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

Abstract

This study provides evidence that the over-export of grains aggravated the severity of China's Great Famine. We collect county-level data for the 1953-1965 period on death rates, birth rates, amounts of grain procured, output of different types of grain, crop productivity, weather conditions, distance to railways, and the number of Chinese Communist Party (CCP) members. We exploit county-level variations in the types of crops each county specialized in to construct Bartik-style measures of export shocks. We regress the death rates on the Bartik export measures and use the weather shocks as instruments for measuring output and consumption. The regression results suggest that increases in grain exports substantially increase death rates, and the effect of grain exports on death rates is larger in counties with lower current output, higher two-period lagged output, larger distance to railways, and a smaller percentage of local CCP members. We also estimate the effects of the procurement policy, examine the relationship between the death rates and the average level of consumption at the county-level during the famine period, and conduct counterfactual experiments to quantify the relative importance of different causes of the Great Famine. The counterfactual experiments indicate that the effect of grain exports explains 12 percent of the excess deaths, which amounts to 1/5 of the effect of the increase in procurement rates between 1957 and 1959. By comparing the distribution of county-level counterfactual changes in death rates if the amount of grain exports in 1959 had been the same as that in 1957, we find that the distribution of the high-export-exposure counties first-order stochastically dominates that of the low-export-exposure counties.

JEL-Codes: F140.

Keywords: famine, over-export of grains, inflexible procurement, Great Leap Forward.

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1 Introduction

China's Great Famine, which raged between 1959 and 1961, caused 16.5 to 30 million excess deaths and 30 to 33 million lost or postponed births. In terms of population loss, it was the worst famine in human history. 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 examines one of the underlying causes of the over-procurement of grains: the export of grains. Between 1957 and 1959, despite the food shortages, the Chinese government increased total grain exports by a factor of 2, from 1.9 to 4.1 million tons (Figure 1); the purpose was to secure foreign currency for repaying foreign loans from the Soviet Union and for importing 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 excess deaths might have been avoided had the government acted swiftly to stop exports and start large-scale imports of grains. In fact, the 9.6 million tons of grain exported during the GLF would have met the caloric needs of 16.7 to 38.9 million people over the three-year period. Therefore, it is natural to infer that grain exports may be one of the leading causes of over-procurement. However, no studies have *quantitatively* assessed the relationship between grain exports and increases in death rates during the Great Famine.

What would have happened to the death rates across different regions in China in 1960 had 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 1957 and 1960 relative to other factors such as a drop in aggregate food production in 1959? What are the observable characteristics of the counties that experienced food shortages due to export-driven over-procurement? To answer these questions, we collect from various sources *county-level* data for the 1953 to 1965 period on the death rates, birth rates, amounts of grain procured, outputs of different types of grain, crop productivity, weather conditions, distance to railways, and the percentage of the local population who were Chinese Communist Party (CCP) members. Using the cross-county variation in crop composition and weather shocks as instruments, we estimate the differential impacts of grain exports on the cross-county death rates in 1960.

The newly constructed county-level dataset is a major contribution of this study, as almost all of the existing empirical studies of the causes of the Great Famine use province-level data.[1]

[1]The exceptions are Bramall (2011), Meng et al. (2015), 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 birth cohort size of survivors constructed from the 1990 China Population Census. Kung and Zhou (2017) analyze how the hometown favoritism of the CCP Central Committee members

Figure 2 shows the sharp increase in the cross-county mean of the death rate during the famine period (1959-1961); during the same period, the coefficient of variations across counties also increases, indicating the presence of substantial heterogeneity in famine severity across counties (see also Figure 1(c) in Meng et al. (2015)). The variance decomposition given in Section 4 indicates that the majority of cross-county variation in changes in death rates between 1957 and 1959 was within provinces rather than across provinces. Figure 3 presents the "heat map" of the geographic distribution of the death rates in China, revealing a substantial variation in death rates across different counties in both 1957 and 1960. The heat map of 1957 is, however, very different from the heat map of 1960, because many of the counties with a low death rate in 1957 experienced high death rates in 1960. These facts indicate the importance of using a time series of county-level data to investigate these changes.

We take two different approaches to quantify the impact of grain exports on death rates in 1960 and its importance relative to other factors. First, we exploit the county-level variation in the types of crops each county specialized in and construct Bartik-style measures for export shocks as $\sum_k \frac{Y_{i,57}^k}{Y_{57}^k} \frac{Export_t^k}{Pop_{it}}$, where the sum is taken across five crop types (rice, soybean, wheat, potato, and others), $\frac{Y_{i,57}^k}{Y_{57}^k}$ is county i's share in the output of crop k in 1957, and $Export_t^k$ is China's total export of crop k in year t, instrumented by international prices of crop k. We regress the death rate on this Bartik measure together with other controls and county-fixed effects using county-level panel data.

The estimated coefficient of this Bartik measure is large and significantly positive, indicating the importance of increases in grain exports in explaining the variation in death rates across counties in 1960. By interacting this Bartik measure with current output, two-period lagged output, distance to railways, and the relative number of local CCP members, we also find that the effect of grain exports on death rates is larger for counties with lower current outputs, higher two-period lagged outputs, larger distances to railways, and smaller shares of local CCP members. Furthermore, regressing county-level grain output on the Bartik measure, we find that a larger export exposure leads to a higher output level, suggesting that more agricultural resources were allocated to counties producing export-oriented crops such as rice and soybean. Taking the difference in death rates between 1958 and 1960 as the baseline "excess death rates," the estimate indicates that the negative effect of export-driven over-procurement dominates the output effect and that, on average across counties, 14 percent of the total excess deaths can be explained by the increase in grain exports between 1957 and 1959.

Second, adopting a more structural approach, we estimate the determinants of the procurement policy and the county-level relationship between death rates and the average level of

affected famine severity at the prefecture-level. They corroborate their prefecture-level findings with a county-level analysis using data from Henan Province. None of these studies analyze how the grain exports are related to mortality or the birth cohort size of the survivors.

consumption during the famine period.

Motivated by the province-level evidence for the impact of the government's progressive and inflexible procurement policy in Meng et al. (2015), we estimate how the procurement rate was determined by the current output, two-period lagged output, and distance to railway at the county-level in the GLF and non-GLF periods. The results indicate that the procurement policy during the GLF period was much more progressive and inflexible than during the non-GLF period. The procurement rate during the GLF period increased the two-period lagged output (progressiveness), but was not affected by contemporaneous output (inflexibility), suggesting that any counties that had decreased their outputs relative to two years prior to the famine year would have been over-procured and suffered from food shortages during the GLF period; in contrast, we find that the procurement rate during the non-GLF period was more responsive to contemporaneous output.

When we split the data into subsamples of counties located near railways and those located far from railways, we find that during the famine period the procurement policies in counties located near railways were more progressive but less inflexible than in counties located far from railways. This may be due to two reasons: it is easier to procure goods from counties located near railways due to low transportation costs, leading to a higher degree of progressiveness; and food could be given back to counties located near railways in the event of a negative output shock, as it would be easier to verify food shortages in counties near railways than in those further away from railways.

To investigate how the consumption shortage caused by over-procurement led to higher death rates, we non-parametrically estimate the relationship between the death rates and the retained consumption per capita using county-level data, while controlling for possible measurement errors due to the misreporting of outputs and procurement; we use weather shocks as a source of exogenous variations. The estimate shows that the death rate is a decreasing function of the average level of consumption, where the death rate sharply increases as consumption per capita decreases below 1,800 calories.

Based on the estimated procurement policy and the estimated relationship between the death rate and the average level of consumption, we conduct various counterfactual experiments at each county to quantify the relative importance of different causes of excess deaths in 1960. The results indicate that the excess deaths in 1960 would have been: (i) lower by 46 percent if the agriculture production in 1959 had been the same as in 1957, (ii) lower by 60 percent if the procurement rate in 1959 had been the same as in 1957, (iii) lower by 10 percent if the weather shocks in 1959 had been the same as in 1957, and (iv) lower by 12 percent if the amount of grain exports in 1959 had been the same as in 1957. The effect of grain exports on the excess deaths is substantial; one-fifth can be explained as the effect of increases in procurement, making it at least as important as the weather shocks.

We further examine how the effect of grain exports on the excess deaths depends on observable county characteristics including whether the county had a comparative advantage in high-export-exposure crops, whether the county had a higher proportion of CCP members, and whether the county experienced good weather shocks in 1957. For the counterfactual scenario that the amount of grain exports in 1959 had been the same as that in 1957, we compare the distribution of county-level changes in death rates across groups of counties divided according to these characteristics. We find that the distribution of the high-export-exposure, low-CCP-members, and good-past-weather group first-order stochastically dominate the distribution in the low-export-exposure, high-CCP-members, and bad-past-weather group, respectively.

Furthermore, we 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 pre-export consumption per capita had been lifted and the remaining counties had raised procurement levels to meet the aggregate export requirement, the total excess deaths would have declined by 7.85%. This suggests that the effect of the aggregate exports on mortality would have been much smaller if the export crops had been procured more flexibly.

We also examine the extent to which the progressiveness and inflexibility of the procurement policy during the famine period are responsible for the excess deaths by conducting the following counterfactual experiment: what if the procurement policy in 1959 had been the same as the procurement policy in 1957. The results show that the excess deaths in 1960 would have been lower by 29 percent if the procurement policy in 1959 had been the same as in 1957.[2] Although the effect of the increasingly progressive and inflexible procurement policy is considerable, the *change* in procurement policies alone cannot explain the entire increase in excess deaths between 1958 and 1960. Our next counterfactual experiment, which considers what would have happened to the death rate in 1958 if the procurement policy in 1957 had been the same as in 1959, shows that the death rate in 1958 would have been higher by 16 percent. Comparing the distribution of county-level counterfactual changes in death rates if the procurement policy in 1957 had been the same as in 1959, we find that the distributions of the far-from-railway, low-CCP-members, and good-past-weather group first-order stochastically dominate those of the near-to-railway, high-CCP-members, and bad-past-weather group, respectively.

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 also the first to attempt to quantify the relative importance of different causes

[2]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."

using the estimated procurement policy and the estimated relationship between the death rate and the retained consumption. We find that the fall in agriculture production, increase in procurement partly driven by grain exports, and the increasingly progressive and inflexible procurement policy all increased the number of excess deaths; no single factor can explain all of the excess deaths. Third, unlike previous studies that rely on province-level panel data, we compile a new dataset on famine severity, grain production, and export exposure at the county-level. We conduct our analyses using within-province cross-county variation to better account for the unobserved heterogeneity across provinces; controlling for province-year-level fixed effects is important in this context, because many political factors could be operating at the province-level.

Broadly speaking, our study is linked to several strands of research in the field of trade. First, it relates to the literature examining how political factors affect trade flows, e.g., 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), Taylor (2011) 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 become 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.

Moreover, our findings are in contrast with the existing literature which find a 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, dampened the consumption volatility and hence alleviated 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 period, the absence of market forces and distorted reporting system led to the inability to quickly gather and aggregate information on supply and demand. The extreme sluggishness of price response resulted in a destabilizing effect of trade. 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. Section 4 presents the spatial distribution of famine severity and underlines the importance of within-province cross-county heterogeneity. Section 5 lays out our theoretical framework and empirical strategy. Section 6 provides the empirical evidence demonstrating that the over 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. Section 8 concludes the paper.

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 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 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).

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

[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.

(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 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.[4] 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).

[4]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.

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).[5]

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.[6] Given these estimates, the net grain exports during the 1958 to 1960 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

[5] 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).

[6] 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.

changes in relative prices over the period. As shown in Panel A of Figure A.4, 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. Lastly, Panel C shows that in the US, the domestic price of rice and soybean increased relative to that of wheat over this period. 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 our dataset, which is compiled from various sources. More details about the data sources and the summary statistics can be found in Appendix A.

3.1 Demographic Data

We collected county-level data on population, number of births and number of deaths for 23 provinces in China, which comprised around 95.4% of China's population in 1953 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. There were 28 province-level divisions in China in the 1950s and 1960s. (The present day provinces Hainan and Chongqing used to belong to Guangdong and Sichuan, respectively. The present day province-level municipality Tianjin belonged to the province Hebei.) We exclude two province-level municipalities, Beijing and Shanghai, where there are few rural counties, and three autonomous regions, Inner Mongolia, Tibet, and Xinjiang, where people faced different economic policies for historical and political reasons.[7]

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[7]The provinces in both our sample and the sample in Meng et al. (2015) are Anhui, Fujian, Guangdong, Heibei, Heilongjiang, Henan, Hubei, Hunan, Jiangsu, Jiangxi, Jilin, Liaoning, Shandong, Shanxi, Shannxi, and Zhejiang.

Hainan and Chongqing used to belong to provinces Guangdong and Sichuan, respectively. The present day province-level municipality Tianjin belonged to province Hebei.) We exclude two province-level municipalities, Beijing and Shanghai, where there were few rural counties, and three autonomous regions, Inner Mongolia, Tibet and Xinjiang, where people faced different economic policies due to historical and political reasons.[8]

The data are mainly collected from the population statistical books published by the provincial Statistics Bureaus in the 1980s. The sample is restricted to rural counties. For most provinces, the sample period is from 1955 to 1965. (To assess total population, we collect data back to 1953.) 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). In total, there are 1,803 rural counties in our sample. 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 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 counterfactual 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. In addition, as shown in Appendix A.1.2, mortality during the famine was highly concentrated: the top 10th percentile of counties account for 52% of the total excess deaths.

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

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

[9]Data for 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.

[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,

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.3. 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.2.1 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 capita declined to 1.77 $kCal$ in the GLF period from 2.11 $kCal$ in the non-GLF period.

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 potential measurement errors in the output 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.

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.

[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.

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 information on potential yields of different crops under various technologies at the 5$\times$5 arc-minute grid level (approximately 9.25 km$\times$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.5. 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

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

[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*.

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 CPC 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 Cross-County Variation in Famine Severity

Panel A of Figure 2 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 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 in the Appendix repeat Figure 2 for each province. In most provinces, the mortality rate increased (birth rate declined) in the famine period and the cross-county variation increased.

Figure 3 shows the 1957 and 1960 mortality rates for the rural counties in our sample. The counties are outlined in grey lines and provinces are outlined in black lines. There are considerable differences in the spatial distributions of theses variables in the non-famine and famine years. More importantly, the cross-county variation in famine severity is substantial, even within provinces.

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 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 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

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

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.

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.

5 Theoretical Framework and Empirical Strategy

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

5.1 Procurement Policies, Retain Rate and Calorie Consumption

Consider the following model of procurement. The government determines the procurement rate so that county i will receive consumption per capita $\bar{c}_{it}$. If the government knows county i's output and population, then the retain rate r_{it} is determined by

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

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

However, procurement policies may be rigid when the government partially relies on past output to determine target consumption. That is,

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

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

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

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

Figure 6 follows the specification (1) and shows the partial regression plots of the log retain rate against past output ($\ln y_{t-2}$) and current output ($\ln y_t$) for 1957 and 1959. In both years, the retain rate is negatively associated with the past output. The negative correlation is stronger in 1959, suggesting that the procurement policies became more rigid in that year. In addition, we find that the retain rate is not correlated with the current output in 1957 and the correlation becomes slightly positive in 1959.

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

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

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

5.2 Outputs, Consumption, Mortality and Birth

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

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

where $f(\cdot)$ is a non-parametric function of the retained caloric consumption.[17] Equation (3) relaxes the linearity assumption adopted in previous studies. As shown in the following sections, the relation between mortality and consumption displays strong non-linearity, which has important implications for quantifying the effects of different underlying shocks.

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

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

Our analysis of birth rates is analogous to our analysis of mortality. The right panel of Figure

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

7 shows the partial regression plots of the death rate against the output shock ($\ln y_{t-2} - \ln y_t$) for 1957 and 1959. We find that the mortality rate is positively correlated with $\ln y_{t-2} - \ln y_t$ in 1959, but the correlation is weak and insignificant in 1957. This finding provides further evidence that procurement policies became more rigid during the GLF period.

5.3 Grain Outputs and Weather Shocks

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

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

where $y_{it}^k = Y_{it}^k / L_{it}^k$ is 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 (4) using different crops' output share in 1957 ($s_i^k = Y_{i,57}^k / Y_{i,57\cdot}$) as weights and link each county's aggregate grain output to its productivity and realized weather conditions:[18]

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

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

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

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

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

6 Empirical Results

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

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

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

where $c_{i,59}$ is the caloric content of the retained grains in 1959, i.e., $y_{i,59} - p_{i,59}$, and γ_p denotes the province fixed effects. We use only the 1959 consumption data and 1960 mortality data to estimate equation (6), because the famine was most severe in 1960 and the caloric content of the retained grain in 1959 is more likely to reflect the actual level of calories available.[19] To further address the potential problem of measurement errors, 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:

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

where $\ln \tilde{y}_{i,59} = \sum_\ell \sum_k \hat{\theta}_2^{k\ell}(s_i^k z_{i,59}^\ell)$ is the summary index of weather shocks derived from regression (5), and $\ln \tilde{y}_{i,57}$ is the corresponding value for 1957. The vector λ_i contains the productivity of different crops and the average weather conditions over the 1953 to 1965 period.[20] We obtain the residuals $\hat{v}_i$ from equation (7) and estimate the following semiparametric model:[21]

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

where $g(\hat{v}_i)$ is a cubic function of $\hat{v}_i$. By controlling for the residuals from (7), the function $f(\ln(c_{i,59}))$ is estimated in Model (8) using the variation in consumption that is attributable to weather shocks.

The estimated non-parametric functions $\hat{f}(\ln(c_{i,59}))$ of Models (6) and (8) are presented as

[19] 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 grains in 1960, because relief plans were implemented in the last year of famine (i.e., 1961), and no detailed data on grain relief is available.

[20] For weather conditions, we consider spring temperature and precipitation and summer temperature and precipitation.

[21] The semiparametric model (8) is estimated using the approach proposed by Robinson (1988). More details are given in Appendix B.3.

the green curve and the blue curve, respectively, in Figure 8. The two reference lines correspond to the two thresholds, i.e., 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 (8) has a steeper slope than that of Model (6), suggesting that the data on caloric consumption are subject to measurement errors. 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.[22]

We estimate the relation between birth rates and caloric consumption analogously. The results are presented in Figure 9. We detect a steeper positive relation between birth rates and caloric consumption using the control function approach.

6.2 Effects of Output Shocks

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

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

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

The regression results for the baseline specification are reported in column (1) of Table 2 Panel A. Column (2) augments the model with county fixed effects. The different specifications all give robust findings that in the GLF period, the elasticity of the retain rate to contemporaneous output becomes statistically insignificant and small in magnitude. In contrast, 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. In

[22] Figure A.12 shows that the squares of the estimated residuals in Model (8) have a downward relationship with the average level of consumption. In Appendix B.1, we argue that this heteroskedasticity is consistent with cross-county heterogeneity in within-county food distribution.

addition, we find that procurement was progressive in the sense that the retain rate decreased with current output in the non-GLF period and had a two-year lagged output in the GLF period.

As shown in column (3), we use the control function to address the concern that the output data may be subject to measurement errors that may bias the estimates. More specifically, we extend Model (9) to

$$\begin{aligned} \ln RetainRate_{it} = & \sum_{\tau} \beta_1^{\tau} \mathbf{1}(t \in \tau) \times \ln y_{it} + \sum_{\tau} \beta_2^{\tau} \mathbf{1}(t \in \tau) \times \ln y_{it-2} \\ & + g(\hat{v}_{it}) + g(\hat{v}_{it-2}) + \phi_i + \gamma_{pt} + \varepsilon_{it} \end{aligned}, \tag{10}$$

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

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

Panel B repeats the regressions using death rate in year $t+1$ as the outcome variable. In the GLF period, the mortality rate was higher when it received 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 (4) and (5), 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, suggesting that procurement policies were rigid in the GLF period, particularly in remote regions. Panel C reports the regression results when birth rate is the outcome variable.

The findings mirror those for the death rate.

Table A.4 in the Appendix shows the robustness of these results when years are grouped into pre-GLF (1953-1957), GLF (1958-1960), and post-GLF (1961-1964) periods. The findings consistently show that procurement was more dependent on contemporaneous output in the pre-GLF and post-GLF periods. In the GLF period, however, past output was a more important determinant, especially in remote regions. For mortality, the results mirror the pattern seen in the retain rate. One of the interesting findings is that in the post-GLF period, birth rates were negatively affected by the past output, even when the procurement policies were more flexible, suggesting that food shortages during the famine had persistent effects on health, and hence adversely affected fertility in the subsequent period. The coefficients reported in Figure A.11 map out the yearly patterns of the effects of output shocks; they are consistent with our baseline findings.

