

Resistance is Futile? Institutional and Geographic Factors in China's Great Leap Famine

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Abstract:

I present evidence that China's state capacity was an important determinant of famine mortality during China's Great Famine (1959-61). I hypothesize that variation arising from the interaction of terrain ruggedness and provincial-level political ideology identifies the propensity for local leaders' willingness to shirk implementation of the 1958 national development plan, the Great Leap Forward. I find that communities under the jurisdiction of a Party Secretary aligned politically with Mao Zedong were differentially shielded from famine conditions by rough terrain. I also find that additional benefit from ruggedness applies to these communities' subsequent economic development and is attributable to the limiting effect rugged terrain had on each provincial authority's ability to administer his territory, including demanding compliance of local leaders during the period.

Key words: China, Famine, Terrain Ruggedness, Economic Development

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1 Introduction

Is Mao Zedong directly responsible for Great Leap Famine? There is no clear conclusion as to whether Mao's Great Leap Forward Development Plan systematically exacerbated mortality rates or if the magnitude of the demographic disaster was the result of natural calamity and randomly committed atrocities. In this article, I offer new empirical evidence on this question based on an important relationship between famine severity and the interaction of provincial political ideology and topography.

Obscurity of the facts is not limited to our understanding of how the Great Leap Forward (GLF) was implemented. It took twenty years for the first estimates of the death toll between 1959 and 1961 to be published for the global community. After the 1982 census, [Ashton \(1984\)](#) calculated the demographic impact of 30 million excess deaths and about 33 million unrealized births during the period 1958-62. Additionally, the famine conditions were mainly confined to rural communities. The survivors' accounts have been limited by poverty and reduced access to publication avenues. Since China opened up to the global community, demographers, historians, anthropologists, and economists have made large strides in furthering our understanding of what happened and what the effects have been. We know that the death toll was greater than 30 million and that the deaths were mostly due to acute starvation ([Cao, 2005](#), [Thaxton, 2008](#), [Meng et al., 2015](#)). Researchers have also established that the Famine has negatively impacted the lives of survivors and their children as well as the greater Chinese economy ([Almond et al., 2008](#), [Chen and Zhou, 2007](#), [Fung and Ha, 2010](#), [Gooch, 2017](#), [Gørgens et al., 2012](#), [Luo et al., 2006](#), [Shi, 2011](#), [Song, 2010](#)).

The causes of the Famine have been a subject of much discussion amongst scholars across a variety of disciplines. Today, only China's government maintains the idea that the Famine was a natural disaster. Generally, researchers accept that either famine conditions were exacerbated by anthropogenic forces or human decisions were the full cause, but there are two principal contentions. The first disagreement is over what part of the Famine was natural and what part was human-made. The second dispute is over who drove the anthropogenic causes. A productive avenue of study has been an accounting of specific GLF policies at the provincial level and their correlation with the death toll at the time. The grain procurement policies, communal dining hall rates, labor reallocation, output inflation have been associated with greater famine deaths ([Bernstein, 2006](#), [Chang and Wen, 1997](#), [Houser et al., 2009](#), [Jones and Poleman, 1962](#), [Kung and](#)

Lin, 2003, Li and Yang, 2005, Lin, 1990, Lin and Yang, 1998, 2000, Liu et al., 2014, Manning and Wemheuer, 2011, MacFarquhar, 1983, Riskin, 1998, Thaxton, 2008, Walker, 1998, Wedeman, 2009, Yang, 1996, Yang and Su, 1998).

If the Famine's anthropogenic origins are associated with GLF policies, who were the decisive administrators? Was the deadly implementation contingent on malevolent local leaders or were the policies destructive by nature and the harm resulting from their implementation should be attributed to the central authorities? Again, the lack of data disrupts analysis. To the best of my knowledge, Meng et al. (2015) has conducted the only empirical study attempting to make a distinction between institutional and localized contributors of famine mortality across China and below the provincial level. First, the authors establish a surprisingly positive relationship between rural mortality and per capita food production at the county-level. Next, Meng provides quantitative evidence that the Great Leap Forward's grain procurement policy was necessary for generating the paradoxical pattern but can only establish this relationship at the provincial level due to lack of data. This study concluded that the centrally-commanded, inflexible and progressive procurement policies were important contributors to overall famine mortality.

