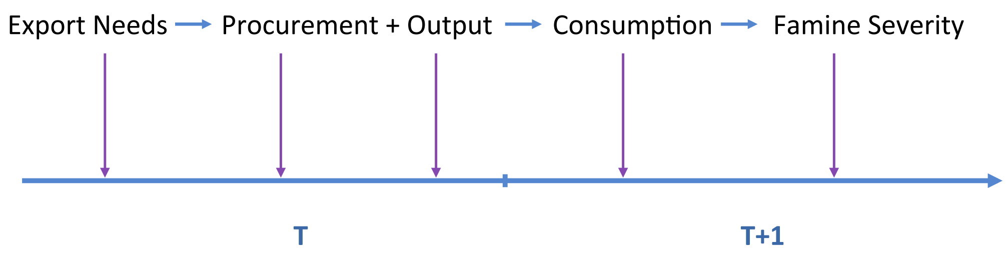


Figure 5: Grain Export, Output and Consumption

Figure 6: Semi-parametric Regression: Death Rate and Log Caloric Consumption

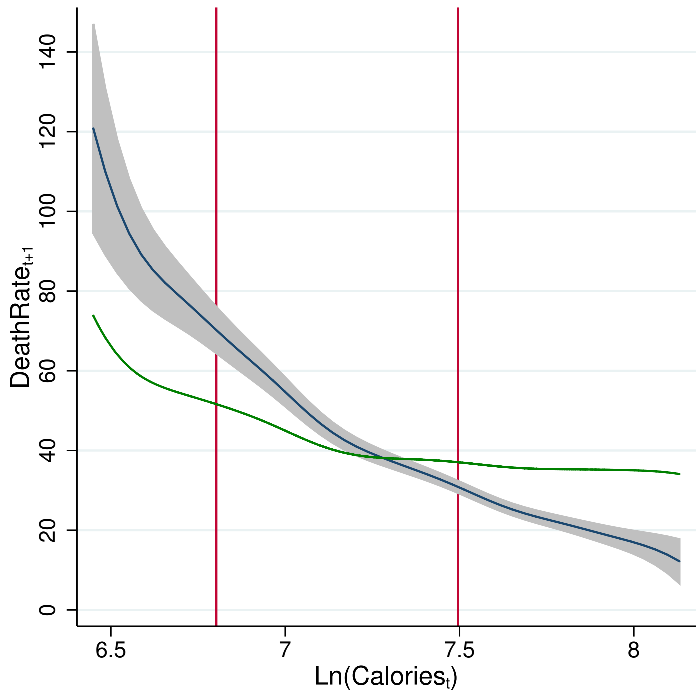


Figure 7: Semi-parametric Regression: Birth Rate and Log Caloric Consumption

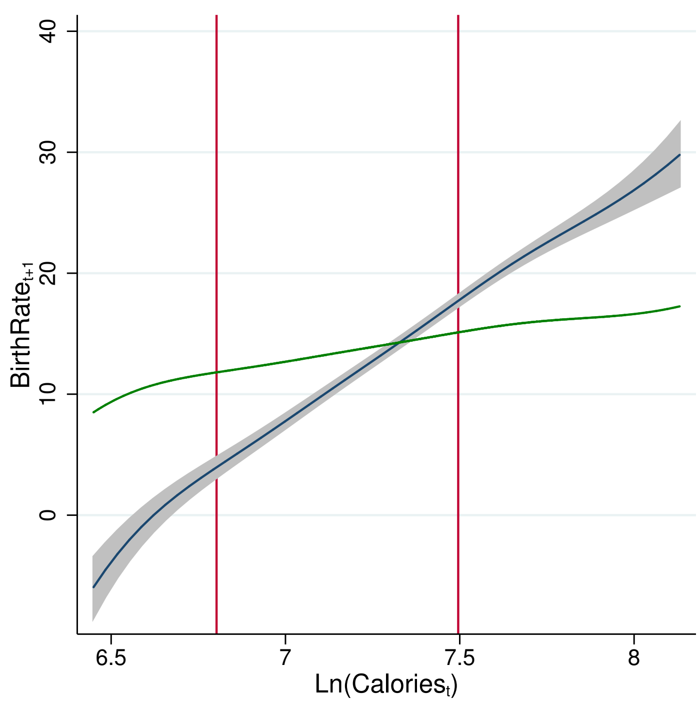


Figure 8: Exports in 1959 Same as in 1957

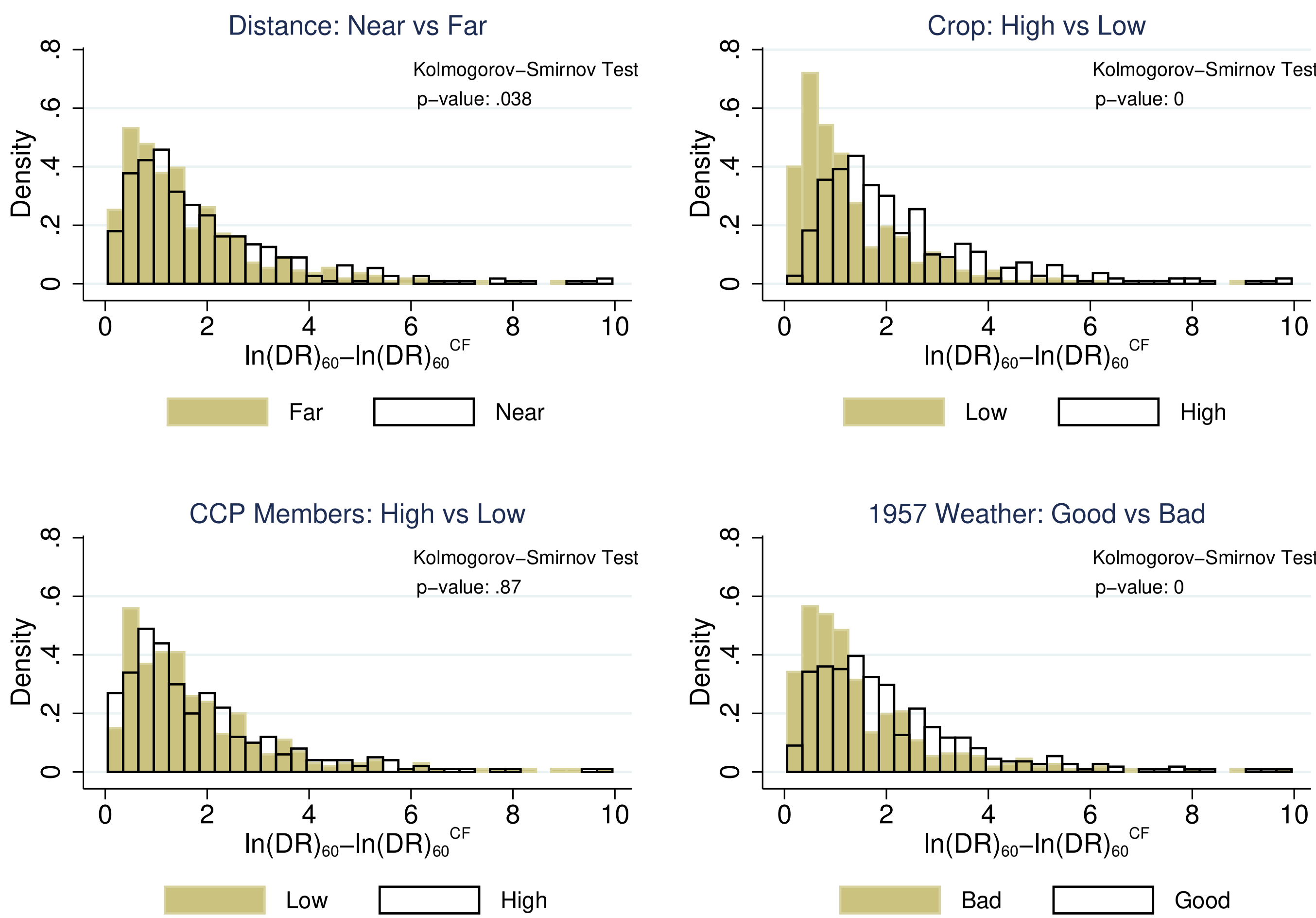


Figure 9: Outputs in 1959 Same as in 1957

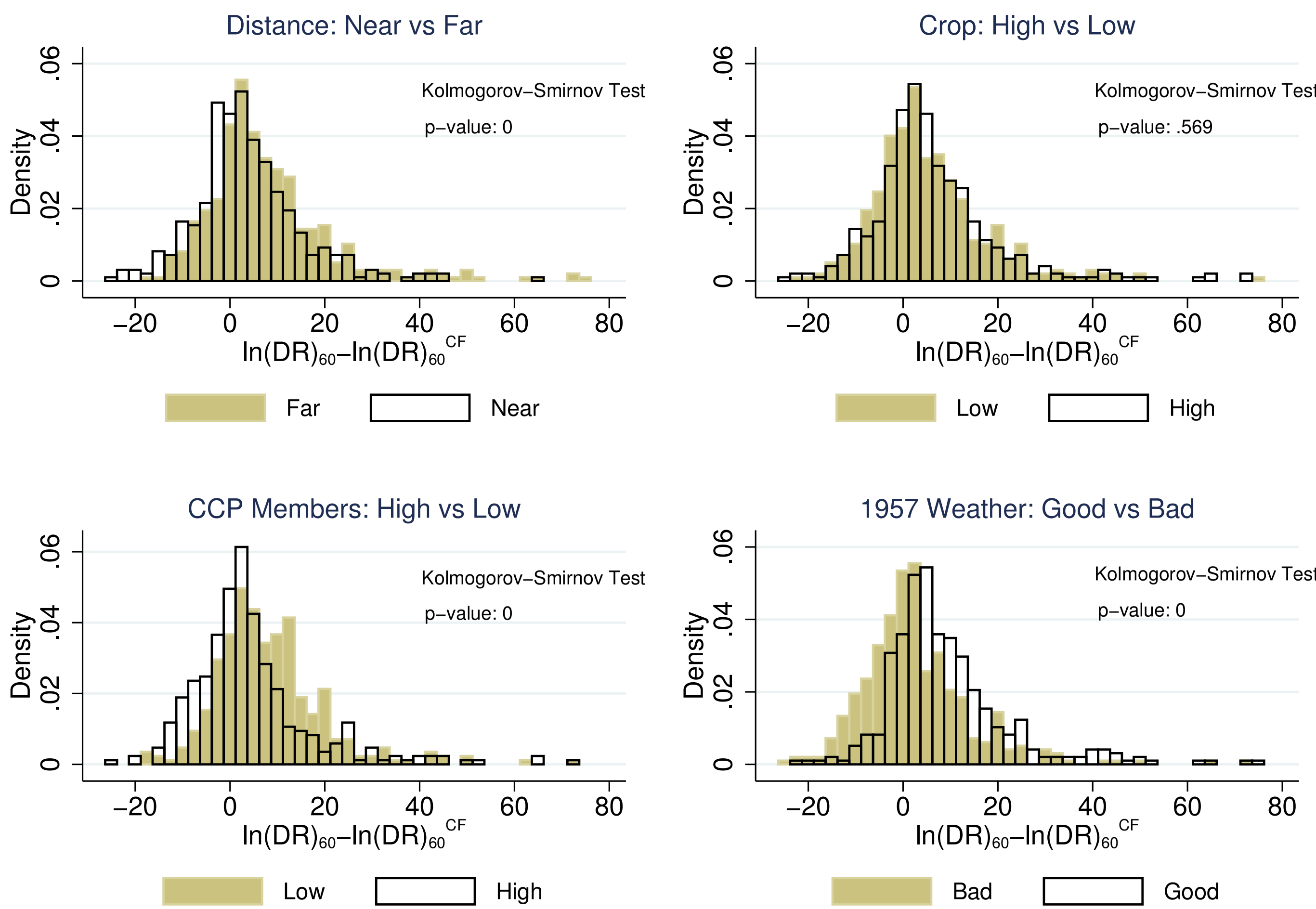


Figure 10: Procurement Rates in 1959 Same as in 1957

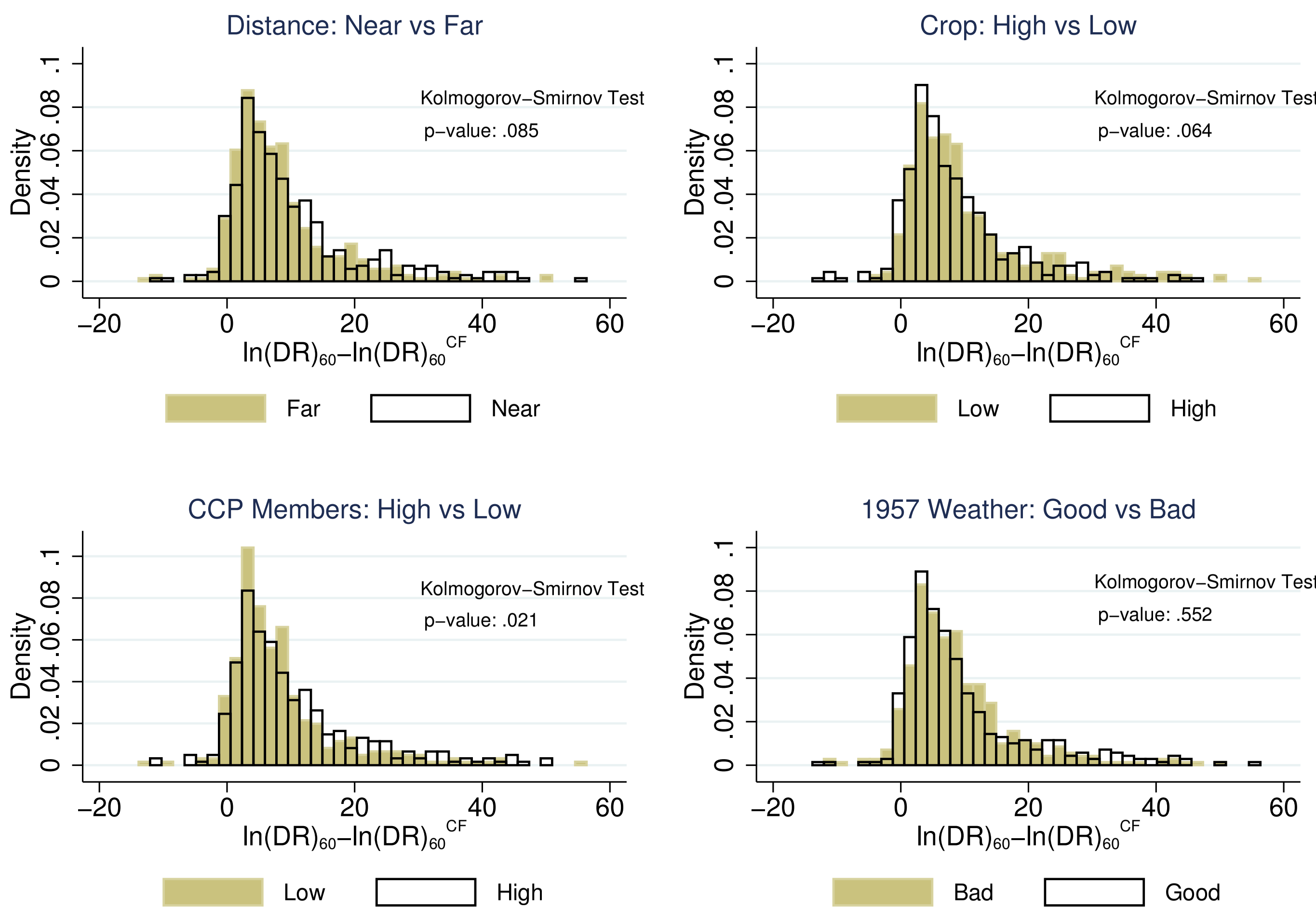


Figure 11: Procurement Policies in 1959 Same as in Non-GLF Period

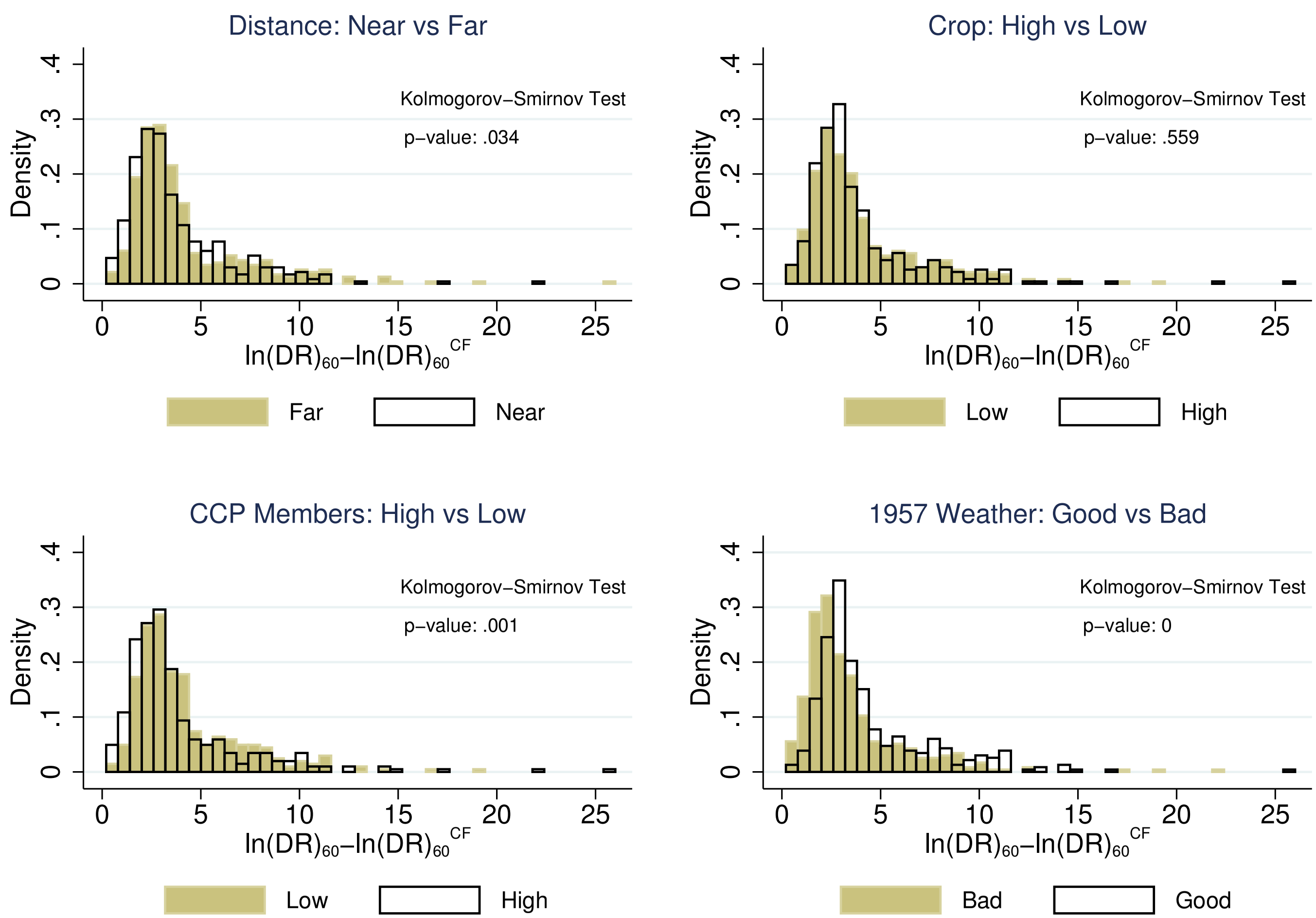


Table 1: Summary Statistics

	All Years	GLF Years	Non-GLF Years
Death Rate$_{it+1}$	13.90	20.59	11.79
	(0.08)	(0.28)	(0.04)
Birth Rate$_{it+1}$ (per 1,000)	32.01	20.19	35.75
	(0.09)	(0.13)	(0.09)
Per capita grain output$_{it}$ (kg)	282.82	266.81	284.69
	(1.08)	(2.03)	(1.35)
Retain Rate$_{it}$	0.75	0.68	0.77
	(0.00)	(0.00)	(0.00)
Per Capita Retained Consumption$_{it}$ (Cal.)	2070.20	1771.86	2113.34
	(9.64)	(17.36)	(12.12)
Per Capita Sown Area$_{it}$ (mu)	3.25	3.12	3.33
	(0.01)	(0.03)	(0.02)
ExpShock$_{it}$ (%)	1.66	3.71	0.96
	(0.02)	(0.06)	(0.01)
Spring Temperature$_{it}$ (C°)	8.16	8.98	7.92
	(0.04)	(0.08)	(0.05)
Summer Temperature$_{it}$ (C°)	21.74	21.73	21.76
	(0.03)	(0.06)	(0.03)
Spring Precipitation$_{it}$ (cm)	5.59	5.68	5.50
	(0.03)	(0.07)	(0.04)
Summer Precipitation$_{it}$ (cm)	14.79	14.32	15.18
	(0.05)	(0.09)	(0.06)
Distance to Railway in 1957$_{i}$ (km)	101.61	0.00	0.00
	(2.47)	(0.00)	(0.00)
CPC Member in 1956$_{i}$ (%)	1.58	0.00	0.00
	(0.03)	(0.00)	(0.00)

Notes: Standard errors are in parentheses.

Table 2: Export and International Prices

	Baseline (1)	Excl. Rice (2)	Extended Sample (3)	Excl. 1958-61 (4)	Excl. Rice & 1958-61 (5)	Excl. $\|\%\Delta\| > 2\%$ (6)
$\ln P_t^k$	2.591*	3.674**	2.756***	2.686**	3.434**	3.039**
	(1.405)	(1.664)	(1.045)	(1.075)	(1.314)	(1.238)
Period	1953-65	1953-65	1953-86	1953-86	1953-86	1953-86
Crop	Y	Y	Y	Y	Y	Y
Year	Y	Y	Y	Y	Y	Y
N	65	52	170	150	120	116
R^2	0.886	0.882	0.773	0.765	0.711	0.805

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1, † p<0.15

Table 3: Export Exposure, Retain Rate, Death Rate, and Birth Rate

Sample:	All	All	Near	Far	All	All	Near	Far
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Dependent Variable $\ln RetainRate_{it}$								
EX_{it}	-0.0052***	-0.0046***	-0.0065***	-0.0043**	-0.0049***	-0.0046***	-0.0067***	-0.0038*
	(0.0013)	(0.0014)	(0.0018)	(0.0021)	(0.0014)	(0.0015)	(0.0019)	(0.0022)
$EX_{it} \times DistRail_i$		0.0068				0.0052		
		(0.0092)				(0.0160)		
$EX_{it} \times CCP\ Member_i$		0.0007				0.0010		
		(0.0011)				(0.0018)		
GLF$\times \ln y_{it}$	-0.0352	-0.0201	-0.1329**	0.0183	-0.0367	-0.0382	-0.1486**	0.0169
	(0.0437)	(0.0460)	(0.0597)	(0.0679)	(0.0473)	(0.0474)	(0.0653)	(0.0719)
GLF$\times \ln y_{it-2}$	-0.1397***	-0.1563***	-0.0834	-0.1740***	-0.1626***	-0.1610***	-0.0860	-0.2066***
	(0.0402)	(0.0427)	(0.0544)	(0.0603)	(0.0437)	(0.0438)	(0.0608)	(0.0624)
Non-GLF$\times \ln y_{it}$	-0.1606***	-0.1619***	-0.1975***	-0.1132***	-0.1651***	-0.1655***	-0.2073***	-0.1242***
	(0.0228)	(0.0243)	(0.0329)	(0.0331)	(0.0257)	(0.0257)	(0.0373)	(0.0375)
Non-GLF$\times \ln y_{it-2}$	0.0038	0.0066	0.0033	-0.0163	-0.0107	-0.0109	-0.0109	-0.0345
	(0.0210)	(0.0215)	(0.0318)	(0.0291)	(0.0225)	(0.0225)	(0.0346)	(0.0313)
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
County Characteristics$\times$Year	N	N	N	N	Y	Y	Y	Y