6.3 Effects of Export Shocks

To study the effect of export expansion on famine severity, we use the cross-crop differences in export expansion and cross-county variation in crop specialization patterns. Consider a Bartik-style index to measure a county's exposure to grain exports:

$$Export_{it} = \sum_k \frac{Y^k_{i,57}}{Y^k_{57}} \frac{Export^k_t}{Pop_{it}} \,, \tag{11}$$

where $\frac{Y^k_{i,57}}{Y^k_{57}}$ is county i's output share of crop k in 1957, and $Export^k_t$ is the amount of crop k exported nationally in period t. Note that $Export^k_t$ embodies a county's exports ($Export^k_{it}$), which we do not observe. A county's export may be correlated with its output shocks, and hence the Bartik measure (11) may be subject to endogeneity issues. [23]

To address this problem, we use an alternative Bartik-style measure of export:

$$Export_{it} = \sum_k \frac{Y^k_{i,57}}{Y^k_{57}} \frac{\widehat{Export}^k_t}{Pop_{it}} \,, \tag{12}$$

where $\widehat{Export}^k_t$ is the exponent of the fitted value from the following regression:

$$\ln Export^k_t = \eta_0 + \eta_1 \ln P^k_t + \phi_k + \gamma_t + \varepsilon_{kt},$$

[23] This potential endogenity is less of a concern when we investigate the effect of export shocks on the log of the retain rate, death rate, and birth rate, as we always control for the current and past output shocks in the regressions (See equation (13)). However, it confounds the estimate when we investigate the effect of export shocks on output (See Section 6.4.).

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. The estimated elasticity of exports to price is 2.38, with a p-value of 1.86. By construction, $\widehat{Export}_t^k$ captures the exogenous component of $Export_t^k$ that is driven by changes in international prices, and $Export_{it}$ in (12) measures the per capita reduction in food availability in kilograms due to export growth that is driven by changes in international prices.[24]

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

$$\begin{aligned} \ln RetainRate_{it} = \alpha Export_{it} + \sum_{\tau} \beta_1^{\tau} \mathbf{1}(t \in \tau) \times \ln y_{it} + \sum_{\tau} \beta_2^{\tau} \mathbf{1}(t \in \tau) \times \ln y_{it-2} \\ + g(\hat{v}_{it}) + g(\hat{v}_{it-2}) + \phi_i + \gamma_{pt} + \varepsilon_{it}, \end{aligned} \tag{13}$$

where $Export_{it}$ is defined as in (12). The estimation of equation (13) using the measure defined in (11) renders qualitatively similar results.

The baseline regression results are presented 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) presents the interaction terms of export exposure with current and past outputs. The coefficient of $Export_t \times \ln y_t$ is positively significant, suggesting that the adverse effect of export expansion was smaller in counties that experienced a positive contemporaneous output shock. Column (3) further introduces the interaction term of export exposure and distance to railway. Consistent with the observation that distance to railways increases transportation costs, the estimated coefficient of $Export \times DistRail$ is positive, albeit statistically insignificant. Column (4) demonstrates how the organizational presence of CCP moderates export shocks. The variable $CCP\ Member$ measures the proportion of the population who had CCP membership in 1956 at the county level (in percentage points). We find that the negative effect of export shock on the retain rate is weaker in counties with higher party membership. The estimated semi-elasticity of retain rate to export shock is 0.034 for a county at the 95th percentile of $CCP\ Member$, whereas the corresponding number for a county at the 5th percentile is 0.027.[25] Therefore, in the procurement of export crops, the Chinese party-state displayed systematic favoritism by extracting fewer resources from, or giving back more food in the event of food shortage to, counties with more party members. This result is consistent with Kung and Zhou (2017), who find that the famine was less severe in the hometowns of Central Committee (CC)

[24]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 $Export_{it}$ captures the caloric loss due to export shocks.

[25]The percentages of people with CCP membership are 3.37% and 0.65% for a county at the 95th percentile and the 5th percentile, respectively.

members.

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 and different samples. In addition, we find that a higher current output dampens the effect of export shock on death rate, whereas a higher past output strengthens it. As shown in columns (3) and (4), the effect of export shock on death rate was larger in the counties further away from railways or with fewer CCP members. These results suggest that the provincial governments were able to verify food shortage more easily in counties located closer to railways or with more CCP members and, hence, these counties received food in the event of food shortages. Columns (5) and (6) show that the ability of positive contemporaneous output shocks to mitigate the adverse effect of export growth was larger for counties further from the railway than for those nearer the railway. There are two potential explanations for this difference: i) it is logistically more costly to transfer unexpected surpluses out of remote regions or ii) the upper level government had little knowledge of the surplus production due to more stagnant information flow from remote regions. Furthermore, the coefficient of $Export_t \times CCP\ Member$ is estimated to be larger in magnitude for the Near Group than for the Far Group, suggesting that party membership plays a more important role for the Near group than for the Far Group in mitigating the effect of export shocks on death rates.

Panel C repeats the regressions but uses birth rate as the outcome variable. In terms of the estimated signs, most of the results mirror those of the death rate, although the estimated coefficients are sometimes insignificant, perhaps because birth rates are less directly affected by famine than death rates.

6.4 Determinants of Grain Output

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

$$\ln y_{it} = \theta \ln h_{it} + \sum_{\ell} \sum_{k} \theta^{k\ell} s_i^k z_{it}^{\ell} + \phi_i + \gamma_{pt} + u_{it} \ , \tag{14}$$

where h_{it} denotes the per capita grain sown area. As reported in column (1) of Table 4, 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 over the 1957 to 1959 period. Our estimate suggests that this reduction in agricultural input led to a decrease in grain output of 0.05 log points.

Column (2) augments the baseline model with the interaction terms $GLF \times DistRail$ and

$GLF \times CCP\ Memeber$. Both estimated coefficients are insignificantly different from zero, suggesting 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 (3), we study the effect of the export shock on grain output. Interestingly, a larger export exposure led to a higher output level, perhaps because more resources were allocated to grain production in counties that were obliged to procure more exports. Column (4) shows that the effect of export shock on output does not vary along the dimensions of distance to railways or CCP membership.

In columns (5), we replace the province×year fixed effects by 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. 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 CCP experienced a larger decline in grain output. The estimated coefficient of the interaction term is negatively significant at the 10% level. Following Kung and Lin (2003) and Meng et al. (2015), column (5) also presents the intensity of the 1957 anti-rightest movement (measured by number of persons purged per million) as a proxy for the political zealousness of the provincial governments. We find that the 1957 political purge had an insignificant effect on grain output during the GLF period. Column (6) shows that after controlling for the county-level variables, log per capita sown area and export exposure, the variables that proxy for the province-level GLF intensity have no significant effect on grain output. In sum, consistent with the existing literature, we find supportive evidence for the effects of province-level GLF policies on grain output level. However, they have no further explanatory power once the county-level shocks are accounted for.

6.5 Robustness

6.5.1 Alternative Measures of Outcome Variables

Table 5 evaluates the robustness of our results to alternative measures of food availability and famine severity. Panel A of Table 5 shows the results of replacing the outcome variable with the log retained calories and then following the specifications used in columns (1), (4)-(6) in Table 3. The results are consistent with Panel A of Table 3. In addition, a positive contemporaneous output shock reduces the negative effect of export shocks in the counties that are further away from railways.

Following Meng et al. (2015), as shown in Panel B of Table 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.8 correlates the change in death (birth) rate over the 1957 to 1960 period with the relative population size of the famine cohort.[26] The relative cohort size is negatively correlated with the change in death rate, 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, using the log population size of a cohort born in year t+1 as the outcome variable closely aligns with the results obtained using the birth rates, as reported in Panel C of Table 3.

6.5.2 Revealed Comparative Advantage

In this section, we 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:

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

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 measures, 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 counties with a comparative advantage in low-export-exposure crops. The estimating equation is

$$\begin{aligned}\ln RetainRate_{it} =& \mu GLF \times RCA_i^{r,s} + \eta GLF \times \bar{\psi}_i + \sum_\tau \beta_1^\tau \mathbf{1}(t \in \tau) \times \ln y_{it} \\ &+ \sum_\tau \beta_2^\tau \mathbf{1}(t \in \tau) \times \ln y_{it-2} + g(\hat{v}_{it}) + g(\hat{v}_{it-2}) + \phi_i + \gamma_{pt} + \varepsilon_{it},\end{aligned} \tag{15}$$

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.[27] As in equation (13), we control

[26] 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.

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

for the current and past outputs and include the corresponding control functions. ϕ_i and γ_{pt} are county and province×year fixed effects, respectively.

The coefficient μ captures the differential declines in the retain rate across counties during the GLF period; the values indicate the extent to which a county has a comparative advantage in rice and soybean. The regression results are reported in column (1) of Table 6. 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 the counties that had a comparative advantage in producing rice and soybean relative to other crops. Column (2) uses the death rate as the outcome variable. We find that during the GLF period, the death rate increased faster in counties with a comparative advantage in rice and soybean. In addition, a higher absolute advantage tended to alleviate the famine. Column (3) shows the results when the birth rate is the outcome variable, and the estimates mirror those in column (2).

As shown in columns (4)-(6), we also use an alternative measure of comparative advantage by replacing $RCA_i^{r,s}$ with the average productivity of rice and soybean, i.e., $\psi_i^{r,s}$. We find that, conditional on the absolute advantage, counties with a higher productivity in rice and soybean experienced, on average, i) a greater reduction in retain rate, ii) a faster increase in mortality, and iii) a larger decline in fertility during the GLF period. These finding are consistent with those in columns (1)-(3).

6.5.3 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.[28] 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.[29]

We repeat the regression in column (3) of Table 3 using these alternative measures, and the results for the death rate are reported in columns (1)-(3) of Table 7. Column (4) further allows

and sorghum).

[28]For each grid on the map, we calculate the difference between the focal grid's elevation and the elevation of the eight adjacent grids. The terrain ruggedness index is computed as the square root of the sum of the eight squared differences. We then average the terrain ruggedness values of all of the grid cells in the county to obtain the average terrain ruggedness measure.

[29]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.

the export effects to be different by *CCP Member*. All of these regression results resemble their counterparts in Table 3. Next, we group counties into "Near" and "Far" groups based on whether the principal component of their distance measures is below or above the median. Columns (5) and (6) show the heterogeneous effects of export shocks on these two groups, respectively. Again, the results are consistent with the previous findings.

We then investigate how the effects of the export shock vary with provincial characteristics. As shown in column (7), we find that an increase in export exposure raises the death rate more in provinces that experienced a more intensive 1957 anti-rightest movement. More importantly, we find that county-level characteristics such as current and past outputs, CCP membership, and remoteness continue to affect exports, even after we include cross-province heterogeneity.

Table A.5 presents the corresponding specifications for the retain rate and birth rate. The results are qualitatively identical to our 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 responses of mortality in 1960 when different economic conditions in 1959 revert to their 1957 levels.[30] Recall that the retained consumption is determined as follows:

$$c_{it} = r_{it}\big(y_{it}, y_{it-2}, EX_{it}, \boldsymbol{\beta_t}\big) y_{it}\big(\boldsymbol{z^{\ell}_{it}}, EX_{it}, h_{it}\big), \tag{16}$$

where the retain rate is a function of contemporaneous and past outputs, export shock, and procurement policies which is captured by $\boldsymbol{\beta_t}$; and the output per capita depends on weather conditions, export exposure, and per capita grain sown area. Using equation (16), we decompose the change in retained consumption in 1959, and consequently the change in mortality in 1960, into the components contributed by the procurement shock (r_{it}) and output shock (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 alternative procedures to obtain the change in excess deaths under different counterfactual scenarios. The first is a more "structural" approach. Specifically, counterfactual changes in the death rate are computed based on counterfactual changes in caloric supply and the estimated non-parametric function $f(\cdot)$. The second approach uses the reduced-form relation between death rate and different underlying shocks. The two procedures will yield

[30] 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. The subsample consists of 780 counties.

similar findings if the underlying shocks affect mortality only through changes in caloric supply.

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

7.1 Counterfactuals Based on Nonparametric Function

Before delving into different counterfactual scenarios, we first look at the data for excess death rates in the sample of counties that have information on caloric consumption. As reported in row (A1) of Table 8, the death rate in 1960 was on average 14.37 (per thousand) higher than in 1958. The cross-county variation is considerable, with a standard deviation of 22.97. The excess death rates translate into a total number of excess deaths of 4,091,420.[31] This number serves as a benchmark for the following counterfactual exercises.

7.1.1 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:

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

We find that the average death rate would have been 13.55 (per thousand) lower in this counterfactual scenario. The implied aggregated number of excess deaths is 3,824,507, which is 93.48% of the actual number of excess deaths. There are at least two reasons why there are fewer excess deaths in the counterfactual scenario than in the historical record. First, our analysis only considers the relation between the death rate and average level of caloric consumption. Within-county inequality in food availability may result in extra deaths. Due to data constraints, this channel is ignored in our study. Second, during the chaotic GLF period, there could be other factors affecting mortality.

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

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

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

.

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 the output had not declined in 1959, the average death rate would have been 5.89 (per thousand) lower and 1,867,595 deaths could have been avoided, which is 45.65% of the actual excess deaths.

Rows (A3.a) and (A3.b) show different determinants of output decline. Specifically, row (A3.a) shows the role of resource diversion in the GLF period. Based on the estimates in column (1) of Table 4, we construct a counterfactual consumption level in 1959, which assumes 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 37.18% lower. In row (A3.b), we consider the counterfactual scenario of no weather shocks in 1959. Without the weather shocks, the number of excess deaths would have been 9.96% lower.

Following a similar procedure, as shown in row (A4), we consider the scenario in which the retain rate in 1959 reverts to the level in 1957, but the output level remains at the actual 1959 level. We find that in this counterfactual setting, the death rate and the total number of excess death would have been 9.3 (per thousand) and 2,452,516 lower, respectively. The decrease in the number of excess deaths amounts to 59.94% of the actual amount. It is worth noting that the combined effects of the output and procurement shocks is larger than that of the consumption shocks (105.59% versus 93.48%) due to the non-linear relation between mortality and caloric consumption.

As shown in row (A5.a), we also quantify the effect of export expansion on excess deaths. More specifically, we apportion the increase in exports of different crops back to each county based on its output share in 1957. In the absence of export expansion, retained consumption would have been higher and the number of excess deaths would have reduced by 25.01%. Next, as shown in row (A5.b), we account for the fact that exports also alter the output levels. As shown in Section 6.4, a county with higher export obligations tends to allocate more resources to grain production, which alleviates the negative effect of exports on the retain rate. We measure the export-induced changes in outputs using the estimate in column (3) of Table 4. In this scenario, the average death rate would have decreased by 1.68 (per thousand). As a result, the number of excess deaths would have been reduced by 501,322, which is 12.25% of the actual excess deaths.

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 outputs with their non-GLF counterparts. Using the estimates in column (3) of Panel A in Table 2, we calculate the changes in the grain retain rate. Second, we translate the implied changes in caloric consumption to counterfactual changes in deaths using the estimated non-parametric function given in Figure 8. As shown in row (A6), the more rigid procurement policies in the GLF period contributed to 28.62% of the excess deaths. As shown 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 2.34 (per thousand) higher in 1958, which is less than 1/6 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 1957 and 1960. Furthermore, the differences between (A6) and (A7) suggest that the inflexible and progressive procurement policies made a larger impact when accompanied by a widespread, large decline in output.

7.1.2 Quantitative Importance of Consumption Inequality

What would have happened if the available food had been equally distributed across the counties? As shown in row (A8), we equalize the average level of consumption across counties, while keeping the aggregate consumption and the within county inequality constant.[32] We find that the in this counterfactual scenario, the total excess deaths would have been 35.71% lower. For the counterfactual experiment presented in row (A9), we equally distribute consumption across counties within a province, while keeping the province-level consumption level unchanged. We find that removing the within-province consumption inequality lowers the total excess deaths by 28.07%. These findings are consistent with Meng et al. (2015); they find that unequal food distribution was one of the main contributors to the severity of the Great Famine. Moreover, we show that the within-province inequality could be a more important factor than the between-province inequality, which aligns with our variation decomposition analysis in Section 4.

We also quantitatively assess how the distribution of export 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 lift their export obligations.[33] The planners could then distribute the aggregate export to the remaining counties based on their consumption share. Similar to the case presented in (A5.b), the output would be adjusted according to the changes in exports. The results given in row (A10) show that had this reallocation of exports occurred, the total excess deaths would have declined by 7.85%. As shown in row (A11), we conduct an analogous

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

[33] The pre-export consumption per capita, $r_{it}y_{it} + Export_{it}$, in these counties was lower than 1,281 Cal.

experiment at the provincial level and find that the within-province redistribution of exports would have lowered the total excess deaths by 9.36%. These findings suggest that the adverse effects of exports on famine would have been greatly mitigated if the export procurement had been more progressive at the contemporaneous consumption level.

7.1.3 Robustness

In Appendices B.4 and B.5, 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.6. We find that the quantitative effects of different underlying shocks closely align with the baseline results given in Table 8.

7.2 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 members (High vs. Low), and iv) whether the county experienced good weather shocks in 1957 (Bad vs. Good).[34]

Figure 10 shows the distributions of the counterfactual changes in the death rate if the 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 8. 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 with a low proportion of CCP members FOSD that of the group with a high proportion of CCP members. 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, with fewer CCP members, or experiencing good past weather shocks were likely

[34] 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.

to suffer more from over procurement due to export expansion; these results are consistent with our reduced-form regression findings. Lastly, the Kolmogorov-Smirnov test fails to reject the equality of the distributions of near-to-railway and far-from-railway groups.

Figure 11 illustrates the scenario where the output in 1957 had remained the same as in 1959, repeating the exercise in Figure 10. 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 the procurement policies were more rigid in regions that were less organized due to low party presence.[35] 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 12. The distribution of the near-to-railway group FOSD that of the far-from-railway group, suggesting that counties nearer railways are more likely to be over-procured due to the lower transportation costs. The distribution of the low-export-exposure group is more skewed to the right than the high-export-exposure group, implying 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.[36]

Finally, Figure 13 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.

[35] As reported in column (2) of Table 4, 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.

[36] 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 2). 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 12, 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.

7.3 Counterfactuals Based on Reduced-Form Regressions

In this section, we present the counterfactual changes in excess deaths based on the reduced-form relation between the death rate and different underlying shocks. The analysis presented in row (A12) uses the estimates in Panel A column (3) of Table 2. We find that in the absence of any output shocks between 1957 and 1959, 949,520 deaths would have been avoided, which amounts to 23.21% of the total excess deaths. Note that the result is not the reduced-form counterpart of that in row (A3), because output shocks affect both the retain rate and potential food supply, and the reduced-form estimates capture the combined effects. As shown in row (A13.a), we quantify the impact of export expansion using the estimate in column (1) of Table 3 Panel B. We find that 19.09% of the excess deaths could be explained by export shocks. Analogously to row (A5.b), the results in row (A13.b) account for the export-induced changes in output. In this case, export shocks explain 14.3% of the excess deaths.[37]

7.4 An Analogous Analysis for Lost/Postponed Births

We conduct an analogous analysis for lost/postponed births; the results are presented in Figure 9 and Panel B of Table 8. We briefly discuss the main findings here. First, the decline in caloric consumption between 1957 and 1959 explains 65.6% of the total lost/postponed births. Second, the relative importance of different underlying shocks is similar to those given in Panel A. For example, the effect of the export shock is about one tenth of the effect of the caloric consumption shock for both death and birth rates. Lastly, compared to the approach based on the non-parametric relation, the reduced-form pass-through yields similar estimates for the effects of export shocks.

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.8), it may also be a noisier proxy for famine severity than death rate.

[37]Based on the counterfactual analysis in row (A13.b), Figure A.13 shows the distributions of the changes in excess death rates for counties with different characteristics. Consistent with the results obtained from the structural approach, the distribution of the low-export-exposure group is more skewed to the right than in the high-export-exposure group, and the distribution of the good-past-weather group FOSD that of the bad-past-weather group.