However, opposing quantitative evidence is provided by Bramall (2011). He analyzes a detailed county-level data set of famine mortality for Sichuan province, one of the provinces most devastated by the Famine, and finds no county-level characteristics that could explain the sub-provincial pattern in the death toll. Bramall's analysis is so detailed that he even knows the counties over which the most callous local leaders presided. Bramall judges that the role of random local leaders was a driving force in the distribution of sub-provincial GLF implementation and famine mortality. But in a case-study of famine deaths in Wuwei county, Anhui province, Cao (2014) reports that communes along a navigable waterway had more grain procured than those set back from the water, and the famine conditions varied with the amount of grain removed.

At the provincial-level, researchers have demonstrated a robust association between GLF implementation and famine mortality. Research has shown that career incentives for the provincial authorities have a strong relationship with the intensity with which the Great Leap Forward policies were implemented in their domain and explain the coinciding famine mortality. Cheek (2015) explains that provincial leaders embraced Mao's

new ideas to catch the Chairman's attention. [Yang et al. \(2014\)](#) provides the clearest empirical evidence for the relationship between provincial authorities ideology and famine severity. Yang identifies Provincial First Party Secretaries who received their positions through a special promotion in 1956 and 1959 instead of moving up through the ranks. Yang also finds provinces with these Secretaries had relatively higher grain procurement rates and mess hall participation rates during the GLF period.

The principal contribution of my study is a rigorous quantitative analysis of the centrally-commanded GLF's role in the Famine at the local level. My estimation strategy draws on two sources of variation in the GLF's implementation from the literature. First, provincial leaders' political attitudes influenced GLF implementation ([Goodman, 1986](#)). Second, local terrain irregularities limited the reach of the state. The legacy of terrain ruggedness in altering the implementation of a detrimental policy has already been documented by [Nunn and Puga \(2012\)](#) in their assessment of the Atlantic Slave Trade. My estimation identification strategy relies on the interaction of the two sources of variation, and only the interaction term can be interpreted as plausibly exogenous. My strategy compares the relationship between famine mortality and terrain ruggedness in provinces governed by Mao's antagonists who conservatively implemented the GLF with those provinces governed Mao's supporters, leaders who embraced adventurism (rash political action) with regard to the GLF ([Goodman, 1986](#)).

My approach has advantages and disadvantages. On the one hand, it allows me to control for province fixed effects. The emphasis on the differential effect also alleviates concerns about omitted variable bias unless the relationship between famine mortality and the omitted factor is different between the conservative and zealous provinces. Additionally, I include two control variables that may have been important in the distribution of the GLF and the famine: average agricultural suitability and population density in 1959. On the other hand, the strategy relies on there being no other characteristics correlated with variation in political ideology at the provincial level. I address this concern with quantitative and qualitative evidence. I use several measures of provincial-level support for Mao and the GLF. Moreover, according to the historical analysis, the incentives for provincial authorities during the GLF were unique to that period. During no other period in Chinese history was extreme exemplification of devotion to the national agenda at the expense of the peoples' well-being essential to a local or regional politician's success.

I find that in provinces governed by adventurers, ruggedness had an additional negative effect on famine mortality, although rugged terrain generally correlated with underdevelopment and was likely to exacerbate famine conditions. This result presents a paradox similar to in spirit to Meng's, presenting a pattern consistent with a centrally commanded and harmful policy. It is possible, as in Nunn and Puga's determination for Africa, that rugged terrain afforded protection to communities from detrimental policies. Research compiled in [Manning and Wemheuer \(2011\)](#) supports accounts of "peasant resistance" and attempts to survive the famine at the local level. My empirical results are maintained to the inclusion additional covariates, various measures of GLF implementation intensity at the province-level, and the removal of outlying observations of ruggedness and famine mortality.

These results provide evidence that the GLF impacted the Famine. In [Gooch \(2017\)](#), I established a causal link between the Famine and economic development today. Following the methodology in Nunn and Puga (2011), I estimate the differential effect of ruggedness on income for provinces lead by adventurers relative to conservatives. I show that, despite the generally detrimental role of ruggedness in development, the rugged terrain had a historical positive effect on income, of which a portion can be accounted for by the history of the Famine.

To assess the magnitude of my estimated effects, I calculate the direct impact of ruggedness on famine and indirect historical impact on income for the three provinces administered by the most infamous adventurers, Li Jingquan of Sichuan province, Wu Zhipu of Henan province, and Zeng Xisheng of Anhui province. In addition to the fact that these three men received their provincial Party Secretary positions by special promotion, I explain their uniqueness, both ideologically and practically, using historical accounts in section [2.2](#). First, within the provinces of Li, Wu, and Zeng, I calculate that a one standard deviation increase in the ruggedness translates to a 1.18 standard deviation decrease in the excess death rate. This means the real average excess death rate was 8.17 percent and the counterfactual rate was only 4.7 percent. Next, I find that this same increase in ruggedness increases GDP per capita in 2010 for districts in Sichuan, Anhui, and Henan from an average of 16,323 RMB to 17,124 RMB while other provinces have a negative association. Finally, I estimate that the significant difference between income today vanishes when famine mortality (1959-61) is taken into account. Therefore, the differential benefit of ruggedness experienced by districts is due to the

limiting effect of the Famine.

