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

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Abstract

This paper provides evidence that over-export of grains aggravated the severity of China's Great Famine. We collect the *county-level* information on the death rate, the birth rate, the procurement amount of grains, the output of different types of grains, crop productivity, weather condition, distance to railways, and the share of local Chinese Communist Party (CCP) members in 1953-1965. We exploit the county-level variation in the types of crops each county specialized in to construct Bartik style measures for export shocks. We regress the death rates on the Bartik export measures and use the weather shocks as instruments for output and consumption. The regression result suggests that an increase in grain exports substantially increases the death rates, where the effect of grain exports on death rates is larger for counties with lower current output, higher two-period lagged output, larger distance to railways, and smaller share of local CCP members. We also estimate the determination of procurement policy as well as 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 excess deaths, which amounts to 1/5 of the effect of increase in procurement rate 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.

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1 Introduction

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

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

What would have happened to the death rates across different regions in China in 1960 had there been no increase in export of grains so that 2.2 million tons of grains had not been procured by the government in 1959? How important is the increase in grain exports to quantitatively explain the surge in the death rates between 1957-1960 relative to other factors such as a fall in aggregate food production in 1959? What are the observable characteristics of counties that experienced food shortage due to export-driven over-procurement? To answer these questions, we collect the *county-level* information over time on the death rate, the birth rate, the procurement amount of grains, the output of different types of grains, crop productivity, weather condition, distance to railways, and the share of local Chinese Communist Party (CCP) members in 1953-1965 from various sources. Using the cross-county variation in crop compositions together with weather shocks as instrument, we estimate the differential impacts of grain exports across counties on the death rates in 1960.

The use of the newly constructed county-level data set is the major thrust of this paper because almost all existing empirical studies on the causes of Great Famine use province-level data.[1] In Figure 2, the cross-county mean of death rates sharply increases during the

[1]The exception is Bramall (2011), Meng et al. (2015), and Kung and Zhou (2017). Bramall (2011) uses county-level data on mortality, output, rainfall, and temprature, but for Sichuan province only. Meng et al.

famine period of 1959-1961; at the same time, 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)). Variance decomposition in section 4 indicates that the majority of cross-county variations on the changes in death rates from 1957 to 1959 is within province rather than across provinces. Figure 3 presents the "heat map" for geographic distribution of the death rates in China, revealing a substantial variation in death rates across different counties in both 1957 and 1960. The heat map in 1957 is, however, very different from the heat map in 1960 because the counties with low death in 1957 often experienced high death in 1960. These facts suggest the importance of investigating county-level data over time.

We take two different approaches to quantify the impact of grain exports on death rates in 1960 and its importance relative to other factors. First, we exploit the county-level variation in the types of crops each county specialized in and construct Bartik style measures for export shocks as $\sum_k \frac{Y^k_{i,57}}{Y^k_{57}} \frac{Export^k_t}{Pop_{it}}$, where the sum is taken across five different crop types (rice, soybean, wheat, potato, and others), $\frac{Y^k_{i,57}}{Y^k_{57}}$ is county i's share in output of crop k in 1957, $Export^k_t$ 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 the county-level panel data.

The estimated coefficient of this Bartik measure is significantly positive and large in magnitude, indicating the importance of an increase in grain exports to explain the variation in death rates across counties in 1960. By interacting this Bartik measure with current output, two-period lagged output, distance to railways, and the share of local CCP members, we also find that the effect of grain exports on death rates is larger for counties with lower current output, higher two-period lagged output, larger distance to railways, and smaller share 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 total excess deaths can be explained by an increase in grain exports between 1957 and 1959.

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

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

consumption during the famine period.

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

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

To investigate how the consumption shortage due to over-procurement led to higher death rates, we non-parametrically estimate the relationship between the death rates and the retained consumption per capita using the county-level data while controlling for possible measurement errors due to mis-reporting of outputs and procurement using 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 1800 calories.

Based on the estimated procurement policy and the estimated relationship between the death rate and the average level of consumption, we conduct the 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, explaining one-fifth of the effect of increase in procurement, and at least as important as the effect of weather shocks.

We further examine how the effect of grain exports on the excess deaths depends on observable county characteristics including whether the county has a comparative advantage in high-export-exposure crops, whether the county has a higher share of CCP members, or whether the county experienced good weather shocks in 1957. 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 across two groups of counties, we find that the distribution of the high-export-exposure, low-CCP-members, and good-past-weather group first-order stochastically dominates that of 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 obligation of counties in the bottom quintile of pre-export consumption per capita had been lifted and, instead, the remaining counties had been procured more to meet the aggregate export requirement, total excess deaths would have declined by 7.85%. This suggests that the effect of aggregate exports on mortality would have been much smaller if exporting crops had been procured more flexibly.

We also examine the extent to which the progressiveness and inflexibility of procurement policy during the famine period is responsible for the excess deaths by conducting the counterfactual experiment of what if the procurement policy in 1959 had been the same as the procurement policy in 1957. The result shows that the excess deaths in 1960 would have been lower by 29 percent if the procurement policy in 1959 had been the same as in 1957.[2] While the effect of increasingly progressive and inflexible procurement policy is considerable, the *change* in procurement policies alone cannot explain a large portion of the increase in excess deaths between 1958 and 1960. Similarly, conducting the counterfactual experiment of what would have happened to the death rate in 1958 if the procurement policy in 1957 had been the same as in 1959, we find that the death rate in 1958 would have been higher by 16 percent. 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 distribution of the far-from-railway, low-CCP-members, and good-past-weather group first-order stochastically dominates that of the near-to-railway, high-CCP-members, and bad-past-weather group, respectively.

Our study complements the literature on the causes of China's Great Famine in several ways. First, this paper is the first in the literature to provide empirical evidence at micro-level to show that over-export of grains is associated with the spatial pattern of famine severity. Second, this paper is also the first in the literature to attempt to quantify the relative importance of

[2]This result is largely consistent with the result of 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."

different causes using the estimated procurement policy and the estimated relationship between the death rate and the retained consumption; a fall of agriculture production, an increase in procurements partly driven by grain exports, and an increasingly progressive and inflexible procurement policy all contributed to total excess deaths; no single factor can explain all of the excess deaths. Third, unlike the previous studies that mainly rely on province-level panel data, we compile a unique dataset on famine severity, grain production and export exposure at county-level. We conduct our analysis using within-province cross-county variation in order 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 paper also links to several strands of trade literatures. 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 constraint on executive, political factors could become dominant determinants of trade flows, which lead to unintended dire consequences. Drawing on the historical setting of China, our empirical analysis complements Pascali's findings of negative gains from trade for 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 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 respond 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 paper also fits in the rapidly growing literature that employs the cross-region differences in initial production specialization pattern 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 while providing the literature reviews. Section 3 describes the dataset. Section 4 presents the spatial distribution of famine severity and underlines the importance of within-province cross-county heterogeneity. Section 5 lays out the theoretical framework and empirical strategy. Section 6 provides empirical evidence that over export of grains during famine years aggravated famine severity and that procurement policies became more rigid during the GLF period. Section 7 presents counterfactual experiments. 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 Chinese agriculture from fragmented household farming into large-scale mechanized production. The initial phase of collectivization (1952-1957) was cautious and smoothed. The production unit was in the form of elementary or advanced cooperative, and usually consisted of 20 to 200 households. Peasants joined the various forms of cooperatives on a voluntary basis and retained the right of withdrawal. Production was planned and organized at the level of cooperative and a household's income depended on their inputs of land, capital goods and labor. In the period 1952-1957, agricultural output grew continuously at an average annual rate of 4.6%. (Lin, 1990; Li and Yang, 2005)

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

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

2.2 The 1959-1961 Great Famine

The Great Famine over 1959-1961 resulted in 16.5 to 30 million excess deaths and 30 to 33 million lost or postponed births.[3] According the official statistics, the national death rate jumped from 11.98 per thousand in 1958 to 25.43 per thousand in 1960 when the famine was most severe. In the meanwhile, birth rate dropped from 29.22 to 20.86 per thousand. Although the famine is a nationwide calamity, there existed considerable differences in famine exposures across regions. For example, while Jiangsu province had an rise in death rate from 9.4 to 18.4 per thousand from 1958 to 1960, its neighbor Anhui province experienced a dramatic increase in death rate from 12.3 to 68.6 per thousand. Moreover, the famine was largely restricted to the rural sector for two reasons. First, the central government gave high priority to urban grain supplies, and hence urban food rations were seldom below the subsistence level. Second, stringent controls over rural-urban migration and even rural-rural migration prohibited starving people from fleeing famine stricken regions. (Lin and Yang, 2000; Meng et al., 2015)

The extant literature on China's Great Famine debate on the primary cause that leads to the nationwide calamity. The first strand of causes are the factors that explained the sudden decline in food-availability. They include factors attributing to the plunge in agricultural output, e.g., a succession of natural disasters (Yao, 1999), forced commualization and removal of exit right (Lin, 1990), diversion of resources from agricultural to heavy industry due to the GLF (Li and Yang, 2005), and also factors causing the waste of food, e.g., consumption inefficiency in commune mess halls (Chang and Wen, 1998; Yang and Su, 1998). The second list of causes focus on the factors resulting in entitlement failures, which include over-procurement of grains from rural sector because of urban-biased food policy (Lin and Yang, 2000), information distortion inside the government system (Fan, Xiong and Zhou, 2016), and the rigid and progressive procurement policy that caused over-procurement of grains from regions that suffered larger negative productivity shock (Meng et al., 2015). The literature also point out the macro

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

implications of the surge in net grain export in the period 1958-1960. (Ashton et al., 1984; Johnson, 1998)

For a massive and widespread famine like the one in China during 1959-1961, there could be a complicated set of factors that interacted and reinforced each other and culminated in a demographic catastrophe. The famine ended in 1962 together with the modification of policies and institutions along multiple dimensions. Extreme policies from the GLF were abandoned. The central government substantially increased grain imports, and transferred a large amount of grains to the rural sector. Rural institutions were altered and resembled those in the pre-GLF years: the role of communes was diminished and production was managed by the elementary or advanced cooperatives; compensation scheme for effort was restored and communal kitchens were abolished; grain procurement rate was reduced and rural trade fairs were reopened. Nevertheless, the grain output in 1962 remained 18.2% lower than the level in 1957, and the pre-famine grain production level was not regained until 1966 (Lin, 1990; Meng et al., 2015).

2.3 The Role of International Trade

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

The upper panel of Figure A.1 shows the trade flows between China and the rest of the world. Both export and import increased up to 1959 and China always maintained a trade surplus. The lower panel presents China's exports and imports of grain products.[4] Export of grain products comprised 12.1%-17.6% of the total export over the period of 1955 to 1960. China barely imported grain products until 1961. Moreover, grain exports climbed to its historical height during the onset of famine. The net export of grain products increased from 0.64 billion RMB (1.92 milliion tons) in 1957 to 0.91 billion RMB (2.62 million tons) in 1958, to 1.32 billion RMB (4.05 million tons) in 1959, and to 0.84 billion RMB (2.77 million tons) in 1960. In 1961, China switched from a net exporter to a net importer of grains with net imports amounting to 0.62 billion RMB (4.4 million tons). Over the period 1962 to 1966, China remained as a grain

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

net importer of grain products (Lin and Yang, 2000).

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

Net grain exports over the period of 1958 to 1960 totaled around 9.6 million tons. Meng et al. (2015) estimate that one kilogram of grains contains 3,587 calories and daily average caloric need is 804 to 1,871.[6] Combined with these estimates, the net grain exports during 1958 to 1960 translates into energy that would suffice the caloric needs of 16.7 to 38.9 million people for three years. These estimates are commensurate with the total population loss during the Great Famine. In 1961, pressured by the food deficiency, China substantially increased grain imports, resulting in a net grain imports of 4.4 million tons which provided 23.2 to 53.9 million person-year caloric needs. As is also pointed out by Ashton et al. (1984), Johnson (1998) and Riskin (1998), massive excess death could have been avoided had the government acted swiftly to stop exports and start large-scale imports of grains.

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

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

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

The increase in rice and soybean exports relative to wheat exports is also aligned with the changes in relative prices over the period. As is shown in Panel A of Figure A.4, the export price of rice was higher than that of wheat through out the period 1955-1960. The relative price surged in 1958 and remained higher than the pre-1958 level in 1959 and 1960. We also find a similar evolution of relative price of soybean to wheat. Panel B displays the export price of rice from Thailand relative to that of wheat from the US over years. This time series resembles that in Panel A, which ensures that the evolution of relative price was not a feature unique to exports from China, but rather driven by international demand and supply forces. Lastly, Panel C shows that the domestic price of rice and soybean increases relative to that of wheat over time in the US. All these findings suggest that in need of meeting the lofty industrialization targets and repaying external debts, the central government chose to expand exports of crops with increasing relative price.

3 Data

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

3.1 Demographic Data

We collected the county-level data on population, number of births and number of deaths for 23 provinces in China, which comprises around 95.4% of China's population in 1953. Death rate is constructed as the ratio of number of deaths to population and converted to per mil value (i.e., deaths per thousand). Birth rate is constructed in a similar way. There were 28 province-level divisions in China during the period of 1950s and 1960s. (The present day provinces Hainan and Chongqing used to belong to provinces Guangdong and Sichuan, respectively. The present day province-level municipality Tianjin belonged to province Hebei.) We exclude two province-level municipalities, Beijing and Shanghai, where there were few rural counties, and three autonomous regions, Inner Mongolia, Tibet and Xinjiang, where people faced different economic policies due to historical and political reasons.[7]

The data are mainly collected from population statistical books published by provincial Statistics Bureaus in the 1980s. The sample is restricted to rural counties. For most provinces, the sample period spans from 1955 to 1965. (For population, we collected data back to 1953.) The number of rural counties varies from 16 in Ningxia province (the smallest province in terms

[7]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.

of both population and area) to 185 in Sichuan (the largest province in terms of both population and area). In total, there are 1803 *rural* counties in our sample. More details about the data sources are listed in Table A.1.[8]

To the best of our knowledge, our paper is the first to compile and use the county-level information on mortality and fertility to study China's Great Famine. In Appendix A.1.1, we show that when aggregating up to the province level, the mortality rates align with the province-level data employed by the existing studies. As is reported in Table 1, the cross-county average death rate was 20.59 (per thousand) in the famine years, which is 8.8 higher than that of the non-famine years. Meanwhile, the average birth rate dropped 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 loss/postponed births in our sample counties during the period of 1959 to 1961. In addition, as is shown in Appendix A.1.2, the famine had a pattern of high concentration in mortality, with the top 10th percentile of counties accounted for 52% of the total excess deaths.

3.2 Procurement and Output Data

We compile a county-level panel data on grain procurement, sown area and output from various sources. The majority of the data is from numerous volumes of the county-level Local Chronicles (county gazetteers).[9] We supplement this data with information collected from various statistical books published by provincial Statistics Bureaus and output data from Ministry of Agriculture of China (MOA)[10]. Similar to our demographic data, the sample is restricted to rural counties and covers the period of 1953 to 1965. The details about data sources are provided in Table A.3. The unbalanced panel covers 1677 counties for output, 1348 counties for sown area and 1405 counties for procurement. Appendix A.2.1 shows that the reporting status

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

[9]Local Chronicles contain historical and current materials on nature, society, economy, culture and politics in a locality. After the upheaval of the Cultural Revolution, Chinese government continued the age-old tradition of the compilation of local gazetteers. A volume of Local Chronicles were published in the early 1990s, recording the dramatic social changes that had occurred between the Republic Era (the 1920s) and the late 1980s. The materials and data in Local Chronicles are sourced from official archives and raw materials from the local communities. More details about Local Chronicles are described in Xue (2010). This archival data has been used in recent studies. For example, Chen, Li and Meng (2013) collect data on the year in which ultrasound machines were introduced in different counties. Almond, Li and Zhang (2013) collect data on the timing of land reform and grain outputs across counties.

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

is uncorrelated with the famine severity. It alleviates the concern that counties self-selected into reporting 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 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.

One may worry that the output and procurement data during the GLF period may not be fully reliable. The sources of data employed in our study may help alleviate the concern due to the following reasons. First, as is discussed in Ashton et al. (1984) and Meng et al. (2015), the data released in the post-Mao reform era have been carefully corrected to address potential reporting errors from Mao-years. Second, because the purpose of compiling county chronicles is to accurately record local history rather than to report to the upper level government, local historians responsible for data collection and compilation have relatively little incentive to manipulate the data (Almond, Li and Zhang, 2013). Despite of all these considerations, we will use data on weather shocks to strip out any potential measurement errors in the output data.

3.3 Data on Regional Agricultural Production

Our empirical analysis also requires the county-level data on crop specialization pattern. To obtain these variables, we use the recently declassified data from *County Statistics on Cultivated Area and Output of Different Crops (1957)*, which is published by the Chinese Ministry of Agriculture.[11] These data reflect the agriculture production across Chinese counties before the GLF and was made available to public only recently. Therefore we consider that it is less likely to have been misreported by the famine-era government.

3.4 Weather Data

The historical weather data are taken from *Terrestrial Air Temperature and Precipitation: Monthly and Annual Time Series (1950-1996), Version 1.01*, which provides monthly averages of temperature and precipitation at 0.5×0.5 degree grid level (approximately 56 km$\times$56 km at the equator).[12] The grid-level estimates are interpolated from an average of 20 weather stations, with correction for elevation. The grid data are mapped to counties. Specifically, for each county-year-month observation, we calculate the average temperature and precipitation using the data of grids that overlap with the county territory. Then, for each county-year observation, we construct variables of average temperature and precipitation in spring (February, March and April) and in summer (May, June and July).