8 Conclusion

The Chinese Great Famine was the worst famine in human history, resulting in 16.5 to 30 million excess deaths between 1959 and 1961. In the midst of this famine, the Chinese government exported 9.6 million tons of grain, equivalent to caloric needs of 16.7 to 38.9 million people; almost no grain was imported into China before 1961. Although previous studies have recognized grain exports as a potentially important cause of the famine, no existing study provides quantitative evidence for the importance of grain exports relative to other factors. Using newly collected county-level data, this study quantitatively assesses the effect of grain exports on death rates. We find that increases in grain exports contributed to 12-14 percent of the excess deaths between 1958 and 1960, and that 59 and 46 percent of the excess deaths can be attributed to the surge in the procurement rate and the fall in agricultural production, respectively. Therefore, one-fifth of the effect of the increase in procurement on excess deaths is attributable to an increase in grain exports. Furthermore, the impact of grain exports on death rates is larger for the counties with lower current outputs, higher two-period lagged outputs, larger distances to railways, and a smaller percentage of local CCP members, suggesting that the effect of grain exports systematically depends on remoteness and political factors represented by the number of CCP members.

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 implemented during the GLF period 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 many CCP members, where verification of food shortages was presumably easier, suggesting that the degree of inflexibility moderates the effect of grain exports on famine. Our 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 food abundance. In this sense, the inflexibility of the procurement policy was a necessary condition for grain exports to have such a large impact on mortality.

Exporting grains during a famine is not a unique feature to the 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, in which a region was exporting grain while people were starving to death (Woodham-Smith, 1964; Sen, 1981; Ghose, 1982; Ravallion, 1987; Davies and Wheatcroft, 2004; Wemheuer, 2015). In particular, in the Soviet-Ukraine famine of 1932-33, the government compulsorily procured grains from the rural area, exporting 1.6 million tons of grains to cope with the foreign debt, under a centrally planned economy with agricultural collectivization (Davies and Wheatcroft, 2004). This amount of grain exports could have fed all 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 potentially 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 the allocation of resources are determined by political factors under inflexible institution.

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

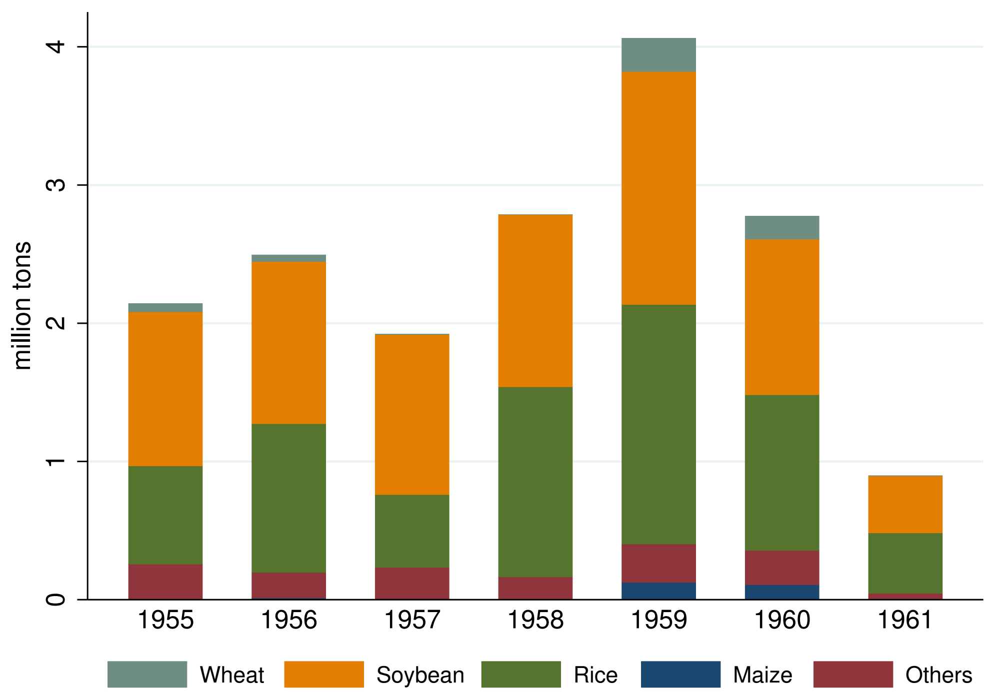


Figure 2: Cross-County Variation in Famine Severity

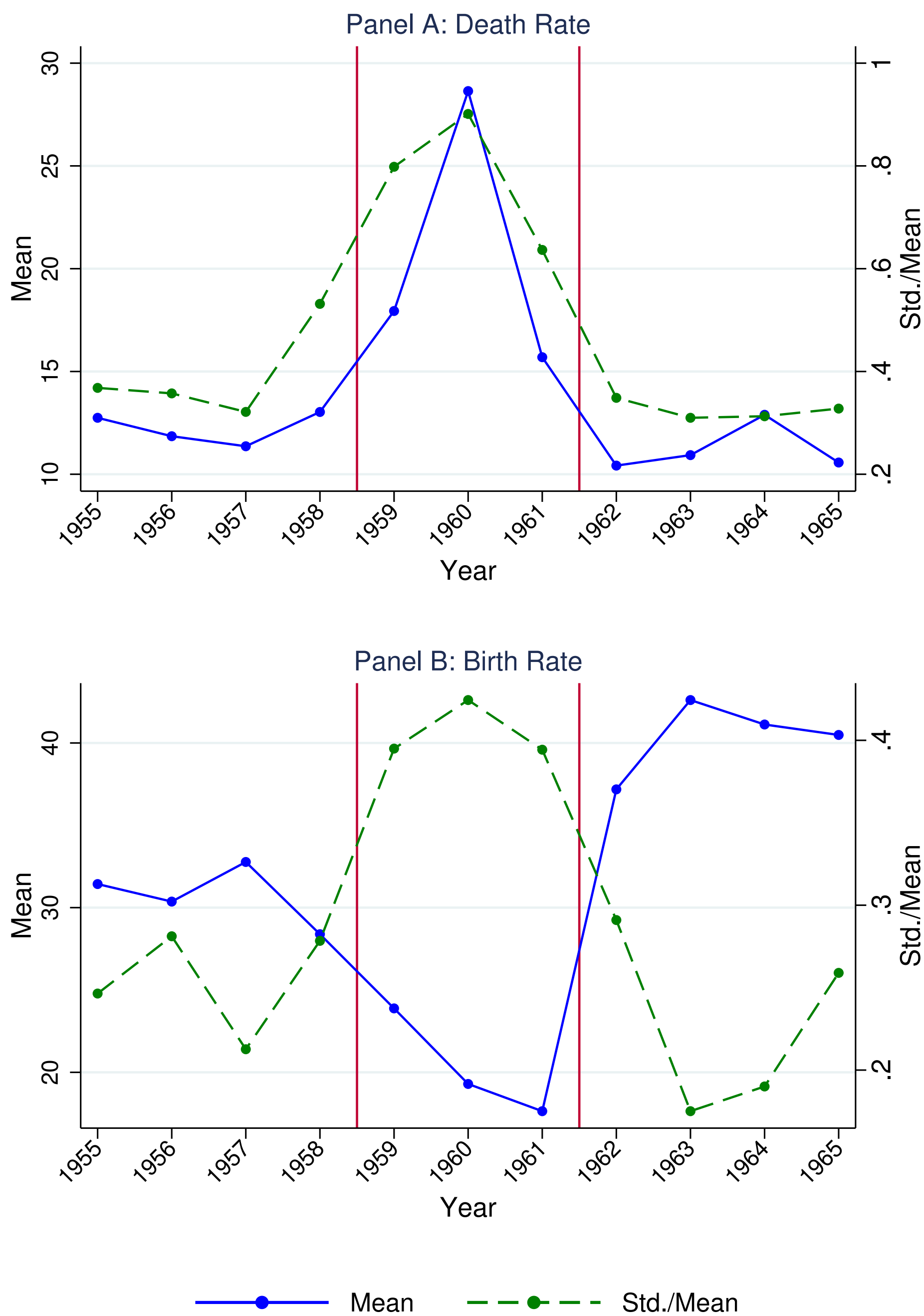
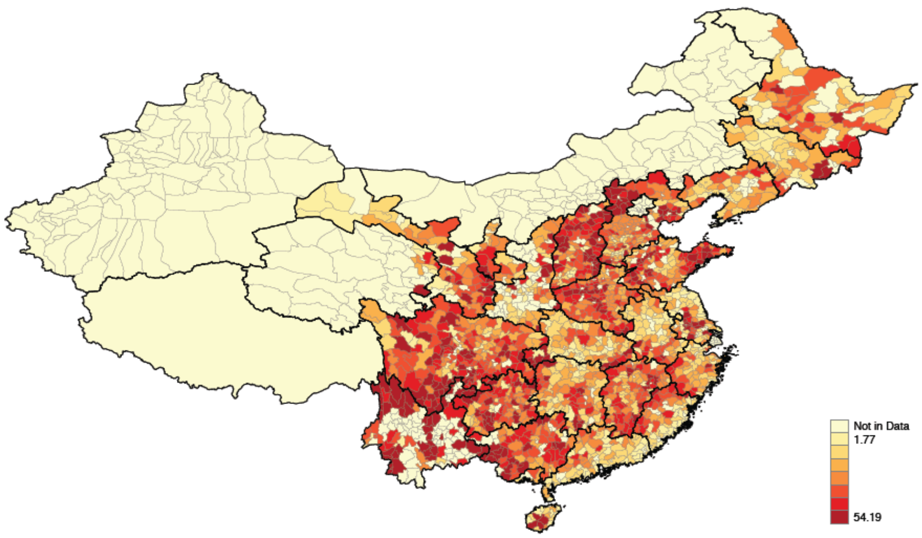
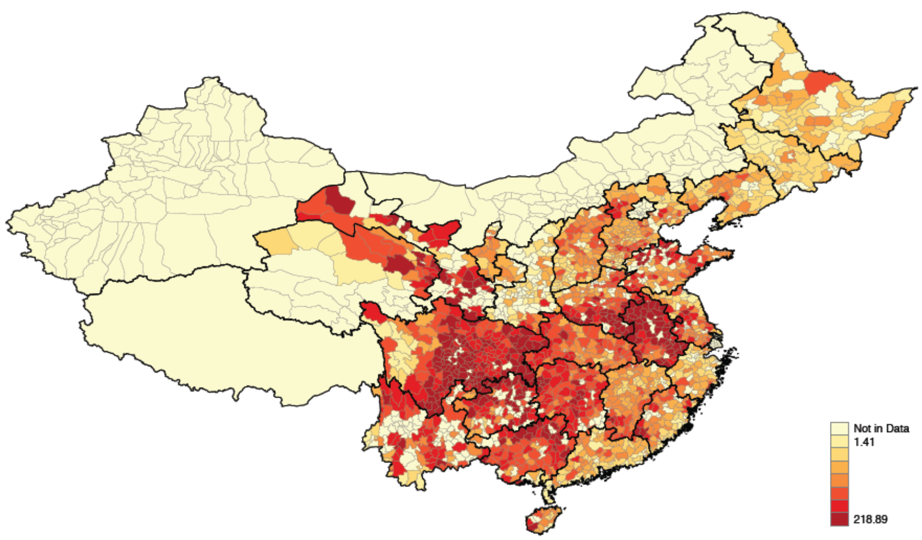