N	10,112	9,073	5,229	4,883	9,073	9,073	4,680	4,393
R^2	0.7974	0.7965	0.8110	0.7917	0.8031	0.8031	0.8173	0.8081

Table 3 (Cont.): Export Exposure, Retain Rate, Death Rate, and Birth Rate

Sample:	All (1)	All (2)	Near (3)	Far (4)	All (5)	All (6)	Near (7)	Far (8)
Panel B: Dependent Variable $DeathRate_{it+1}$								
EX_{it}	0.5307***	0.6465***	0.6831***	0.5314**	0.6058***	0.5839***	0.6649***	0.5893*
	(0.1401)	(0.1525)	(0.1937)	(0.2506)	(0.1619)	(0.1677)	(0.2136)	(0.3064)
$EX_{it} \times DistRail_i$		1.9395*				-1.0755		
		(1.0025)				(1.4631)		
$EX_{it} \times CCP\ Member_i$		-0.4471***				-0.4916***		
		(0.0947)				(0.1536)		
GLF$\times \ln y_{it}$	-28.0680***	-30.5320***	-16.1310***	-37.6027***	-26.7902***	-25.9855***	-16.9074***	-36.1263***
	(4.7975)	(5.0425)	(4.2560)	(9.3792)	(4.7130)	(4.6596)	(4.6443)	(9.5849)
GLF$\times \ln y_{it-2}$	33.5837***	36.6361***	21.1306***	44.0586***	33.5082***	32.7115***	20.3373***	45.9618***
	(5.7761)	(6.0646)	(5.4182)	(10.2305)	(5.5510)	(5.4369)	(5.5325)	(10.2561)
Non-GLF$\times \ln y_{it}$	4.2194***	4.4537***	3.0347**	4.0343	4.3175***	4.5775***	1.7523	5.1682**
	(1.3034)	(1.3233)	(1.4927)	(2.4777)	(1.3904)	(1.3806)	(1.6619)	(2.5298)
Non-GLF$\times \ln y_{it-2}$	1.1919	1.8298	0.3246	2.4518	1.6692	1.7773	0.5374	3.7145
	(1.2355)	(1.2979)	(1.1424)	(2.1802)	(1.3275)	(1.3263)	(1.2971)	(2.2979)
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
County Characteristics$\times$Year	N	N	N	N	Y	Y	Y	Y
N	12,273	10,926	6,385	5,888	10,926	10,926	5,647	5,279
R^2	0.6451	0.6443	0.7002	0.6481	0.6534	0.6553	0.7080	0.6662

Table 3 (Cont.): Export Exposure, Retain Rate, Death Rate, and Birth Rate

Sample:	All	All	Near	Far	All	All	Near	Far
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel C: Dependent Variable $BirthRate_{it+1}$								
EX_{it}	-0.1396***	-0.1978***	-0.1066*	-0.2031**	-0.1826***	-0.1876***	-0.1741***	-0.1596*
	(0.0448)	(0.0515)	(0.0585)	(0.0831)	(0.0473)	(0.0563)	(0.0572)	(0.0930)
$EX_{it} \times DistRail_i$		-0.7077				-0.1899		
		(0.4544)				(0.6683)		
$EX_{it} \times CCP\ Member_i$		0.0300				-0.0385		
		(0.0365)				(0.0586)		
GLF$\times \ln y_{it}$	7.0340***	6.3606***	1.8498	14.0109***	6.0425***	6.1120***	3.6662	9.8944**
	(1.9590)	(2.0518)	(2.4119)	(3.6734)	(2.1027)	(2.1093)	(2.5888)	(3.9541)
GLF$\times \ln y_{it-2}$	-3.0362	-2.8561	0.1738	-6.3399*	-1.6380	-1.7091	0.9196	-2.7670
	(1.9886)	(2.0980)	(2.3634)	(3.7437)	(2.0897)	(2.0999)	(2.4398)	(4.0123)
Non-GLF$\times \ln y_{it}$	7.2887***	6.5382***	5.8879***	10.7499***	6.5801***	6.5996***	6.5500***	8.8398***
	(1.2119)	(1.2946)	(1.5269)	(1.9836)	(1.3381)	(1.3372)	(1.7112)	(2.2147)
Non-GLF$\times \ln y_{it-2}$	-2.8955***	-2.6977**	-3.2549**	-2.5585	-1.6142	-1.6025	-1.4596	-1.4410
	(1.1075)	(1.1698)	(1.4342)	(1.8034)	(1.2670)	(1.2676)	(1.6107)	(2.0927)
Province×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
County Characteristics×Year	N	N	N	N	Y	Y	Y	Y
N	12,287	10,939	6,386	5,901	10,939	10,939	5,647	5,292
R^2	0.7969	0.7975	0.8021	0.8042	0.8034	0.8034	0.8124	0.8118

Notes: County characteristics include population density,average agricultural productivity, distance to railway networks, distance to the provincial capital, terrain ruggedness, average spring temperature and precipitation, average summer temperature and precipitation, whether the county is the hometown of a CCP Central Committee member in the 8th Congress, and the percentage of population with CCP membership in 1956. Robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 4: Export Exposure and Grain Resale