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

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

3.5 Other Data

The data on productivity of cultivating different crops are from the Food and Agriculture Organization (FAO)'s *Global Agro-Ecological Zones (GAEZ) V3.0* database, which provides high resolution information on potential yields of different crops under various technologies at 5×5 arc-minute grid level (approximately 9.25 km×9.25 km at the equator). The potential yields are estimated using agronomic models and based on climate conditions, soil type, elevation and topography. Unlike directly observed yields, the potential yields at a given location are a function of local biophysical conditions, and hence they are plausibly exogenous to other economic activities. We construct the potential yields of rice, soybean, wheat, potato and other main staple crops at county-level, by computing the average potential yields of grids that fall within the county boundary.[13]

The map of historical railroad network in 1957 China is obtained from the US Central Intelligence Agency (CIA). We digitize the scanned map as displayed in Figure A.5. Rail transport was the dominant mode of freight transport in the famine era. According to National Bureau of Statistics China, rail transport comprised more than 75% of the total freight transport during 1958 to 1961.[14] Moreover, because of the weight of grains, their transport could largely rely on railroad (Donaldson , 2016). We also view the distance to railways as a proxy for the extent of information frictions, since collecting information on realized outputs and famine severity was more costly in the remote regions.

We also collect the county-level data on the number of local Chinese Communist Party (CCP) members in 1956 from various volumes of Local Chronicles.[15] The data covers 1450 rural counties. Table 1 shows that the average share of population with CPC membership was 1.57 percentage point in the pre-GLF period. The organizational presence of the party also displayed a 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 mortality rate and its coefficient of variation (cv). We find that, accompanied with the surge in death rate, the variation also increased substantially during the famine period. Panel B corresponds to the time series for birth rate, and finds that the cross county variation in birth rate peaked in the famine period in

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

[14]Data is from *60 Years of New China Statistical Book*

[15]We use the 1957 data for a few counties with missing information for year 1956.

contrast with the dip of the average. The findings suggest there existed considerable variation in famine severity across China. Figures A.6 and A.7 in the Appendix repeat Figure 2 for each province. For most provinces, mortality rate increased (birth rate declined) in the famine period while its variation rises.

Figure 3 shows the 1957 and 1960 mortality rate for rural counties in our sample. Counties are outlined in grey lines and provinces are outlined in black lines. There exist considerable differences in spatial distributions between non-famine and famine years. More importantly, the cross-county variation in famine severity is substantial, even within a province.

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

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

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

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

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

5 Theoretical Framework and Empirical Strategy

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

5.1 Procurement Policies, Retain Rate and Calorie Consumption

Consider the following model of procurement. The government determines the procurement rate so that the county i will receive the consumption per capita $\bar{c}_{it}$. If the government had known the county i's output and population, then the retained rate r_{it} would have been 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 retained rate denoted by $r_{it} = \frac{Y_{it} - P_{it}}{Y_{it}} = C_{it}/Y_{it}$ represents the fraction of output retained by the county. In this case, the target consumption $\bar{c}_{it}$ equals actual consumption c_{it}.

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

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

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

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

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

Figure 6 follows the specification (1) and shows the partial regression plots of log retained rate against past output ($\ln y_{t-2}$) and current output ($\ln y_t$) for years 1957 and 1959. In both years, retained rate is negatively associated with the past output. The negative correlation is stronger in 1959, suggesting the procurement policies became more rigid. In addition, we find that the retained rate is uncorrelated with current output in 1957 and the correlation became slightly positive in 1959.

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

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

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

5.2 Outputs, Consumption, Mortality and Birth

We link the death rate in period $t+1$ to retained consumption 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 retained caloric consumption.[16] Equation (3) relaxes the linearity assumption adopted in the existing literature. As is shown in the following sections, the relation between mortality and consumption displays strong non-linearity, which has important implications when we quantify the effects of different underlying shocks.

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

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

The analysis for birth is analogous to mortality. The right panel of Figure 7 shows the partial regression plots of death rate against the output shock ($\ln y_{t-2} - \ln y_t$) for years 1957 and 1959. We find that mortality rate is positively correlated with $\ln y_{t-2} - \ln y_t$ in 1959, but the correlation is weak and insignificant for 1957. This finding provides another supportive 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:

$$\ln y^k_{it} = \theta^k_0 + \theta^k_1 \psi^k_i + \sum_\ell \theta^{k\ell}_2 z^\ell_{it} + \nu^k_{it}\ , \tag{4}$$

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

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

Due to the lack of data on output and labor input by crop, we aggregate equation (4) using different crops' output share in 1957 ($s_i^k = Y_{i,57}^k / Y_{i,57}$.) as weights and link the a county's aggregate grain output to its productivity and realized weather conditions:[17].

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

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, and we will refer it as "weather index" or "weather shock" henceforth.

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 only use the 1959 consumption data and 1960 mortality data to estimate equation (6). This is because the famine was most severe in 1960 and the caloric content of retained grain in 1959 was more likely to reflect the actual level of calorie supply than the other two years of famine.[18] To further address the potential problem of measurement

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

[18]The amount of retained grains in 1958 is likely to understate the true amount of food available in 1959, as the inventory of foods might not be completely exhausted at the start of the famine. On the other hand, the actual level of calorie supply in 1961 may not be fully reflected by the retained consumption in 1960 because

errors, we adopt the control function approach as is described below.

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

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

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 that is derived from regression (5) and $\ln \tilde{y}_{i,57}$ is the corresponding value for 1957. The vector λ_i contains productivity of cultivating different crops and the average weather conditions over 1953 and 1965.[19] We obtain the residuals $\hat{v}_i$ from equation (7) and estimate the following semiparametric model:[20]

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

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 of consumption attributable to weather shocks.

The estimated non-parametric functions $\hat{f}(\ln(c_{i,59}))$ of model (6) and model (8) are presented by the green curve and the blue curve in Figure 8, respectively. The two reference lines corresponding the two thresholds, i.e., logarithms of 900 and 1800 calories per person-day. We find that death rate decreases monotonically with caloric consumption. The gradient is steeper at the lower end and flattens out when consumption level is sufficiently high. In addition, we find that estimated function of model (8) has a steeper slope than that of model (6), which suggests that the data on caloric consumption are subject to measurement errors. The slope of estimated function remains negative even above 1800 calories per person-day. We interpret this as suggestive 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 1800 calories per person-day.[21]

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

relief plans stepped in in the last year of famine (i.e., 1961), and no detailed data on grain relief is available.

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

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

[21]Figure A.12 shows that the squares of estimated residuals in model (8) has 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.

6.2 Effects of Output Shocks

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

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

where $\ln(RetainRate)_{it}$ is the log retain rate of county i in year t; $\mathbf{1}(t \in \tau)$ is an indicator variable that equals to 1 if year t belongs to period $\tau \in \{GLF, NonGLF\}$, where GLF period covers 1958-1960 and $NonGLF$ period covers 1953-1957 and 1961-1964; the vector λ_i contains county-specific controls; γ_{pt} denotes province×year dummies that capture policy shocks at the province level.

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

In column (3), we use the control function to address the concern that the output data may be subject to measurement errors which may bias the estimates. More specifically, we extend the 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 when the past output became a significant determinant.

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

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

Table A.4 in the appendix shows the robustness of these results when years are grouped into the pre-GLF (1953-1957), GLF (1958-1960) and post-GLF (1961-1964) periods. We obtain consistent findings 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 the remote regions. For mortality, the results follow a mirror pattern as of the retain rate. One of the interesting findings is that in the post-GLF period, birth rate was negatively affected by the past output, although procurement policies was more flexible. This finding suggests that food shortage during the famine had persistent effects on health and hence adversely affected fertility in the subsequent period. Coefficients reported in Figure A.11 map out the yearly pattern of the effects of output shocks, which are also consistent with our baseline findings.

6.3 Effects of Export Shocks

To study the effect of export expansion on famine severity, we employ the cross-crop differences in export expansion and cross-county variation in crop specialization pattern. 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 while $Export^k_t$ is the national export of of crop k in period t. A concern about this measure is that $Export^k_t$ embodies the exports of a county itself ($Export^k_{it}$), which we don't observe. A county's export may be correlated with its output shocks, and hence the Bartik measure (11) may be subject to endogeneity issues. [22]

To address this problem, we employ 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:

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

where P^k_t is the export price of crop k in year t, and ϕ_k and γ_t are crop and time fixed effects. The estimated elasticity of export to price is 2.38 with p-value of 1.86. By construction, $\widehat{Export}^k_t$ captures the exogenous component of $Export^k_t$ that is driven by changes in international prices, and $Export_{it}$ in (12) measures the per capita reduction in food availability in kilogram due to export growth driven by international price changes.[23]

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

$$\begin{aligned} \ln RetainRate_{it} = {} & \alpha Export_{it} + \sum_\tau \beta^\tau_1 \mathbf{1}(t \in \tau) \times \ln y_{it} + \sum_\tau \beta^\tau_2 \mathbf{1}(t \in \tau) \times \ln y_{it-2} \\ & + g(\hat{v}_{it}) + g(\hat{v}_{it-2}) + \phi_i + \gamma_{pt} + \varepsilon_{it}, \end{aligned} \tag{13}$$

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

The baseline regression result is presented column (1) of Table 3 Panel A. We find that counties that were more exposed grain exports had lower retain rate on average. Column (2) includes the interaction terms of export exposure with current and past outputs. The coefficient of $Export_t \times \ln y_t$ is positively significant, which suggests that the adverse effect of export expansion was smaller in counties that experienced a positive contemporaneous output shock.

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

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

Column (3) further introduces the interaction term of export exposure and distance to railway. Consistent with the prior that distance to railways increases transportation costs, the estimated coefficient of $Export \times DistRail$ is positive, albeit statistically insignificant. Column (4) investigates how the organizational presence of CCP affects the effect of export shocks. The variable $CCP\ Member$ measures the share of population with CCP membership in 1956 at the county level (in percentage point). We find that the negative effect of export shock on 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 $CCP\ Member$ while the corresponding number for a county at the 5th percentile is 0.027.[24] Therefore, for procurement of exporting crops, Chinese party-state displayed systematic favoritism by extracting less resources from, or giving back more foods 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 CCP Central Committee members.

Panel B investigates the reduced-form relation between mortality and export exposure. Resonating with the findings in Panel A, a higher export exposure raised the death rate. The result is robust across various specifications and different samples. In addition, we find that a higher current output dampens the effect of export shock on death rate while a higher past output strengthens it. In columns (3) and (4), the effect of export shock on death rate is larger in the counties further away from railways or with less CCP members. The results suggest that the provincial government were able to verify food shortage more easily if counties are located closer to railways or have more CCP members and, hence, these counties received back food in the event of food shortage to avoid famine. In columns (5) and (6), the impact of positive contemporaneous output shock to mitigate the adverse effect of export growth is larger for the Far group than for the Near group. Two potential explanations for this difference are: i) it is logistically more costly to transfer the unexpected surplus products out of the remote regions, and ii) the upper level government had little knowledge of the surplus products due to more stagnant information flow in the remote regions. Furthermore, the coefficient of $Export_t \times CCPMember$ is estimated larger in magnitude for the Near Group than for the Far Group, suggesting that party membership plays 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 replaces the outcome variable by birth rate. 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.

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

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 per capita grain sown area. As is 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 acre over the period 1957 to 1959. Our estimate suggests that this reduction in agricultural input led to a decrease in grain output by 0.05 log point.

Column (2) augments the baseline model with interaction terms $GLF \times DistRail$ and $GLF \times CCP\ Memeber$. Both estimated coefficients are insignificantly different from zero, which suggest that the decline in output during the GLF period did not systematically vary by the distance to railway or the CCP presence. In column (3), we study the effect of export shock on grain output. Interestingly, a larger export exposure leads to a higher output level. One possible explanation is that more resources were allocated to grain production in counties that were obliged to procure more to export. Column (4) shows that the effect of export on output does not vary along the dimensions of distance to railways and 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 provides a consistency test of our county-level findings with the extant literature that employ the province-level data. Following Li and Yang (2005) and Meng et al. (2015), we use steel output per capita as a proxy for the GLF zealousness. 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 late "liberation" by CCP experienced a larger decline in grain output. The estimated coefficient of the interaction term is negatively significant at 10% level. Following Kung and Lin (2003) and Meng et al. (2015), column (5) also employs the intensity of the 1957 anti-rightest movement (measured by number of persons purged per million) to proxy for the political zealousness of a province. We find that the 1957 political purge has 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 replaces the outcome variable by log retained calories and follow the specifications in columns (1), (4)-(6) in Table 3. We obtain the results that 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 the railways.

Following Meng et al. (2015), in Panel B of Table 5, we use the birth cohort sizes of survivors observed in the 1990 China Population Census to proxy for famine severity at the county level. Figure A.8 correlates the change in death (birth) rate over 1957 and 1960 with the relative population size of famine cohort.[25] On the one hand, the relative cohort size is negatively correlated with the change in death rate but fails to capture the observations with a large surge of mortality. On the other hand, it is more closely associated with the change in fertility. Reflecting the close association between the birth cohort sizes and the birth rates, the result of using the log population size of cohort born in year t+1 as the outcome variable closely aligns that of using the birth rates 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. For this we construct a measure of revealed comparative advantage (RCA) according to

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

The numerator of the RCA measure is county i's share in national outputs of crop k. The denominator is county i's share of national outputs in 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.

[25] As discussed in Meng et al. (2015), the birth cohort size of survivors has a drawback that it cannot capture the mortality rates of the elderly and that 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.

Using the constructed RCA measures, we test the hypothesis that the counties with a comparative advantage in producing high-export-exposure crops (rice and soybean) experienced a larger decline in retain rate relative to counties with a comparative advantage in low-export-exposure crops. The estimating equation is

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

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 absolute advantage.[26] As in equation (13), we control 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 retain rate across counties during the GLF period depending on the extent to which the 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 with a comparative advantage in producing rice and soybean relative to other crops. Column (2) replaces the outcome variable by death rate. We find that during the GLF period, mortality rate increased relatively faster in counties with a comparative advantage in rice and soybean. In addition, a higher absolute advantage tends to alleviate the famine. Column (3) takes birth rate as the outcome variable and the estimates mirror those in column (2).

In columns (4)-(6), we use an alternative measure of comparative advantage by replacing $RCA_i^{r,s}$ by 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 producing rice and soybean on average experienced i) greater reduction in retain rate, ii) faster increase in mortality, and iii) 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 heterogeneous effects of export shocks. First, following Nunn and Puga (2012), we construct

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

terrain ruggedness index (TRI) for each county.[27] We consider that counties with high TRI are more likely to locate in secluded 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 center. Third, since different measures of remoteness are positively correlated, we extract the principal component of distance to railways, distance to provincial capital and TRI, and take it as an alternative measure of remoteness.[28]

We repeat the regression in column (3) of Table 3 using these alternative measures, and the results for death rate are reported in columns (1)-(3) of Table 7. Column (4) further allows the export effects to be different by *CCP Member*. All these regression results resemble their counterparts in Table 3. Next, we group counties into "Near" and "Far" groups based on whether their principal component of the distance measures is below or above the median. Columns (5) and (6) explore the heterogeneous effects of export shocks for these two groups separately. Again, the results are consistent with the previous findings.

We then investigate how the effects of export vary by provincial characteristics in column (7). We find that an increase in export exposure raises mortality rate more in provinces that experienced a more intensive 1957 anti-rightest movement. More importantly, we find the county-level characteristics like current and past outputs, CCP membership and remoteness still affect the effects of export, even after we include the cross-province heterogeneity.

Table A.5 present the corresponding specifications for retained 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 aimed at inferring the roles of different underlying shocks in shaping the famine severity. To do so, we study the responses of mortality in 1960 when different economic conditions in 1959 revert to their 1957 levels.[29] Recall that the retained consumption is determined by:

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

where the retain rate is a function of contemporaneous and past outputs, export shock, and procurement policies that is captured by $\boldsymbol{\beta_t}$; the output per capita depends on weather condi-

[27]For each grid on map, we calculate its difference in elevation with 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 across all grid cells in the county to obtain the average terrain ruggedness measure.

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

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

tions, export exposure and per capita grain sown area. Based on equation (16), we decompose the change in retained consumption in 1959 and consequently the change in mortality in 1960 into the components contributed by procurement shock (r_{it}) and output shock (y_{it}). Then, we assess the quantitative importance of different underlying factors that determine procurement and output. We also quantify the effect of unequal rural food distribution.

We adopt two alternative procedures to obtain the change in excess deaths under different counterfactual scenarios. The first is a more "structural" approach. In particular, counterfactual change in death rate is computed based on the counterfactual change in caloric supply 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 may yield similar findings if the underlying shocks affect mortality only through altering caloric supply.