To verify my estimates, I conduct a discontinuity analysis at the border of conservative and adventurous provinces. Looking at the differential effect of ruggedness on famine mortality close to the border reduces the likelihood of unobservable characteristics biasing my results. The estimates suggest that for communities close to the border, ruggedness negatively affected famine mortality and alleviated the detrimental effect of the demographic disaster on subsequent economic development.

These findings contribute to several existing literatures. First, my finding adds to the debate about the causal role of the Great Leap Forward in the Great Famine. My results provide empirical evidence anthropogenic forces exacerbated famine mortality. Second, my analysis furthers out understanding of who is responsible for the lethality of GLF policies. I uncover a trend in GLF implementation dependent on ruggedness which suggests that if a community could get away with not implementing the GLF to some degree, then they would not. These results provide evidence that goals of the central Party contributed significantly to famine mortality.

Finally, my findings contribute to the historical debate about the importance of Communist institutions and policies for Chinese living standards. Particularly, since 1979, the Chinese government has made political and economic decisions that have improved the well-being of its citizens. My finding that the GLF affects today income disparities brings to light the consequential ways Mao Zedong's decisions persist.

The paper is organized as follows. Section 2 provides historical background on the Great Leap Forward and Great Famine. Section 3 outline the microfoundations and conceptual basis for the research. Section 4 describes the data used in the analysis. Section 5 presents the core hypotheses and estimating equations. Section 6 presents the baseline results. Section 7 reports the discontinuity analysis. Section 8 offers concluding remarks.

2 Historical Background

2.1 PRC Development Policies and Consequences, 1949-1961

In 1949, the Chinese Communist Party (CCP) established the People's Republic of China (PRC). The PRC followed a turbulent half-century for the Chinese which included the fall of the long-standing Qing Dynasty in 1908, the rise and fall of the Nationalist's Republic of China (1912-49), the Japanese occupation of Northeast China (1933-46), World War II, and Chinese Civil War fought between the Communists and the Nationalist (1946-1949).

During the first half of the PRC's first decade, the CCP developed initial plans for the country's transition to a socialist state. The early policies implemented by the CCP included state control of the media, the grain market, and the redistribution of land to a large number of previous non-landowning farmers. By 1955, the CCP had written up and was ready to implement their First Five-Year Plan (FFYP) which laid out guidelines for development for (1952-57).¹ The policies of the First FYP initialized developments for the socialist industrialization of the PRC yet embodied to a certain degree a gradual transition towards socialist and relied on a mentality of volunteerism among its citizens. The increased investment in large-scale industry, transportation and irrigation infrastructure, determinants of people's standard of living such as public health and literacy. The Plan states that one-third of peasants will organize themselves into elementary cooperatives (Li, 1955).

Almost immediately Mao called for acceleration or a "leap forward" in the development speed for industry and agriculture beyond that stipulated by the FFYP. This initial surge between the summer of 1955 and spring of 1956 is now known as the Small Leap Forward. Mao's sudden demand for a speed up in the transition to a socialist state in July 1955 conflicted with the principles of "gradualness" and "volunteerism" guiding China's institutional evolution up to that point in time. To put this "leap" into context, Mao doubled the target number of households (1.3 million of 110 million) to be in cooperatives within 14 months (Mao, 1955b). In December 1955, Mao claimed an increase of 300 percent in four months (Mao, 1955a). This acceleration was supported by the release of the 12-Year Agricultural Program in January 1956. This 12-Year plan supported a rapid transition to a socialist state. For example, the following year, 1956, the

¹The FFYP was finalized late. It was written for the years 1952-57 but was not ready until 1954.

new Program called for 85 percent of rural households to join a cooperative (CCP Political Bureau, 1956, Pepper, 1996).