Dependent Var.:	$PerCapitaResale_{it+1}$	$\ln RetainRate_{it}$	$DeathRate_{it+1}$
	(1)	(2)	(3)
EX_{it}	-0.057	-0.002	1.214***
	(0.237)	(0.002)	(0.415)
$EX_{it} \times DistRail_i$	-1.838	-0.052***	15.016***
	(2.149)	(0.013)	(3.108)
$EX_{it} \times CCP\ Member_i$	0.543**	0.007***	-1.931***
	(0.225)	(0.001)	(0.278)
GLF$\times \ln y_{it}$	35.485***	0.108	-48.471***
	(9.444)	(0.071)	(13.670)
GLF$\times \ln y_{it-2}$	-10.296	-0.308***	51.562***
	(7.434)	(0.068)	(15.629)
NonGLF$\times \ln y_{it}$	5.244	-0.230***	2.559
	(6.203)	(0.030)	(3.157)
NonGLF$\times \ln y_{it-2}$	-1.417	0.054**	3.659
	(6.743)	(0.025)	(2.502)
Province×Year	Y	Y	Y
County	Y	Y	Y
Control function	Y	Y	Y
N	1,507	1,526	1,642
R^2	0.678	0.801	0.561

Notes: Based on the sample of Henan an d Hubei provinces. Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table 5: Determinants of County-Level Grain Outputs

Dependent Var.: ln $GrainOutput_{it}$	(1)	(2)	(3)	(4)	(5)	(6)	(7)
ln Per Capita Sown Area$_{it}$	0.624***		0.630***	0.541***	0.550***		0.588***
	(0.028)		(0.029)	(0.032)	(0.033)		(0.035)
GLF× ln Per Capita Sown Area$_{it}$		0.613***					
		(0.030)					
Non-GLF× ln Per Capita Sown Area$_{it}$		0.629***					
		(0.028)					
GLF×$DistRail_i$			0.028				
			(0.051)				
GLF×$CCP\ Member_i$			0.004				
			(0.006)				
EX_{it}				0.001	0.001		-0.003
				(0.002)	(0.002)		(0.003)
$EX_{it} \times DistRail_i$					0.005		
					(0.014)		
$EX_{it} \times CCP\ Member_i$					0.002		
					(0.001)		
Per Capita Steel Output$_{it}$						-0.487	-0.881
						(0.699)	(0.745)
GLF× Late Liberation$_i$						-0.062*	-0.032
						(0.035)	(0.030)
GLF× Intensity of the 1957 Anti-Rightest Movement$_i$						0.127	0.202
						(0.636)	(0.625)
County	Y	Y	Y	Y	Y	Y	Y
Province×Year	Y	Y	Y	Y	Y		
Year						Y	Y
N	14,125	14,125	12,613	11,651	10,397	14,125	11,651
R^2	0.858	0.858	0.858	0.868	0.868	0.755	0.825

Notes: All of the regressions control for weather conditions. The standard errors in columns (5) and (6) are clustered at the province× year level. Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 6: Robustness – Different Outcome Variables

Dependent Var.:	$RetainRate_{it}$	$\ln Calorie_{it}$	$\ln DeathRate_{i,t+1}$	$\ln BirthRate_{i,t+1}$	$\ln CohortSize_{i,t+1}$
	(1)	(2)	(3)	(4)	(5)
EX_{it}	-0.0021***	-0.0052***	0.0103***	-0.0081***	-0.0034*
	(0.0007)	(0.0013)	(0.0029)	(0.0022)	(0.0020)
GLF$\times \ln y_{it}$	-0.0336	0.9648***	-0.6086***	0.3230***	0.3751***
	(0.0262)	(0.0437)	(0.1228)	(0.0943)	(0.1049)
GLF$\times \ln y_{it-2}$	-0.0745***	-0.1397***	0.7918***	-0.1818*	-0.2169**
	(0.0235)	(0.0402)	(0.1284)	(0.0993)	(0.1072)
Non-GLF$\times \ln y_{it}$	-0.1224***	0.8394***	0.1967***	0.1897***	0.1076**
	(0.0153)	(0.0228)	(0.0491)	(0.0405)	(0.0500)
Non-GLF$\times \ln y_{it-2}$	0.0121	0.0038	-0.0125	-0.0756**	0.0055
	(0.0142)	(0.0210)	(0.0477)	(0.0366)	(0.0447)
Province×Year	Y	Y	Y	Y	Y
County	Y	Y	Y	Y	Y
Control function	Y	Y	Y	Y	Y
N	10,112	10,112	12,273	12,287	11,926
R^2	0.8132	0.9595	0.7292	0.7933	0.9434

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

Table 7: Robustness: Alternative Specifications and Measures of Export Shocks

	Different price elasticity	Per Capita ExportShock	Different lags	Different lags	Comparative Advantage		IV
					RCA	Suitability	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: Dependent Variable $\ln RetainRate_{it}$							
EX_{it}	-0.005***	-0.002***	-0.005***	-0.005***			-0.006***
	(0.001)	(0.000)	(0.001)	(0.001)			(0.001)
GLF$\times RCA_i^{rs}$					-0.020**		
					(0.009)		
GLF$\times\psi_i^{rs}$						-0.007*	
						(0.004)	
GLF$\times\bar{\psi}_i$					-0.001	0.006	
					(0.003)	(0.005)	
GLF$\times \ln y_{it}$	-0.036	-0.017	-0.037	0.000	0.043	0.031	-0.055
	(0.044)	(0.044)	(0.047)	(0.054)	(0.046)	(0.046)	(0.061)
GLF$\times \ln y_{i,t-1}$			-0.104**	-0.054			
			(0.041)	(0.042)			
GLF$\times \ln y_{it-2}$	-0.139***	-0.146***		-0.115***	-0.202***	-0.195***	-0.138***
	(0.040)	(0.040)		(0.043)	(0.042)	(0.043)	(0.050)
Non-GLF$\times \ln y_{it}$	-0.161***	-0.159***	-0.146***	-0.166***	-0.179***	-0.181***	-0.156***
	(0.023)	(0.023)	(0.023)	(0.023)	(0.022)	(0.022)	(0.022)
Non-GLF$\times \ln y_{i,t-1}$			0.028	0.016			
			(0.021)	(0.022)			
Non-GLF$\times \ln y_{it-2}$	0.004	0.002		0.004	0.022	0.020	-0.011
	(0.021)	(0.021)		(0.021)	(0.020)	(0.020)	(0.025)
N	10,112	10,112	9,889	9,889	9,182	9,182	10,112
R^2	0.797	0.797	0.795	0.796	0.804	0.803	0.786
Panel B: Dependent Variable $DeathRate_{i,t+1}$							
EX_{it}	0.559***	0.133***	0.584***	0.534***			0.652***
	(0.147)	(0.039)	(0.156)	(0.141)			(0.148)
GLF$\times RCA_i^{rs}$					3.402***		
					(0.718)		
GLF$\times\psi_i^{rs}$						1.028***	
						(0.315)	
GLF$\times\bar{\psi}_i$					-0.593*	-1.605***	
					(0.350)	(0.377)	
GLF$\times \ln y_{it}$	-27.970***	-33.803***	-18.395***	-30.667***	-30.138***	-31.595***	-37.130***
	(4.798)	(4.951)	(3.524)	(4.811)	(5.679)	(5.617)	(7.744)
GLF$\times \ln y_{i,t-1}$			15.456***	5.229***			
			(3.456)	(1.562)			
GLF$\times \ln y_{it-2}$	33.497***	31.984***		34.457***	37.006***	35.846***	40.215***
	(5.777)	(5.866)		(5.885)	(6.666)	(6.732)	(7.454)
Non-GLF$\times \ln y_{it}$	4.269***	4.062***	-0.579	4.524***	3.756***	4.154***	3.050**
	(1.308)	(1.309)	(1.436)	(1.314)	(1.427)	(1.501)	(1.320)
Non-GLF$\times \ln y_{i,t-1}$			-2.938***	0.109			
			(1.041)	(0.274)			
Non-GLF$\times \ln y_{it-2}$	1.168	0.725		1.422	1.319	1.082	0.281
	(1.236)	(1.285)		(1.247)	(1.233)	(1.302)	(1.591)
N	12,273	12,273	12,028	12,028	11,142	11,142	12,273
R^2	0.645	0.644	0.639	0.645	0.659	0.658	0.536
Province$\times$Year	Y	Y	Y	Y	Y	Y	Y
County	Y	Y	Y	Y	Y	Y	Y
Control function	Y	Y	Y	Y	Y	Y	N

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

Table 8: Placebo Tests: Effects of Past and Future Export Shocks

Dependent Var.	$\ln RetainRate_{it}$		$DeathRate_{it+1}$		$BirthRate_{it+1}$	
	62-65	54-57	62-65	54-57	62-65	54-57
	(1)	(2)	(3)	(4)	(5)	(6)
EX_{it-4}	-0.001		0.016		-0.023	
	(0.001)		(0.024)		(0.067)	
EX_{it+4}		-0.000		0.031		0.052
		(0.001)		(0.024)		(0.052)
Province×Year	Y	Y	Y	Y	Y	Y
County	Y	Y	Y	Y	Y	Y
Control function	Y	Y	Y	Y	Y	Y
N	2,872	3,074	3,748	3,681	3,751	3,685
R^2	0.906	0.897	0.820	0.682	0.769	0.648

Notes: All regressions control for contemporaneous log output, and two-period lagged log output. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 9: Heterogeneous Effects of Export Exposure on Death Rate: Alternative Measures of Distance

Dependent Var. :	$\ln RetainRate_{it+1}$			$DeathRate_{it+1}$		
	(1)	(2)	(3)	(4)	(5)	(6)
EX_{it}	-0.004***	-0.005***	-0.004***	0.607***	0.641***	0.702***
	(0.001)	(0.001)	(0.001)	(0.140)	(0.148)	(0.157)
$EX_{it} \times TRI_i$	0.061			3.181		
	(0.052)			(5.369)		
$EX_{it} \times DistCap_i$		0.002			1.257***	
		(0.005)			(0.357)	
$EX_{it} \times DistPCA_i$			0.079			20.085***
			(0.074)			(7.463)
$EX_{it} \times CCP\ Member_i$	0.001	0.001	0.001	-0.402***	-0.456***	-0.454***
	(0.001)	(0.001)	(0.001)	(0.087)	(0.095)	(0.094)
GLF$\times \ln y_{it}$	-0.019	-0.018	-0.017	-30.781***	-28.598***	-29.633***
	(0.046)	(0.046)	(0.046)	(5.095)	(4.818)	(4.955)
GLF$\times \ln y_{it-2}$	-0.155***	-0.158***	-0.158***	36.896***	35.051***	36.096***
	(0.043)	(0.042)	(0.043)	(6.113)	(5.812)	(5.993)
Non-GLF$\times \ln y_{it}$	-0.161***	-0.161***	-0.161***	4.549***	4.733***	4.682***
	(0.024)	(0.024)	(0.024)	(1.315)	(1.327)	(1.331)
Non-GLF$\times \ln y_{it-2}$	0.007	0.007	0.007	1.891	1.811	1.815
	(0.022)	(0.022)	(0.022)	(1.307)	(1.293)	(1.295)
Province×Year	Y	Y	Y	Y	Y	Y
County	Y	Y	Y	Y	Y	Y
Control function	Y	Y	Y	Y	Y	Y
N	9,073	9,073	9,073	10,926	10,926	10,926
R^2	0.797	0.796	0.796	0.644	0.645	0.645

Notes: The estimated coefficient of $X_t \times DistPCA$ is multiplied by 100. Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 10: Counterfactural Exercises Based on Semi-parametric Regressions

Panel A: Change in Deaths	$\Delta DeathRate$ mean	$\Delta DeathRate$ std	implied number of excess deaths	% of actual excess deaths
(A1) From Data: $DeathRate_{60} - DeathRate_{58}$	14.66	23.19	4053054	100
Approach 1: Based on the Non-Parametric Function				
(A2) Caloric consumption in 1959 same as in 1957	13.90	17.14	3766056	92.92
(A3) Output in 1959 same as in 1957	6.00	13.26	1820674	44.92
(A3.a) Land inputs in 1959 same as in 1957 (#)	4.91	9.00	1259472	36.42
(A3.b) No weather shocks in 1959	0.89	5.33	402816	9.94
(A4) Procurement rate in 1959 same as in 1957	9.66	11.59	2458859	60.67
(A5) Export exposure in 1959 same as in 1957	2.17	3.04	604606	14.92
(A6) Procurement policies in 1959 same as in Non-GLF period	3.94	3.86	1088651	26.86
(A7) Procurement policies in 1957 same as in GLF period	2.24	1.74	585910	14.74
(A8) Consumption equally distributed across the nation in 1959	4.13	17.94	1428118	35.24
(A9) Consumption equally distributed within provinces in 1959	3.92	15.46	1142366	28.19
(A10) Redistribute exports in 1959 across the nation	0.66	3.91	235892	5.82
(A11) Redistribute exports in 1959 within the province	0.70	3.88	225492	5.56
Approach 2: Based on Reduced-Form Regressions				
(A12) Output in 1959 same as in 1957	3.71	7.53	1126522	27.79
(A13) Export exposure in 1959 same as in 1957	2.62	1.98	713424	17.60

Panel B: Change in Births	$\Delta BirthRate$ mean	$\Delta BirthRate$ std	implied number of lost births	% of actual lost births
(B1) From Data: $BirthRate_{58} - BirthRate_{60}$	9.26	9.99	2637231	100
Approach 1: Based on the Non-Parametric Function				
(B2) Caloric consumption in 1959 same as in 1957	6.60	6.26	1752632	66.46
(B3) Output in 1959 same as in 1957	2.46	4.96	745988	28.29
(B3.a) Land inputs in 1959 same as in 1957 (#)	2.07	2.53	507727	22.07
(B3.b) No weather shocks in 1959	0.33	2.06	165664	6.28
(B4) Procurement rate in 1959 same as in 1957	4.22	3.51	1032031	39.13
(B5) Export exposure in 1959 same as in 1957	0.86	0.85	233875	8.87
(B6) Procurement policies in 1959 same as in Non-GLF period	1.59	0.83	424374	16.09
(B7) Procurement policies in 1957 same as in GLF period	1.26	0.65	321721	12.34
(B8) Consumption equally distributed across the nation in 1959	0.44	6.82	279475	10.60
(B9) Consumption equally distributed within provinces in 1959	0.65	5.65	196800	7.46
(B10) Redistribute exports in 1959 across the nation	0.03	1.19	30536	1.16
(B11) Redistribute exports in 1959 within the provinces	0.06	1.16	28211	1.07
Approach 2: Based on Reduced-Form Regressions				
(B12) Output in 1959 same as in 1957	0.93	1.89	283315	10.74
(B13) Export exposure in 1959 same as in 1957	0.69	0.52	187612	7.11

Notes: The implied number of excess deaths is the sum of the excess deaths in the 760 counties with data on caloric consumption in both 1957 and 1959. (#) The change in excess mortality (lost births) due to counterfactual changes in per capita sown areas is calculated for the 652 counties with information on caloric consumption and sown area in both 1957 and 1959. The actual number of excess deaths (lost births) in these counties was 3,457,626 (2,300,905).