Figure 3: Number of Deaths per 1,000 in 1957 and 1960



(a) Number of deaths per 1,000 in 1957



(b) Number of deaths per 1,000 in 1960

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

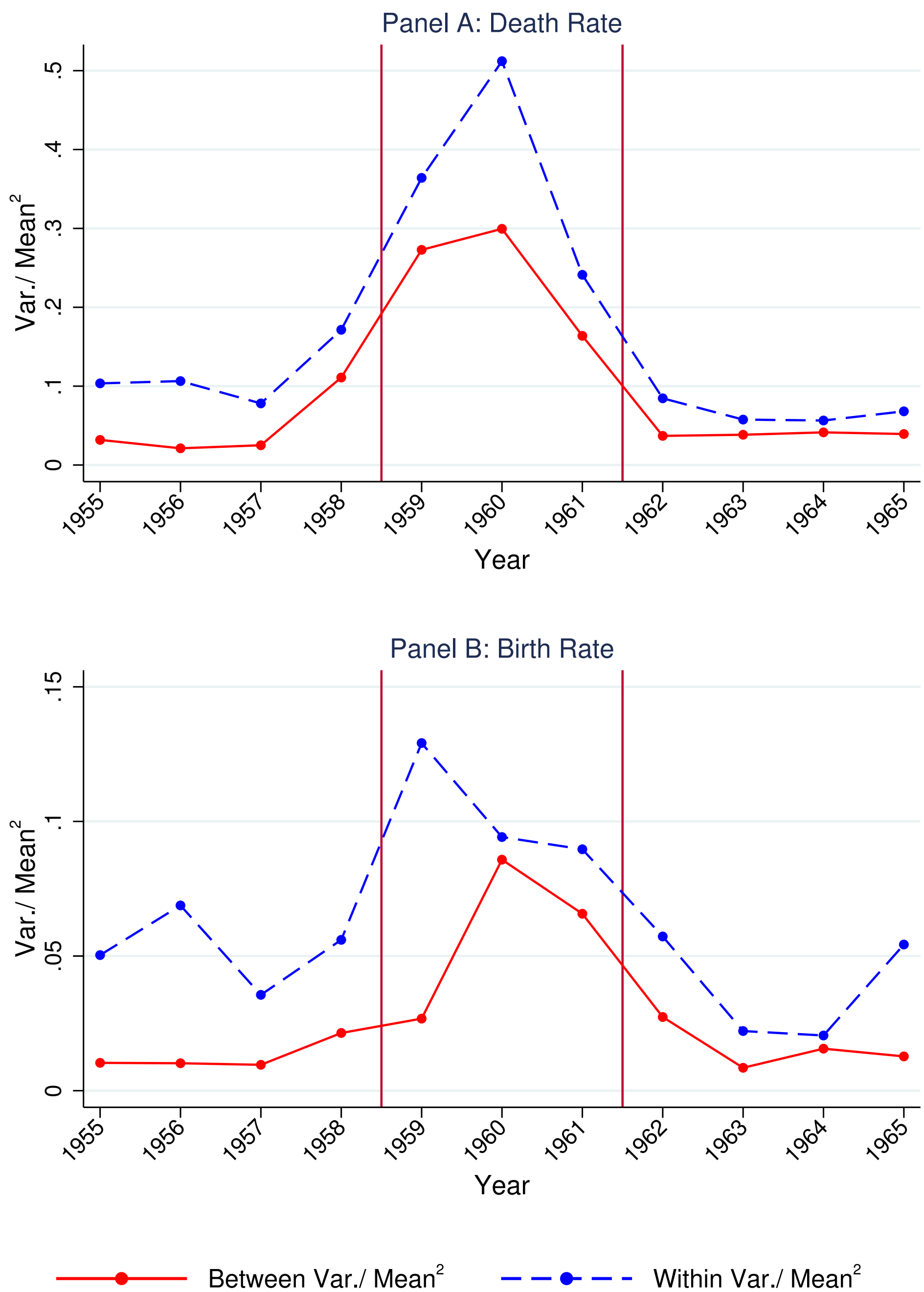


Figure 5: Correlation between Changes in Mortality and Birth Rates

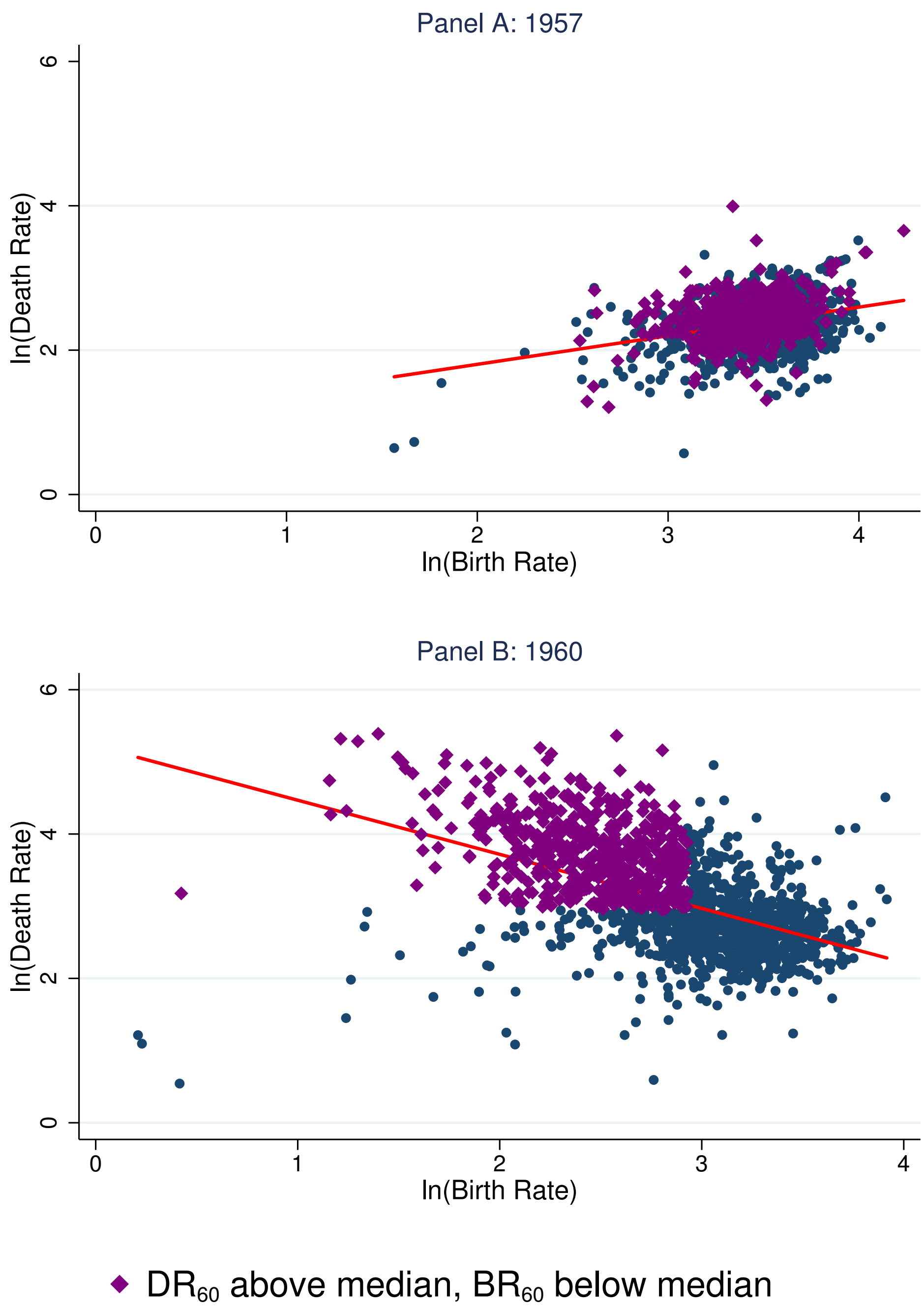
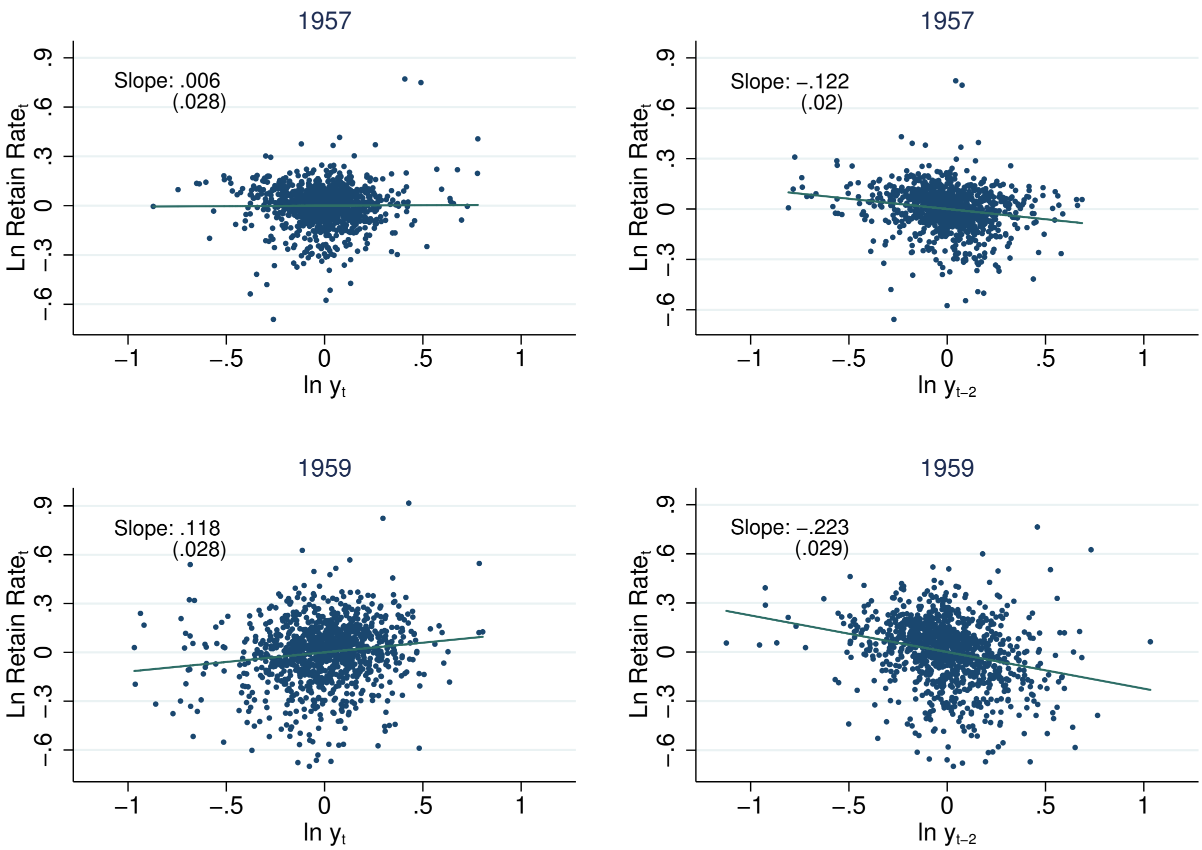
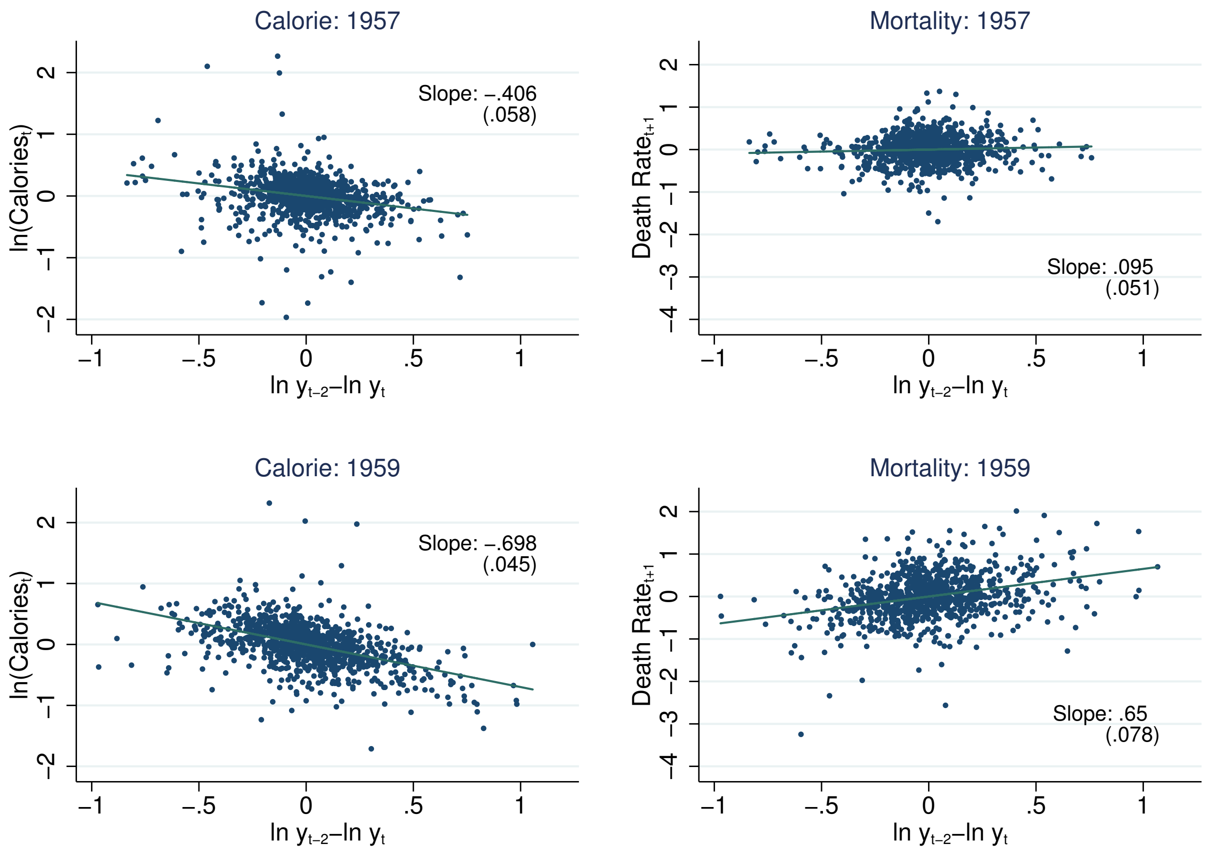


Figure 6: Correlation between Log Retain Rate and Outputs



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

Figure 7: 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 8: Semi-parametric Regression: Death Rate and Log Caloric Consumption