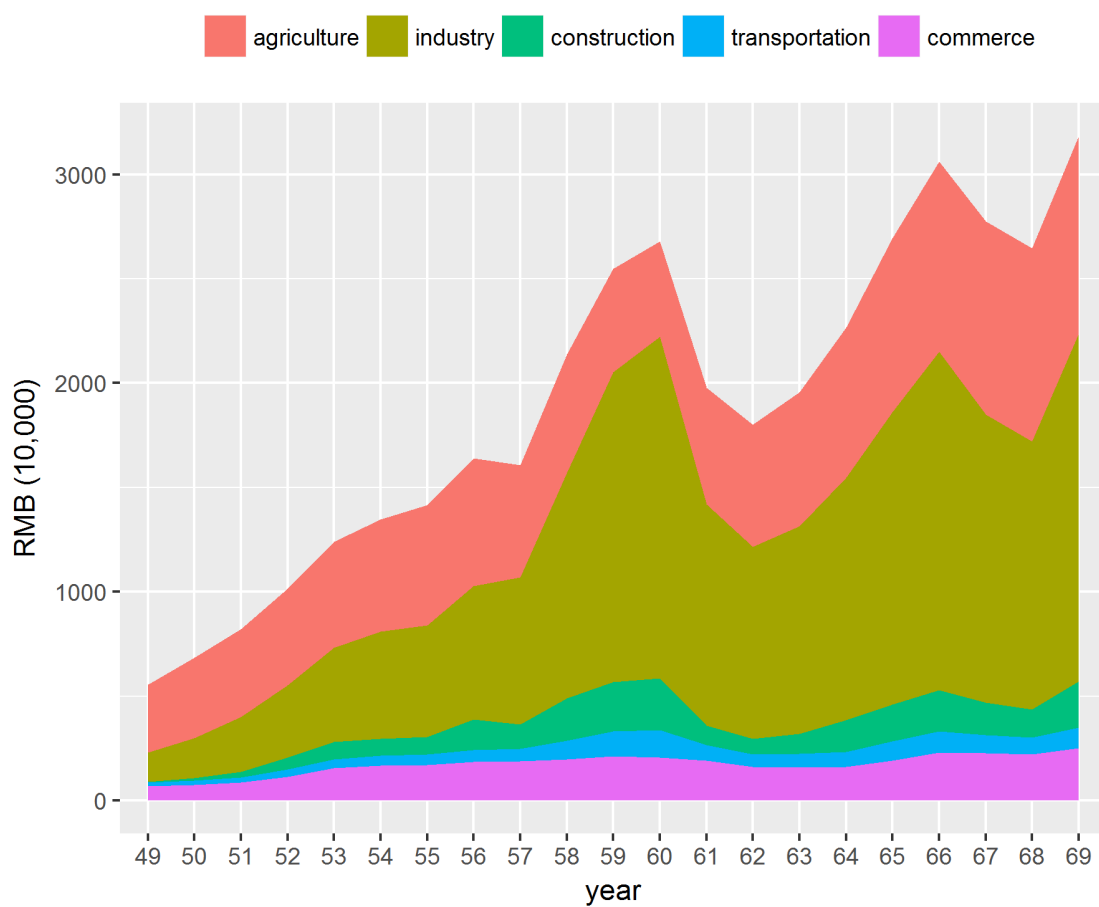
By late summer 1956, it became apparent that the methods of transformation of China's agricultural sector were not working well. Localized famine conditions were reported in Guangxi province, and peasants began to hoard grain. The Party authorities in the area allowed a limited free market to open up which quickly turned into an uncontrolled black market. In the fall of 1956, the peasants' burden was identified as the newly enlarged cooperative system. Peasants reacted by withdrawing from the collectives which in turn led to the dissolution of some collectives. Between fall of 1956 and summer 1957, 570,000 people move from rural areas to cities. The relative scale back in net grain procurement after the Small Leap Forward (1956 as compared with 1955) is presented together with the decrease of net procurement after the Great Leap Forward (1959 as compared with 1962) in 4.

Despite the unsuccessful Small Leap Forward, Mao wanted China to embark on an even more vigorous acceleration. He planned for the next "leap forward" to coincide with the implementation of the Second Five-Year Plan (SFYP) which was to start in a year (1958). Mao referred to the SFYP as China's Great Leap Forward (GLF). To reset the national narrative, state-run media rename the reports of opposition in the rural communities as "class struggles," and labeled the critics of rapid political transition and development "rightest". In preparation for the next "leap forward" extensive re-education and purges of cadres with localist and rightest tendencies took place.

The slogans accompanying the announcement of another "leap forward" were similar to those that spurred the 1956 acceleration, however, in the fall of 1957, Mao personally escalated the rhetoric. He set a goal for China's industrial development to surpass Britain within 15 years. In Lui Shaoqi's May 1958 speech launching the GLF, he reiterates Mao's "militant call" and warns against allowing misgivings to interrupt progress. The ramp-up of industry between 1957 and 1961 is apparent in the national statistics presented in figure 1 and the magnitude of industry output was unmatched again until the late 1960s.