A Data Appendix

A.1 Demographic Data

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

To examine the reliability of this new dataset, we cross-check our data with the province-level data used by Lin and Yang (2000) and Meng et al. (2015).[55] 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 indication that our data systematically over or under report the death rates. (The correlation coefficient of the two series is 0.991.) This result is expected, as both our data and the data used by the two comparative studies come from China's Statistics Bureaus.

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

In this subsection, we show that aggregate numbers of excess deaths and lost/postponed births derived from our county-level data are consistent with the estimates in the existing literature. To this end, we take the 1957 death/birth rate as the benchmark death/birth rates (i.e., they would have been the 1959-1961 death/birth rates 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 lost/postponed births during the Great Famine are given by

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

and

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

The total excess deaths are 15.74 million and the total lost/postponed births are 18.59 million. These numbers amount to 0.03 and 0.035 of the 1957 population in the sample. (The total excess deaths as a share of the national population is 0.024 and the total lost births as a share of the national population is 0.029.)

A.1.3 Cross-County Variation in Famine Severity

Panel A of Figure A.3 shows the cross-county average of the mortality rates and its coefficient of variation (cv). We find that, along with the surge in the death rates, the variation in mortality rates between counties increased substantially during the famine period. Panel B presents the

[55] Both studies use data drawn from the statistical yearbooks issued by the National Statistics Bureau (NBS).

corresponding time series for birth rates; it shows that the cross-county variation in birth rates peaked in the famine period, corresponding to the dip in the average birth rate. These findings suggest there was considerable variation in famine severity across China. Figures A.6 and A.7 repeat Figure A.3 for each province. In most provinces, the mortality rate increased (birth rate declined) in the famine period and the cross-county variation increased.

We further decompose the variation in mortality rates into 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 A.4 shows the results for the decomposition of the variation by year. We find that the within-county component contributes more to the overall variation throughout the sample period. In addition, both the between and within component surge in the famine period. Panel B shows the results of an analogous analysis of birth rates. We find a similar pattern: the within component is always larger than the between component, and both of them increase over the famine period.

Figure A.5 provides another snapshot of the data. It shows that the correlation of death and birth rates changes from positive in 1957 to negative in 1960. The purple dots are the counties with a death rate above the median and a birth rate below the median in 1960, indicating that they are the counties that experienced more severe famine; however, the death and birth rates are more or less randomly distributed among them in 1957.

A.2 Output and Procurement Data

A potential concern is a self-selection bias in 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 the retain rate over the sample period and (ii) counties with incomplete data. Panel A of Figure A.8 plots the average death rate across years by county group. The two series closely track each other in the non-famine years. In 1959, the counties with incomplete data on the retain rate have a higher average death rate. However, in 1960 the pattern is reversed. Panel B presents the corresponding plot for birth rates. For most of the years, there is no significant difference between the groups. The findings in Figure A.8 suggest that our data are unlikely to be subject to severe selective reporting.

B Supplementary Results and Discussions

B.1 Derivation of Equation (8)

From (7), the actual consumption per capita is given by

$$\begin{aligned} c_{it} &= \hat{c}_t + y_{it} - \sum_k (1+\zeta_t^k) y_{i,t-2}^k \\ &= \hat{c}_t + y_{it} - y_{i,t-2} - \sum_k \frac{Y_{i,t-2}^k}{Y_{t-2}^k} \frac{\hat{C}_t^k - C_{t-2}^k}{N_{i,t-2}} - \sum_k \frac{Y_{i,t-2}^k}{Y_{t-2}^k} \frac{P_t^k - P_{t-2}^k}{N_{i,t-2}} \\ &= \hat{c}_t + y_{it} - \sum_k \frac{Y_{i,t-2}^k}{Y_{t-2}^k} \frac{\hat{C}_t^k}{N_{i,t-2}} - \sum_k \frac{Y_{i,t-2}^k}{Y_{t-2}^k} \frac{P_t^k}{N_{i,t-2}}, \end{aligned} \tag{25}$$

where the second equality follows from (5) while the last equality holds because, with $Y_{t-2}^k = C_{t-2}^k + P_{t-2}^k$, we have

$$\begin{aligned} & y_{i,t-2} - \sum_k \frac{Y_{i,t-2}^k}{Y_{t-2}^k} \frac{C_{t-2}^k}{N_{i,t-2}} - \sum_k \frac{Y_{i,t-2}^k}{Y_{t-2}^k} \frac{P_{t-2}^k}{N_{i,t-2}} \\ &= \sum_k \frac{Y_{i,t-2}^k}{Y_{t-2}^k} \frac{Y_{t-2}^k}{N_{i,t-2}} - \sum_k \frac{Y_{i,t-2}^k}{Y_{t-2}^k} \frac{C_{t-2}^k}{N_{i,t-2}} - \sum_k \frac{Y_{i,t-2}^k}{Y_{t-2}^k} \frac{P_{t-2}^k}{N_{i,t-2}} \\ &= \sum_k \frac{Y_{i,t-2}^k}{Y_{t-2}^k} \frac{0}{N_{i,t-2}} = 0. \end{aligned}$$

Suppose $\hat{C}_t^k / Y_{t-2}^k \approx \kappa_t$ for all k so that, at the crop level, the targeted retained consumption is proportional to output and this share is similar across crops. Then, dividing both sides of (25) by y_{it}, we have

$$\frac{c_{it}}{y_{it}} \approx 1 - \kappa_t \frac{y_{it-2}}{y_{it}} - \sum_k \frac{Y_{i,t-2}^k}{Y_{t-2}^k} \frac{P_t^k}{Y_{it}} + \frac{\hat{c}_t}{y_{it}}$$

Using the approximation $c_{it}/y_{it} - 1 \approx \ln(c_{it}/y_{it})$, $y_{it-2}/y_{it} - 1 = \ln y_{it-2} - \ln y_{it}$, and $\hat{c}_t/y_{it} - 1 = \ln \hat{c}_t - \ln y_{it}$, the above equation can be written as

$$\ln c_{it} = (1 - \kappa_t + \ln \hat{c}_t) + \kappa_t (\ln y_{it} - \ln y_{it-2}) - \sum_k \frac{Y_{i,t-2}^k}{Y_{t-2}^k} \frac{P_t^k}{Y_{it}} + \varepsilon_{it}, \tag{26}$$

where ε_{it} contains approximation errors. Equation (26) with (4) gives (8).

The assumption that $\hat{C}_t^k / Y_{t-2}^k \approx \kappa_t$ for all k is important here, which greatly simplifies the derivation. Since we don't observe $\hat{C}_t^k$, the assumption is not testable. We now briefly discuss how the violation of this assumption may have affected our estimates.

Denote $\kappa_t^k = \hat{C}_t^k / Y_{t-2}^k$ so that $\tilde{\kappa}_t^k = \kappa_t^k - \kappa_t \neq 0$ if the assumption is violated. Then, the error term ε_{it} contains the following component: $-\sum_k (Y_{i,t-2}^k / Y_{it}) \tilde{\kappa}_t^k$.

It is plausible that the higher export demand of crop k, X_t^k, forces the central government to set the lower target consumption level for crop k, $\hat{C}_t^k$. Then we expect that the within-year correlation between X_t^k / Y_{t-2}^k and $\tilde{\kappa}_t^k$ across crops is negative (i.e., an increase in export of crop k is associated with a decline in the planned retained rate for crop k relative to other crops to meet its higher export demand). In this case, our estimate provides a lower bound for the effect of export because the omitted variable $-\sum_k (Y_{i,t-2}^k / Y_{it}) \tilde{\kappa}_t^k$ gives an upward bias of the export effect, and we will underestimate the effect of export. Furthermore, in our empirical analysis, we find that the estimated effect of export shocks remain stable across different specifications with respect to the inclusion of county fixed effects, province-year fixed effects, and the interaction terms between county-level observables and year dummies which partially controls the approximation error, suggesting that the bias due to the approximation error may not be a major concern.

B.2 Investigating Export Effects Using Province-Level Data

In this section, we investigate the effects of grain exportation on famine severity by estimating the following equation:

$$DeathRate_{pt+1} = \beta_x EX_{pt} + \sum_{\tau} \beta_1^{\tau} \mathbf{1}(t \in \tau) \times \ln y_{pt} + \sum_{\tau} \beta_2^{\tau} \mathbf{1}(t \in \tau) \times \ln y_{pt-2} + x_{pt}' \gamma + \phi_t + u_{it}.$$

EX_{pt} is constructed in a similar way as the county-level measure; y_{pt} and y_{pt-2} are the constructed output measures from Meng et al.(2015); x_{pt} is a vector of province-year-level covariates, including the share of urban population and the principal component of GLF indicators[56]; and ϕ_t denotes year fixed effects.

Table A.9 reports the regression results. Agreeing with our county-level results, we find that death rates are positively associated with past output during the GLF period. We also detect that a higher export exposure may aggregate the famine at the province level, however the estimated effect is not always significant, probably due to a lack of statistical power.

B.3 Estimating the Non-Parametric Relation Between Mortality and Calorie Intake

We use the 1959 consumption data and 1960 mortality data to estimate the semiparametric equation (24). To reduce the noise introduced by outliers, the observations with retained consumption

[56] Following Meng et al. (2015), the principal component of GLF intensity is extracted from a dummy for late liberation, the share of the population that was purged during the 1957 Anti-Right movement, the growth in steel production, and the negative growth in sown area for agriculture production during 1958-1961.

below the 2.5th percentile and above the 97.5 percentile are dropped.

In equation (24), we allow the province-level policy shocks and the county-level predetermined characteristics to have independent effects on mortality. As the curse of dimensionality prevents us from estimating a fully non-parametric model in all of these dimensions, we account for these covariates in a partially linear framework. For this purpose, we estimate the effects of the covariates of equation (24) from a double-residual regression (Robinson, 1988), and then estimate the non-parametric relation between mortality and calorie intake $f(\cdot)$ after removing the effect of the covariates. (Specifically, the STATA package *semipar* is used to implement Robinson's approach.)

B.4 Residual Squares and Log Caloric Consumption

Figure A.16 shows that the squares of the estimated residuals from Model (24) decrease with consumption per capita.[57] One potential source of this heteroskedasticity is cross-county heterogeneity in within-county food distribution. Two counties with the same *average* consumption may experience very different death rates if one county distributes food more unequally than the other. Unequal food distribution matters more when consumption per capita is low, as when there is an abundance of food, the death rate is unlikely to rise due to moderate consumption inequality. In contrast, when the average calorie supply just meets the requirement for survival, mortality rates are heavily affected by food distribution. Therefore, unobserved differences in within-county food distribution may lead to a downward sloping relationship between the variance of regression errors and consumption per capita. Unfortunately, we do not have any county-level measurement on how food is distributed across individuals within a county.

B.5 Linear Spline Regressions: Control Function vs IV Approach

In this section, we re-estimate the relation between mortality and caloric consumption using a linear spline regression model. Column (1) in Table A.10 reports the estimated spline coefficients. We find that mortality is negatively correlated with the log caloric consumption both below and above the cutoff (log 1,500 calories). However, the slope is much steeper when the caloric consumption falls below the threshold. Column (2) includes the control function to address the potential endogeneity problem of caloric consumption.[58] The spline coefficients are larger in magnitude, which suggests the existence of a classical measurement error problem. Yet, we still find a diminishing effect of caloric consumption on mortality. Next, we take an IV approach to estimate the spline regression. Specifically, we take the fitted value from equation (23) as an instrument for caloric

[57] We use the pairwise bootstrap to construct the confidence interval in Figure 6, which provides asymptotically valid inferences under heteroskedastic errors in regression analysis.

[58] Note that the control function is a cubic function of $\hat{v}_i$, which is constructed following the method given in Section 7.1.

consumption. The result is reported in column (3). We find a significantly negative effect of caloric consumption on mortality below the cutoff. However, when caloric consumption exceeds 1,500, the slope becomes positive although it is insignificantly different from zero. (The slope coefficient is 31.7 with a p-value 0.205.) To avoid this issue of non-monotonicity, in column (4), we restrict the slope coefficient to be zero when caloric consumption is above 1,500. Columns (5)-(7) repeat the exercises for birth rates. In sum, the detected diminishing effects of caloric consumption on mortality and fertility are consistent with the findings in Figures 6 and 7.

B.6 Counterfactual Simulations Based on the Spline Regressions

In this section, we take estimates from Table A.10 to simulate the changes in mortality under different counterfactual scenarios. The purpose of this exercise is to substantiate the robustness of our quantitative findings to alternative regression models and statistical methods to correct for endogeneity problems. Panels A and B of Table A.11 report the results for the counterfactual analysis when the relation between mortality and calorie intake is estimated using the models in column (2) and (4) in Table A.10, respectively. For the counterfactual experiments (A2)-(A7), the estimated changes in mortality obtained from the IV approach are similar to those obtained from the control function approach. Moreover, for these cases, the estimates in both panels resemble the baseline findings in Table 10 of the main text.

Panel B row (A8) shows that equalizing consumption per capita across the nation completely eliminates the famine. This prediction deviates from the one obtained based on the non-parametric approach. This difference is due to the fact that different approaches render different estimated relations between mortality and caloric intake when the consumption per capita surpasses the threshold 1,500 Cal. The estimates from the IV spline regression indicate that mortality will not further decline with county average caloric intake when the consumption level is sufficiently large. Therefore, the reallocation of consumption from the *relatively* food abundant regions to the food deficient regions has little impact on the former regions. In contrast, according to our non-parametric estimates, county average caloric consumption still affects mortality even when the consumption level is higher than the minimum caloric requirement for survival. (As discussed in the main text, one possible explanation for this finding is that a higher average consumption level could lower the mortality that results from within-county unequal food distribution.) As a result, the redistribution could increase mortality in *relatively* food abundant regions, which offsets the declines in mortality in the regions experiencing food scarcity.