In the following subsections, we first use the estimated non-parametric function to quantify the effect of different underlying shocks and 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 into the data of excess death rate for the sample of counties with information on caloric consumption. As is reported in row (A1) of Table 8, the death rate in 1960 was on average 14.37 (per thousand) higher than that in 1958. The cross-county variation is considerable with a standard deviation of 22.97. The excess death rates translates into a total number of excess deaths that amounts to 4,091,420.[30] 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 avoided had the caloric consumption in 1959 was the same as that in 1957. If food deficiency was the only cause of the famine, one would expect this number to be very close to the actual number of excess death. Based on the estimated non-parametric function, we calculate the change in death rate for each county according to

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

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

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

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

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

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

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) explore different determinants in output decline. In particular, row (A3.a) examine the role of resource diversion in the GLF period. Based on the estimates in column (1) of Table 4, we construct the counterfactual consumption level in 1959, assuming the per capita grain sown area to be the same as 1957. We find that in the absence of resource diversion, the number of excess deaths 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 the similar procedure, row (A4) considers the case that the retained rate in 1959 reverted to the level in 1957 while the output level remained the same as it was in 1959. 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 number of excess deaths amounts to 59.94% of the actual amount. It is worth noting that the combined effects of output shocks and procurement shocks is larger than that of the consumption shocks (105.59% versus 93.48%) due to the non-linear relation between the mortality and caloric consumption.

In row (A5.a), we quantify the effect of export expansion on excess deaths. More specifically, we apportion the increase in exports of different crops back to each county according to 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, row (A5.b) accounts for the fact that exports also alter the output level. As is shown in section 6.4, a county with more export obligation tends to allocate more resource to grain production, which alleviates the negative effect of export on retain rate. We measure the export induced changes in outputs using the estimate in column (3) of Table 4. In this case, the average death rate would have decreased by 1.68 (per thousand). As a result, the number of excess deaths would have reduced by 501,322, which is 12.25% of the actual excess deaths.

Then we ask the following question: how would the number of deaths change if the procurement policies were more flexible. To answer this question, we proceed in two steps. First, we replace the GLF period's elasticities of retain rate to contemporaneous and past outputs by their non-GLF counterparts. Based on the estimates in column (3) of Panel A in Table 2, we calculate the changes in grain retain rate. Second, we translate the implied changes in caloric consumption to counterfactual change in deaths using the estimated non-parametric function in Figure 8. Row (A6) shows that the more rigid procurement policies in the GLF period contributed to 28.62% of the excess deaths. Row (A7) considers an alternative counterfactual experiment in which the procurement policies in 1957 had been the same as the GLF period. The counterfactual change in death rate 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 in the GLF period alone cannot explain a large portion of excess deaths between 1957 and 1960. Furthermore, the difference between (A6) and (A7) suggests that the inflexible and progressive procurement policies matters more when it is accompanied with a widespread large decline in output.

7.1.2 Quantitative Importance of Consumption Inequality

What if available food is equally distributed across the counties? In row (A8), we equalize the average level of consumption across counties while keeping the aggregate consumption as well as the within county inequality constant.[31] We find that the counterfactual total excess deaths would have been 35.71% lower in this case. For the counterfactual experiment in row (A9), we equally distribute consumption across counties within a province, while keeping the province-level consumption level unchanged. We finding that removing within-province consumption inequality would lower total excess deaths by 28.07%. These findings are consistent with Meng et al. (2015) that unequal food distribution is 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.

[31] In this counterfactual, the county-level average of consumption is equalized across counties but there remains inequality within each county as implied by the estimated downward relation between death rate and the average level of caloric consumption in Figure 8.

We also quantitatively assess how the distribution of export procurement affected the famine severity. We consider a counterfactual scenario that the central planner could identify the famine-stricken counties (i.e., counties in the bottom quintile of pre-export consumption per capita) and lift their export obligations.[32] The planner then would distribute the aggregate export to the remaining counties based on their consumption share. Similar to the case of (A5.b), the output would be adjusted according to the changes in export. Row (A10) shows that had this reallocation of export occurred, total excess deaths would have declined by 7.85%. In row (A11), we conduct an analogous experiment at the province level and find that the within-province redistribution of export would lower the total excess deaths by 9.36%. These findings suggest that the adverse effects of export on famine would be greatly mitigated if export procurement had been more progressive in 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. In particular, we employ the control function estimates and IV estimates of the spline regression in Table A.6. We find that the quantitative effects of different underlying shocks closely align with the baseline results in Table 8.

7.2 Counterfactual Changes in Mortality and County Characteristics

In this section, we link the changes in mortality of various counterfactual scenarios, $DeathRate_{i,60} - DeathRate^{CF}_{i,60}$, to different observable county characteristics, including i) whether the county is located near to or far away from the railways (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 share of CCP members in population (High vs Low), and iv) whether the county experienced good weather shocks in 1957 (Bad vs Good).[33]

Figure 10 shows the distributions of counterfactual changes in death rate if the export exposure in 1959 had been the same as that in 1957. The figures are generated based on the counterfactual experiment in row (A.5.b) of Table 8. We report the p-value of Kolmogorov-

[32] The pre-export consumption per capita, $r_{it}y_{it} + Export_{it}$, in these counties was lower than 1281 Cal.

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

Smirnov equality-of-distributions test in the upper-right corner of each figure. As is 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 low share of CCP members FOSD that of the group with high share 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 that specialized in high-export-exposure crops, had fewer CCP members or experienced good past weather shocks were likely to suffer more from over procurement due to export expansion, which are consistent with our reduced-form regression findings. Lastly, Kolmogorov-Smirnov test fails to reject the equality of the distributions of near-to-railway and far-from-railway groups.

Figure 11 considers what if the output in 1957 had remained the same as that in 1959, and repeats the exercises in Figure 10. We find the distribution of the far-from-railway group FOSD that of the near-to-railway group. This is partly due to the fact that procurement policies were more rigid in the 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. A potential explanation is that the procurement policies were more rigid in regions with low organizational presence of the party.[34] The distribution of the good-past-weather group FOSD that of the bad-past-weather group. This finding is mechanical as the counterfactual 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 discuss the counterfactual case that the retain rate in 1959 had been the same as that 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. The finding suggests that counties nearer to railways were 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 relative to the high-export-exposure group. This finding implies that export shock may affect consumption and mortality independently of the procurement for the domestic distributional purpose. 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.[35]

[34] As is reported in column (2) of Table 4, the decline in output in the GLF period was not systematically correlated with *CCP Member*. Therefore, the detected difference in the distributions is unlikely a result of differential output declines in high-CCP-members group and low-CCP-members group.

[35] On the one hand, a good 1957 weather shock decreased retain rate in 1957, as retain rate is negatively linked to contemporaneous output in non-GLF period (Table 2). One the other hand, a good 1957 weather shock also reduced 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 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.

Last but not least, Figure 13 reports the results for the counterfactual scenario that procurement policies in 1959 had been less rigid. The distribution of the far-from-railway group is more skewed to the right. As is 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 difference between the distributions of the high- and low-export-exposure groups.

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 death rate and different underlying shocks. Row (A12) employs the estimates in Panel A column (3) of Table 2. We find that in absence of output shock between 1957 and 1959, 949,520 deaths would have 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). This is because output shocks affect both retained rate and potential food supply, and the reduced-form estimates capture the combined effects. 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), row (A13.b) accounts for the export-induced change in output. In this case, export shocks explain 14.3% of the excess deaths.[36]

7.4 An Analogous Analysis for Lost/Postponed Births

We conduct an analogous analysis for lost/postponed births 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 that in Panel A. For example, the effect of export shock is about one tenth of the effect of caloric consumption shock for both death and birth. Lastly, compared to the approach based on the non-parametric relation, the reduced-form pass-through yields similar estimates for the effects of export shocks.

Compared to mortality, we find that calorie intake has a lower explanatory power on fertility. This could be because there were other factors that independently affected the fertility during the famine period. For example, the zealous devotion to labor-intensive GLF projects could lead to spousal separation and postponement of marriage. In addition, fertility could be strategically

[36]Based on the counterfactual analysis in row (A13.b), Figure A.13 shows the distributions of 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 relative to the high-export-exposure group, and the distribution of the good-past-weather group FOSD that of the bad-past-weather group.

postponed nationwide in a turbulent period. These factors make birth rate a less ideal proxy for famine severity than death rate. Since relative cohort size is more correlated with birth rate than mortality rate (Figure A.8), it may also be a noisier proxy for famine severity than death rate.

8 Conclusion

The Chinese Great Famine were the worst famine in human history, resulting in 16.5 to 30 million excess deaths over three years from 1958 to 1960. In the midst of famine, the Chinese government exported 9.6 million tons of grains, equivalent to caloric needs of 16.7 to 38.9 million people, and China barely imported grains until 1961. While the existing literature recognizes grain exports as one of the potentially important causes of famine, no existing study provides quantitative evidence on the importance of grain exports relative to other factors. Using newly collected county-level data sets, this article quantitatively assesses the effect of grain exports on death rates. Our result shows that an increase in grain exports contributed to 12-14 percent of excess deaths between 1958 and 1960 while 59 and 46 percent of excess deaths were attributed to the surge in procurement rate and the fall of agricultural production, respectively. Therefore, one-fifth of the effect of increase in procurements on excess deaths is attributable to an increase in grain exports. Furthermore, the impact of grain exports on death rates is found to be larger for the counties with lower current output, higher two-period lagged output, larger distance to railways, and smaller share of local CCP members, suggesting that the effect of grain exports systematically depends on the measure of remoteness as well as a political factor represented by CCP membership.

It is important to emphasize that we quantify the effect of grain exports in our counterfactual experiment under a *ceteris paribus* assumption. Most importantly, we keep the inflexible procurement policy during the GLF period held constant. If the procurement policy had been flexible and the government had been able to collect information and respond to food shortage quickly, then the effect of grain exports would have been smaller. In fact, we find that the effect of export grains on death rates is smaller for the counties located closer to railways as well as the counties with many CCP members, where verification of food shortage is presumably easier, suggesting that the degree of inflexibility matters for 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 procurement policy was prerequisite for grain exports to have such a large impact on mortality.

Exporting grains during famine is not unique to the China's Great Famine. In the history, we have witnessed several episodes of "export-driven famine," 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-Ukrain famine of 1932-33, in which a region was exporting grains while people were starving to deaths (Woodham-Smith, 1964; Sen, 1981; Ghose, 1982; Ravallion, 1987; Davies and Wheatcroft, 2004; Wemheuer, 2015). In particular, in the Soviet-Ukrain famine of 1932-33, the government compulsorily procured grains from the rural area, exporting 1.6 million tonnes of grains to cope with the foreign debt, under 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-Ukrain famine and the China's great famine, this paper's study is potentially useful for better understanding the causes of the Soviet-Ukrain famine.

More broadly, this study provides insight on the importance of institution quality and political factors that determine the consequence of international trade. Under centrally planned economy in which information on demand and supply was not quickly aggregated up and in which bureaucrats and farmers did not have proper incentive to correctly report production, the international trade resulted in severe consequences. China's great famine is an extreme example that the gains from trade can be negative when the pattern of trade as well as the allocation of resources is determined by political factors under inflexible institution.

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

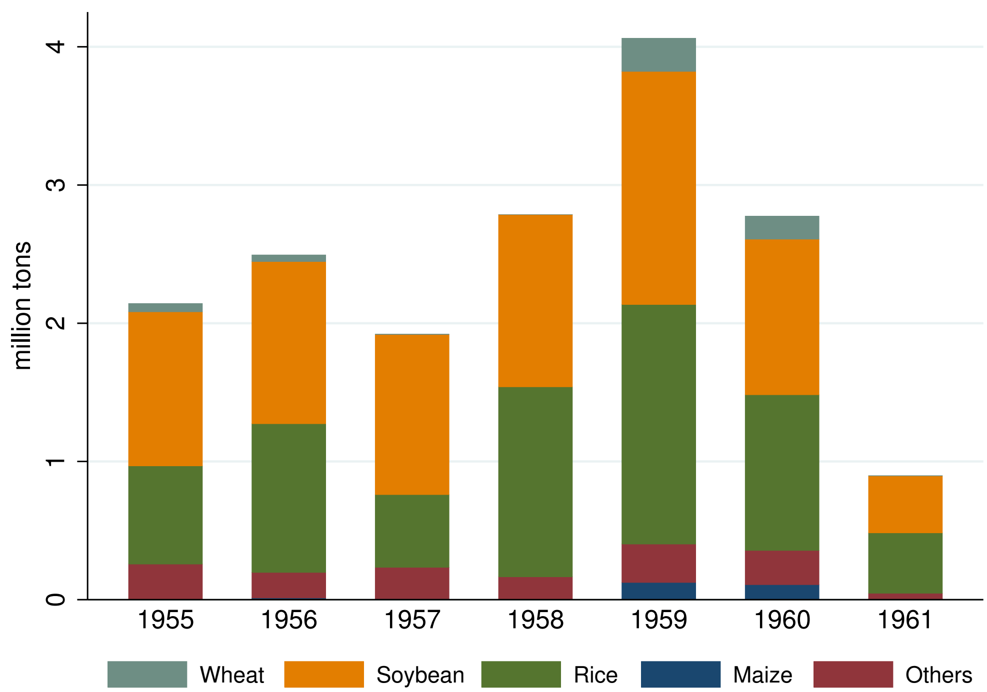


Figure 2: Cross-County Variation in Famine Severity

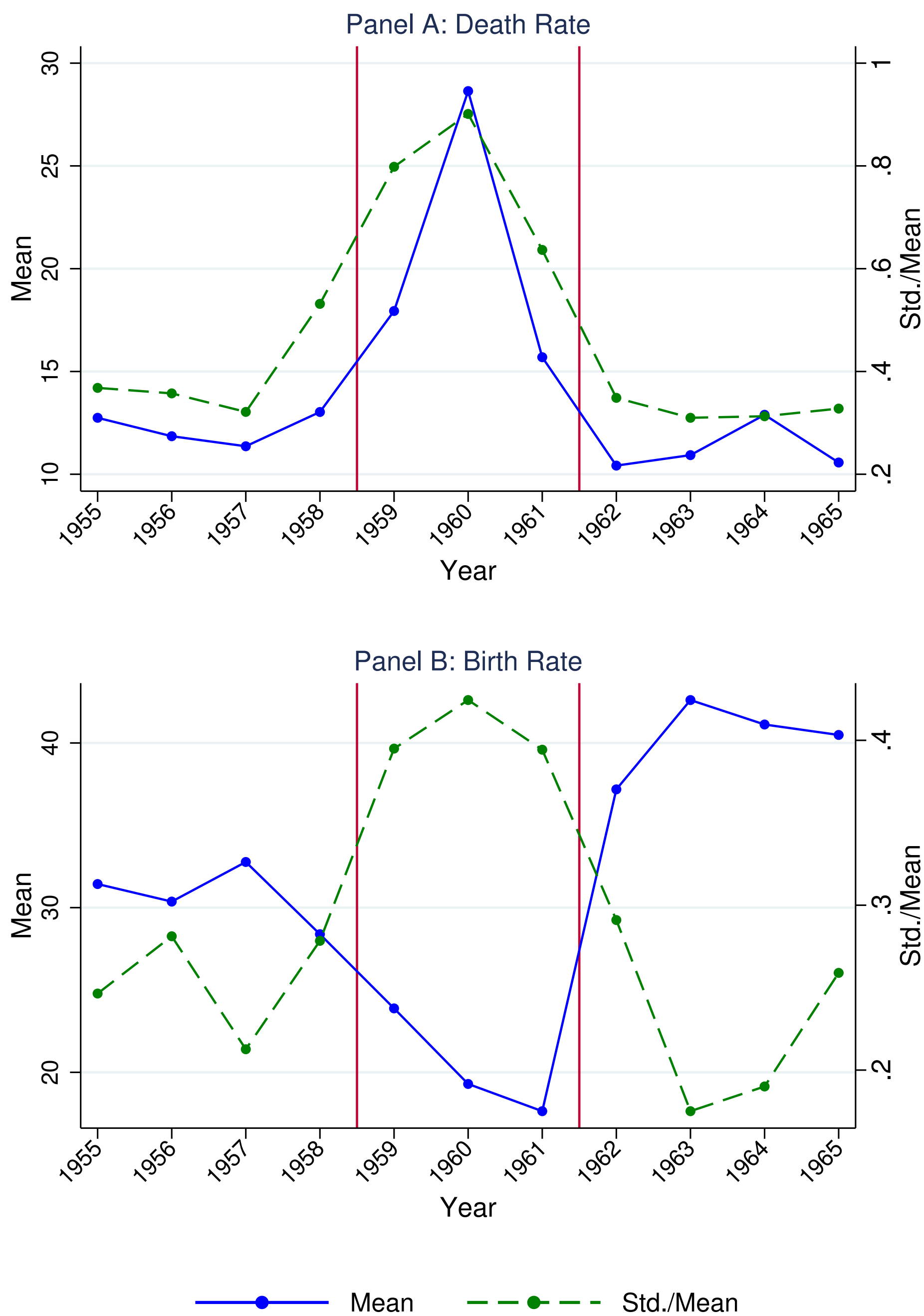
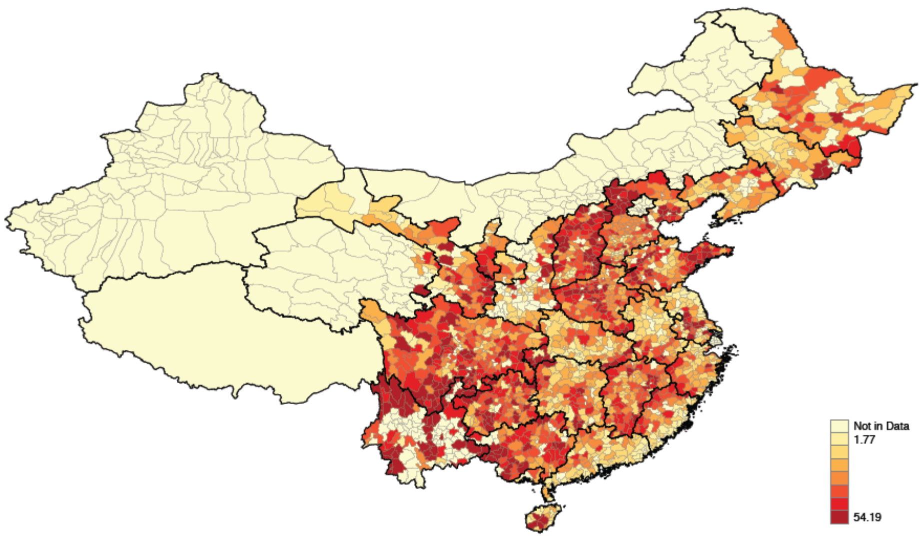
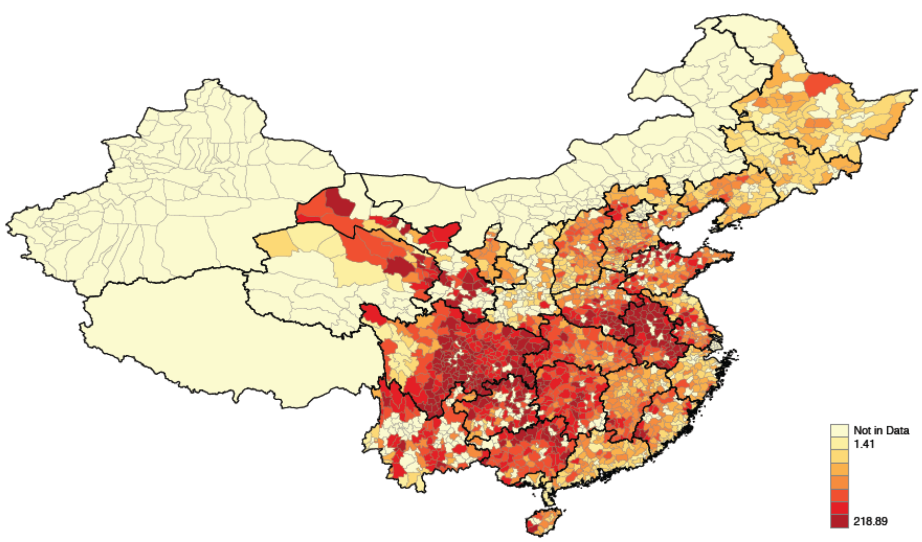