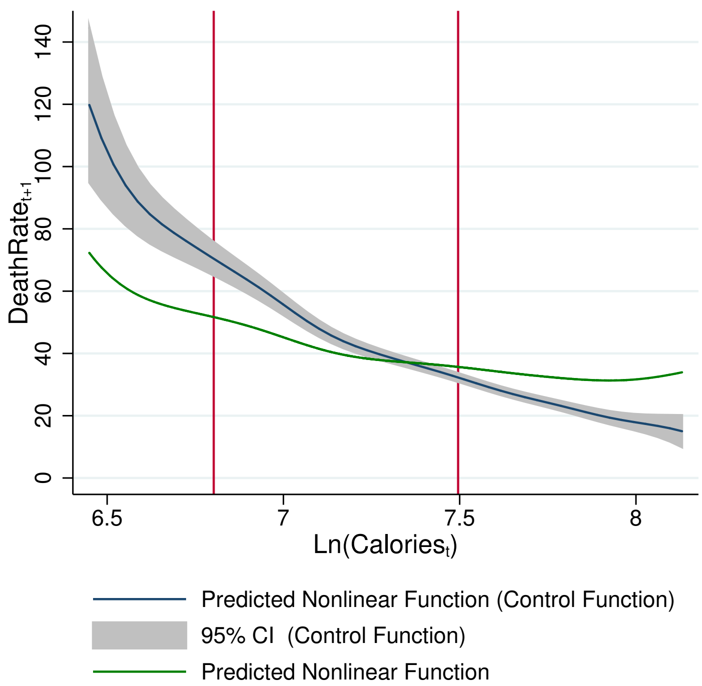


Figure 9: Semi-parametric Regression: Birth Rate and Log Caloric Consumption

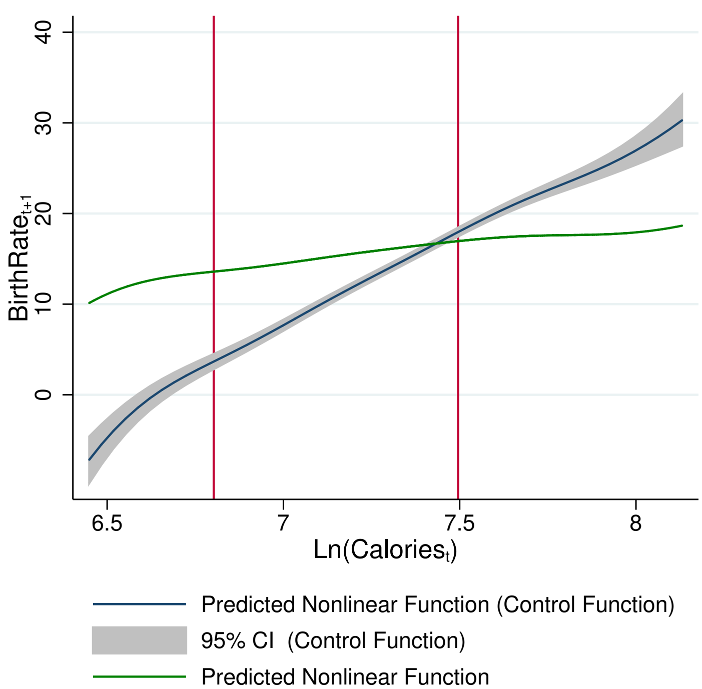


Figure 10: Exports in 1959 Same as in 1957

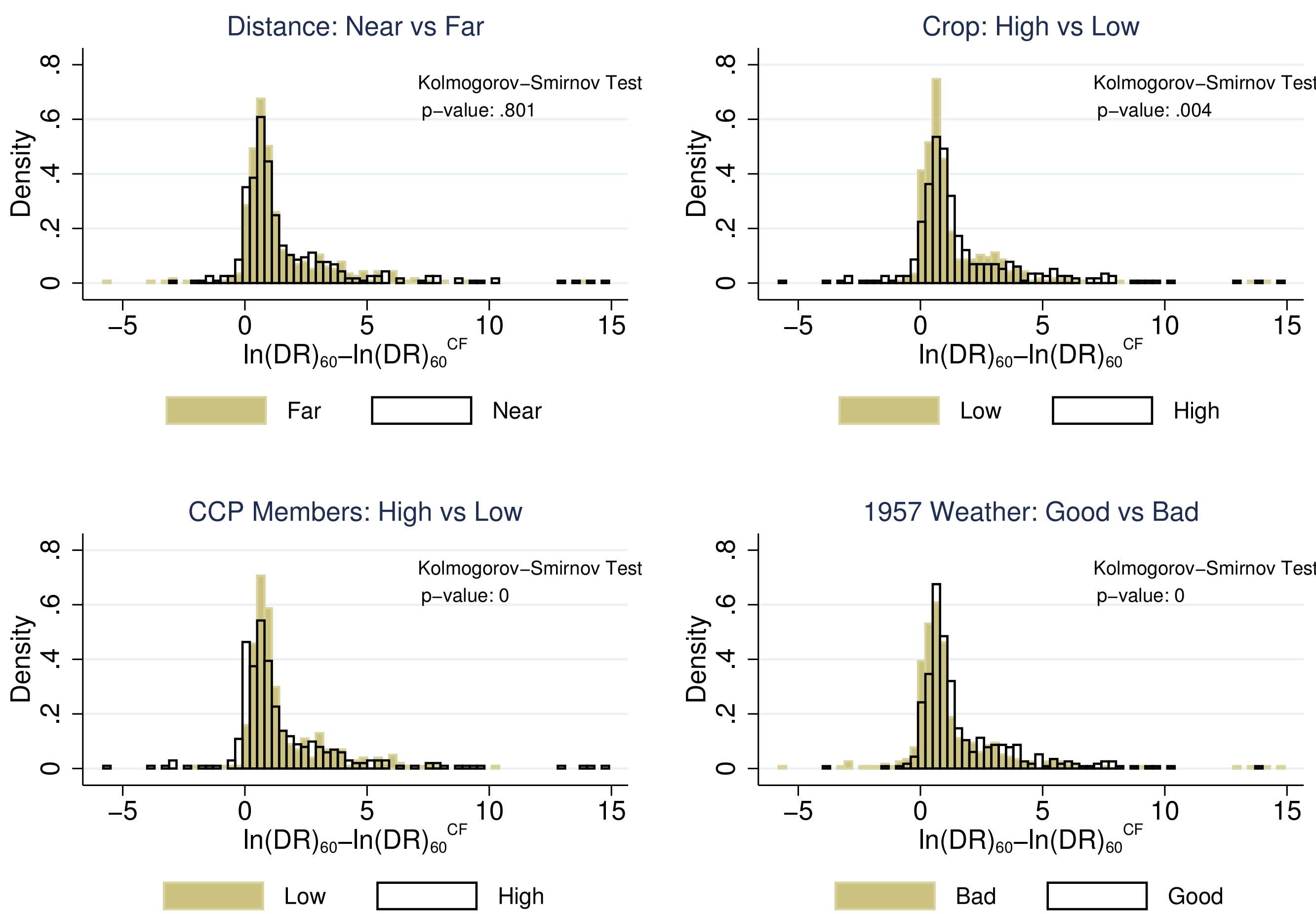


Figure 11: Outputs in 1959 Same as in 1957

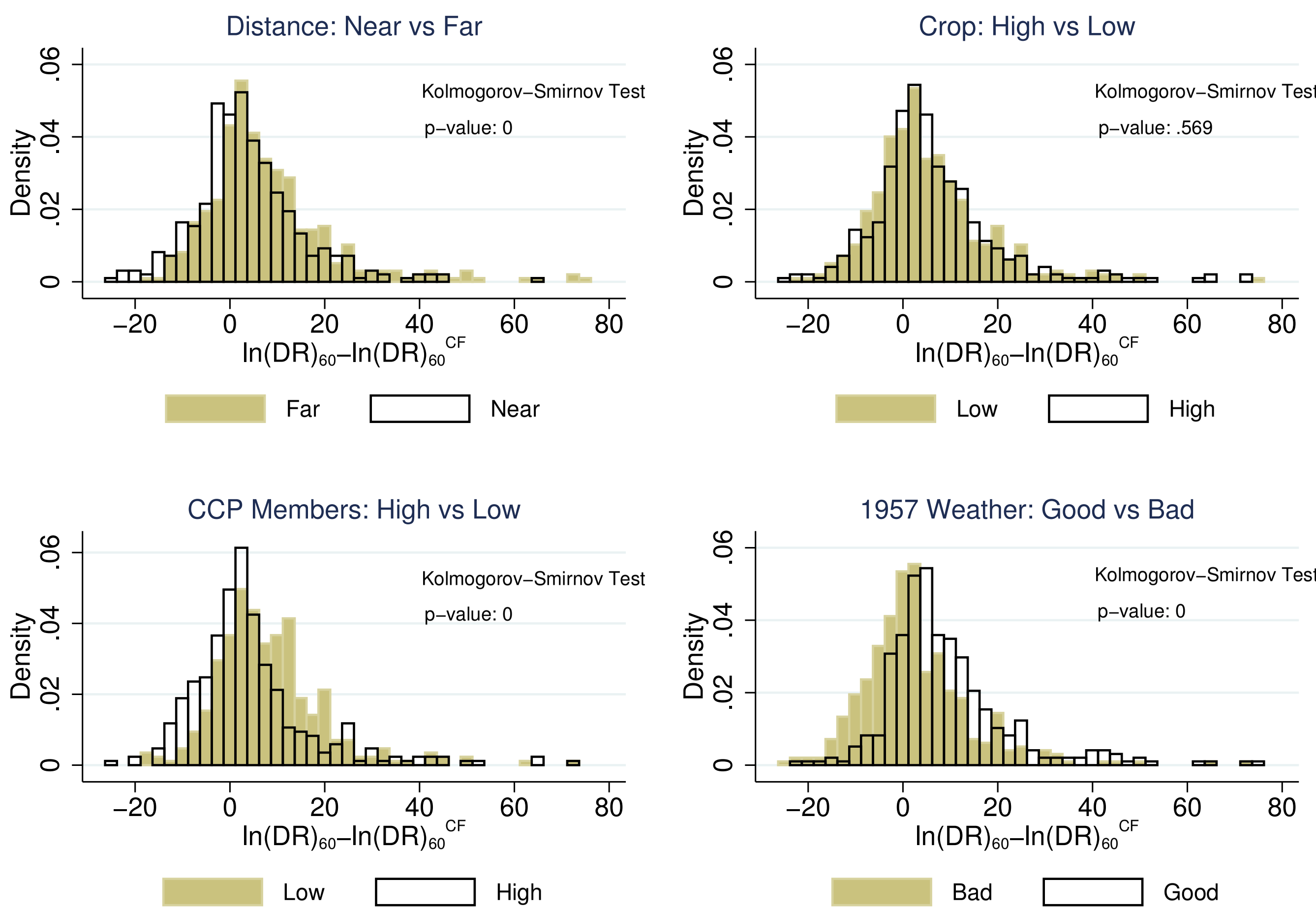


Figure 12: Procurement Rates in 1959 Same as in 1957

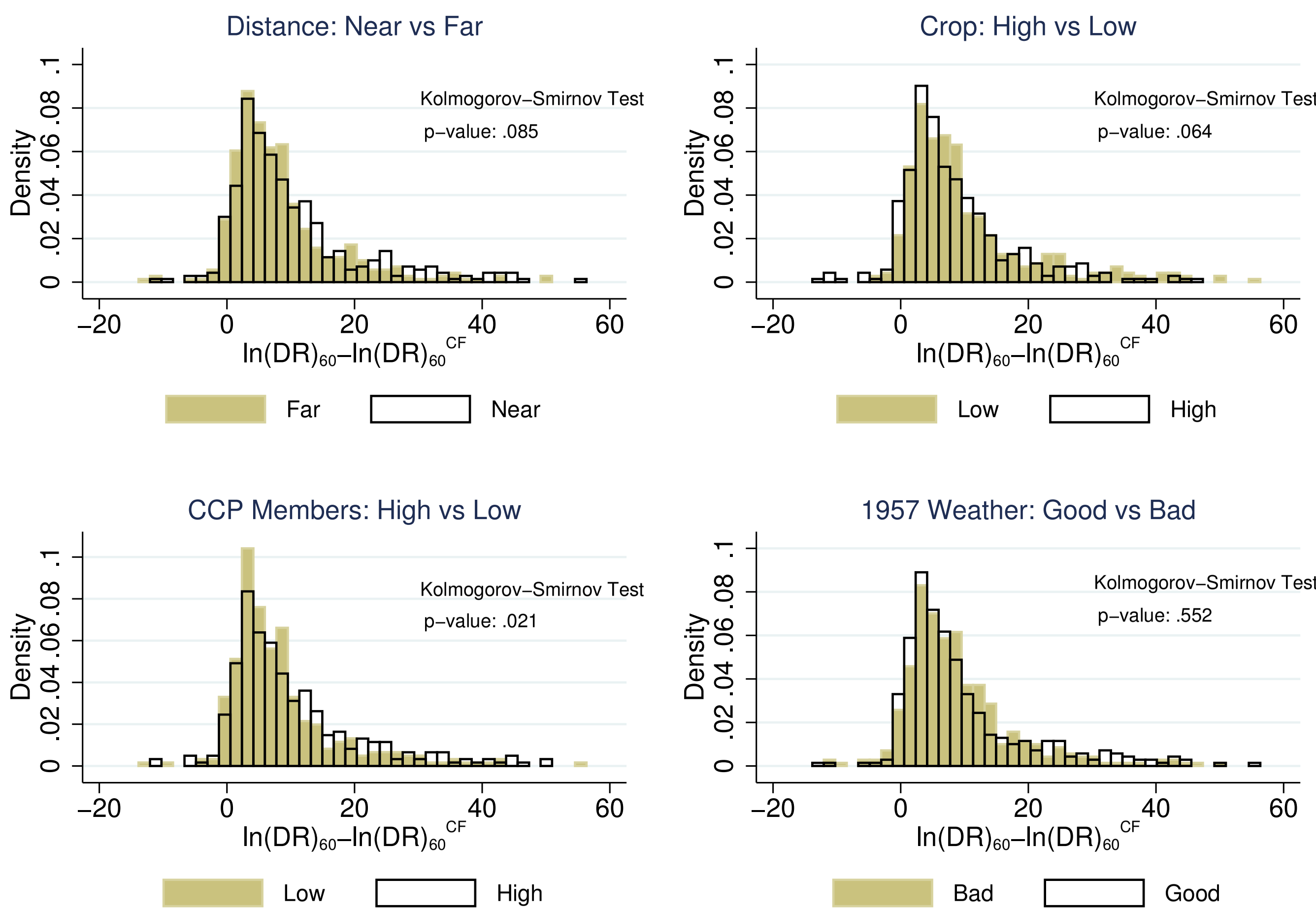


Figure 13: Procurement Policies in 1959 Same as in Non-GLF Period

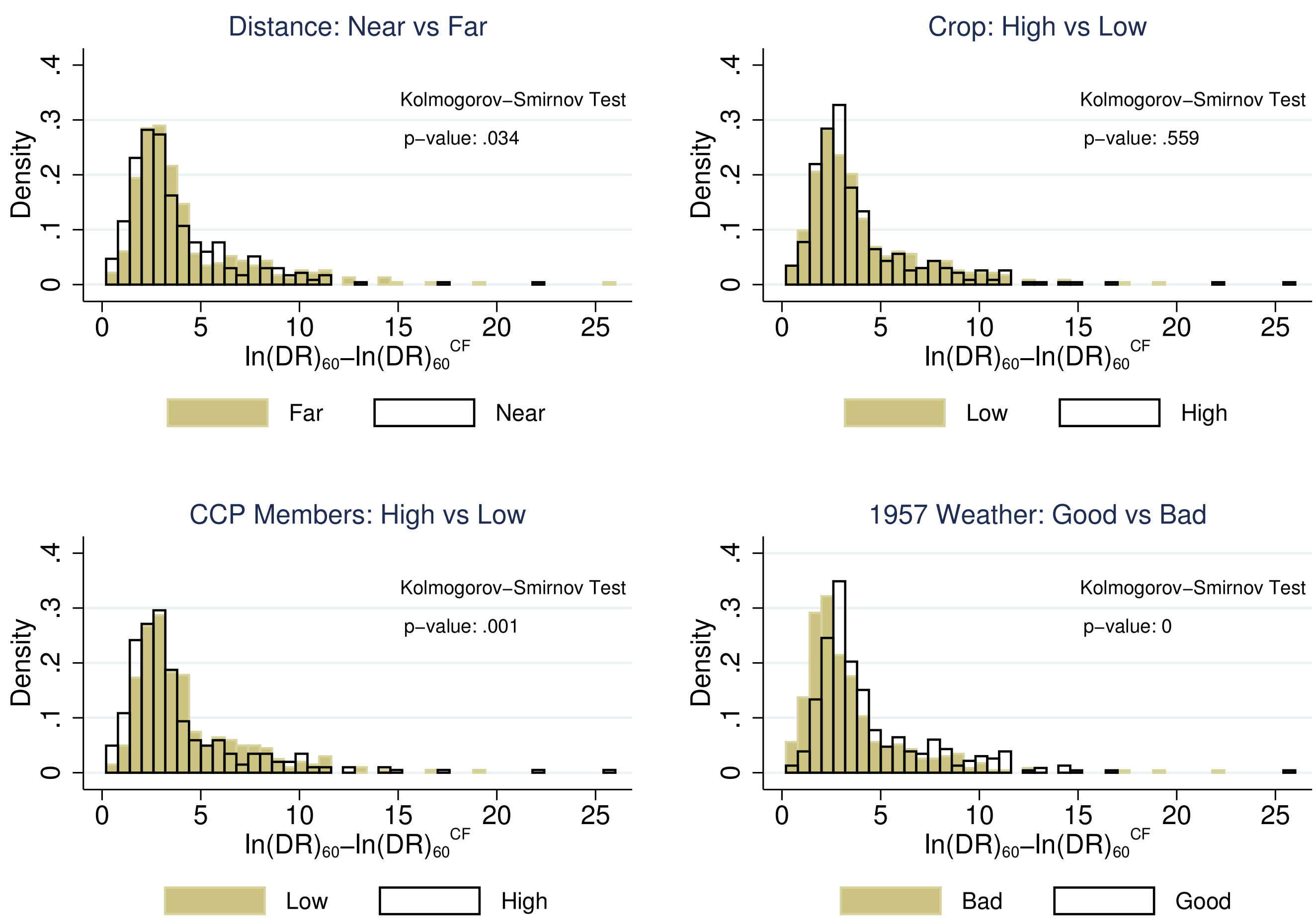


Table 1: Summary Statistics

	All Years	GLF Years	Non-GLF Years
Death Rate$_{t+1}$	13.90	20.59	11.79
	(0.08)	(0.28)	(0.04)
Birth Rate$_{t+1}$ (per 1,000)	32.01	20.19	35.74
	(0.09)	(0.13)	(0.09)
Per capita grain output$_t$ (kg)	282.85	266.80	284.73
	(1.08)	(2.03)	(1.35)
Retain Rate$_t$	0.75	0.68	0.77
	(0.00)	(0.00)	(0.00)
Per Capita Retained Consumption$_t$ (Cal.)	2,070.69	1,772.45	2,114.02
	(9.67)	(17.39)	(12.18)
Per Capita Sown Area$_t$ (mu)	3.25	3.13	3.33
	(0.01)	(0.03)	(0.02)
Export$_t$ (kg)	4.38	10.35	2.87
	(0.04)	(0.16)	(0.03)
Spring Temperature$_t$ (C°)	8.17	8.99	7.93
	(0.04)	(0.08)	(0.05)
Summer Temperature$_t$ (C°)	21.75	21.73	21.76
	(0.03)	(0.06)	(0.03)
Spring Precipitation$_t$ (cm)	5.59	5.67	5.50
	(0.03)	(0.07)	(0.04)
Summer Precipitation$_t$ (cm)	14.79	14.32	15.18
	(0.05)	(0.09)	(0.06)
Distance to Railway in 1957 (km)	101.61	-	-
	(2.47)	-	-
CPC Member in 1956 (%)	1.57	-	-
	(0.026)	-	-

Notes: Standard errors are in parentheses.

Table 2: Output Shocks, Retain Rate, Death Rate, and Birth Rate

	All	All	All	Near	Far
	(1)	(2)	(3)	(4)	(5)
Panel A: Dependent Variable $\ln RetainRate_t$					
GLF$\times \ln y_t$	0.004	-0.001	-0.053	-0.127**	-0.006
	(0.017)	(0.013)	(0.041)	(0.056)	(0.064)
GLF$\times \ln y_{t-2}$	-0.085***	-0.061***	-0.134***	-0.092*	-0.163***
	(0.017)	(0.013)	(0.038)	(0.052)	(0.058)
Non-GLF$\times \ln y_t$	-0.071***	-0.055***	-0.166***	-0.199***	-0.124***
	(0.008)	(0.008)	(0.021)	(0.031)	(0.031)
Non-GLF$\times \ln y_{t-2}$	-0.018***	-0.011**	-0.007	-0.006	-0.023
	(0.006)	(0.005)	(0.019)	(0.029)	(0.027)
N	10,642	10,642	10,065	5,202	4,863
R^2	0.501	0.793	0.796	0.810	0.790
Panel B: Dependent Variable $DeathRate_{t+1}$					
GLF$\times \ln y_t$	-9.111***	-7.960***	-24.290***	-14.899***	-34.714***
	(1.324)	(1.285)	(4.504)	(4.735)	(8.876)
GLF$\times \ln y_{t-2}$	9.803***	9.635***	31.354***	20.857***	41.605***
	(1.241)	(1.153)	(5.630)	(6.330)	(9.738)
Non-GLF$\times \ln y_t$	-0.270	0.037	4.919***	3.217**	4.662**
	(0.167)	(0.315)	(1.279)	(1.599)	(2.313)
Non-GLF$\times \ln y_{t-2}$	0.263*	1.015***	2.731**	1.868*	3.152
	(0.146)	(0.279)	(1.148)	(1.106)	(2.003)
N	13,033	13,033	12,260	6,379	5,881
R^2	0.535	0.621	0.641	0.691	0.646
Panel C: Dependent Variable $BirthRate_{t+1}$					
GLF$\times \ln y_t$	3.732***	4.328***	8.174***	2.465	17.515***
	(0.467)	(0.484)	(1.812)	(2.155)	(3.656)
GLF$\times \ln y_{t-2}$	-2.465***	-2.491***	-3.240*	0.659	-8.940**
	(0.441)	(0.474)	(1.898)	(2.323)	(3.636)
Non-GLF$\times \ln y_t$	3.609***	4.215***	8.232***	7.256***	10.731***
	(0.439)	(0.419)	(1.171)	(1.506)	(1.950)
Non-GLF$\times \ln y_{t-2}$	-2.597***	-2.164***	-3.150***	-3.677***	-2.126
	(0.378)	(0.366)	(1.046)	(1.310)	(1.762)
N	13,050	13,050	12,274	6,380	5,894
R^2	0.716	0.794	0.797	0.802	0.804
Province$\times$Year	Y	Y	Y	Y	Y
County		Y	Y	Y	Y
Control function			Y	Y	Y

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

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

	All (1)	All (2)	All (3)	All (4)	Near (5)	Far (6)
Panel A: Dependent Variable $\ln RetainRate_t$						
$Export_t$	-0.002***	-0.017***	-0.017***	-0.021***	-0.019***	-0.025**
	(0.001)	(0.006)	(0.006)	(0.006)	(0.007)	(0.012)
$Export_t \times \ln y_t$		0.004*	0.004*	0.003	0.002	0.005
		(0.002)	(0.002)	(0.002)	(0.003)	(0.004)
$Export_t \times \ln y_{t-2}$		-0.001	-0.001	-0.001	0.001	-0.002
		(0.002)	(0.002)	(0.002)	(0.003)	(0.004)
$Export_t \times DistRail$			0.004	0.001		
			(0.003)	(0.004)		
$Export_t \times CCP\ Member$				0.001***	0.001	0.001
				(0.000)	(0.001)	(0.001)
GLF$\times \ln y_t$	-0.049	-0.098**	-0.099**	-0.094*	-0.132*	-0.027
	(0.041)	(0.046)	(0.046)	(0.049)	(0.068)	(0.073)
GLF$\times \ln y_{t-2}$	-0.125***	-0.093**	-0.092*	-0.108**	-0.092	-0.163**
	(0.037)	(0.047)	(0.047)	(0.051)	(0.069)	(0.077)
Non-GLF$\times \ln y_t$	-0.165***	-0.174***	-0.174***	-0.181***	-0.202***	-0.139***
	(0.021)	(0.022)	(0.022)	(0.024)	(0.034)	(0.034)
Non-GLF$\times \ln y_{t-2}$	-0.005	-0.001	-0.001	-0.001	-0.002	-0.017
	(0.019)	(0.021)	(0.021)	(0.022)	(0.033)	(0.033)
N	10,065	10,065	10,065	8,662	4,442	4,220
R^2	0.797	0.798	0.798	0.795	0.804	0.797
Panel B: Dependent Variable $DeathRate_{t+1}$						
$Export_t$	0.237***	1.195**	1.130**	1.714***	1.273**	3.886***
	(0.055)	(0.487)	(0.483)	(0.535)	(0.509)	(0.976)
$Export_t \times \ln y_t$		-0.562***	-0.538***	-0.540***	-0.555**	-0.881**
		(0.188)	(0.188)	(0.200)	(0.242)	(0.376)
$Export_t \times \ln y_{t-2}$		0.404**	0.384**	0.334*	0.444*	0.310
		(0.185)	(0.186)	(0.195)	(0.247)	(0.362)
$Export_t \times DistRail$			0.883**	1.018**		
			(0.437)	(0.490)		
$Export_t \times CCP\ Member$				-0.152***	-0.218***	-0.075**
				(0.032)	(0.043)	(0.030)
GLF$\times \ln y_t$	-24.761***	-16.639***	-16.959***	-16.239***	-7.840**	-25.033***
	(4.461)	(3.924)	(3.932)	(3.948)	(3.366)	(7.962)
GLF$\times \ln y_{t-2}$	30.550***	22.757***	22.924***	22.232***	13.236***	33.383***
	(5.403)	(4.435)	(4.436)	(4.356)	(4.032)	(7.892)
Non-GLF$\times \ln y_t$	4.892***	6.039***	5.875***	6.010***	4.772**	6.232***
	(1.253)	(1.398)	(1.394)	(1.431)	(1.864)	(2.315)
Non-GLF$\times \ln y_{t-2}$	2.655**	1.376	1.383	1.590	0.822	2.674
	(1.136)	(1.161)	(1.159)	(1.203)	(1.303)	(2.080)
N	12,260	12,260	12,260	10,485	5,379	5,106
R^2	0.643	0.646	0.647	0.653	0.695	0.662

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

	All	All	All	All	Near	Far
	(1)	(2)	(3)	(4)	(5)	(6)
Panel C: Dependent Variable $BirthRate_{t+1}$						
$Export_t$	-0.058**	-0.634***	-0.612***	-0.713***	-0.544**	-1.176**
	(0.024)	(0.197)	(0.196)	(0.215)	(0.228)	(0.471)
$Export_t \times \ln y_t$		0.017	0.008	0.016	0.068	0.082
		(0.058)	(0.059)	(0.063)	(0.070)	(0.152)
$Export_t \times \ln y_{t-2}$		0.079	0.086	0.083	-0.006	0.096
		(0.067)	(0.067)	(0.073)	(0.079)	(0.179)
$Export_t \times DistRail$			-0.300**	-0.393**		
			(0.153)	(0.156)		
$Export_t \times CCP\ Member$				0.034**	0.058***	0.017
				(0.016)	(0.021)	(0.021)
GLF$\times \ln y_t$	8.289***	7.993***	8.101***	7.940***	2.714	14.610***
	(1.806)	(1.962)	(1.960)	(2.059)	(2.498)	(4.023)
GLF$\times \ln y_{t-2}$	-3.043	-3.622*	-3.679*	-2.948	1.121	-7.189
	(1.887)	(2.110)	(2.109)	(2.276)	(2.635)	(4.457)
Non-GLF$\times \ln y_t$	8.239***	8.187***	8.243***	8.186***	7.135***	10.223***
	(1.169)	(1.172)	(1.172)	(1.261)	(1.665)	(2.074)
Non-GLF$\times \ln y_{t-2}$	-3.132***	-3.429***	-3.432***	-3.100***	-3.169**	-2.312
	(1.046)	(1.066)	(1.066)	(1.134)	(1.440)	(1.895)
N	12,274	12,274	12,274	10,498	5,379	5,119
R^2	0.797	0.797	0.797	0.800	0.806	0.807
Province×Year	Y	Y	Y	Y	Y	Y
County	Y	Y	Y	Y	Y	Y
Control function	Y	Y	Y	Y	Y	Y

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

Table 4: Determinants of County-Level Grain Outputs

	(1)	(2)	(3)	(4)	(5)	(6)
ln Per Capita Sown Area	0.623***	0.625***	0.618***	0.604***		0.640***
	(0.028)	(0.030)	(0.029)	(0.030)		(0.032)
$GLF \times DistRail$		0.032				
		(0.051)				
$GLF \times CCP\ Member$		0.002				
		(0.006)				
$Export_t$			0.002***	0.003**		0.004***
			(0.001)	(0.001)		(0.001)
$Export_t \times DistRail$				0.002		
				(0.005)		
$Export_t \times CCP\ Member$				0.000		
				(0.001)		
Per Capita Steel Output					-0.000	-0.001
					(0.001)	(0.001)
GLF× Late Liberation					-0.062*	-0.018
					(0.035)	(0.028)
GLF× Intensity of the 1957 Anti-Rightest Movement					0.125	-0.189
					(0.637)	(0.590)
County	Y	Y	Y	Y	Y	Y
Province×Year	Y	Y	Y	Y		
Year					Y	Y
N	14,082	12,077	14,082	12,077	14,082	14,082
R^2	0.858	0.858	0.858	0.859	0.756	0.819

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 5: Robustness – Different Outcome Variables

Dep. Var.:	Panel A: $\ln Calorie_t$				Panel B: $\ln CohortSize_{t+1}$			
	All	All	Near	Far	All	All	Near	Far
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$Export_t$	-0.002***	-0.021***	-0.019***	-0.025**	-0.004***	-0.019	-0.014	-0.037
	(0.001)	(0.006)	(0.007)	(0.012)	(0.001)	(0.012)	(0.011)	(0.030)
$Export_t \times \ln y_t$		0.003	0.002	0.005		0.005	0.008**	0.002
		(0.002)	(0.003)	(0.004)		(0.003)	(0.003)	(0.007)
$Export_t \times \ln y_{t-2}$		-0.001	0.001	-0.002		-0.004	-0.008*	0.003
		(0.002)	(0.003)	(0.004)		(0.004)	(0.004)	(0.009)
$Export_t \times DistRail$		0.001				-0.010		
		(0.004)				(0.012)		
$Export_t \times CCP\ Member$		0.001***	0.001	0.001		0.003***	0.006***	0.002**
		(0.000)	(0.001)	(0.001)		(0.001)	(0.001)	(0.001)
GLF$\times \ln y_t$	0.951***	0.906***	0.868***	0.973***	0.336***	0.237**	-0.000	0.692***
	(0.041)	(0.049)	(0.068)	(0.073)	(0.096)	(0.116)	(0.135)	(0.221)
GLF$\times \ln y_{t-2}$	-0.125***	-0.108**	-0.092	-0.163**	-0.191*	-0.108	0.227	-0.641***
	(0.037)	(0.051)	(0.069)	(0.077)	(0.099)	(0.122)	(0.149)	(0.219)
Non-GLF$\times \ln y_t$	0.835***	0.819***	0.798***	0.861***	0.122***	0.071	0.118*	0.042
	(0.021)	(0.024)	(0.034)	(0.034)	(0.047)	(0.052)	(0.068)	(0.084)
Non-GLF$\times \ln y_{t-2}$	-0.005	-0.001	-0.002	-0.017	-0.047	-0.035	0.038	-0.060
	(0.019)	(0.022)	(0.033)	(0.033)	(0.041)	(0.046)	(0.062)	(0.078)
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
N	10,065	8,662	4,442	4,220	11,913	10,236	5,280	4,956
R^2	0.959	0.961	0.959	0.966	0.944	0.943	0.943	0.946

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

Table 6: Comparative Advantage, Retain Rate, Death Rate, and Birth Rate

Dep. Var.:	$\ln RetainRate_t$ (1)	$DeathRate_{t+1}$ (2)	$BirthRate_{t+1}$ (3)	$\ln RetainRate_t$ (4)	$DeathRate_{t+1}$ (5)	$BirthRate_{t+1}$ (6)
$GLF \times RCA^{r,s}$	-0.019**	3.305***	-0.615*			
	(0.009)	(0.715)	(0.371)			
$GLF \times \psi^{r,s}$				-0.007*	1.091***	-0.466**
				(0.004)	(0.320)	(0.185)
$GLF \times \bar{\psi}$	-0.001	-0.652*	0.091	0.006	-1.701***	0.484**
	(0.003)	(0.349)	(0.160)	(0.005)	(0.378)	(0.216)
GLF$\times \ln y_t$	-0.010	-28.165***	8.896***	-0.018	-26.582***	8.551***
	(0.044)	(5.126)	(1.986)	(0.043)	(5.078)	(1.994)
GLF$\times \ln y_{t-2}$	-0.173***	33.267***	-4.558**	-0.168***	32.451***	-4.328**
	(0.040)	(6.184)	(2.010)	(0.040)	(6.244)	(2.047)
NonGLF$\times \ln y_t$	-0.187***	4.361***	7.521***	-0.188***	4.597***	7.496***
	(0.021)	(1.340)	(1.261)	(0.021)	(1.402)	(1.258)
NonGLF$\times \ln y_{t-2}$	0.008	1.893	-3.498***	0.008	2.143*	-3.533***
	(0.019)	(1.198)	(1.121)	(0.019)	(1.206)	(1.115)
Province$\times$Year	Y	Y	Y	Y	Y	Y
County	Y	Y	Y	Y	Y	Y
Control function	Y	Y	Y	Y	Y	Y
N	9,136	11,129	11,143	9,136	11,129	11,143
R^2	0.803	0.658	0.799	0.803	0.657	0.799

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

Table 7: Heterogeneous Effects of Export Exposure on Death Rate: Alternative Measures of Distance