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

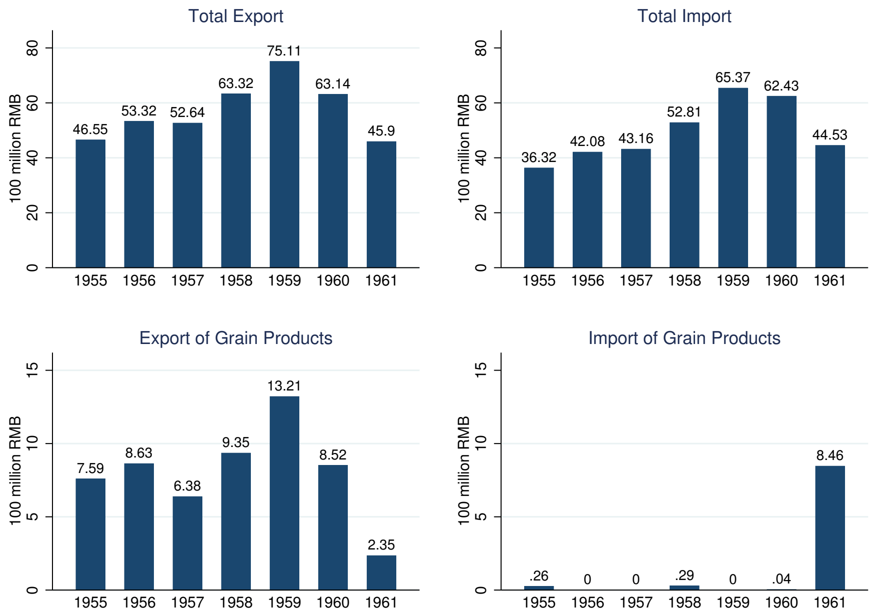
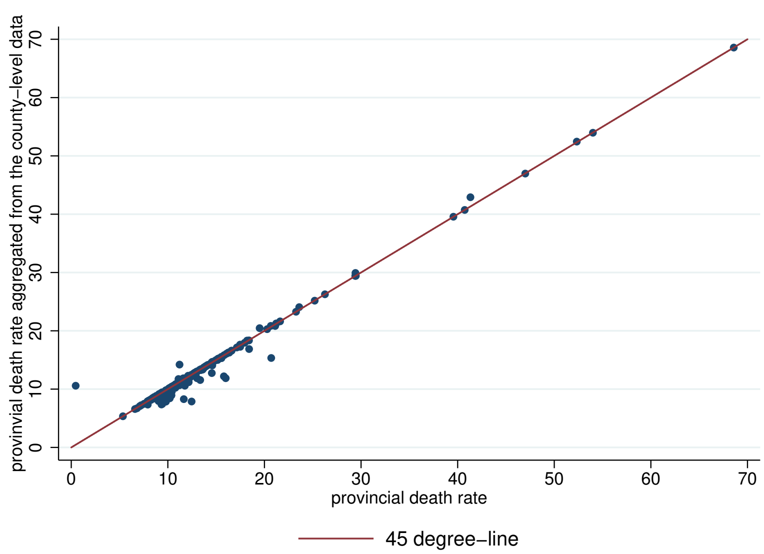