Figure 3: The Number of Deaths per 1000 Population in 1957 and 1960



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



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

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

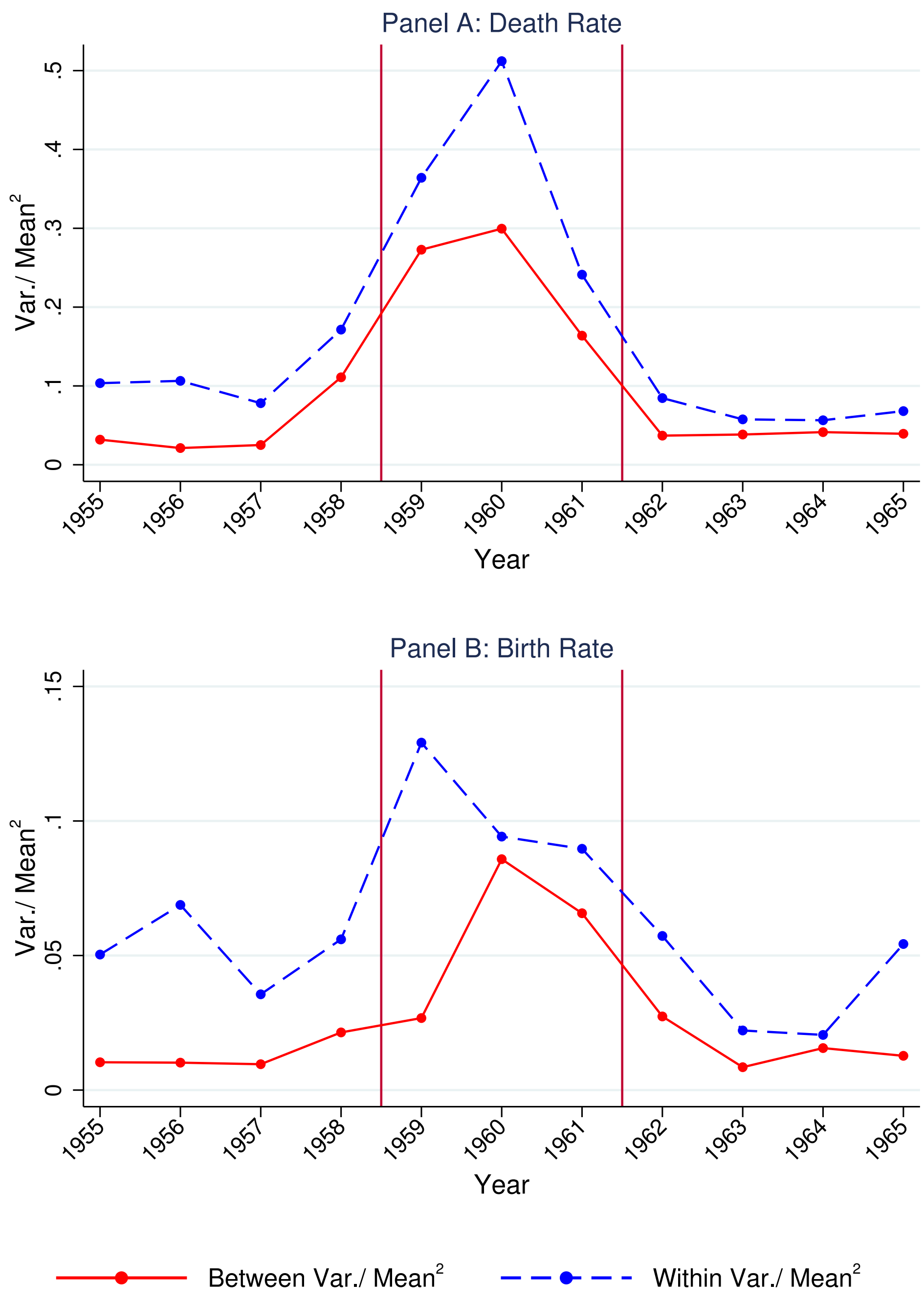


Figure 5: Correlation between Changes in Mortality and Birth Rates

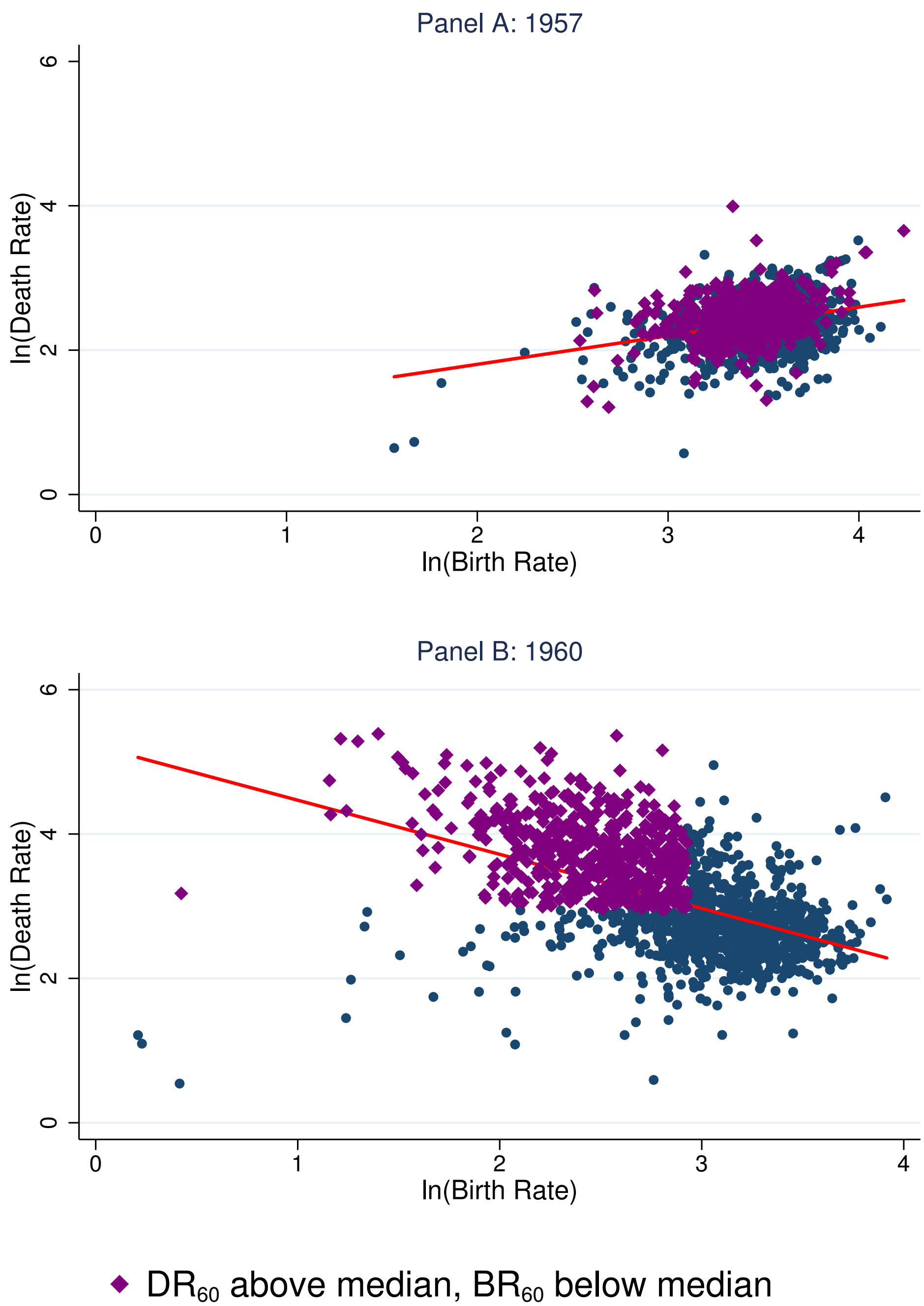
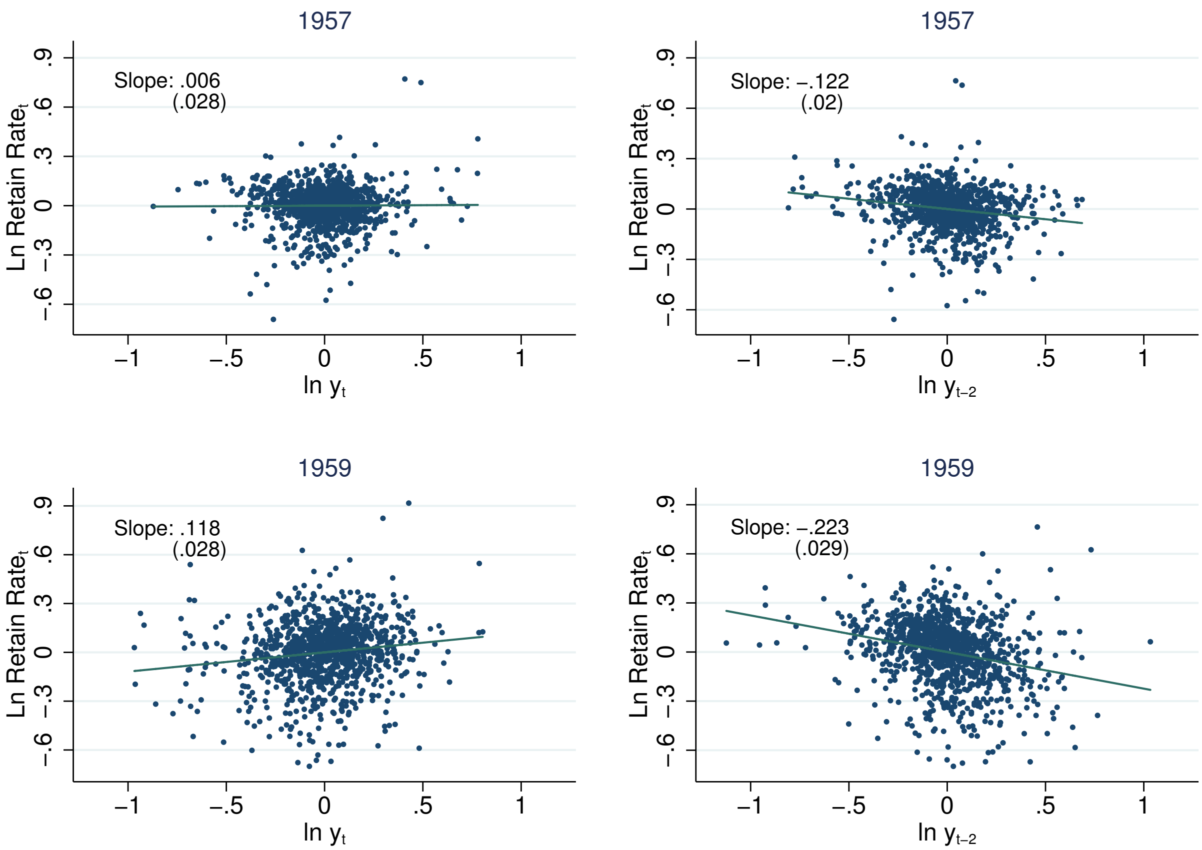
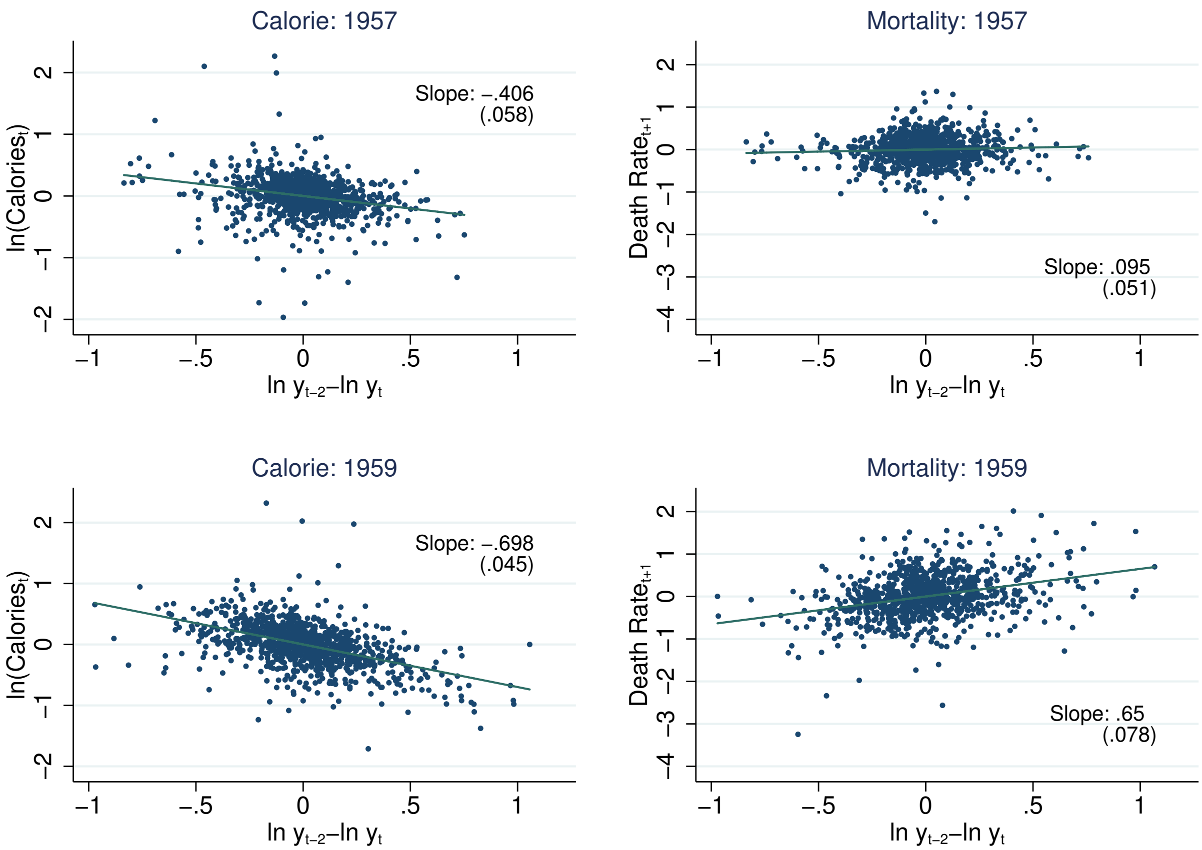


Figure 6: Correlation between Log Retained Rate and Outputs



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 year 1957, and the lower panel corresponds to year 1959.