Dep. Var. : $DeathRate_{t+1}$	All (1)	All (2)	All (3)	All (4)	Near (5)	Far (6)	All (7)
$Export_t$	1.084**	1.031**	1.145**	1.787***	2.044**	1.860***	1.057**
	(0.487)	(0.506)	(0.487)	(0.535)	(0.818)	(0.578)	(0.501)
$Export_t \times \ln y_t$	-0.560***	-0.498***	-0.504***	-0.497**	-0.726***	-0.627	-0.373**
	(0.189)	(0.189)	(0.190)	(0.200)	(0.259)	(0.388)	(0.179)
$Export_t \times \ln y_{t-2}$	0.413**	0.355*	0.365*	0.304	0.510**	0.366	0.189
	(0.186)	(0.185)	(0.187)	(0.195)	(0.249)	(0.376)	(0.183)
$Export_t \times TRI$	3.045*						
	(1.842)						
$Export_t \times DistCap$		0.288**					
		(0.117)					
$Export_t \times DistPCA$			7.441***	9.418***			10.451***
			(2.803)	(3.128)			(3.045)
$Export_t \times CCP\ Member$				-0.166***	-0.272***	-0.052*	-0.141***
				(0.036)	(0.050)	(0.029)	(0.038)
$Export_t \times$ Per Capita Steel Output							-0.001
							(0.001)
$Export_t \times$ Late Liberation							0.135
							(0.136)
$Export_t \times$ Anti-Rightest Movement Intensity							8.047*
							(4.315)
GLF$\times \ln y_t$	-16.714***	-16.462***	-16.723***	-15.999***	-11.687***	-24.857***	-16.663***
	(3.931)	(3.897)	(3.924)	(3.933)	(3.543)	(8.586)	(4.006)
GLF$\times \ln y_{t-2}$	22.885***	22.634***	22.829***	22.188***	17.591***	31.840***	23.285***
	(4.443)	(4.412)	(4.434)	(4.348)	(3.848)	(9.107)	(4.472)
Non-GLF$\times \ln y_t$	6.194***	5.998***	6.012***	6.195***	7.130***	3.279	5.964***
	(1.402)	(1.396)	(1.402)	(1.437)	(1.863)	(2.555)	(1.364)
Non-GLF$\times \ln y_{t-2}$	1.333	1.483	1.430	1.694	1.741	2.871	2.011*
	(1.161)	(1.172)	(1.166)	(1.208)	(1.532)	(2.132)	(1.190)
Province×Year	Y	Y	Y	Y	Y	Y	Y
County	Y	Y	Y	Y	Y	Y	Y
Control function	Y	Y	Y	Y	Y	Y	Y
N	12,260	12,260	12,260	10,485	5,334	5,151	10,485
R^2	0.647	0.647	0.647	0.654	0.731	0.633	0.655

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

Table 8: Counterfactural Exercises Based on Semi-parametric Regressions

Panel A: Change in Deaths	$\Delta DeathRate$ mean	std	implied number of excess deaths	% of actual excess deaths
(A1) From Data: $DeathRate_{60} - DeathRate_{58}$	14.37	22.97	4,091,420	100
Approach 1: Based on the Non-Parametric Function				
(A2) Caloric consumption in 1959 same as in 1957	13.55	16.69	3,824,507	93.48
(A3) Output in 1959 same as in 1957	5.89	12.92	1,867,595	45.65
(A3.a) Land inputs in 1959 same as in 1957 (#)	4.82	8.65	1,288,971	37.18
(A3.b) No weather shocks in 1959	0.89	5.14	407,408	9.96
(A4) Procurement rate in 1959 same as in 1957	9.30	11.11	2,452,516	59.94
(A5.a) Export exposure in 1959 same as in 1957	3.60	3.88	1,023,423	25.01
(A5.b) Export exposure in 1959 same as in 1957 (incl. output effects)	1.68	2.80	501,322	12.25
(A6) Procurement policies in 1959 same as in Non-GLF period	4.11	3.48	1,170,873	28.62
(A7) Procurement policies in 1957 same as in GLF period	2.52	1.50	652,073	16.43
(A8) Consumption equally distributed across the nation in 1959	4.05	17.49	1,460,952	35.71
(A9) Consumption equally distributed within provinces in 1959	3.77	15.11	1,148,330	28.07
(A10) Redistribute exports in 1959 across the nation	1.03	3.63	321,124	7.85
(A11) Redistribute exports in 1959 within the provinces	1.28	3.50	382,962	9.36
Approach 2: Based on Reduced-Form Regressions				
(A12) Output in 1959 same as in 1957	3.01	6.10	949,520	23.21
(A13.a) Export exposure in 1959 same as in 1957	2.94	2.08	781,015	19.09
(A13.b) Export exposure in 1959 same as in 1957 (incl. output effects)	2.21	1.56	585,010	14.30

Panel B: Change in Births	$\Delta BirthRate$ mean	std	implied number of lost births	% of actual lost births
(B1) From Data: $BirthRate_{58} - BirthRate_{60}$	9.53	9.87	2,758,184	100
Approach 1: Based on the Non-Parametric Function				
(B2) Caloric consumption in 1959 same as in 1957	6.61	6.41	1,822,811	65.60
(B3) Output in 1959 same as in 1957	2.51	5.07	792,511	28.52
(B3.a) Land inputs in 1959 same as in 1957 (#)	2.13	2.67	545,731	22.60
(B3.b) No weather shocks in 1959	0.35	2.08	174,717	6.29
(B4) Procurement rate in 1959 same as in 1957	4.23	3.64	1,073,901	38.65
(B5.a) Export exposure in 1959 same as in 1957	1.52	1.06	419,487	15.10
(B5.b) Export exposure in 1959 same as in 1957 (incl. output effects)	0.59	0.71	172,309	6.20
(B6) Procurement policies in 1959 same as in Non-GLF period	1.76	0.75	486,487	17.51
(B7) Procurement policies in 1957 same as in GLF period	1.46	0.56	369,959	14.18
(B8) Consumption equally distributed across the nation in 1959	0.61	6.96	337,522	12.15
(B9) Consumption equally distributed within provinces in 1959	0.76	5.80	236,811	8.52
(B10) Redistribute exports in 1959 across the nation	0.19	0.95	60,295	2.17
(B11) Redistribute exports in 1959 within the provinces	0.32	0.88	98,229	3.35
Approach 2: Based on Reduced-Form Regressions				
(B12) Output in 1959 same as in 1957	1.05	2.05	319,542	11.50
(B13) Export exposure in 1959 same as in 1957	0.72	0.51	190,632	6.86
(B13.b) Export exposure in 1959 same as in 1957 (incl. output effects)	0.47	0.33	125,020	4.50

Notes: The implied number of excess deaths is the sum of the excess deaths in the 780 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 666 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 3,466,838 (2,414,739).

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).[38] 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

We calculate the number of excess deaths and lost/postponed births during the Great Famine as follows. For each county, 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.)

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

A.2 Output and Procurement Data

A.2.1 Selection Issue

A potential concern is a self-selection bias in the counties 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.3 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.3 suggest that our data are unlikely to be subject to severe selective reporting.

A.3 Weather Data

The upper panels in Figure A.10 plot the distributions of spring and summer precipitation in the famine years (1959-61) and the distributions of their historical means (1950-59). For both seasons, the distributions in 1959 are more skewed to the right than those of the historical mean, indicating that most counties experienced more precipitation than ususal. This is in line with the reported widespread flooding in 1959.[39] In contrast, the distribution of precipitation in 1960 has a larger density at small values, particularly in the summer, which is consistent with the documented extensive drought in 1960.[40] In addition, 1961 had more precipitation in the spring and less precipitation in the summer than in regular years. The lower panels of Figure A.10 show the corresponding distributions of temperature. The famine years have warmer springs than regular years. The distributions of summer temperatures in 1959 and 1960 resemble those of the historical mean, whereas the distribution in 1961 shows larger densities at higher temperature.

[39] The Yellow River flooded eastern China in July 1959. According to the International Disaster Center, it was the third deadliest natural disaster in China's history. (See http://www.emdat.be/database) Other regions suffered from massive flooding as well. For example, floods inundated 810 thousand hectares in Guangdong in June (Ashton et al., 1984).

[40] As discussed in Ashton et al. (1984), the hardest-hit regions were Hebei, Shandong, Shanxi, and Henan Provinces, where the drought lasted for 6-7 months.

B Supplementary Results and Discussions

B.1 Residual Squares and Log Caloric Consumption

Figure A.12 shows that the squares of the estimated residuals from Model (8) decrease with consumption per capita.[41] 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.2 Robustness: Yearly Patterns in the Effects of Output Shocks

We also augment the regression model (10), allowing the elasticities of the retain rate of contemporaneous and past outputs to vary across years. The respective coefficients β_1^τ and β_2^τ map out the evolution of procurement policies over time. The regression results are reported in the left panel of Figure A.11. 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.

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 (8). To reduce the noise introduced by outliers, the observations on retained consumption below the 2.5th percentile and above the 97.5 percentile are dropped.

In equation (8), 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

[41] We use the pairwise bootstrap to construct the confidence interval in Figure 8, which provides asymptotically valid inferences under heteroskedastic errors in regression analysis.

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 (8) 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 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.6 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.[42] 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 (7) as an instrument for caloric 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 28.07 with a p-value 0.274.) 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 8 and 9.

B.5 Counterfactual Simulations Based on the Spline Regressions

In this section, we take estimates from Table A.6 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.7 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.6, respectively. For the counterfactual experiments (A2)-(A7), the estimated changes in mortality obtained from the IV approach are similar to those obtained

[42] Note that the control function is a cubic function of $\hat{\nu}_i$, which is constructed following the method given in Section 6.1.

from the control function approach. Moreover, for these cases, the estimates in both panels resemble the baseline findings in Table 8 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)

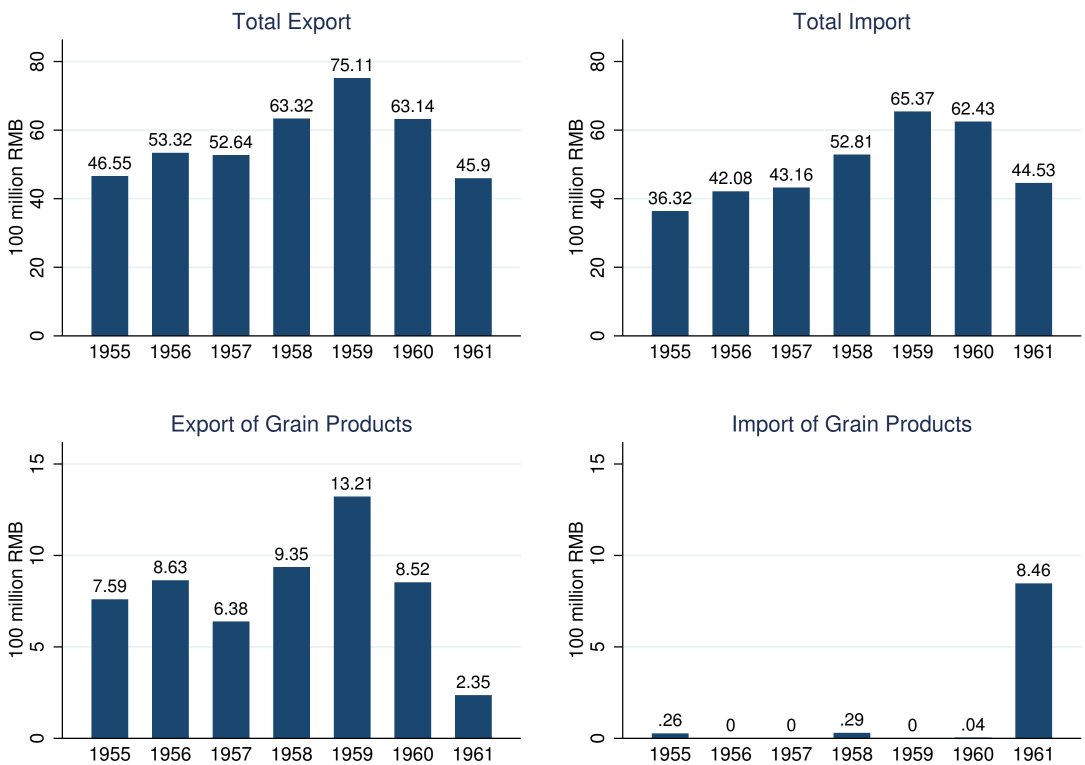
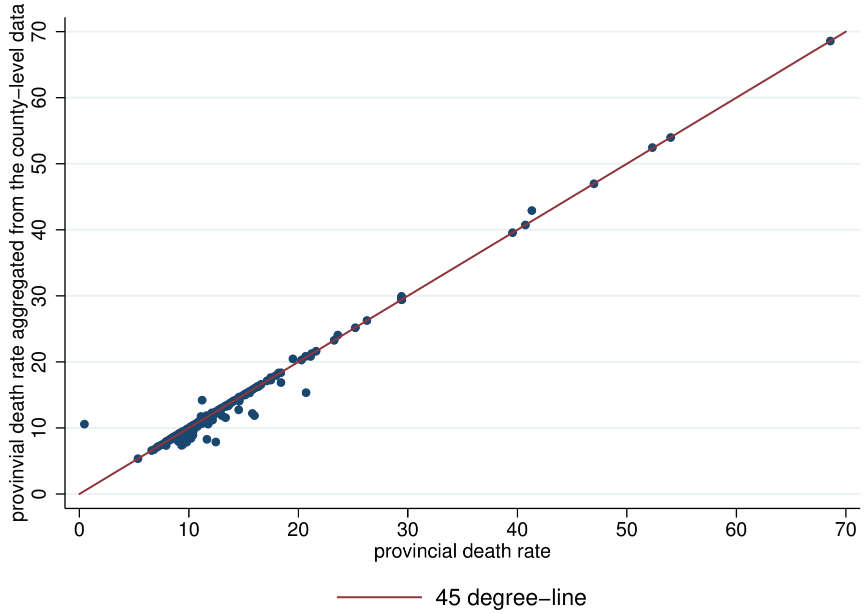