Figure A.2: Comparison of the Province-Level Death Rates from Different Sources



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

Figure A.3: Cross-County Variation in Famine Severity

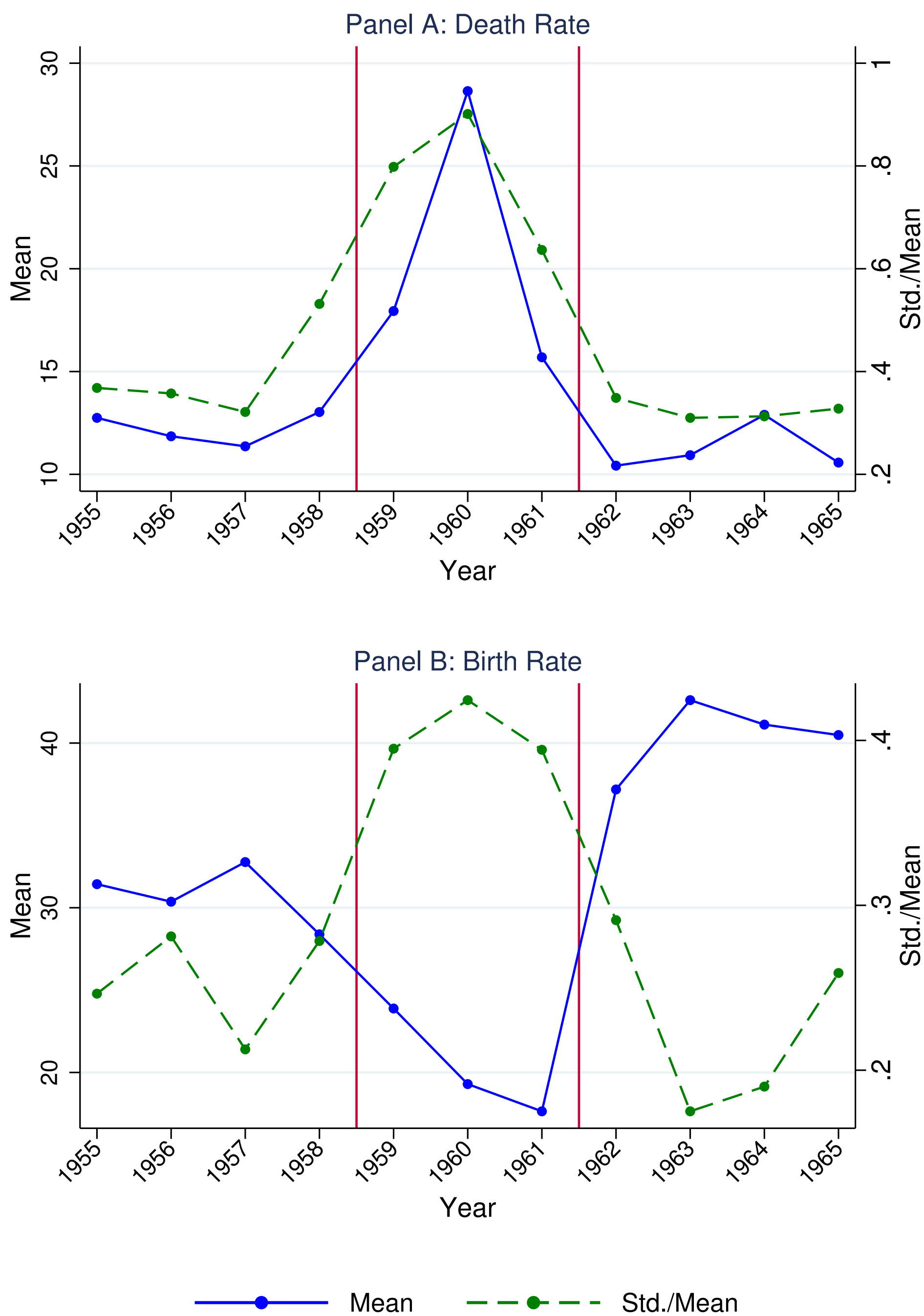


Figure A.4: Decomposition of Within- versus Between-Province Variation

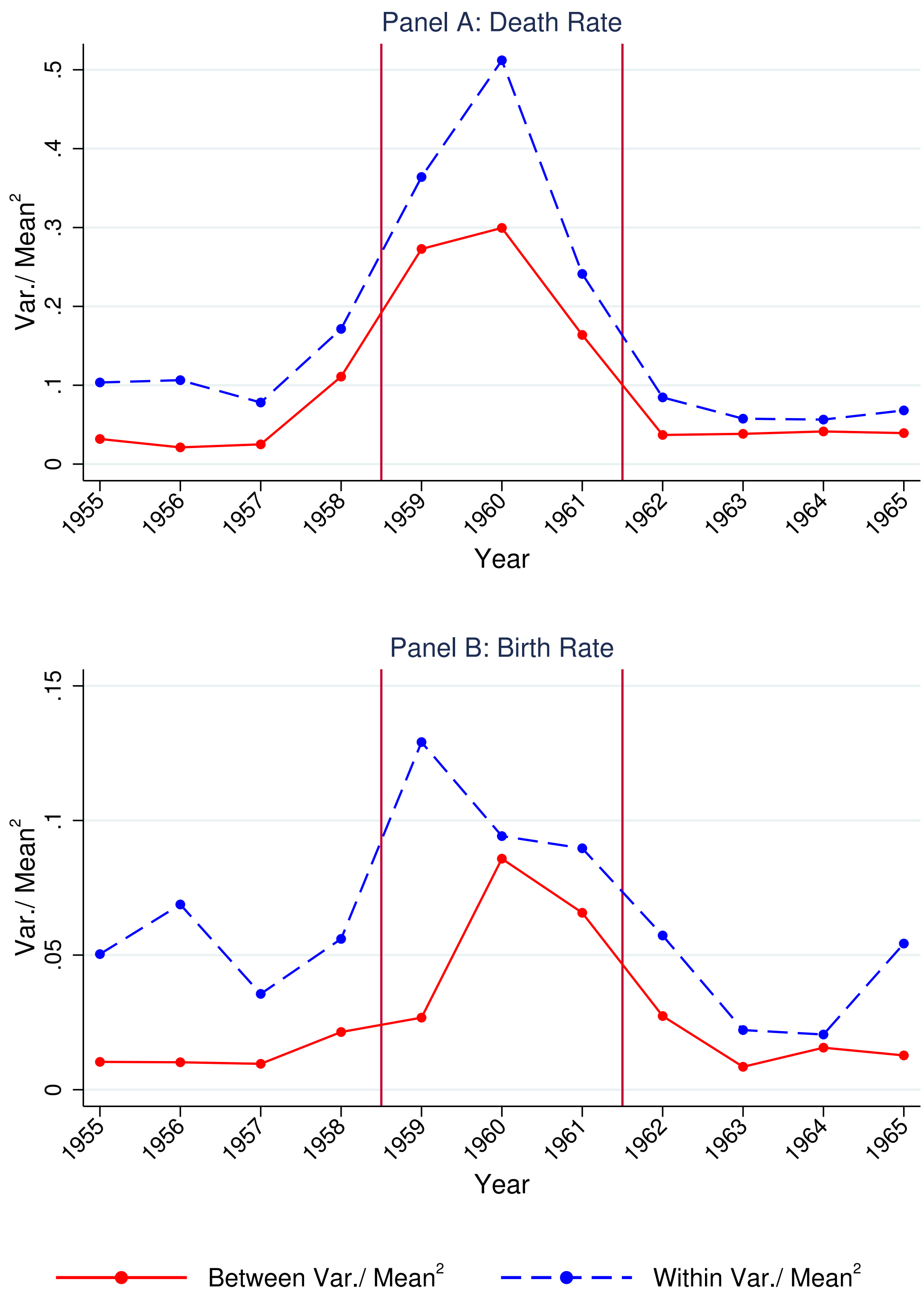


Figure A.5: Correlation between Changes in Mortality and Birth Rates

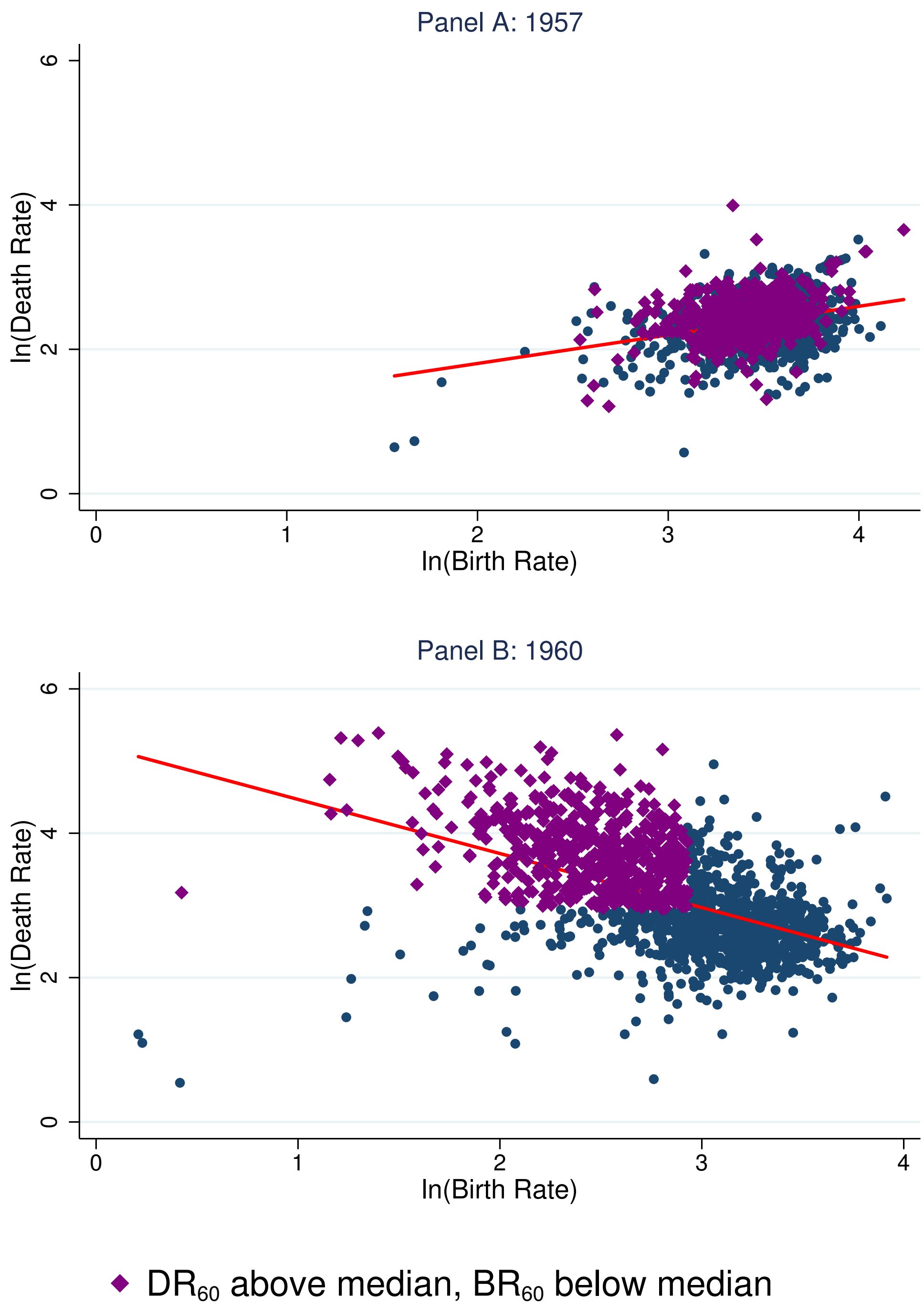


Figure A.6: Within Province Variation in Death Rate by Year

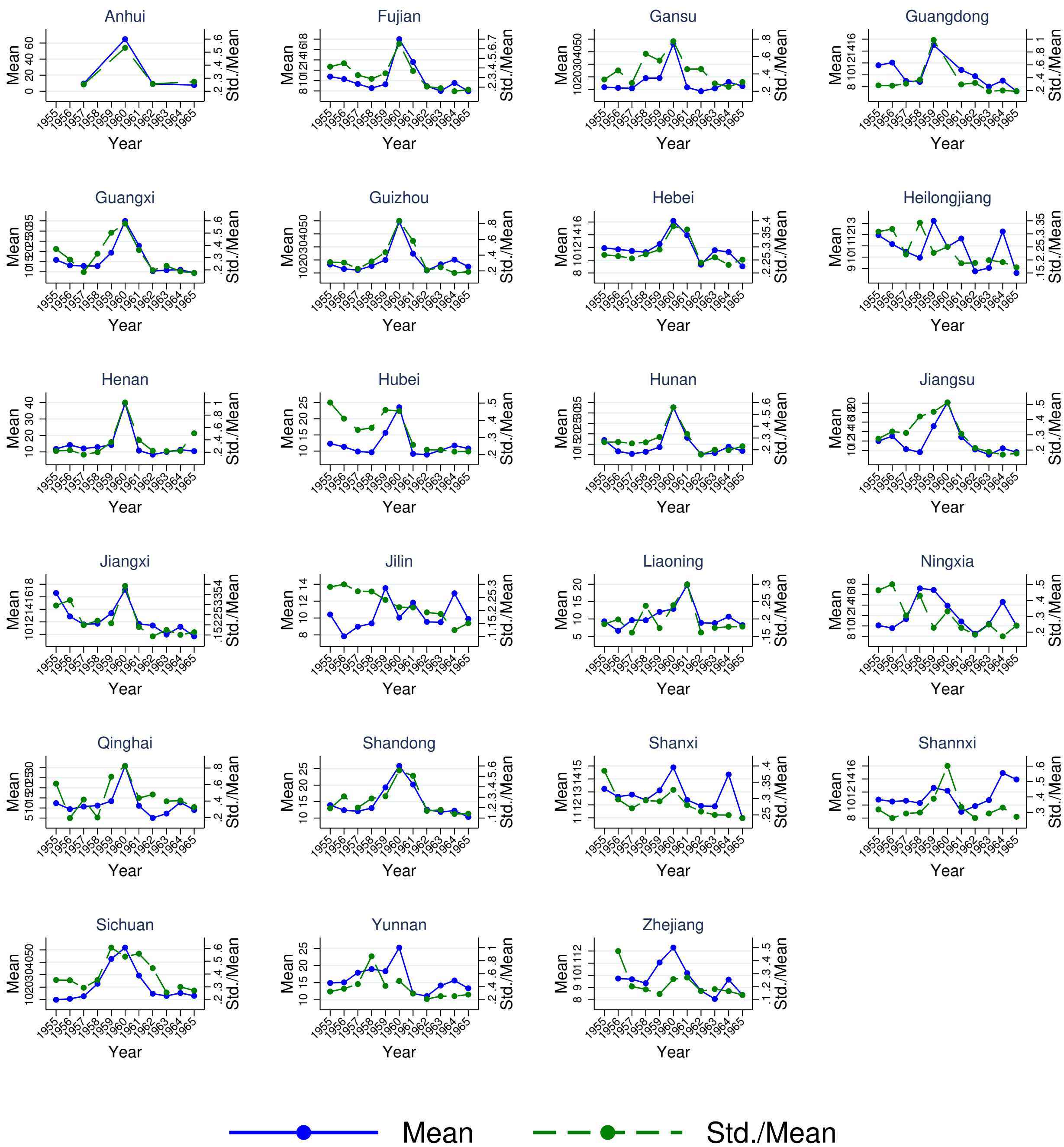


Figure A.7: Within Province Variation in Birth Rate by Year

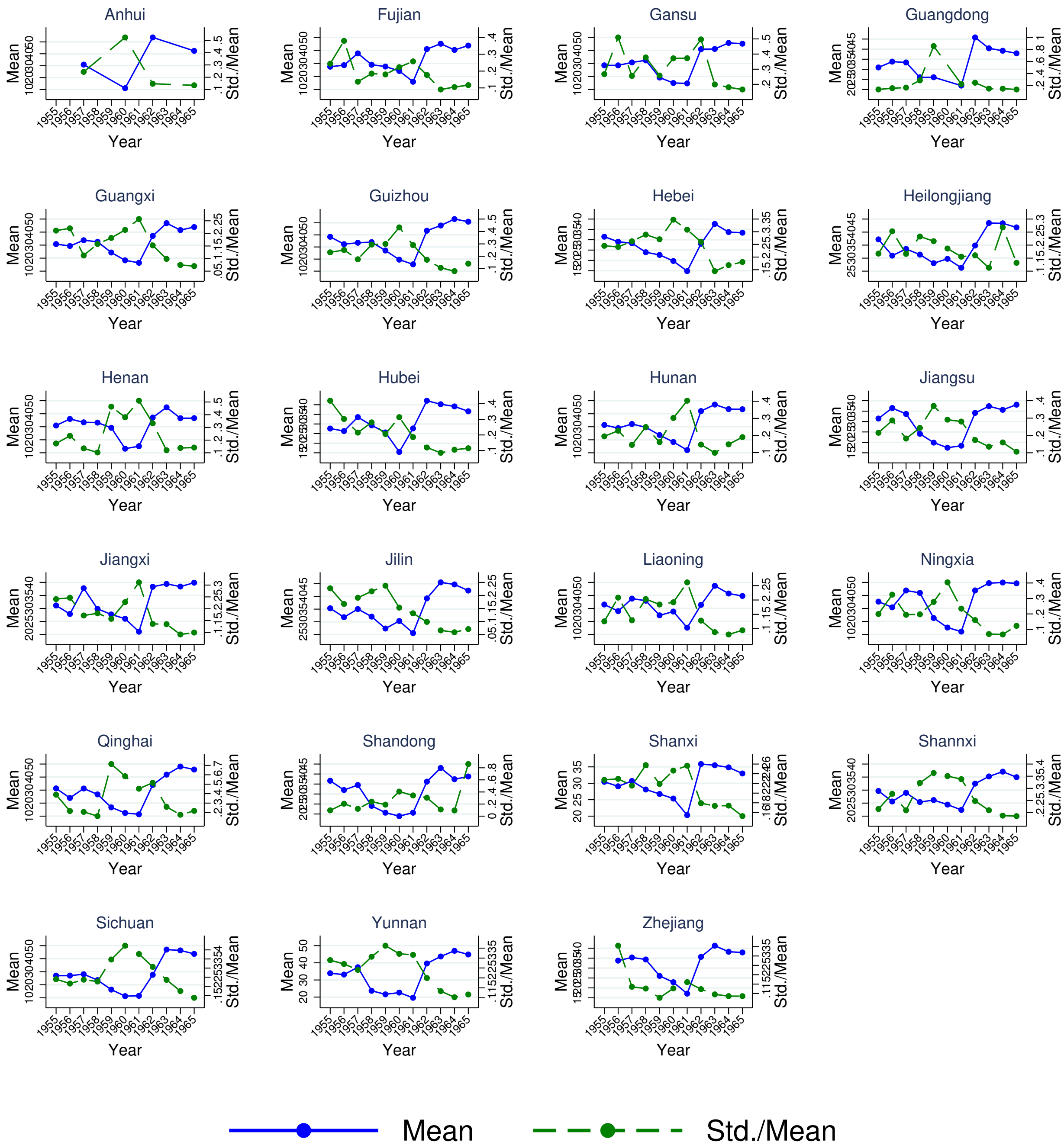


Figure A.8: Mean Death and Birth Rates by Reporting Status

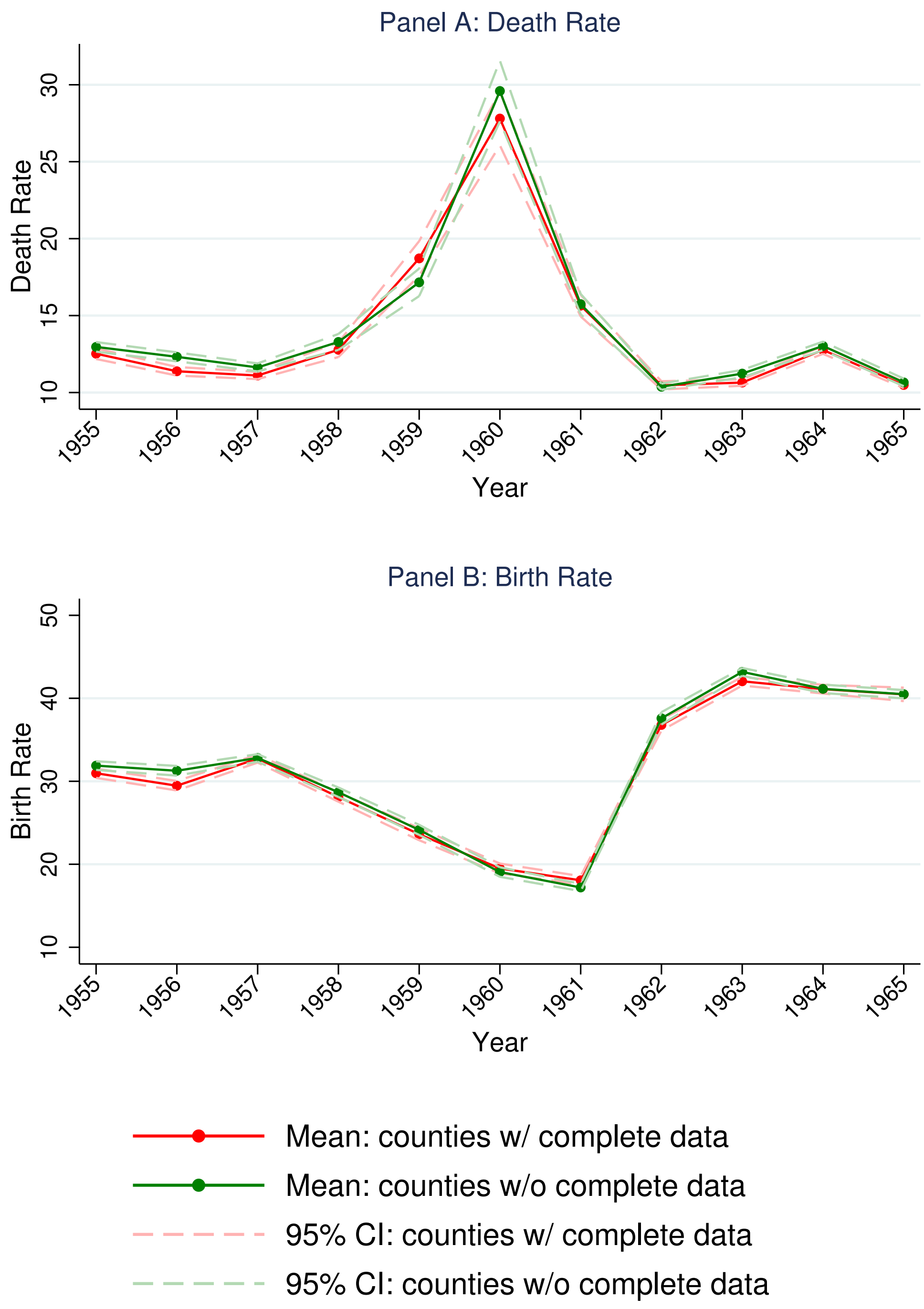
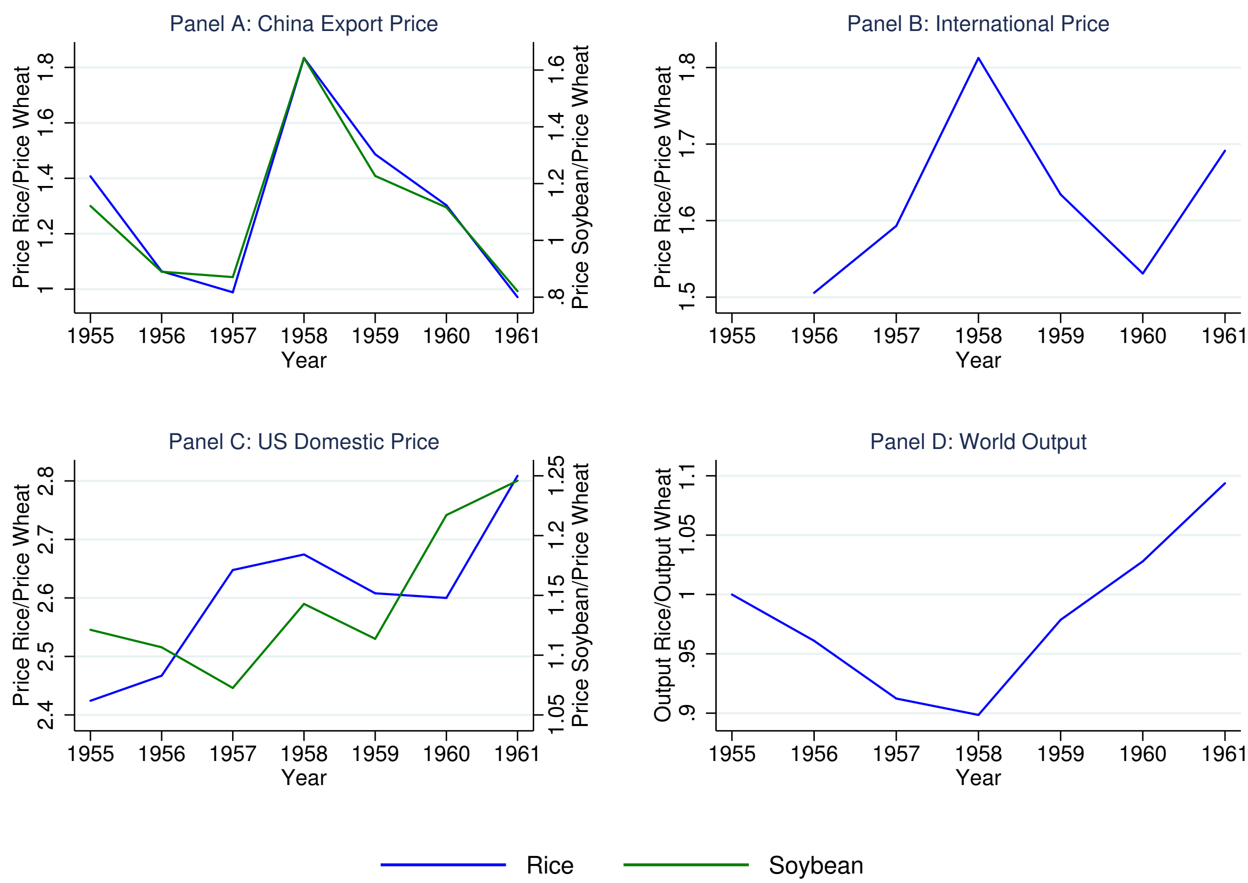