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



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

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

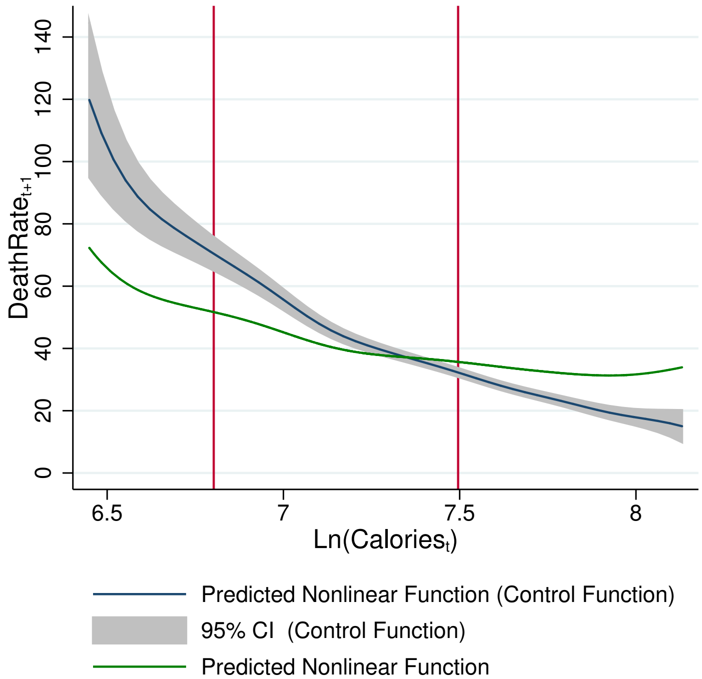


Figure 9: Semi-parametric Regression: Birth Rate and Log Caloric Consumption

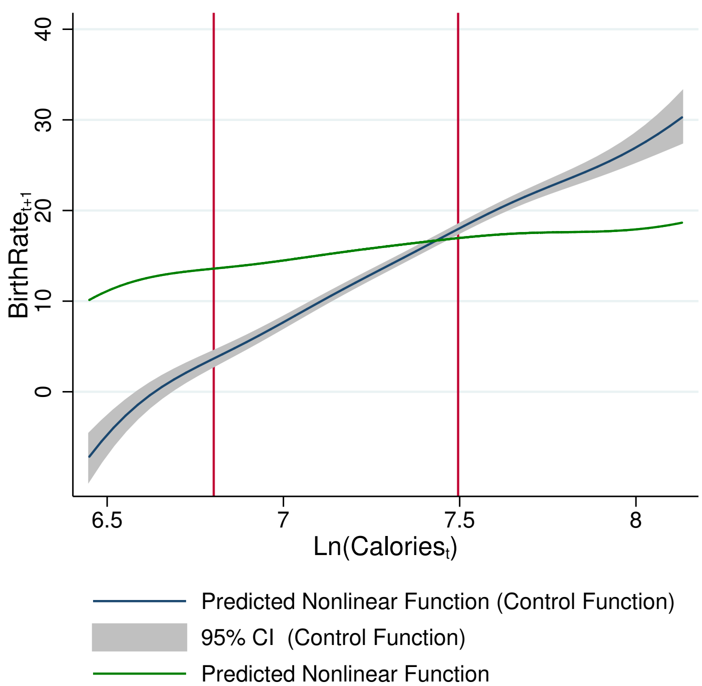


Figure 10: Export in 1959 Same as 1957

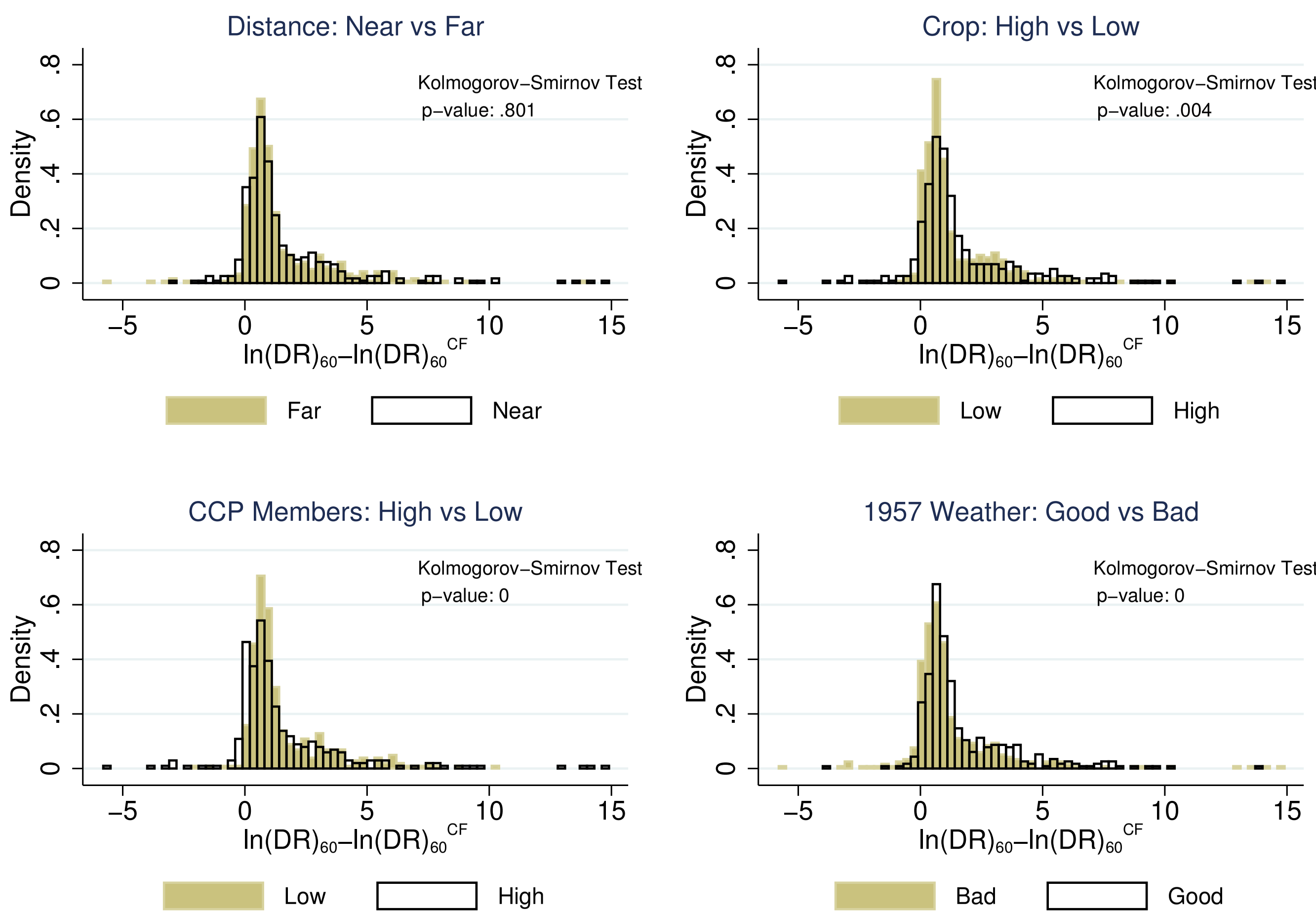


Figure 11: Output in 1959 Same as 1957

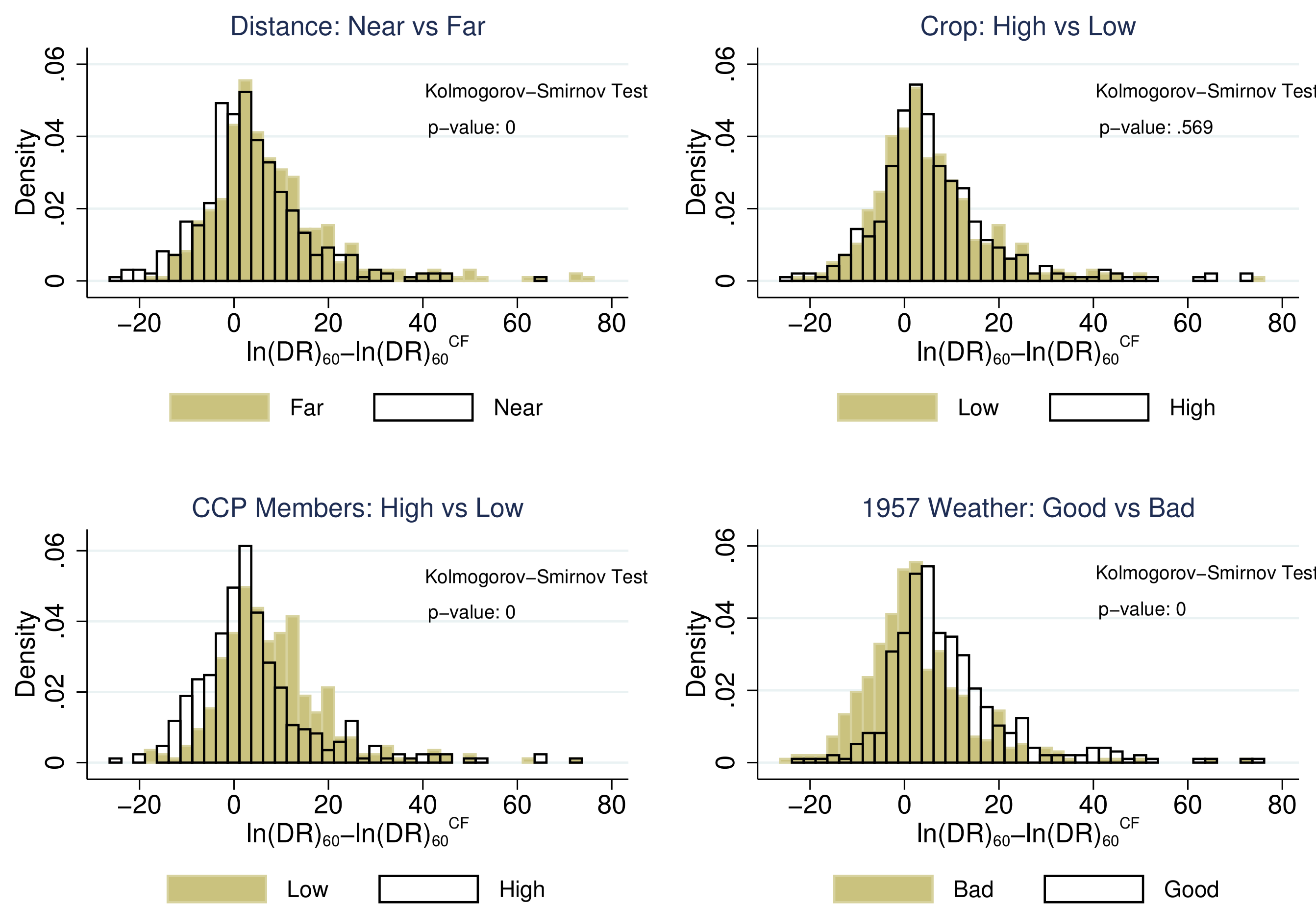


Figure 12: Procurement Rate in 1959 Same as 1957

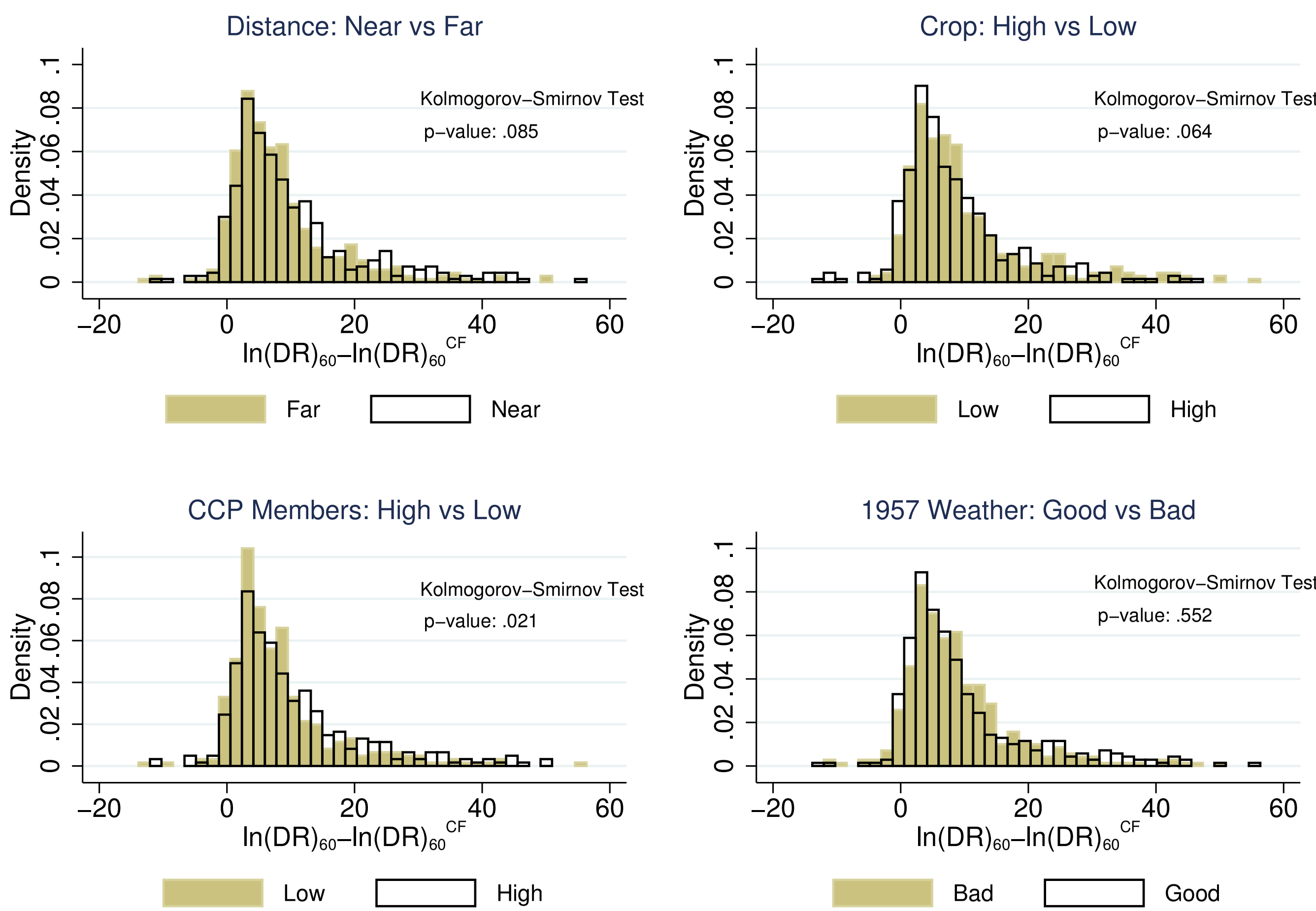


Figure 13: Procurement Policies in 1959 same as Non-GLF Period

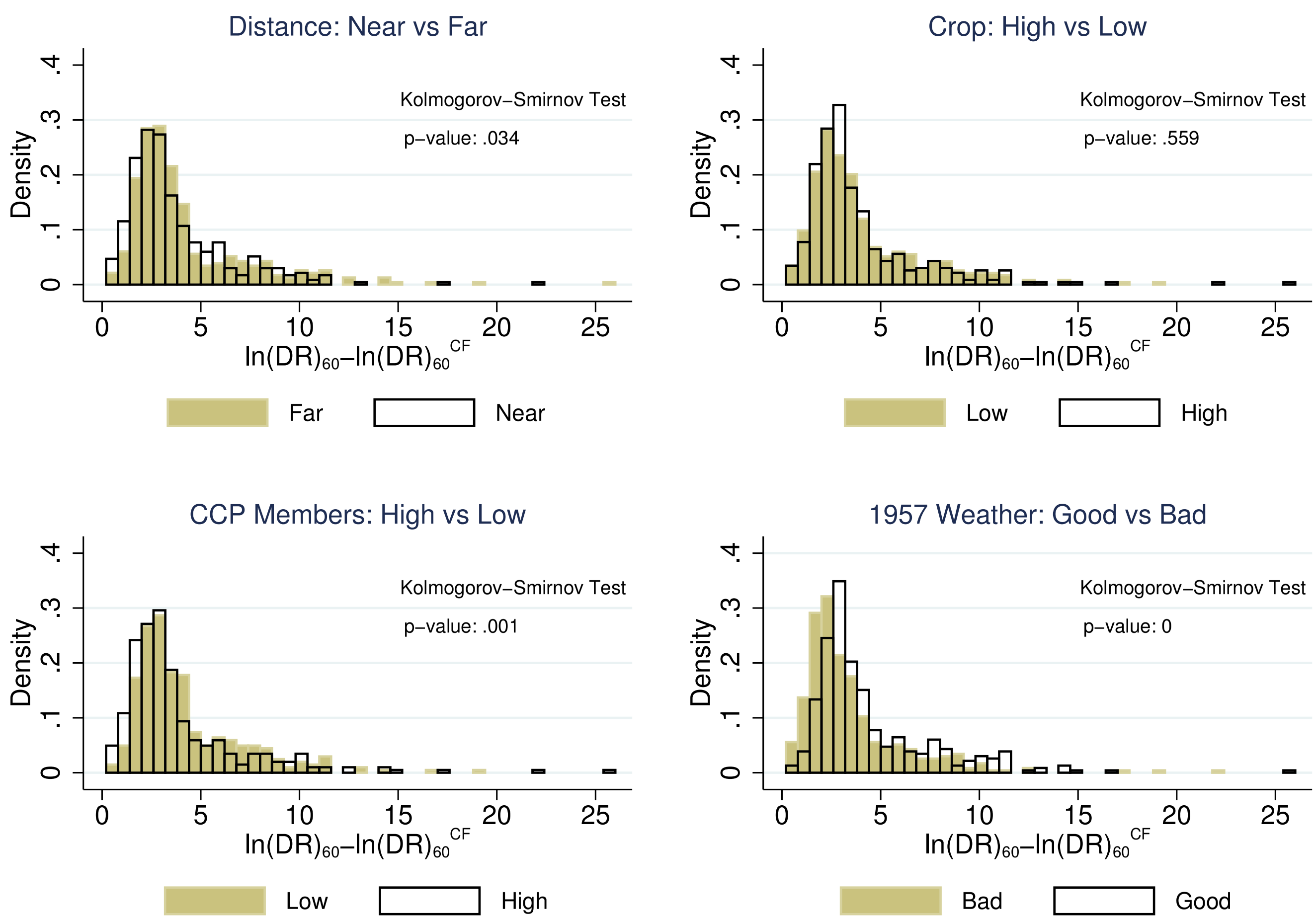


Table 1: Summary Statistics

	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 1000)	32.01	20.19	35.74
	(0.09)	(0.13)	(0.09)
output per capita_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.)	2070.69	1772.45	2114.02
	(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 in parentheses.