Figure A.2: Comparison of the Province-Level Death Rates from Different Sources



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

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

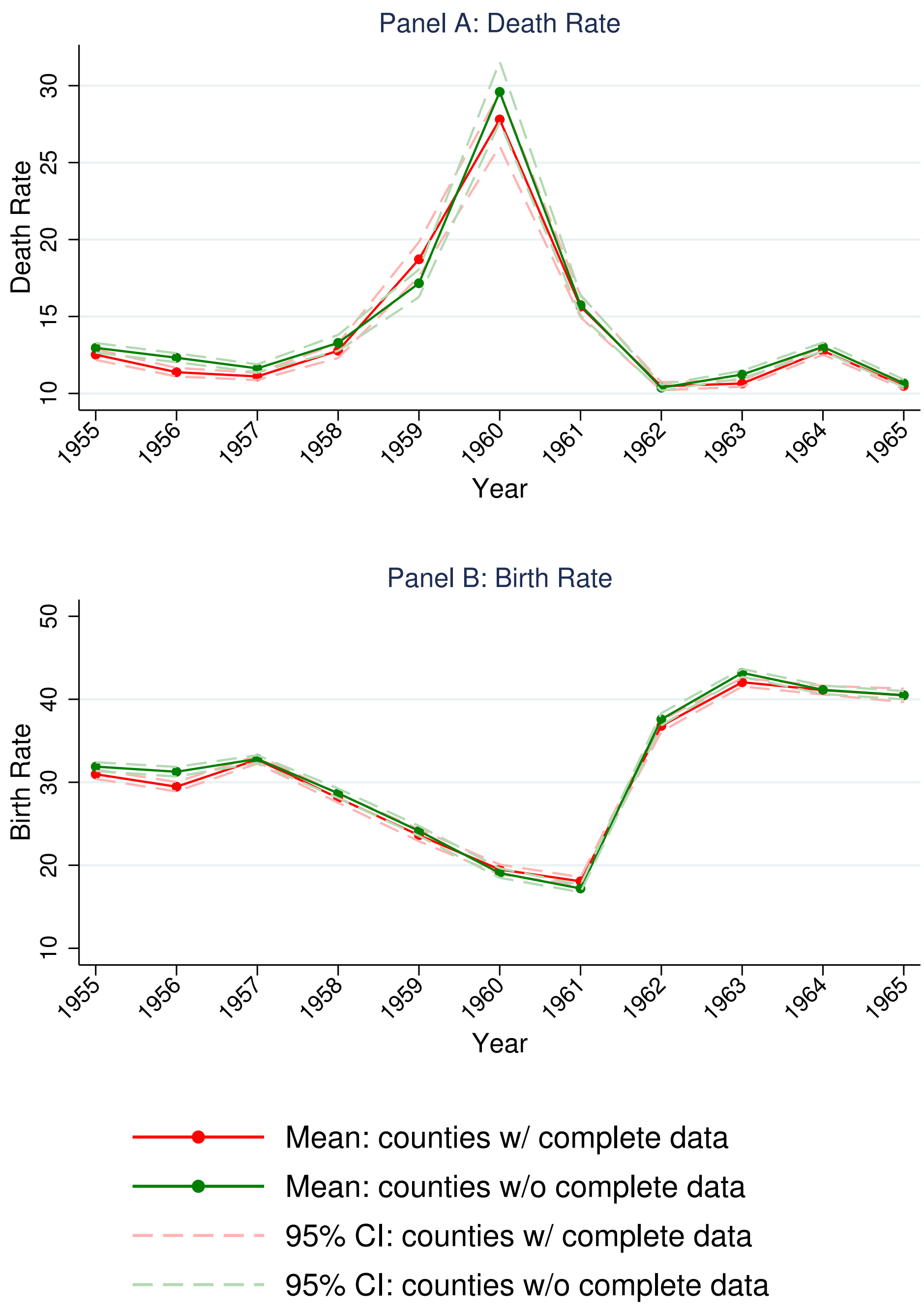


Figure A.4: Relative Price over 1955-1961

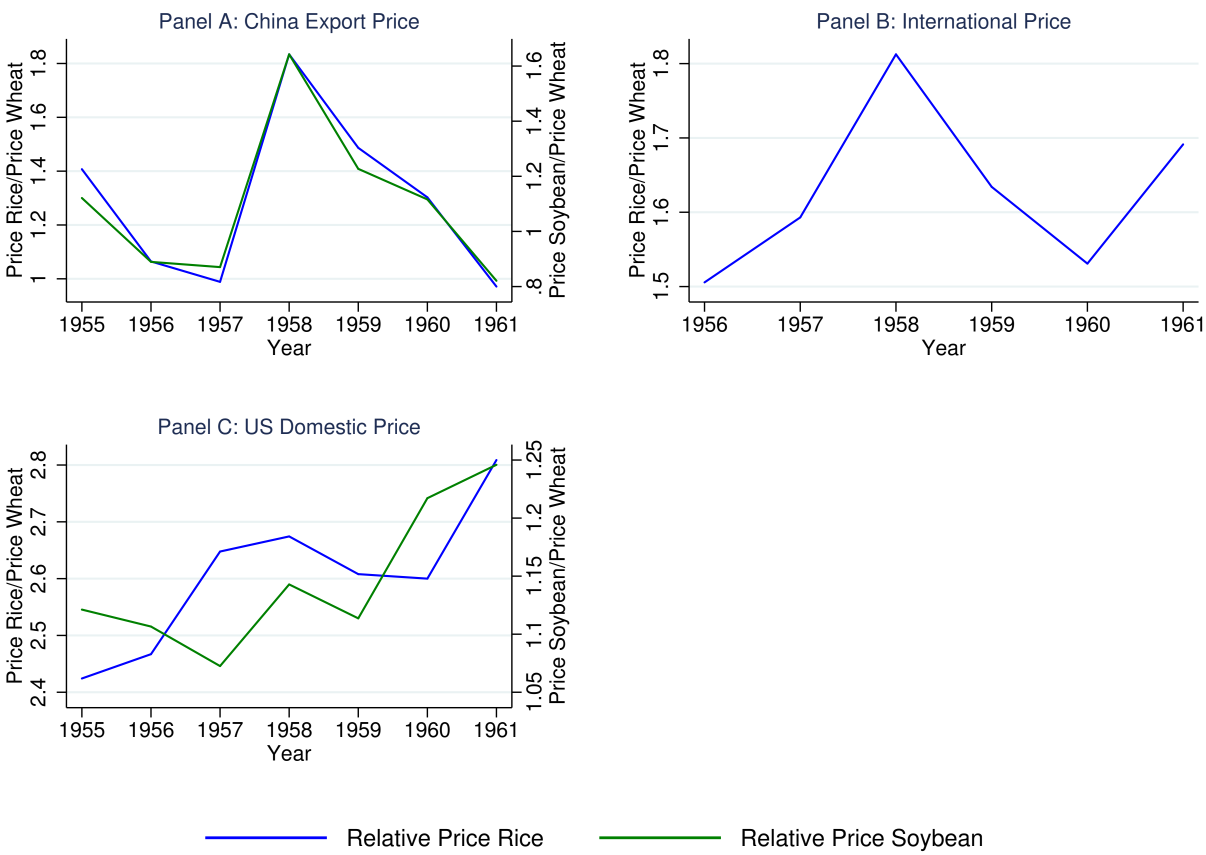


Figure A.5: Railway Network in 1957

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

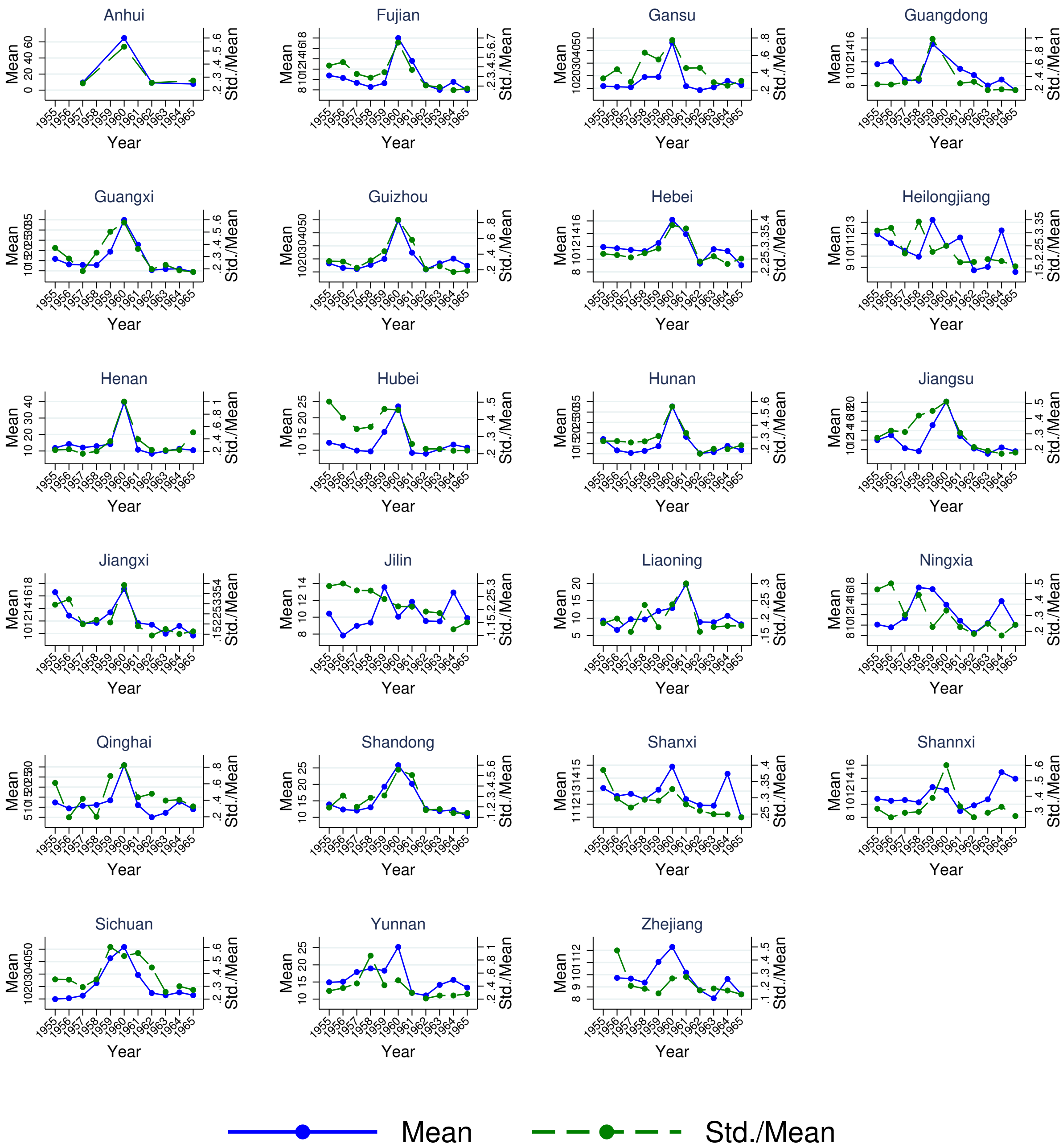


Figure A.7: Within Province Variation in Birth Rate by Year

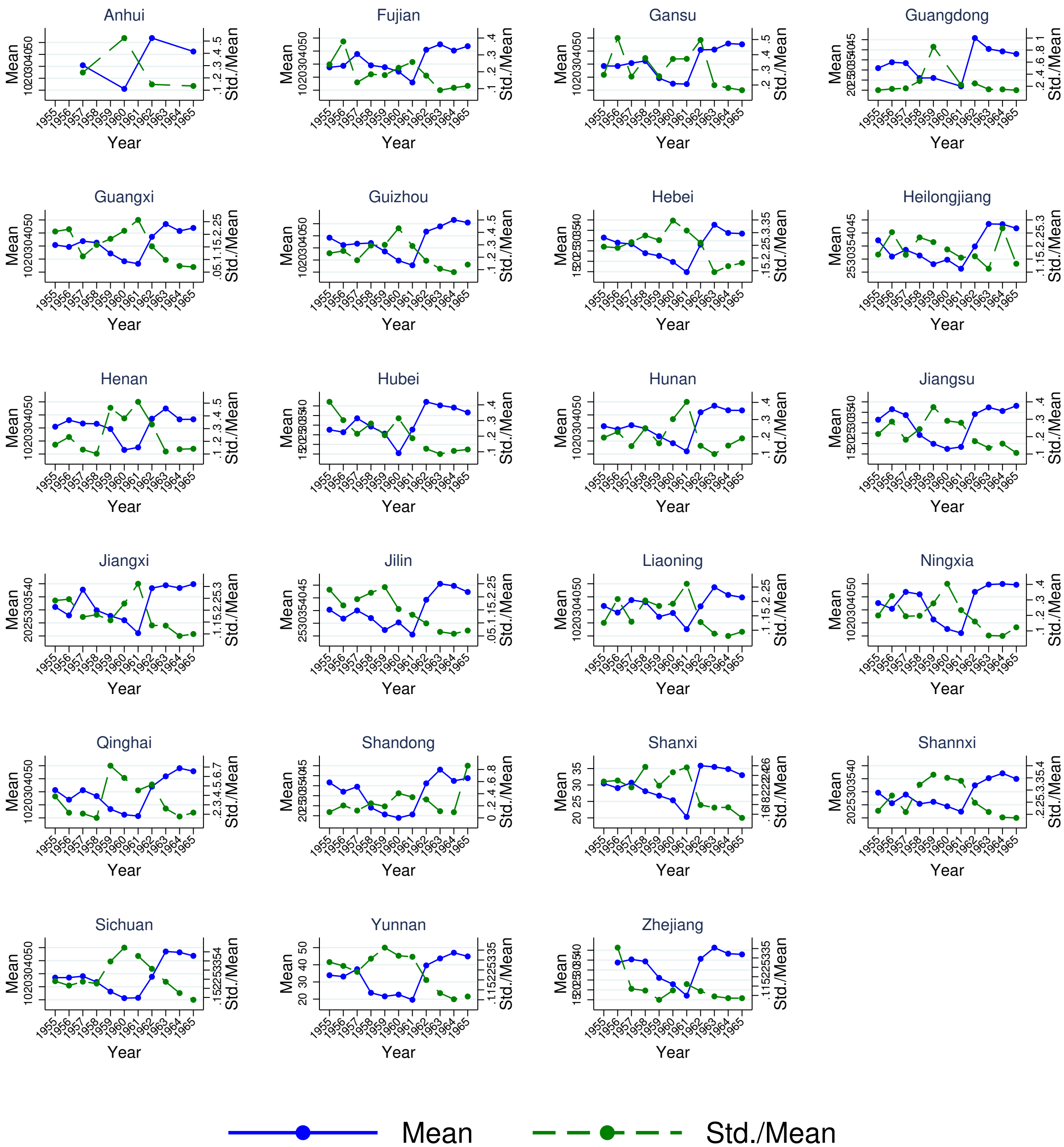
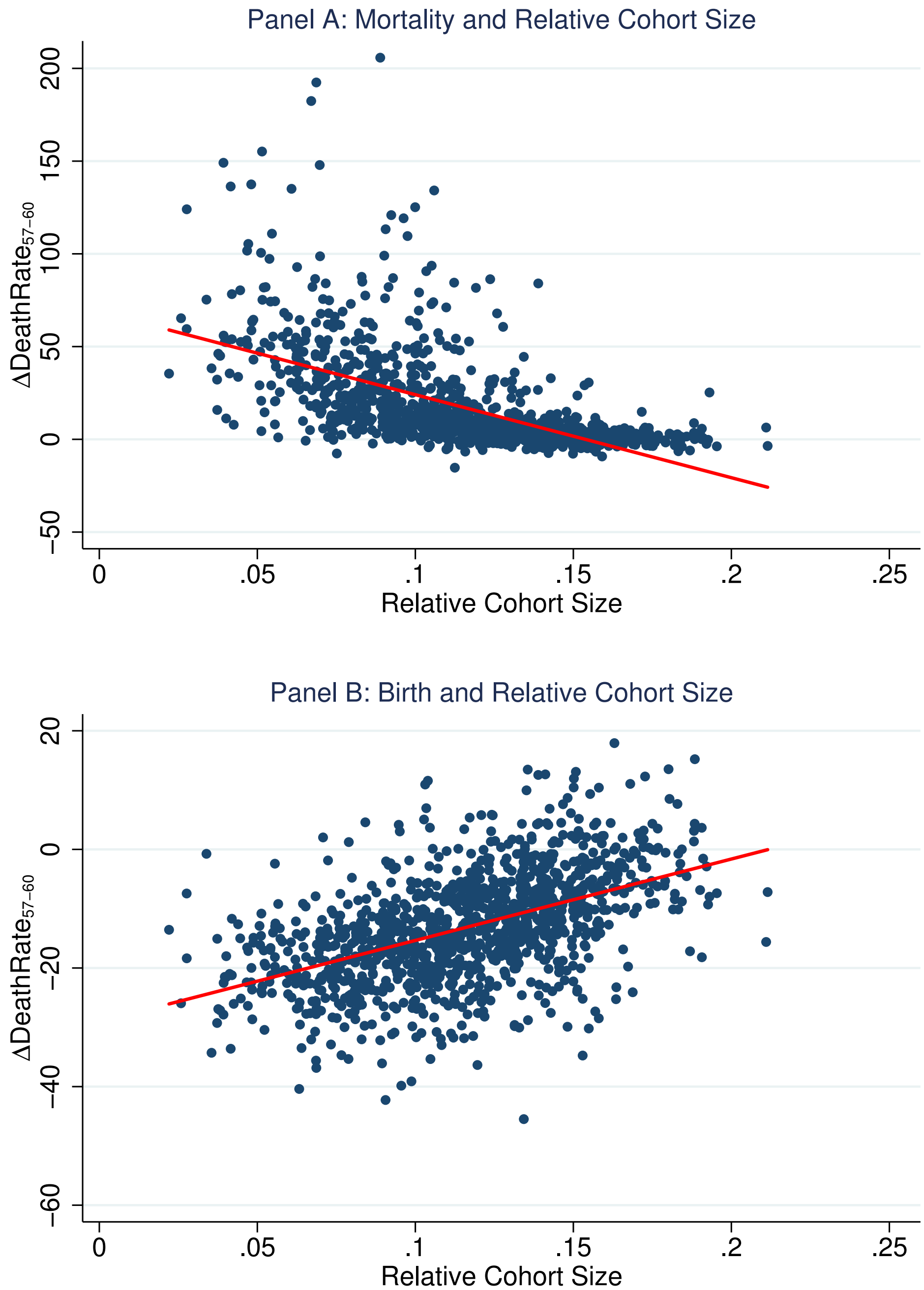
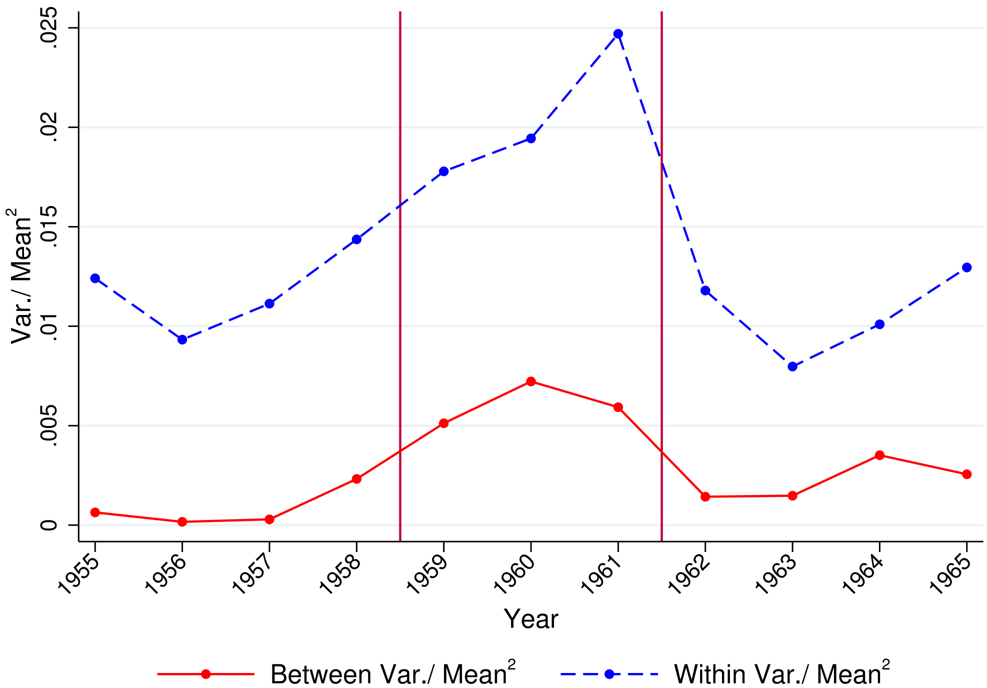


Figure A.8: Correlation of Death and Birth Rates with Relative Cohort Size



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.9: 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.10: Kernel Densities of Precipitation and Temperature in Spring and Summer: 1959-1961

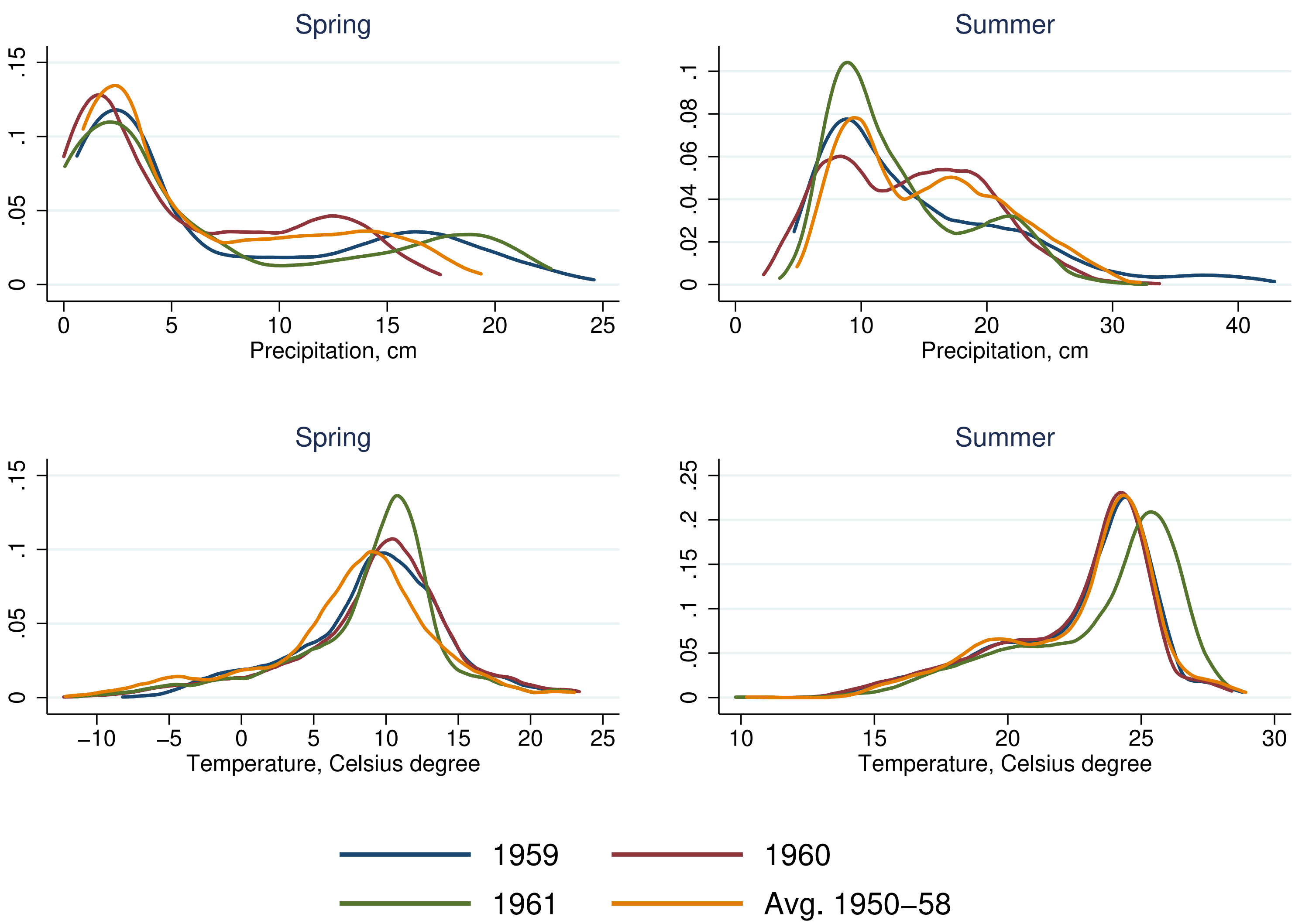


Figure A.11: Effects of Contemporaneous and Past Outputs: Estimated Coefficients and Corresponding 95% Confidence Intervals of Interaction Terms $\mathbf{1}(t \in \tau) \times \ln y_{it}$ and $\mathbf{1}(t \in \tau) \times \ln y_{it-2}$