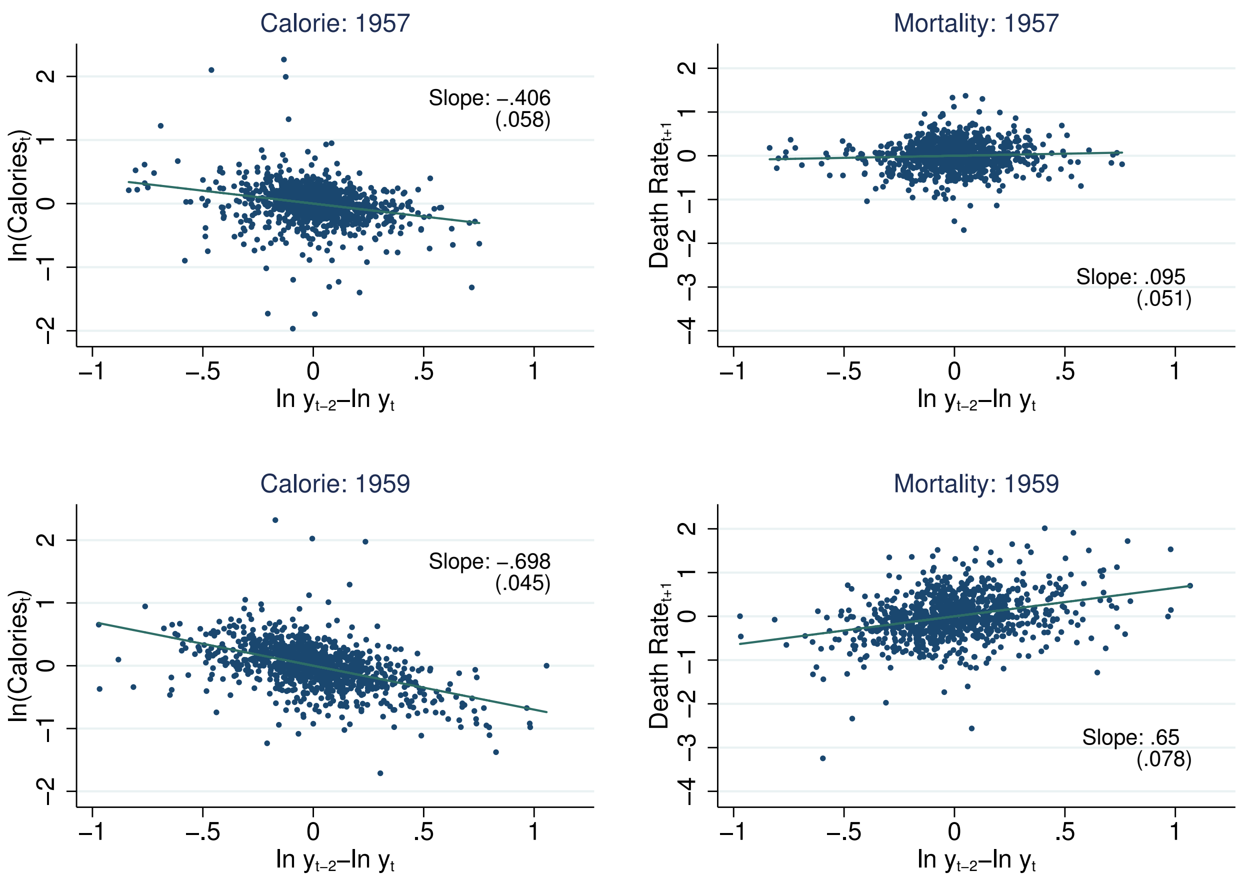
Figure A.9: Railway Network in 1957

Figure A.10: Relative Price and Output over 1955-1961



Note: China's export price are calculated using the data on export value and quantity from *China Customs Statistics Yearbooks*. The international prices of rice and wheat are proxied by the export price of rice from Thailand and export price of wheat from the US, respectively (Palacpac, 1977). The US domestic prices are obtained from *Statistical Abstract of the United States: 1960-62* by the US Census Bureau. The data on world output of rice and wheat are from *The State of Food and Agriculture: 1965* by FAO.

Figure A.11: Correlations between Calories, Death Rates, 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 1957, and the lower panel corresponds to 1959.

Figure A.12: Procurement for Domestic Purposes and Export

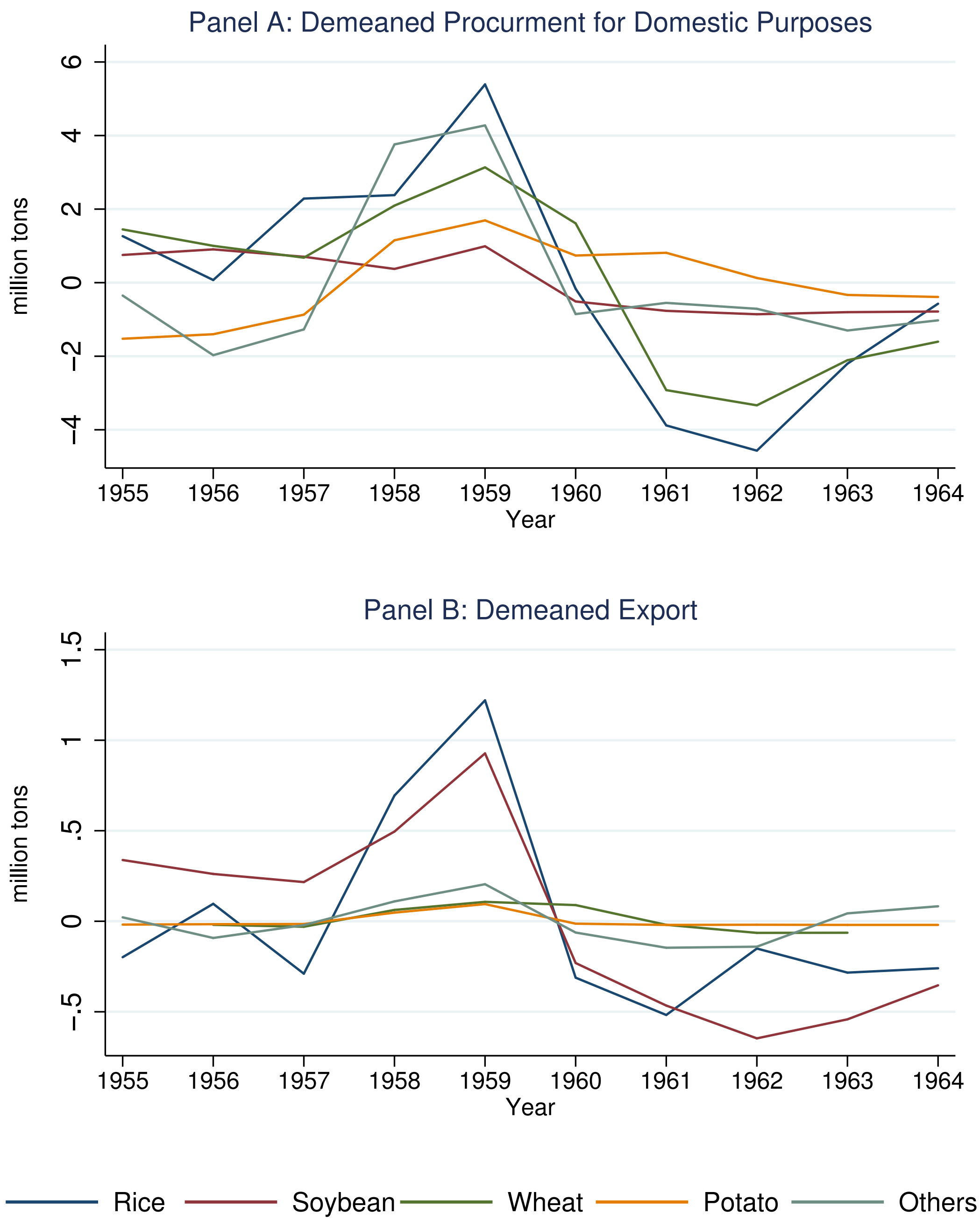


Figure A.13: Effects of Contemporaneous and Past Outputs: Estimated Coefficients and Corresponding 95% Confidence Intervals of Interaction Terms $\mathbf{1}(t \in \tau) \times \ln y_{it}$ and $\mathbf{1}(t \in \tau) \times \ln y_{it-2}$

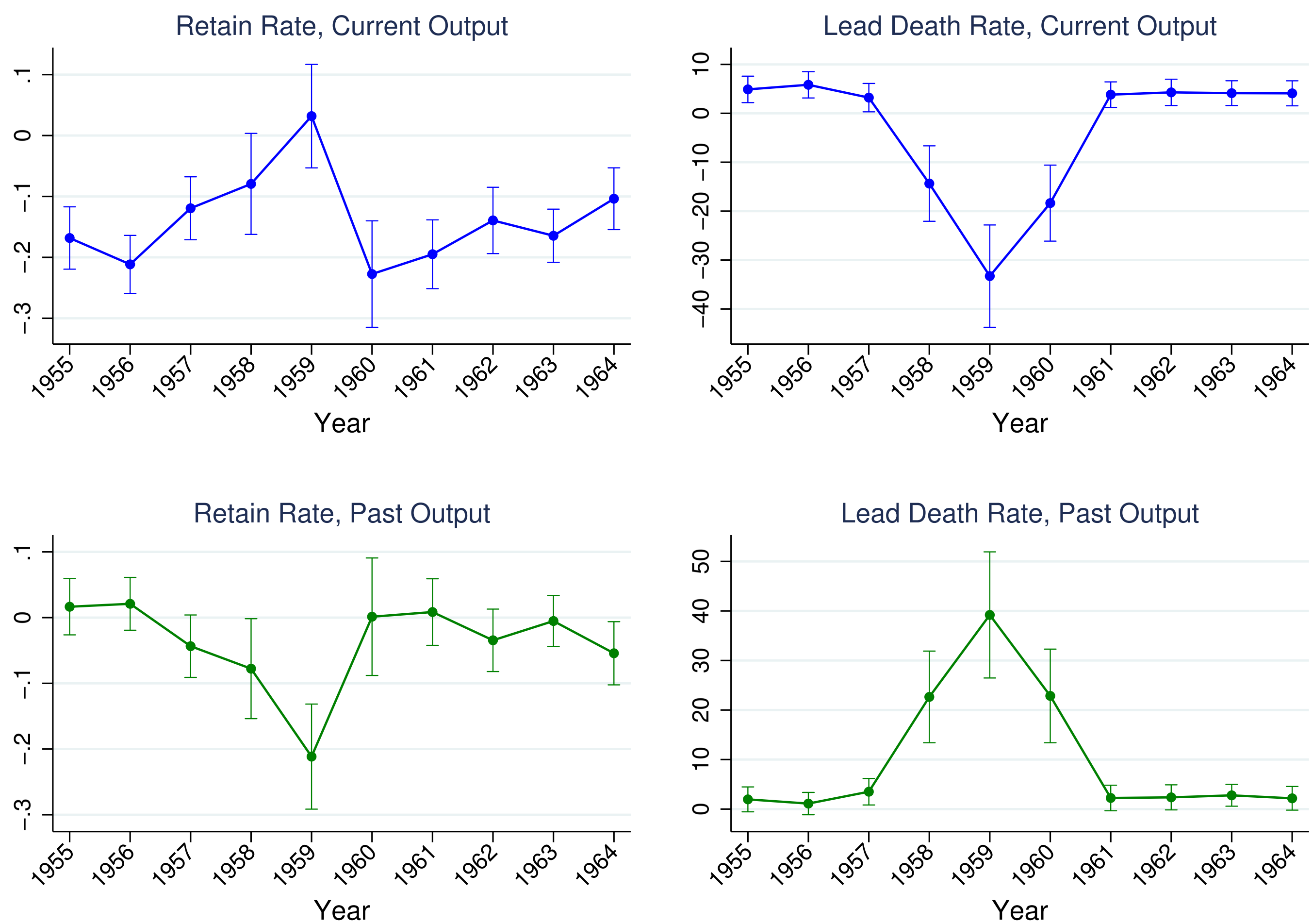
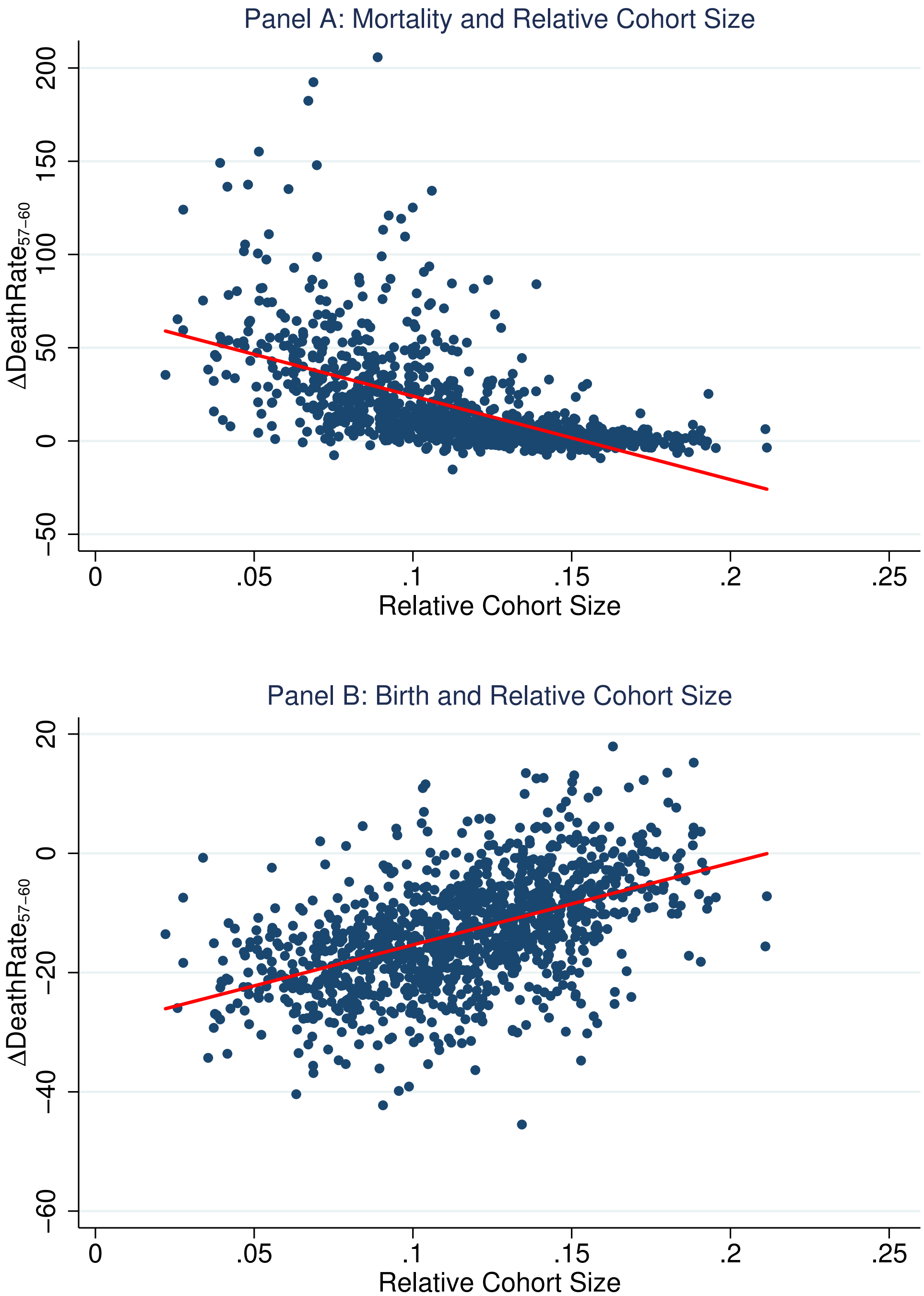
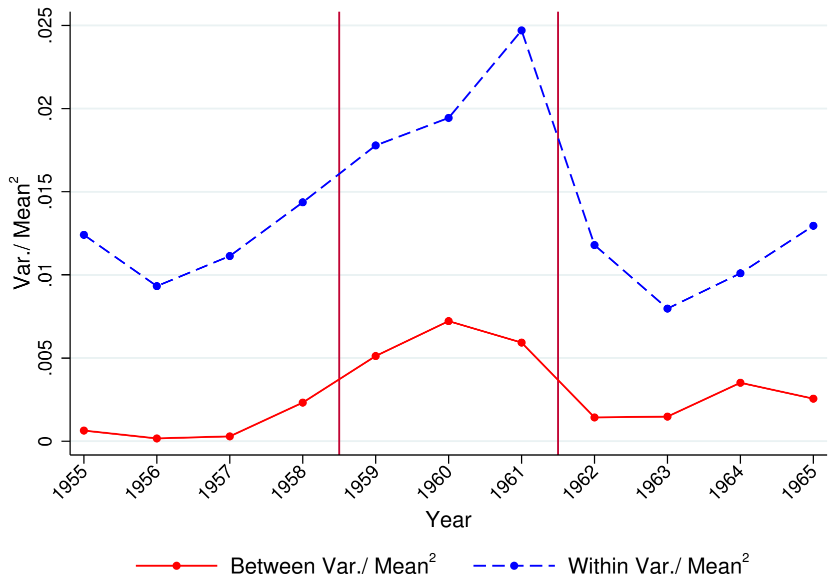