Table 2: Output Shocks, Retained Rate, Death and Birth Rates

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

Table 3: Export Exposure, Retained Rate, Death and Birth Rates

	All	All	All	All	Near	Far
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Dependent Variable $\ln RetainRate_t$						
$Export_t$	-0.002***	-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, Retained Rate, Death and Birth Rates

	All (1)	All (2)	All (3)	All (4)	Near (5)	Far (6)
Panel C: Dependent Variable $BirthRate_{t+1}$						
$Export_t$	-0.058**	-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 in parentheses. *** p<0.01, ** p<0.05, * p<0.1,

Table 4: Determinants of County-Level Grain Output

	(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					0.125	-0.189
Anti-Rightest Movement					(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 regressions control for weather conditions. Standard errors in columns (5) and (6) are clustered at the province× year level. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 5: Table: 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 in parentheses. *** p<0.01, ** p<0.05, * p<0.1

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

Dep. Var.:	$\ln RetainRate_t$	$DeathRate_{t+1}$	$BirthRate_{t+1}$	$\ln RetainRate_t$	$DeathRate_{t+1}$	$BirthRate_{t+1}$
	(1)	(2)	(3)	(4)	(5)	(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×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 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$\times$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
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: Estimated coefficient of $Export_t \times DistPCA$ is multiplied by 100. Robust standard errors 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	$\Delta DeathRate$ std	implied number of excess deaths	% of actual excess deaths
(A1) From Data: $DeathRate_{60} - DeathRate_{58}$	14.37	22.97	4091420	100
Approach 1: Based on the Non-Parametric Function				
(A2) Caloric consumption in 1959 same as 1957	13.55	16.69	3824507	93.48
(A3) Output in 1959 same as 1957	5.89	12.92	1867595	45.65
(A3.a) Land inputs in 1959 same as 1957 (#)	4.82	8.65	1288971	37.18
(A3.b) No weather shocks in 1959	0.89	5.14	407408	9.96
(A4) Procurement rate in 1959 same as 1957	9.30	11.11	2452516	59.94
(A5.a) Export exposure in 1959 same as 1957	3.60	3.88	1023423	25.01
(A5.b) Export exposure in 1959 same as 1957 (incl. output effects)	1.68	2.80	501322	12.25
(A6) Procurement policies in 1959 same as Non-GLF period	4.11	3.48	1170873	28.62
(A7) Procurement policies in 1957 same as GLF period	2.52	1.50	652073	16.43
(A8) Consumption equally distributed across the nation in 1959	4.05	17.49	1460952	35.71
(A9) Consumption equally distributed within provinces in 1959	3.77	15.11	1148330	28.07
(A10) Redistribute export in 1959 across the nation	1.03	3.63	321124	7.85
(A11) Redistribute export in 1959 within the provinces	1.28	3.50	382962	9.36
Approach 2: Based on Reduced-Form Regressions				
(A12) Output in 1959 same as 1957	3.01	6.10	949520	23.21
(A13.a) Export exposure in 1959 same as 1957	2.94	2.08	781015	19.09
(A13.b) Export exposure in 1959 same as 1957 (incl. output effects)	2.21	1.56	585010	14.30

Panel B: Change in Births	$\Delta BirthRate$ mean	$\Delta BirthRate$ std	implied number of lost births	% of actual lost births
(B1) From Data: $BirthRate_{58} - BirthRate_{60}$	9.53	9.87	2758184	100
Approach 1: Based on the Non-Parametric Function				
(B2) Caloric consumption in 1959 same as 1957	6.61	6.41	1822811	65.60
(B3) Output in 1959 same as 1957	2.51	5.07	792511	28.52
(B3.a) Land inputs in 1959 same as 1957 (#)	2.13	2.67	545731	22.60
(B3.b) No weather shocks in 1959	0.35	2.08	174717	6.29
(B4) Procurement rate in 1959 same as 1957	4.23	3.64	1073901	38.65
(B5.a) Export exposure in 1959 same as 1957	1.52	1.06	419487	15.10
(B5.b) Export exposure in 1959 same as 1957 (incl. output effects)	0.59	0.71	172309	6.20
(B6) Procurement policies in 1959 same as Non-GLF period	1.76	0.75	486487	17.51
(B7) Procurement policies in 1957 same as GLF period	1.46	0.56	369959	14.18
(B8) Consumption equally distributed across the nation in 1959	0.61	6.96	337522	12.15
(B9) Consumption equally distributed within provinces in 1959	0.76	5.80	236811	8.52
(B10) Redistribute export in 1959 across the nation	0.19	0.95	60295	2.17
(B11) Redistribute export in 1959 within the provinces	0.32	0.88	98229	3.35
Approach 2: Based on Reduced-Form Regressions				
(B12) Output in 1959 same as 1957	1.05	2.05	319542	11.50
(B13) Export exposure in 1959 same as 1957	0.72	0.51	190632	6.86
(B13.b) Export exposure in 1959 same as 1957 (incl. output effects)	0.47	0.33	125020	4.50

Notes: The implied number of excess deaths is the sum of excess deaths of 780 counties with data on caloric consumption in both 1957 and 1959. (#) The change in excess mortality (lost births) due to counterfactual change in per capita sown area is calculated for 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 reliaility of this new dataset, we cross-check with the province-level data employed by Lin and Yang (2000) and Meng et al. (2015).[37] Figure A.2 plots the province-level death rates aggregated from our county-level data against the existing provincial-level data. The scatter points cluster along the 45 degree line and there is no pattern that our data systematically over or under report death rates. (The correlation coefficient of the two series is 0.991.) This result is expected, as both our data and the data employed by the existing studies come from China's Statistics Bureaus.

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

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

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

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

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

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

A.2 Output and Procurement Data

A.2.1 Selection Issue

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

A.3 Weather Data

The upper panels in Figure A.10 plot the distributions of spring and summer precipitation in famine years (1959-61) and the distributions of their historical means (1950-59). For both seasons the distributions of year 1959 are more skewed to the right than those of the historical mean, indicating that most counties experienced more precipitation than regular years. This is in line with the reported widespread floods in 1959.[38] In contrast, the distributions of year 1960 have a larger density at small values, which pattern is more evident in summer and is consistent with the documented extensive drought in 1960.[39] In addition, year 1961 had more precipitation in spring and fewer precipitation in summer than regular years. The lower panels of Figure A.10 shows the corresponding distributions for temperature. The famine years have warmer springs than regular years. For summer, the distributions of year 1959 and year 1960 resemble that of the historical mean, while the distribution of year 1961 has larger densities at large values of temperature.

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

[39]As is discussed in Ashton et al. (1984), the hardest regions were Hebei, Shandong, Shanxi, and Henan Provinces, where droughts 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 estimated residuals from model (8) is decreasing in consumption per capita. 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 county. Unequal food distribution matters more when consumption per capita is lower. This is because, when there is an abundance of food, death rate is unlikely to rise due to a moderate consumption inequality. In contrast, when the average calorie supply just meets the requirement for survival, mortality rate would be heavily affected by food distribution. Therefore, unobserved differences in within-county food distribution may lead to a downward sloping relationship between 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 Pattern of the Effects of Output Shocks

We also augment the regression model (10) allowing the elasticities of retain rate to 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 from 1958. The elasticities reverted back to their pre-GLF level from 1960. The right panel repeats the analysis but replaces the dependent variable by lead death rate. The patterns of the estimates mirror their counterparts in the left panel.

B.3 Estimating 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 noises introduced by the outliers, the observations with 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. Since the curse of dimensionality prevents us from estimating a fully nonparametric 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. (In particular, the STATA package *semipar* is employed 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 1500 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.[40] The spline coefficients are larger in magnitude, which suggests the existence of 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. In particular, 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 1500, the the slope becomes positive although it is insignificantly different from zero. (The slope coefficient is 28.07 with 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 1500. Columns (5)-(7) repeat the exercises for birth rates. In sum, the detected diminishing effects of caloric consumption on mortality and fertility is 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

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

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

Panel B row (A8) shows that equalizing consumption per capita across the nation can completely eliminate the famine. This prediction deviates from the one obtained based on the non-parametric approach. Such difference is due to the fact that different approaches render different estimated relation between mortality and caloric intake when the consumption per capita surpasses the threshhold 1,500 Cal. The estimates from the IV spline regression indicate that mortality won't 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 caloric requirement for survival. (As is discussed in the main text, one possible explanation for this finding is that higher average consumption level could lower 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 of the food scarce regions.

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

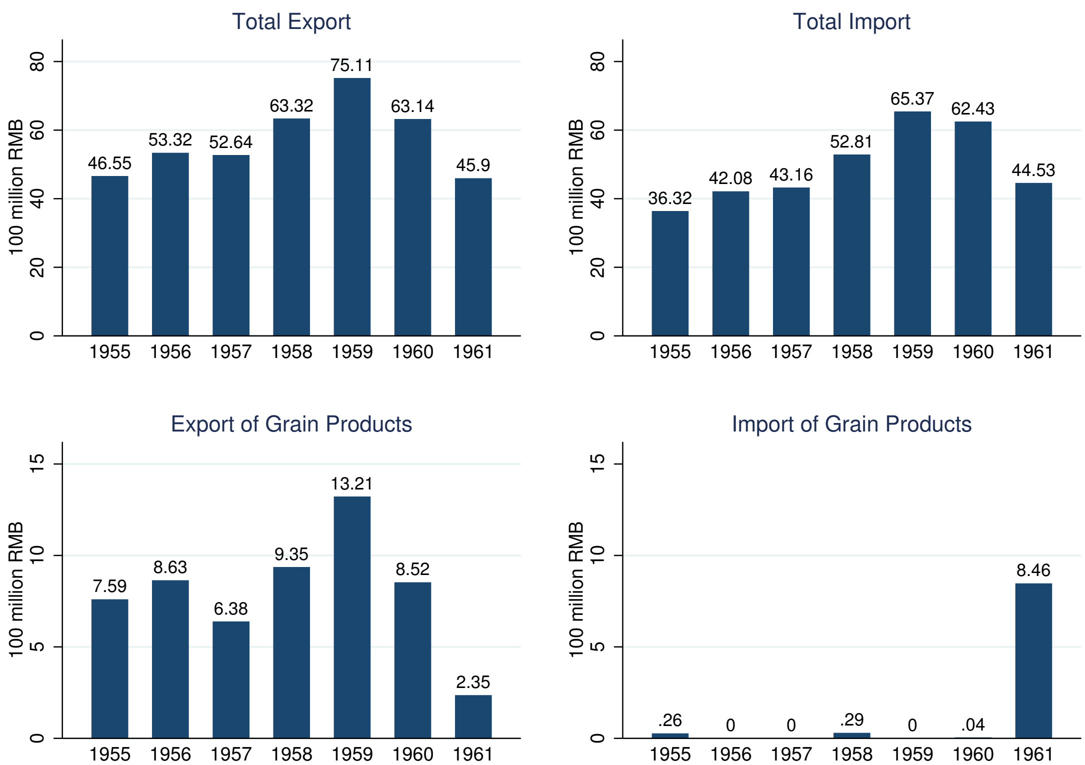
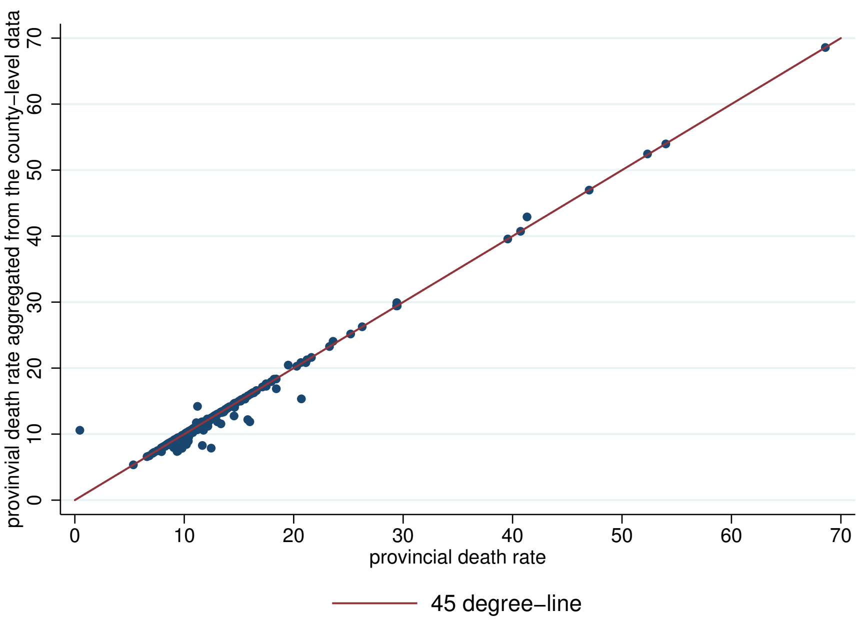