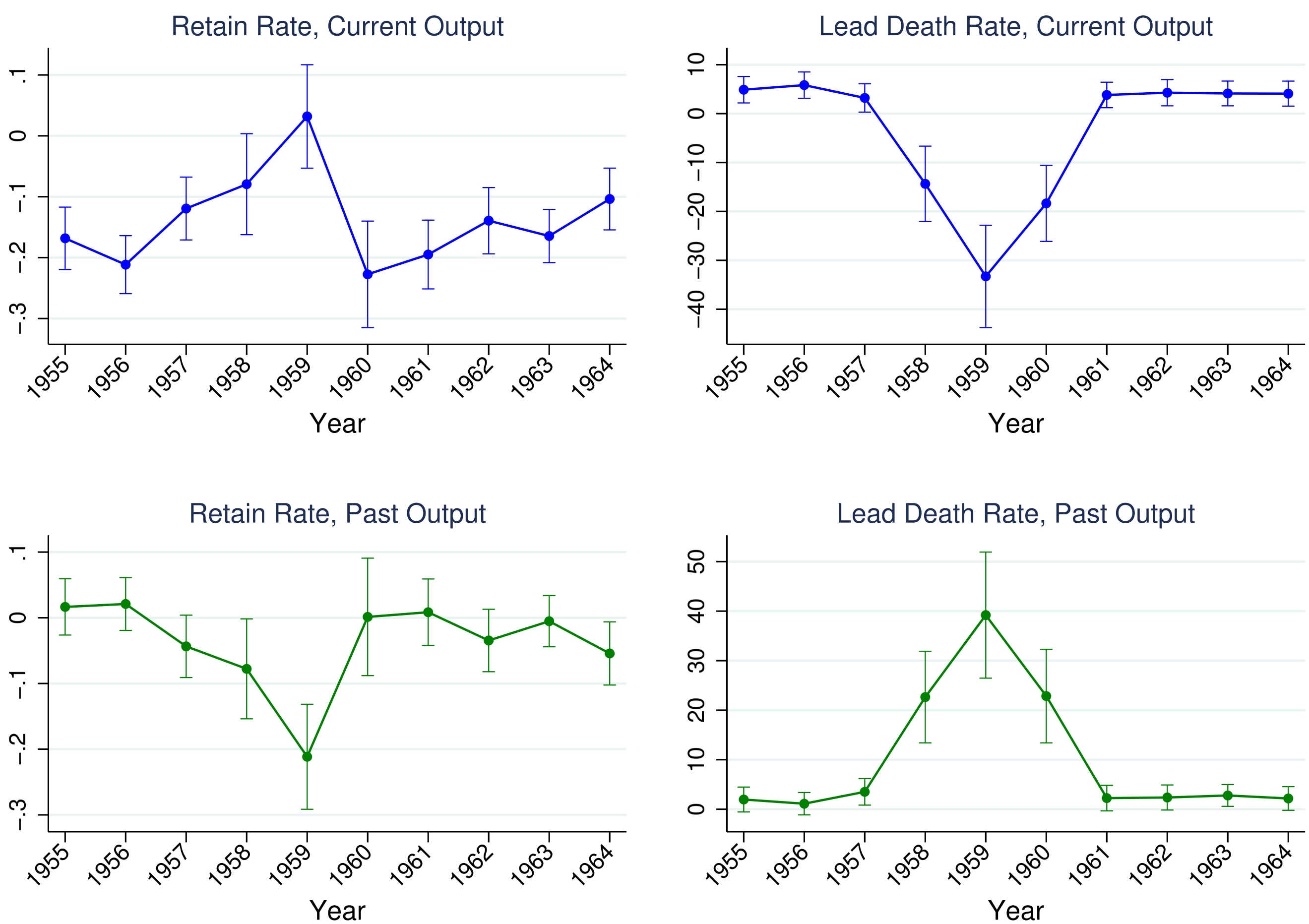
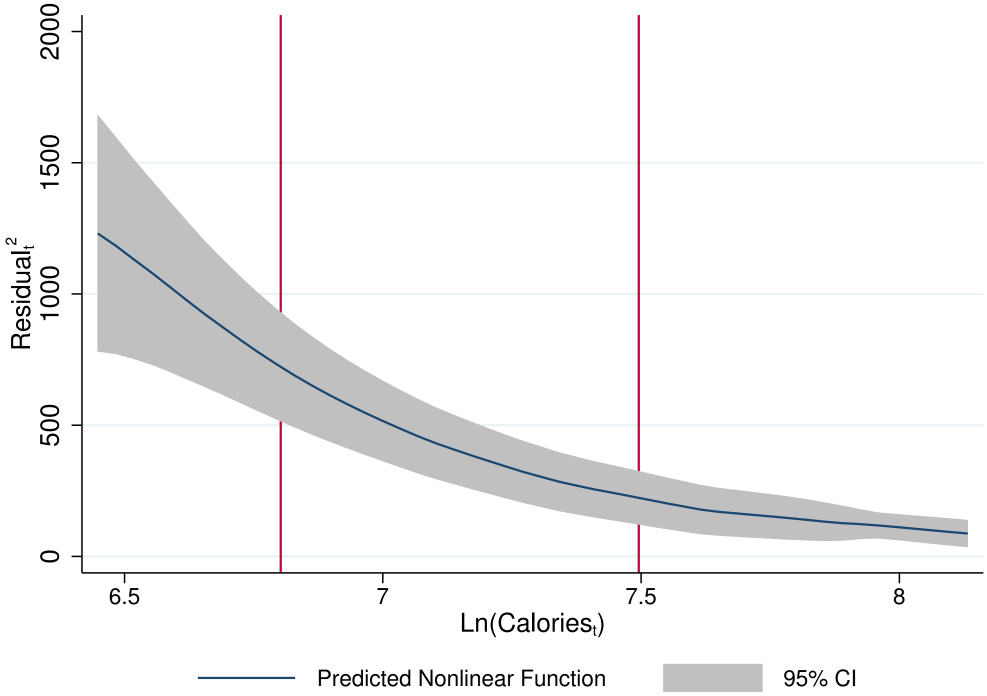


Figure A.12: Residual Squares and Log Caloric Consumption



Note: The figure shows the non-parametric relation between the squared residual of Model (8) and the county average caloric consumption.

Figure A.13: Exports in 1959 Same as in 1957

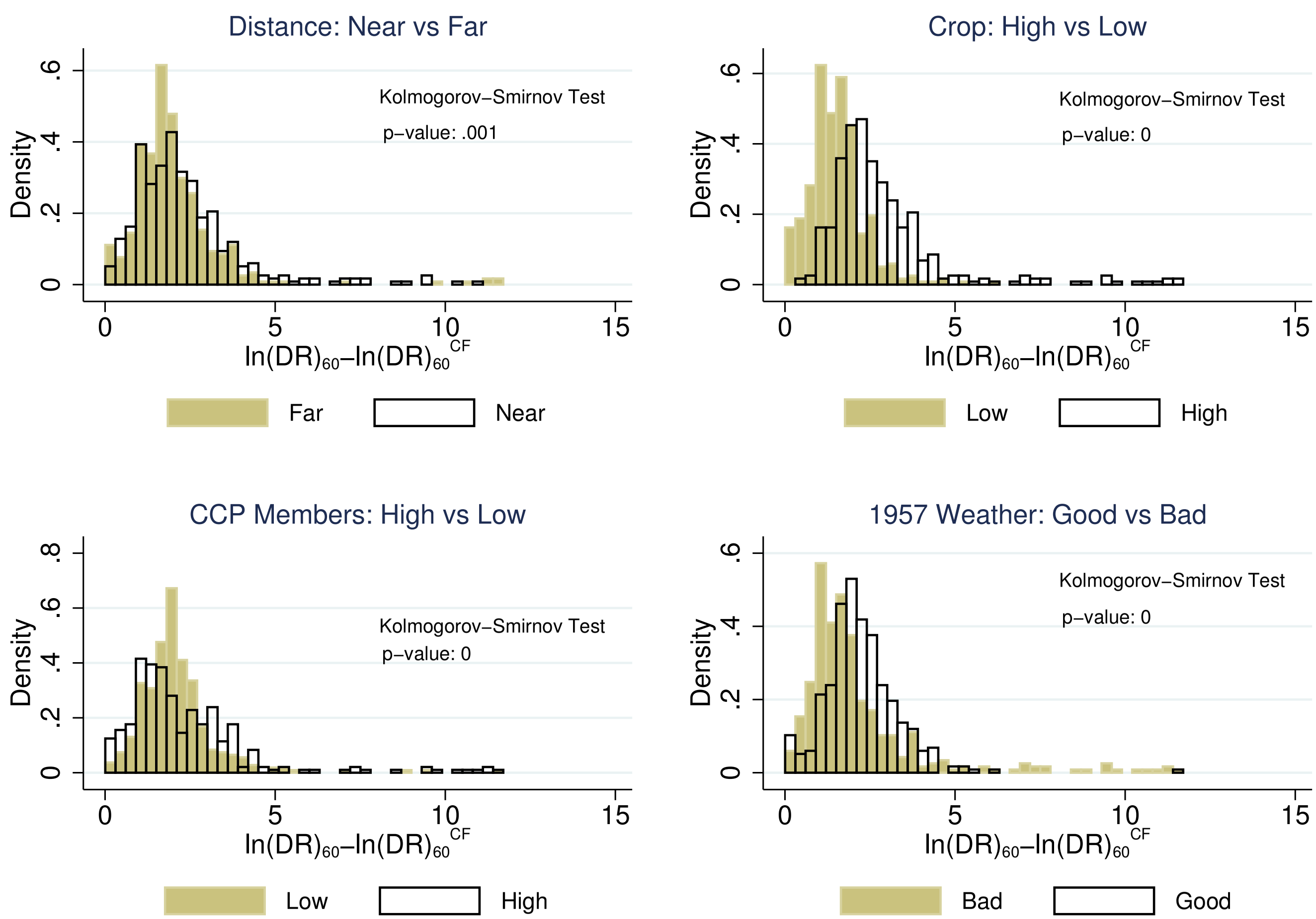


Table A.1: Data Sources for Death and Birth Rates

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 (1)	Total Lost Births (2)	Top 10 percent $\Delta DeathRate_{it,57}$: Excess Deaths (3)	Top 10 percent $\Delta DeathRate_{it,57}$: Share of Total (4)	Bottom 10 percent $\Delta BirthRate_{it,57}$: Lost Births (5)	Bottom 10 percent $\Delta BirthRate_{it,57}$: Share of Total (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 (7)	1959-61 total excess deaths as a share of: 1957 national population (8)	1959-61 total lost births as a share of: 1957 population in sample (9)	1959-61 total lost births as a share of: 1957 national population (10)
0.030	0.024	0.035	0.029

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

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

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

Note: Province codes are in the parentheses.

Table A.4: Table: Outputs Shocks, Retain Rate, Death Rate and Birth Rate – by Period

Dep. Var.:	$\ln RetainRate_t$			$DeathRate_{t+1}$			$BirthRate_{t+1}$		
	All	Near	Far	All	Near	Far	All	Near	Far
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
PreGLF$\times \ln y_t$	-0.223***	-0.274***	-0.168***	6.669***	4.762**	6.013*	1.433	2.151	2.539
	(0.027)	(0.038)	(0.041)	(1.732)	(2.076)	(3.148)	(1.588)	(2.018)	(2.743)
PreGLF$\times \ln y_{t-2}$	0.035	0.054	0.009	1.844	0.828	2.601	1.362	-0.243	3.411
	(0.023)	(0.036)	(0.029)	(1.383)	(1.308)	(2.394)	(1.316)	(1.713)	(2.275)
GLF$\times \ln y_t$	-0.060	-0.131**	-0.015	-24.024***	-14.736***	-34.512***	7.411***	2.244	16.187***
	(0.041)	(0.056)	(0.065)	(4.520)	(4.739)	(8.904)	(1.818)	(2.154)	(3.683)
GLF$\times \ln y_{t-2}$	-0.140***	-0.099*	-0.168***	31.496***	21.012***	41.480***	-4.051**	0.227	-9.944***
	(0.038)	(0.052)	(0.058)	(5.637)	(6.345)	(9.757)	(1.914)	(2.333)	(3.682)
PostGLF$\times \ln y_t$	-0.136***	-0.161***	-0.099***	3.999***	2.423	3.680	10.968***	8.996***	14.465***
	(0.024)	(0.035)	(0.033)	(1.295)	(1.594)	(2.385)	(1.234)	(1.601)	(2.042)
PostGLF$\times \ln y_{t-2}$	-0.051**	-0.052	-0.064*	3.747***	2.894**	3.672	-7.051***	-5.390***	-8.062***
	(0.023)	(0.032)	(0.037)	(1.297)	(1.331)	(2.481)	(1.271)	(1.533)	(2.214)
Province$\times$Year	Y	Y	Y	Y	Y	Y	Y	Y	Y
County	Y	Y	Y	Y	Y	Y	Y	Y	Y
Control function	Y	Y	Y	Y	Y	Y	Y	Y	Y
N	10,065	5,202	4,863	12,260	6,379	5,881	12,274	6,380	5,894
R^2	0.797	0.810	0.791	0.641	0.691	0.646	0.799	0.804	0.806

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

Table A.5: Heterogeneous Effects of Export Exposure on Death Rate: Alternative Measures of Distance

	All	All	All	All	Near	Far	All
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: Dependent Variable $\ln RetainRate_t$							
$Export_t$	-0.017***	-0.017***	-0.016***	-0.020***	-0.010	-0.031***	-0.021***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.010)	(0.008)	(0.007)
$Export_t \times \ln y_t$	0.003*	0.004*	0.004*	0.004*	0.001	0.007*	0.004*
	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.004)	(0.002)
$Export_t \times \ln y_{t-2}$	-0.001	-0.002	-0.001	-0.001	-0.001	-0.002	-0.001
	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.004)	(0.002)
$Export_t \times TRI$	0.031*						
	(0.018)						
$Export_t \times DistCap$		0.003*					
		(0.002)					
$Export_t \times DistPCA$			0.061**	0.042			0.045
			(0.026)	(0.028)			(0.028)
$Export_t \times CCP\ Member$				0.001***	0.002**	0.000	0.001**
				(0.000)	(0.001)	(0.000)	(0.000)
$Export_t \times$ Per Capita Steel Output							-0.000
							(0.000)
$Export_t \times$ Late Liberation							0.002
							(0.002)
$Export_t \times$ Anti-Rightest Movement Intensity							-0.026
							(0.033)
GLF$\times \ln y_t$	-0.095**	-0.096**	-0.097**	-0.093*	-0.117*	0.053	-0.104**
	(0.046)	(0.046)	(0.046)	(0.049)	(0.062)	(0.090)	(0.050)
GLF$\times \ln y_{t-2}$	-0.095**	-0.093**	-0.093**	-0.108**	-0.124*	-0.187**	-0.103**
	(0.047)	(0.047)	(0.047)	(0.050)	(0.066)	(0.093)	(0.051)
Non-GLF$\times \ln y_t$	-0.172***	-0.174***	-0.174***	-0.180***	-0.242***	-0.050	-0.183***
	(0.022)	(0.022)	(0.022)	(0.024)	(0.030)	(0.040)	(0.024)
Non-GLF$\times \ln y_{t-2}$	-0.001	0.001	-0.000	-0.000	-0.000	-0.008	0.002
	(0.021)	(0.021)	(0.021)	(0.022)	(0.031)	(0.036)	(0.022)
N	10,065	10,065	10,065	8,662	4,485	4,177	8,662
R^2	0.798	0.798	0.798	0.795	0.812	0.796	0.795

Table A.5 (Cont.): Heterogeneous Effects of Export Exposure on Death Rate: Alternative Measures of Distance

	All	All	All	All	Near	Far	All
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel B: Dependent Variable $BirthRate_{t+1}$							
$Export_t$	-0.602***	-0.613***	-0.622***	-0.739***	-0.739**	-0.682**	-0.336
	(0.198)	(0.196)	(0.196)	(0.216)	(0.299)	(0.313)	(0.235)
$Export_t \times \ln y_t$	0.016	0.009	0.003	0.006	0.084	-0.105	-0.088
	(0.058)	(0.059)	(0.059)	(0.063)	(0.070)	(0.150)	(0.065)
$Export_t \times \ln y_{t-2}$	0.076	0.085	0.088	0.090	0.011	0.202	0.163**
	(0.067)	(0.068)	(0.067)	(0.073)	(0.084)	(0.162)	(0.073)
$Export_t \times TRI$	-0.892						
	(0.657)						
$Export_t \times DistCap$		-0.036					
		(0.049)					
$Export_t \times DistPCA$			-1.754*	-2.861***			-3.454***
			(1.018)	(1.092)			(1.085)
$Export_t \times CCP\ Member$				0.038**	0.053**	0.013	0.023
				(0.016)	(0.027)	(0.018)	(0.017)
$Export_t \times$ Per Capita Steel Output							0.001
							(0.000)
$Export_t \times$ Late Liberation							-0.149**
							(0.062)
$Export_t \times$ Anti-Rightest Movement Intensity							-2.968**
							(1.456)
GLF$\times \ln y_t$	8.015***	7.971***	8.012***	7.833***	8.753***	11.400***	8.499***
	(1.966)	(1.962)	(1.961)	(2.057)	(2.524)	(4.256)	(2.051)
GLF$\times \ln y_{t-2}$	-3.659*	-3.607*	-3.639*	-2.910	-1.877	-7.951*	-3.510
	(2.114)	(2.109)	(2.108)	(2.271)	(2.598)	(4.624)	(2.232)
Non-GLF$\times \ln y_t$	8.142***	8.192***	8.193***	8.115***	9.999***	7.118***	8.361***
	(1.174)	(1.172)	(1.173)	(1.261)	(1.649)	(2.422)	(1.256)
Non-GLF$\times \ln y_{t-2}$	-3.417***	-3.443***	-3.442***	-3.129***	-2.730*	-3.237*	-3.324***
	(1.067)	(1.067)	(1.067)	(1.134)	(1.444)	(1.896)	(1.129)
N	12,274	12,274	12,274	10,498	5,334	5,164	10,498
R^2	0.797	0.797	0.797	0.800	0.805	0.810	0.801
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	Y

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

Table A.6: Spline Regressions: Death/Birth Rate and Calorie Intake

Dep. Var.:	$DeathRate_{t+1}$				$BirthRate_{t+1}$		
	OLS	Control Function	IV	IV (Constrained)	OLS	Control Function	IV
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\ln c_t$	-31.095***	-66.637***	-126.492***	-117.076***	5.847***	20.848***	27.969***
	(6.760)	(12.345)	(36.233)	(31.107)	(1.150)	(3.353)	(8.750)
$(\ln c_t - \ln(1500))$	24.460***	40.874***	156.997***	117.076	-3.033	-2.476	-13.399
$\times \mathbf{1}(c_t > 1500)$	(9.337)	(10.590)	(57.213)	–	(1.966)	(2.571)	(16.356)
Province	Y	Y	Y	Y	Y	Y	Y
N	920	884	884	884	920	884	884
R^2	0.383	0.414	0.011	0.038	0.471	0.491	0.050

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.7: Robustness: Counterfactural Exercises

	$\Delta DeathRate$ mean	std	implied number of excess deaths	% of actual excess deaths
(A1) From Data: $DeathRate_{60} - DeathRate_{58}$	14.37	22.97	4091420	100
Panel A: Spline Regression and Control Function Approach				
(A2) Caloric consumption in 1959 same as in 1957	13.14	14.99	3,684,578	90.06
(A3) Output in 1959 same as in 1957	5.41	12.63	1,738,808	42.50
(A3.a) Agricultural Inputs in 1959 same as in 1957	4.60	6.27	1,216,286	35.08
(A3.b) No weather shocks in 1959	0.67	4.96	349,793	8.55
(A4) Procurement rate in 1959 same as in 1957	9.14	9.83	2,409,656	58.90
(A5.a) Export exposure in 1959 same as in 1957	3.40	3.14	960,157	23.47
(A5.b) Export exposure in 1959 same as in 1957 (incl. output effects)	1.50	1.89	443,567	10.84
(A6) Procurement Policies in 1959 same as in Non-GLF period	3.85	2.58	1,094,924	26.76
(A7) Procurement policies in 1957 same as in GLF period	2.34	1.54	523,167	12.79
(A8) Consumption equally distributed across the nation in 1959	5.66	16.51	1,870,731	45.72
(A9) Consumption equally distributed within provinces in 1959	2.11	16.12	720,650	17.61
(A10) Redistribute export in 1959 across the nation	0.69	2.49	206,607	5.05
(A11) Redistribute export in 1959 within the provinces	0.67	2.52	195,768	4.78
Panel B: Spline Regression and Constrained IV Approach				
(A2) Caloric consumption in 1959 same as in 1957	12.70	22.75	3,697,212	90.36
(A3) Output in 1959 same as in 1957	6.26	19.76	2,060,925	50.37
(A3.a) Agricultural Inputs in 1959 same as in 1957	5.32	10.90	1,488,433	42.93
(A3.b) No weather shocks in 1959	0.51	7.89	318,123	7.78
(A4) Procurement rate in 1959 same as in 1957	10.44	17.63	2,942,846	71.93
(A5.a) Export exposure in 1959 same as in 1957	4.13	6.19	1,219,787	29.81
(A5.b) Export exposure in 1959 same as in 1957 (incl. output effects)	2.24	3.39	670,508	16.39
(A6) Procurement policies in 1959 same as in Non-GLF period	4.54	5.84	1,358,493	33.20
(A7) Procurement policies in 1957 same as in GLF period	0.95	3.18	320,922	7.84
(A8) Consumption equally distributed across the nation in 1959	14.57	23.27	4,267,540	104.30
(A9) Consumption equally distributed within provinces in 1959	3.89	26.26	1,358,569	33.21
(A10) Redistribute exports in 1959 across the nation	1.45	4.17	418,913	10.24
(A11) Redistribute exports in 1959 within the provinces	1.29	4.30	372,288	9.10

Notes: The implied number of excess deaths is the sum of the excess deaths in 780 counties with data on caloric consumption for both 1957 and 1959. In rows (A3.a) the change in excess mortality (lost births) due to counterfactual changes in per capita sown area is calculated for 666 counties with information on caloric consumption and sown area for both 1957 and 1959. The actual number of excess deaths (lost births) in these counties was 3,466,838 (2,414,739).