Figure A.14: Correlation of Death and Birth Rates with Relative Cohort Size



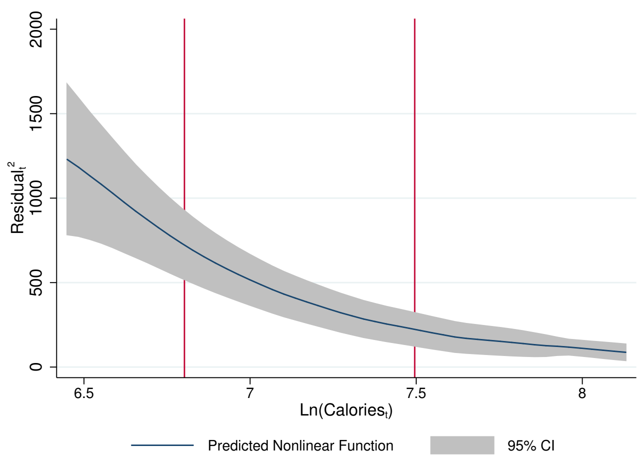
Note: The figure correlates the increase in death (birth) rate over the 1957 to 1960 period with the relative size of the famine birth cohort. The y-axis is the change in death (birth) rate over the 1957 to 1960 period. The x-axis is the population size of the famine birth cohorts (1959-1961), normalized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

Figure A.15: Decomposition of Within- versus Between-Province Variation – Relative Cohort Size



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

Figure A.16: Residual Squares and Log Caloric Consumption



Note: The figure shows the non-parametric relation between the squared residual of Model (24) and the county average caloric consumption.

Table A.1: Data Sources for Death 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 parentheses.

Table A.2: Famine Severity and Concentration

Year	Total Excess Deaths	Total Lost Births	Top 10 percent $\Delta DeathRate_{it,57}$ Excess Deaths	Top 10 percent $\Delta DeathRate_{it,57}$ Share of Total	Bottom 10 percent $\Delta BirthRate_{it,57}$ Lost Births	Bottom 10 percent $\Delta BirthRate_{it,57}$ Share of Total
	(1)	(2)	(3)	(4)	(5)	(6)
1959	3,801.372	-4,548.173	2,318.716	0.610	-1,028.363	0.226
1960	9,667.090	-6,742.743	4,634.940	0.479	-1,460.015	0.217
1961	2,274.805	-7,297.030	1,266.120	0.557	-1,359.642	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 lost births as a share of 1957 population in sample	1959-61 total lost 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: Actual Population and Predicted Population

	1959		1960		1961	
	(1)	(2)	(3)	(4)	(5)	(6)
$DeathRate_{it-1}$	0.000	-0.000	-0.000	0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$DistRail_i$		-0.049		0.060		-0.021
		(0.060)		(0.074)		(0.042)
$DeathRate_{it-1} \times DistRail_i$		0.001		-0.003		0.002
		(0.002)		(0.002)		(0.003)
N	1,123	1,123	1,169	1,169	1,217	1,217
R^2	0.000	0.001	0.000	0.003	0.000	0.001
Correlation between $\ln Pop_{t+1}$ and $\ln \widehat{Pop}_{it}$	0.995		0.982		0.996	

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

Table A.4: 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.

Table A.5: China's Share in World Export

	Mean	Min	Max	Period
Rice	0.090	0.027	0.223	1954-1986
Soybean	0.031	0.005	0.088	1967-1986
Wheat	0.001	0.000	0.011	1954-1986
Potato	0.021	0.000	0.077	1958-1986
Others	0.011	0.001	0.040	1954-1986

Notes: The data on world export of different crops are obtained from several volumes of *The State of Food and Agriculture* (FAO). The information on world export of soybean reported by FAO starts from 1957, and the information of world export of potato starts from 1958. The data on China's export of different crops across the sample periods are obtained from *Historical Materials of Food Issues in Contemporaneous China* published by the Ministry of Commerce.

Table A.6: Estimates of Control Functions

Dep. Var.	$\ln RetainRate_{it}$ (1)	$DeathRate_{it+1}$ (2)	$BirthRate_{it+1}$ (3)
$GLF \times \hat{\nu}_{it}$	0.031*	-9.354***	3.965***
	(0.018)	(1.529)	(0.613)
$GLF \times \hat{\nu}_{it-2}$	-0.007	3.482***	-1.594**
	(0.018)	(1.111)	(0.637)
$NonGLF \times \hat{\nu}_{it}$	-0.051***	0.152	4.013***
	(0.008)	(0.297)	(0.450)
$NonGLF \times \hat{\nu}_{it-2}$	-0.019***	1.026***	-1.747***
	(0.006)	(0.267)	(0.357)
Province×Year	Y	Y	Y
County	Y	Y	Y
N	10,112	12,273	12,287
R^2	0.795	0.634	0.795

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

Table A.7: Relation between Procurement for Domestic Purposes and Export Demand Shocks

Dependent Var.	$\Delta \ln X_t^k$ (1)	$\Delta \ln D_t^k$ (2)	$\Delta \ln D_t^k$ (3)	ΔX_t^k (4)	ΔD_t^k (5)
$\Delta \ln P_t^k$	2.299**	-0.002		-189.184	
	(1.041)	(0.450)		(181.883)	
$\Delta \ln \widehat{X}_t^k$			-0.001		
			(0.189)		
$\Delta \widehat{X}_t^k$					0.225
					(0.514)
Year	Y	Y	Y	Y	Y
N	60	60	60	60	60
R^2	0.489	0.352	0.352	0.489	0.485

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

Table A.8: Export Shocks and Domestic Procurement Shocks

Dependent Var.:	$\ln RetainRate_{it}$ (1)	$DeathRate_{it+1}$ (2)	$BirthRate_{it+1}$ (3)
EX_{it}	-0.0054***	0.5125***	-0.1076**
	(0.0015)	(0.1737)	(0.0517)
$DomProc_{it}$	0.0004	0.0827***	-0.0665***
	(0.0004)	(0.0269)	(0.0151)
GLF$\times \ln y_{it}$	-0.0271	-24.6981***	4.3620**
	(0.0475)	(4.7455)	(2.1521)
GLF$\times \ln y_{it-2}$	-0.1666***	32.6271***	-0.9311
	(0.0440)	(5.6032)	(2.1142)
Non-GLF$\times \ln y_{it}$	-0.1568***	6.0050***	5.2244***
	(0.0250)	(1.3865)	(1.3773)
Non-GLF$\times \ln y_{it-2}$	-0.0141	1.0555	-1.1210
	(0.0225)	(1.3566)	(1.2704)
Province$\times$Year	Y	Y	Y
County	Y	Y	Y
Control function	Y	Y	Y
County Characteristics$\times$Year	Y	Y	Y
N	9,073	10,926	10,939
R^2	0.8032	0.6542	0.8039

Notes: County characteristics include population density,average agricultural productivity, distance to railway networks, distance to the provincial capital, terrain ruggedness, average spring temperature and precipitation, average summer temperature and precipitation, whether the county is the hometown of a CCP Central Committee member in the 8th Congress, and the percentage of population with CCP membership in 1956. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table A.9: Export Effects: Province-Level Regressions

Dependent Var: $DeathRate_{pt+1}$	(1)	(2)	(3)	(4)
EX_{pt}	2.162	1.703	3.643*	3.878
	(1.633)	(1.779)	(1.964)	(2.381)
$GLF \times \ln y_{pt}$		-5.925	-8.966	-3.183
		(5.996)	(5.912)	(4.397)
$GLF \times \ln y_{pt-2}$		11.868	11.774	12.227*
		(7.235)	(7.280)	(7.068)
$NonGLF \times \ln y_{pt}$		0.032	0.526	4.018
		(1.337)	(1.460)	(2.966)
$NonGLF \times \ln y_{pt-2}$		0.374	-1.868	1.210
		(1.155)	(1.603)	(2.380)
$GLF \times GLF\ principal\ component_p$			-2.162	-1.547
			(1.694)	(1.364)
$NonGLF \times GLF\ principal\ component_p$			-0.780**	
			(0.318)	
$Share\ Urban\ Population_p$			-31.410***	-27.693
			(9.894)	(35.380)
Year	Y	Y	Y	Y
Province	N	N	N	Y
N	170	170	170	170
R^2	0.344	0.390	0.509	0.601

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

Table A.10: Spline Regressions: Death/Birth Rate and Calorie Intake

Dep. Var.:	$DeathRate_{it+1}$				$BirthRate_{it+1}$		
	OLS	Control Function	IV	IV (Constrained)	OLS	Control Function	IV
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\ln c_{it}$	-30.435***	-70.103***	-131.039***	-124.281***	5.307***	19.853***	29.718***
	(7.257)	(13.710)	(38.095)	(35.300)	(1.253)	(3.504)	(8.730)
$(\ln c_{it} - \ln(1500))$	29.041***	44.024***	162.737***		-1.330	-0.339	-14.839
$\times \mathbf{1}(c_{it} > 1500)$	(10.008)	(11.578)	(56.980)		(2.127)	(2.731)	(15.397)
Province	Y	Y	Y	Y	Y	Y	Y
N	805	805	805	805	806	806	806
R^2	0.393	0.408	-0.017	-0.015	0.473	0.495	0.014

Notes: For the regressions in columns (3), (4), and (7), the Angrist-Pischke F-statistics of the first stages are all above the Stock-Yogo 10 percent threshold for weak instruments. The F-statistics are 12.53, 25.54, and 12.418, respectively. The robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table A.11: Robustness: Counterfactural Exercises

	$\Delta DeathRate$		implied number	% of actual
	mean	std	of excess deaths	excess deaths
(A1) From Data: $DeathRate_{60} - DeathRate_{58}$	14.66	23.19	4053053.50	100
Panel A: Spline Regression and Control Function Approach				
(A2) Caloric consumption in 1959 same as in 1957	13.65	15.60	3680407	90.81
(A3) Output in 1959 same as in 1957	5.58	13.12	1716464	42.35
(A3.a) Agricultural Inputs in 1959 same as in 1957	4.73	6.51	1196470	34.60
(A3.b) No weather shocks in 1959	0.66	5.24	353859	8.73
(A4) Procurement rate in 1959 same as in 1957	9.62	10.40	2450271	60.45
(A5) Export exposure in 1959 same as in 1957	2.04	2.47	566614	13.98
(A6) Procurement Policies in 1959 same as in Non-GLF period	3.75	2.97	1033203	25.49
(A7) Procurement policies in 1957 same as in GLF period	2.09	1.79	476918	11.77
(A8) Consumption equally distributed across the nation in 1959	6.03	17.19	1900670	46.89
(A9) Consumption equally distributed within provinces in 1959	2.17	16.75	722202	17.82
(A10) Redistribute export in 1959 across the nation	0.50	3.22	177798	4.39
(A11) Redistribute export in 1959 within the provinces	0.47	3.23	148198	3.66
Panel B: Spline Regression and Constrained IV Approach				
(A2) Caloric consumption in 1959 same as in 1957	13.65	24.41	3803698	93.85
(A3) Output in 1959 same as in 1957	6.64	21.14	2084601	51.43
(A3.a) Agricultural Inputs in 1959 same as in 1957	5.66	11.56	1508247	43.62
(A3.b) No weather shocks in 1959	0.68	8.42	388418	9.58
(A4) Procurement rate in 1959 same as in 1957	11.38	19.20	3092012	76.29
(A5) Export exposure in 1959 same as in 1957	2.60	4.61	748819	18.48
(A6) Procurement policies in 1959 same as in Non-GLF period	4.73	6.38	1363989	33.65
(A7) Procurement policies in 1957 same as in GLF period	0.99	3.50	334262	8.25
(A8) Consumption equally distributed across the nation in 1959	15.63	25.00	4392995	108.39
(A9) Consumption equally distributed within provinces in 1959	4.10	28.00	1398310	34.50
(A10) Redistribute exports in 1959 across the nation	1.24	5.36	375813	9.27
(A11) Redistribute exports in 1959 within the provinces	1.14	5.42	325723	8.04

Notes: The implied number of excess deaths is the sum of the excess deaths in the 760 counties with data on caloric consumption in both 1957 and 1959. (#) The change in excess mortality (lost births) due to counterfactual changes in per capita sown areas is calculated for the 652 counties with information on caloric consumption and sown area in both 1957 and 1959. The actual number of excess deaths (lost births) in these counties was 3,457,626 (2,300,905).