Figure A.2: Comparison of the Province-Level Death Rates from Different Sources



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

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

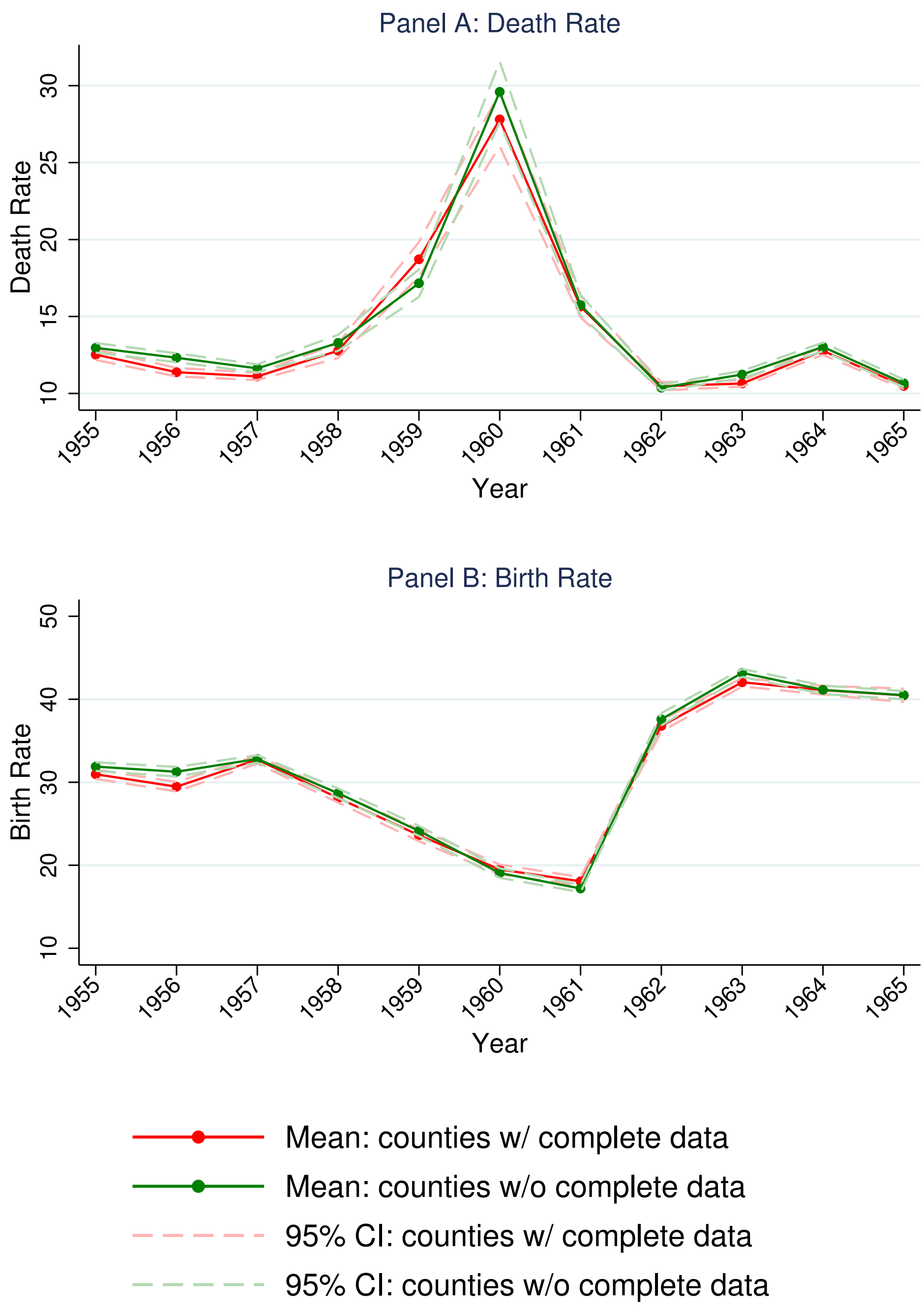


Figure A.4: Relative Price over 1955-1961

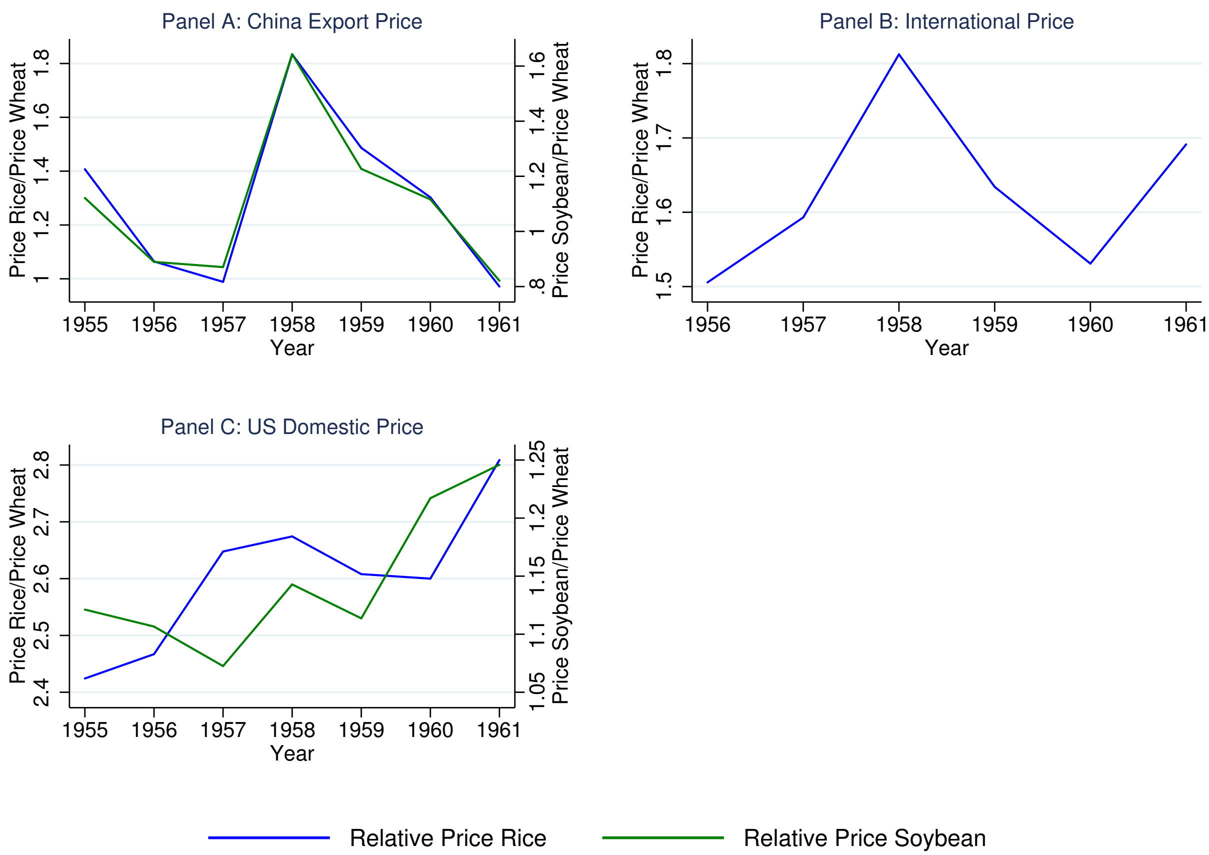


Figure A.5: Railway Network in 1957

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

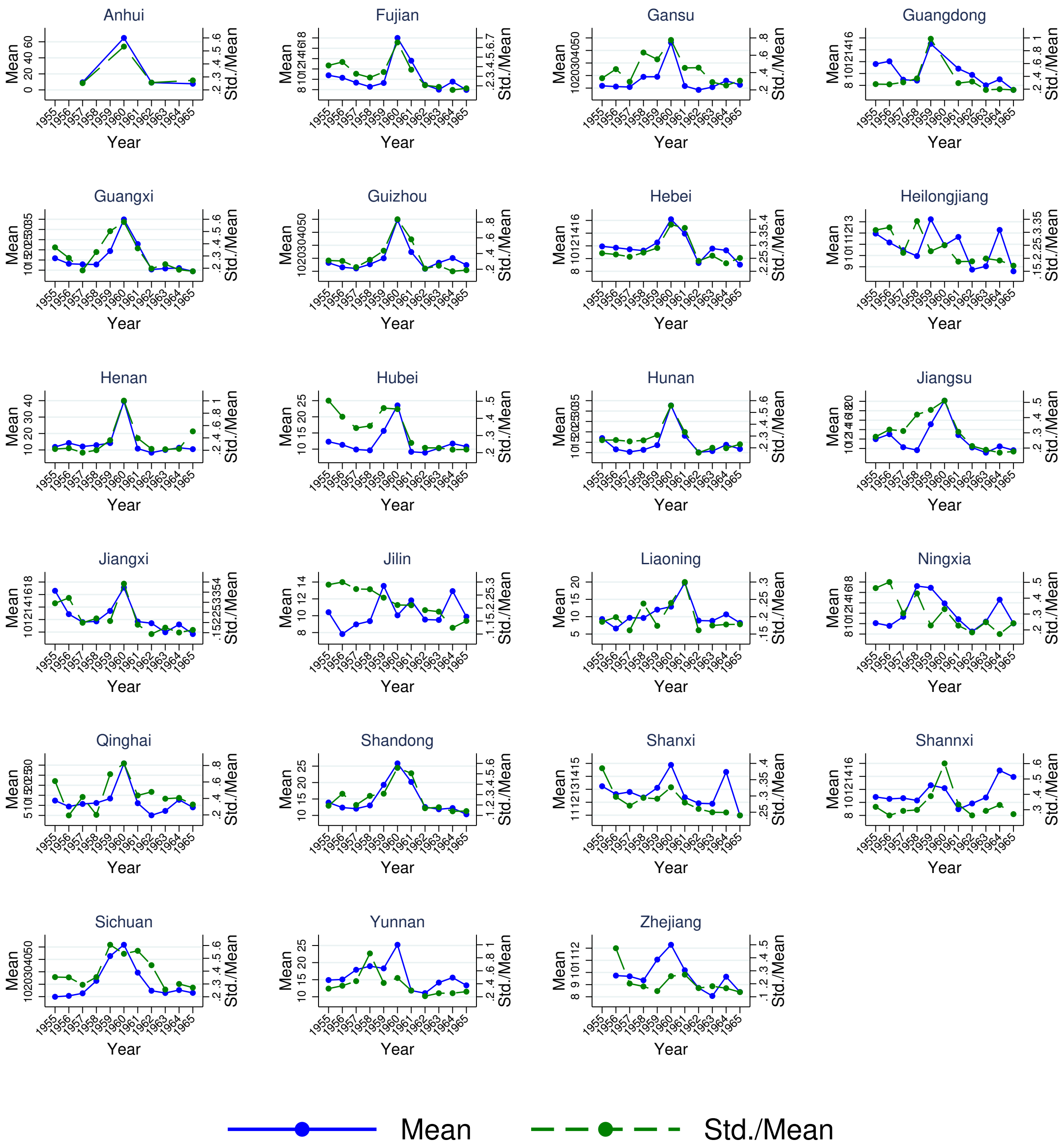


Figure A.7: Within Province Variation in Birth Rate by Year

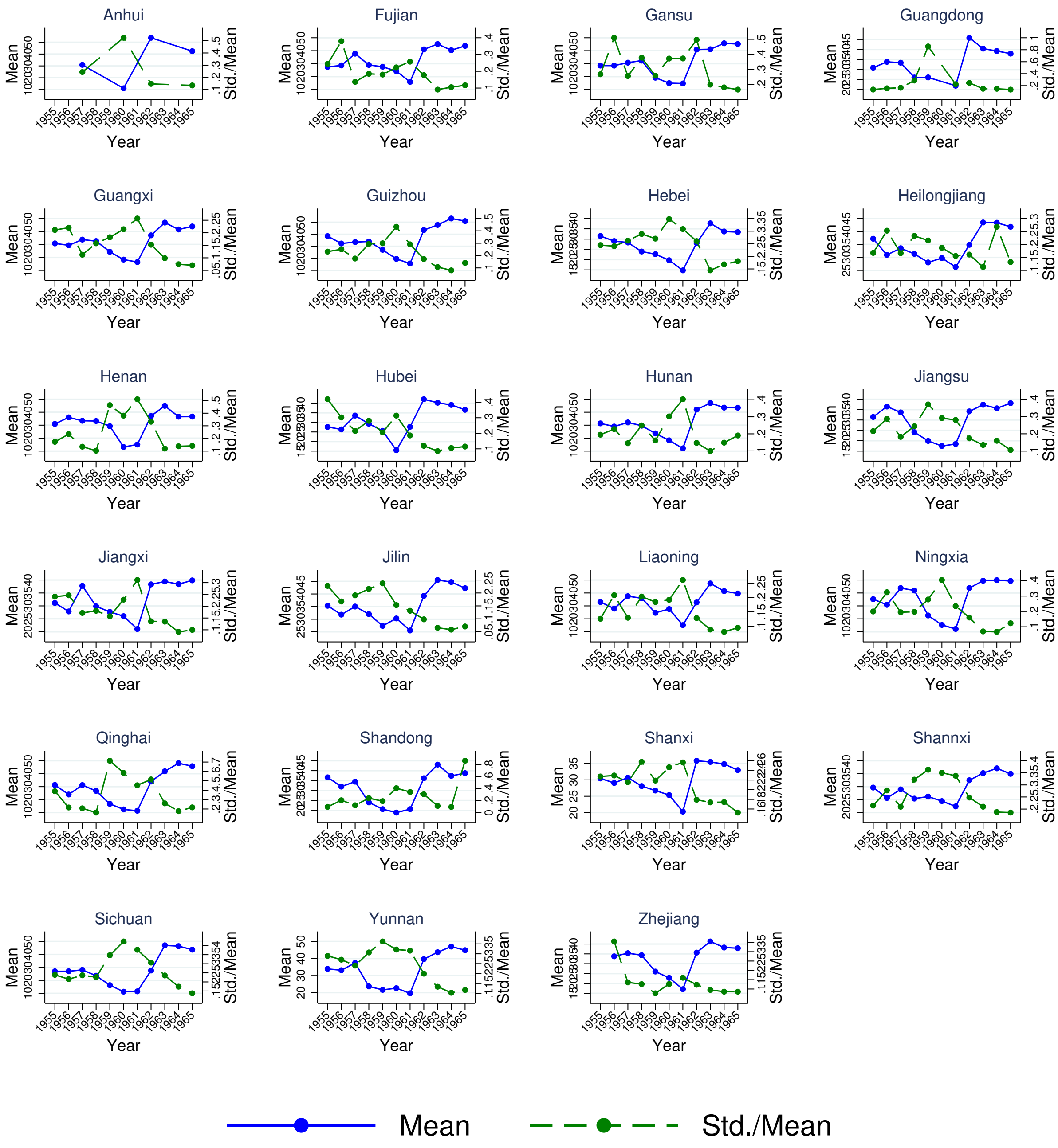
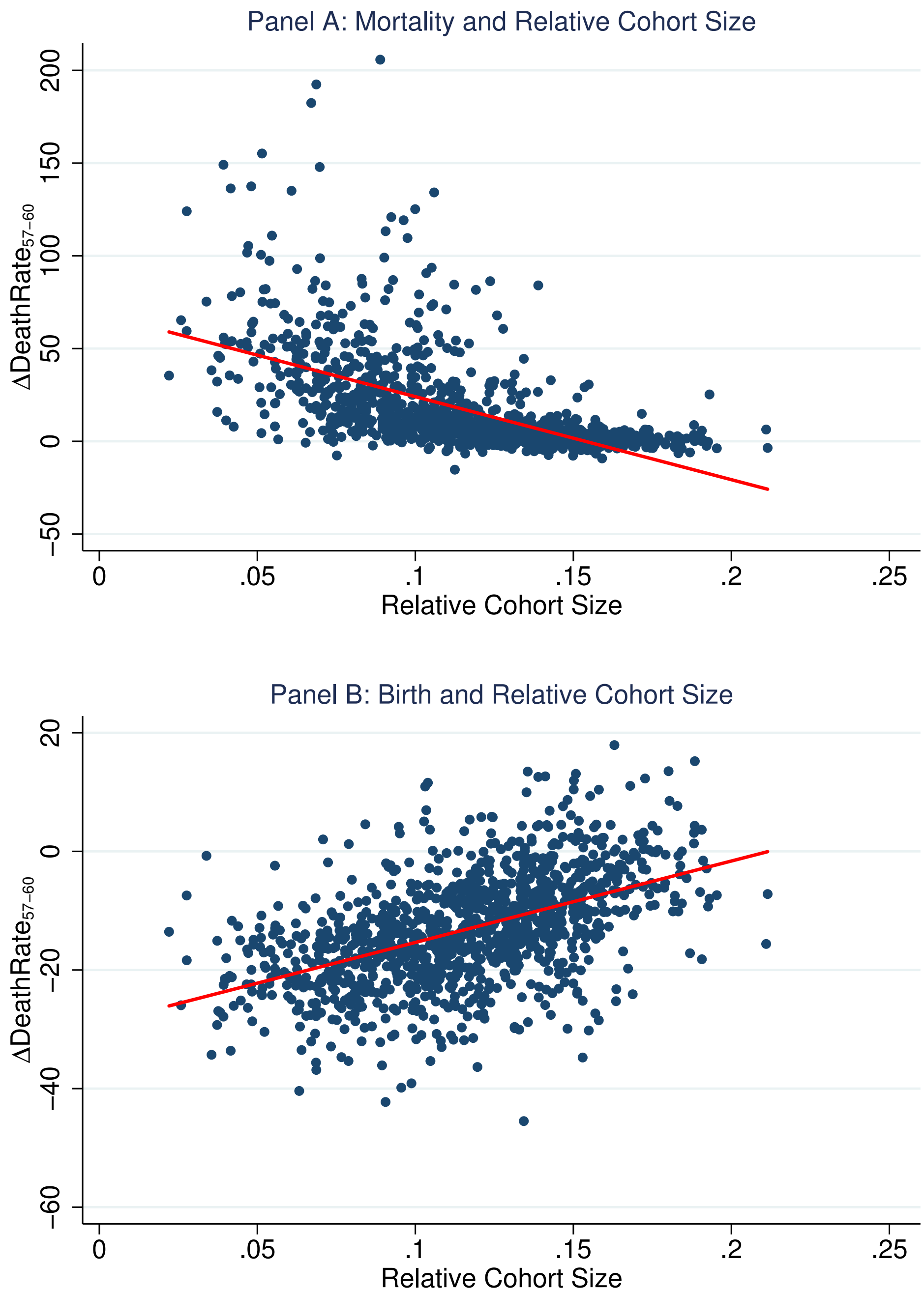
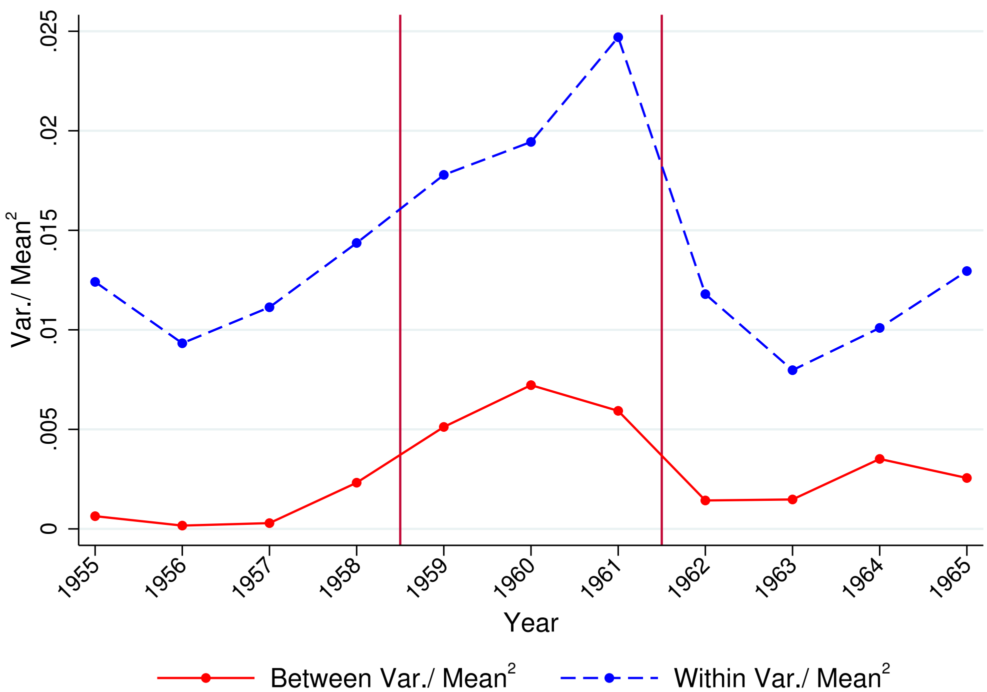


Figure A.8: Correlation of Death and Birth Rates with Relative Cohort Size



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

Figure A.9: Decomposition of Within- versus Between-Province Variation – Relative Cohort Size



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

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

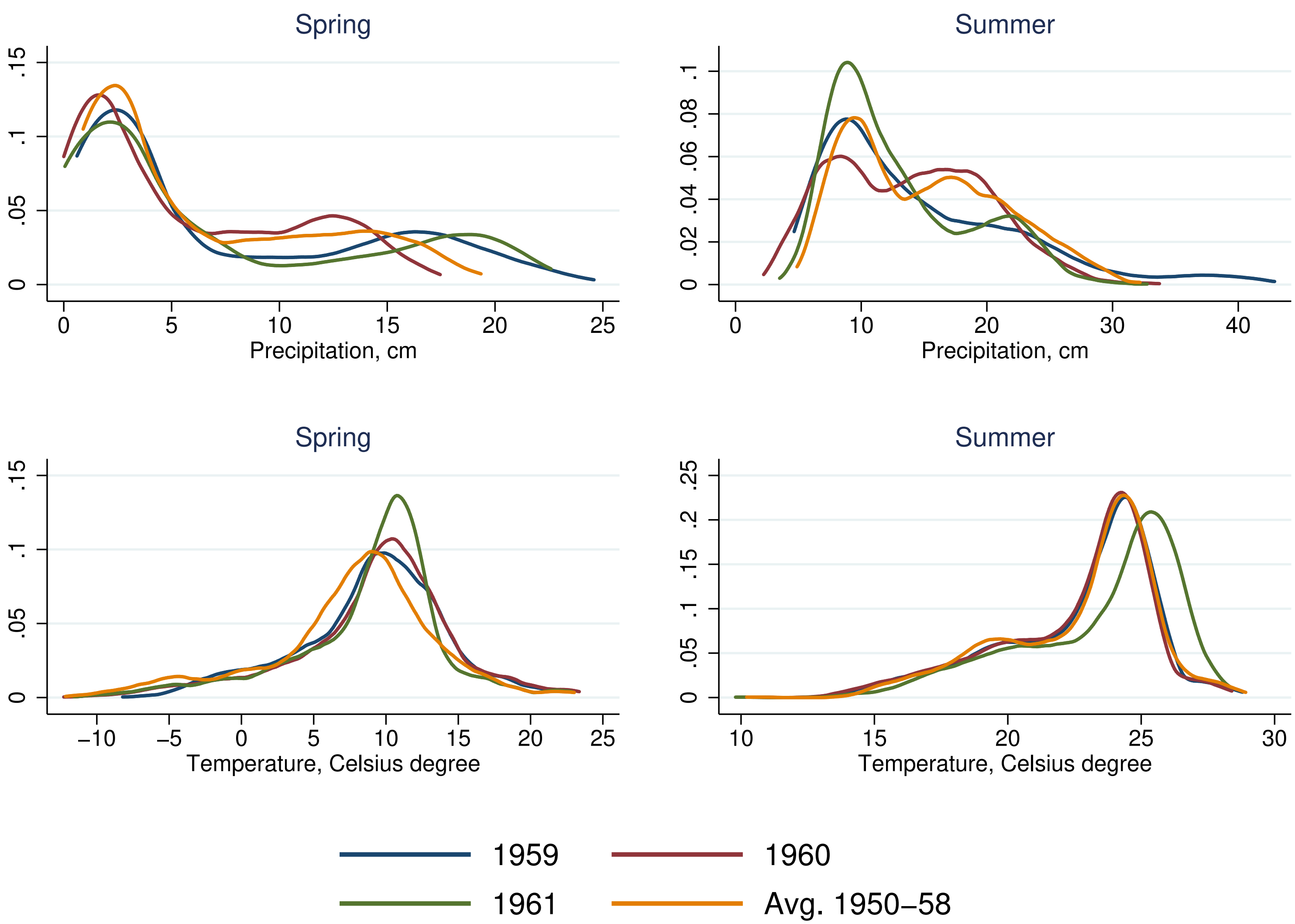


Figure A.11: Effects of Contemporaneous and Past Outputs: Estimated Coefficients and Corresponding 95% Confidence Intervals of Interaction Terms $\mathbf{1}(t \in \tau) \times \ln y_{it}$ and $\mathbf{1}(t \in \tau) \times \ln y_{it-2}$

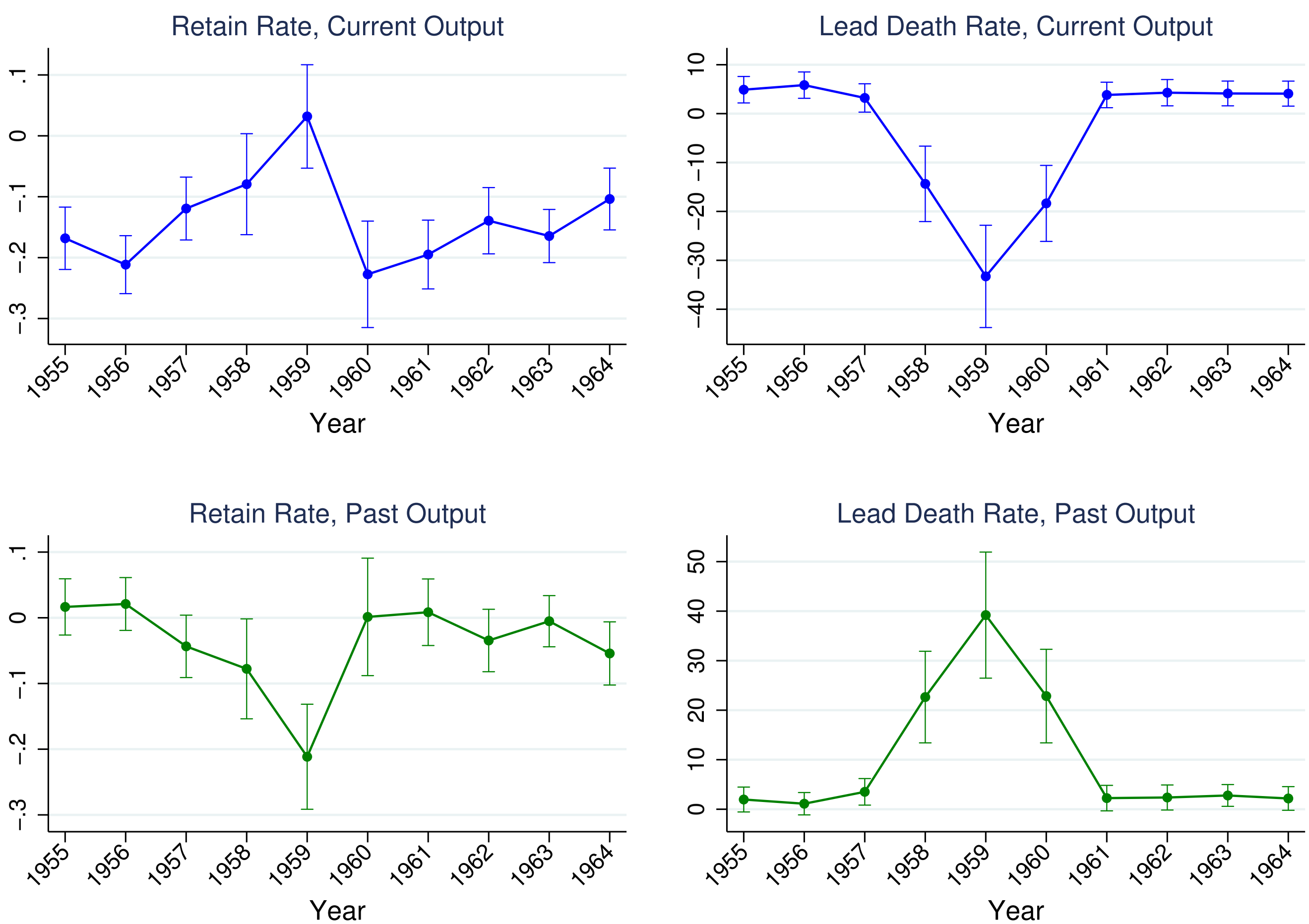
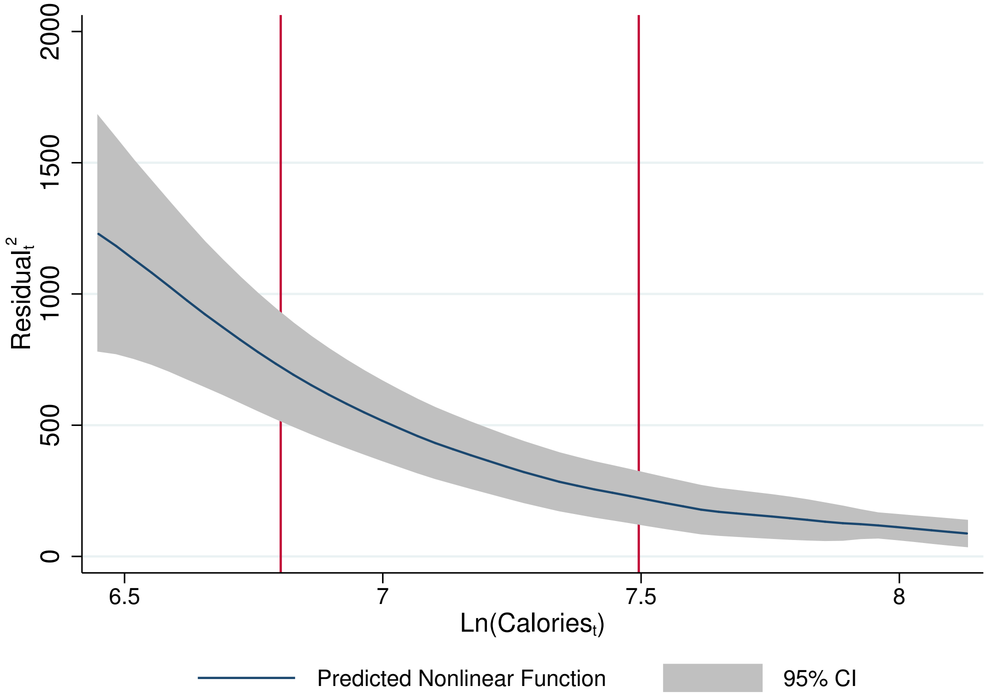


Figure A.12: Residual Squares and Log Caloric Consumption



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

Figure A.13: Export in 1959 Same as 1957

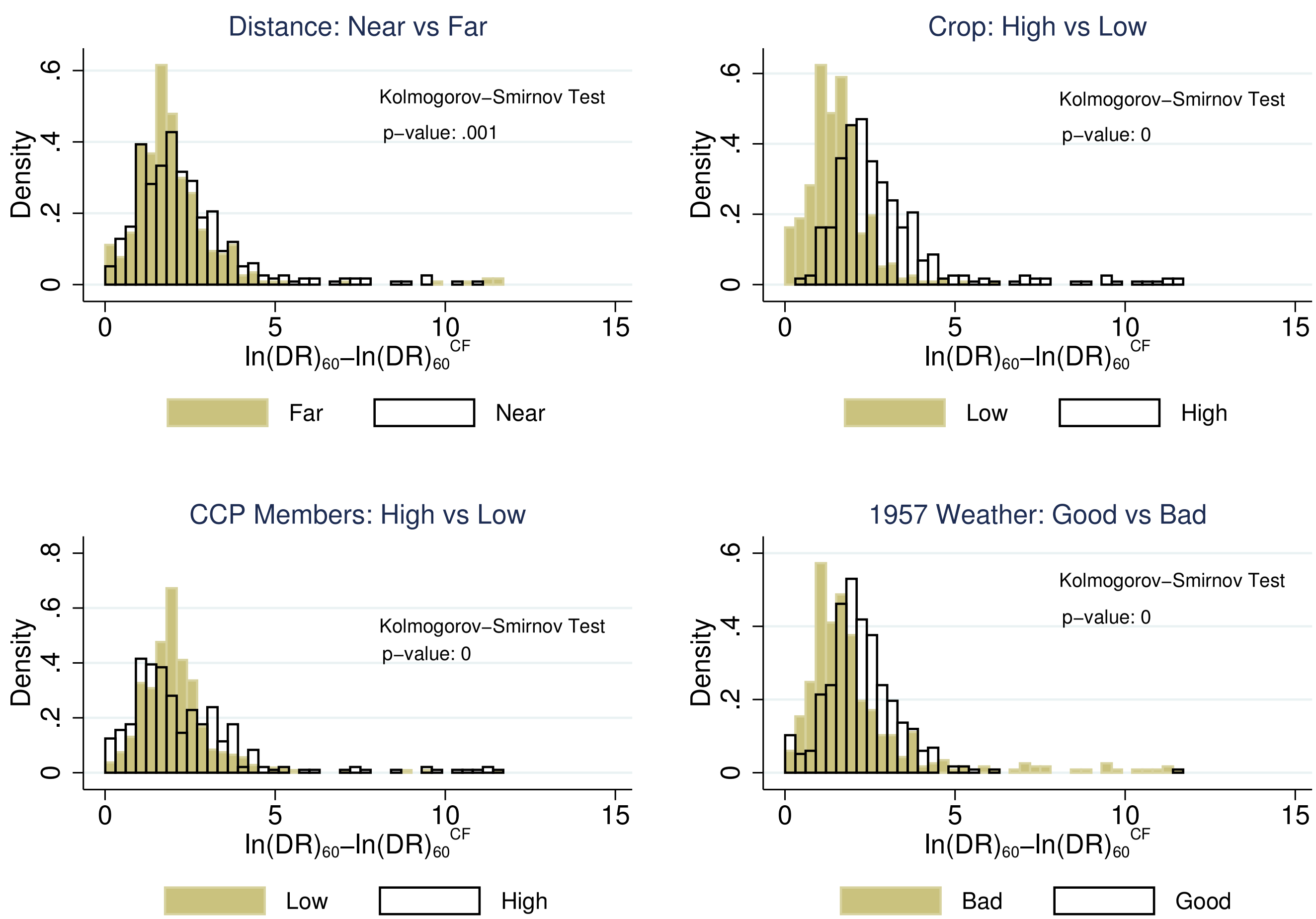


Table A.1: Data Sources of Mortality and Birth Rates

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

Note: Province codes are in the parentheses.

Table A.2: Famine Severity and Concentration

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

1959-61 total excess deaths as a share of: 1957 population in sample (7)	1959-61 total excess deaths as a share of: 1957 national population (8)	1959-61 total loss births as a share of: 1957 population in sample (9)	1959-61 total loss 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, Retained Rate, Death and Birth Rates – 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 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 (1)	All (2)	All (3)	All (4)	Near (5)	Far (6)	All (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×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: Estimated coefficient of $Export_t \times DistPCA$ is multiplied by 100. Robust standard errors 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 in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table A.7: Robustness: Counterfactural Exercises

	$\Delta DeathRate$ mean	$\Delta DeathRate$ 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 1957	13.14	14.99	3684578	90.06
(A3) Output in 1959 same as 1957	5.41	12.63	1738808	42.50
(A3.a) Agricultural Inputs in 1959 same as 1957	4.60	6.27	1216286	35.08
(A3.b) No weather shocks in 1959	0.67	4.96	349793	8.55
(A4) Procurement Rate in 1959 same as 1957	9.14	9.83	2409656	58.90
(A5.a) Export exposure in 1959 same as 1957	3.40	3.14	960157	23.47
(A5.b) Export exposure in 1959 same as 1957 (incl. output effects)	1.50	1.89	443567	10.84
(A6) Procurement Policies in 1959 same as Non-GLF period	3.85	2.58	1094924	26.76
(A7) Procurement Policies in 1957 same as GLF period	2.34	1.54	523167	12.79
(A8) Consumption equally distributed across the nation in 1959	5.66	16.51	1870731	45.72
(A9) Consumption equally distributed within provinces in 1959	2.11	16.12	720650	17.61
(A10) Redistribute export in 1959 across the nation	0.69	2.49	206607	5.05
(A11) Redistribute export in 1959 within the provinces	0.67	2.52	195768	4.78
Panel B: Spline Regression and Constrained IV Approach				
(A2) Caloric consumption in 1959 same as 1957	12.70	22.75	3697212	90.36
(A3) Output in 1959 same as 1957	6.26	19.76	2060925	50.37
(A3.a) Agricultural Inputs in 1959 same as 1957	5.32	10.90	1488433	42.93
(A3.b) No weather shocks in 1959	0.51	7.89	318123	7.78
(A4) Procurement Rate in 1959 same as 1957	10.44	17.63	2942846	71.93
(A5.a) Export exposure in 1959 same as 1957	4.13	6.19	1219787	29.81
(A5.b) Export exposure in 1959 same as 1957 (incl. output effects)	2.24	3.39	670508	16.39
(A6) Procurement Policies in 1959 same as Non-GLF period	4.54	5.84	1358493	33.20
(A7) Procurement Policies in 1957 same as GLF period	0.95	3.18	320922	7.84
(A8) Consumption equally distributed across the nation in 1959	14.57	23.27	4267540	104.30
(A9) Consumption equally distributed within provinces in 1959	3.89	26.26	1358569	33.21
(A10) Redistribute export in 1959 across the nation	1.45	4.17	418913	10.24
(A11) Redistribute export in 1959 within the provinces	1.29	4.30	372288	9.10

Notes: The implied number of excess deaths is the sum of excess deaths of 780 counties with data on caloric consumption in both 1957 and 1959. In rows (A3.a) the change in excess mortality (lost births) due to counterfactual change in per capita sown area is calculated for 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).