A priority of the GLF was the establishment of People's Communes, enlarged and formalized version of earlier agricultural cooperatives. People's Communes corresponded to townships or even county-units. Each commune conducted its administrative, governmental, economic, and industrial functions. Commune

Figure 1: National revenue figures by industry type, 1949-69



Source: NBS (1990)

administrators mobilized labor for public works in agriculture, provided financing for the industry, and coordinated agricultural with industrial production. Other elements of collectivization were being tried around the country. The larger communes enabled administrators to more quickly mobilize labor for the construction of irrigation and water conservation works. The abolishment of family life was also a principal feature of the commune system, and the CCP leader and propaganda were clear about this objective. Without traditional family life, women would be free from household work and could contribute to the agricultural and industrial production potential in their commune.

The Party administered the GLF in stark contrast to their previous ideology of gradualness and volunteerism. GLF policies were implemented with the help of the People's Liberation Army, and full collectivization of agricultural communities took place within two months, August to October 1958. The role of the Army was formalized in a resolution crafted by the CCP to direct the Great Leap Forward which stipulated that cadres treat the peasants gently and let the Militia carry out stricter enforcement. Strict enforcement means that participation in the GLF was mandatory. For the rural person, this means that neither commune assignment and participation nor enrollment in a regional industrial project or irrigation project was not changeable.

In the late winter of 1958, rural communities across China began to experience food shortages. Chinese national statistics show that the death rate grew and birth rate fell between 1959 and 1961 resulting in an unprecedented negative population growth rate (figure 2). The CCP officially refers to the demographic catastrophe as the "Three Years of Natural Disasters" for which there was an excess of 15 million deaths. In this research, I use excess death rates in 1959, 60, and 61 from [Cao \(2005\)](#) who estimates 32.5 million unnatural deaths. [Meng et al. \(2015\)](#) emphasizes that mortality above the normal rate in these three years was almost entirely due to acute starvation and not associate disease commonly accompanying famine conditions at other times ([Thaxton, 2008](#)).

The persistence of GLF implementation and conditions through the winter of 1960-61 is not clear. In the spring of 1961, a year before the set end of the Great Leap Forward, the policies were aborted, and aid was distributed to disaster areas. Why famine conditions persisted after 1959 and what happened in the aftermath of the famine are both poorly recorded.

Figure 2: PRC birth, death, and growth rates, 1949-69



Source: NBS (1990)

2.2 Evidence of a Heterogenous Perspective on Socialist Transition

The stability of the CCP rested on the control that Mao Zedong wielded through an intense personality cult (Westad, 2003). However, this dependence on Mao also created an extremely politically charged environment during the 1950s and beyond (Harvard University, 1962). Two fundamental features of the PRC political scene were rarely questioned, first, CCP political control and, second, the fact that China was on a path towards becoming a socialist state. However, what was debated was the aggressiveness with which CCP policies pursued ideological and development goals.

In 1956, with the onset of the Small Leap Forward, the nature of the debate changed when Mao personally aligned himself with policies that supported a rapid pace of development. A good example of this polarization is the 12-Year Agricultural Development Plan. The plan was a touchstone of the political debate because of Mao's personal investment in it (MacFarquhar, 1983). According to Goodman (1986), even though the simplification of 1955-57 policy debates as those for or against Mao's policies is imperfect, the distinction can provide a useful guide. Mao, the master political strategist, had cultivated a dichotomous political scene in which he represented ideals of the PRC. Conservatives who argued against leftist policies their actions were also regarded as antagonists of Mao, while adventurists were supporters of Mao.

A strong attempt to consolidate the Party's perspective in line with Mao through propaganda, political interventions and personal offenses took place during the second half of the 1950s. Mao's political initiative, Hundred Flower campaign (1957-58), began as an opportunity for dynamic conversation about PRC policies but ended as means by which to out conservatives. In 1957 and 1958, the rectification campaign ousted administrators at many levels of government. Additionally, conservatives who did not lose their positions underwent self-criticism sessions to shed their rightist tendencies.

However, at the precipice of the SFYP, some Chinese continued to vocalize their anxiety. A local cadre in Fujian province was confused by the Party's support for another "leap forward" in 1958. He said, "We were very vigorous in the first half of 1956 and were censured in the second half of the year. This year we're asked to be even more vigorous. Is there a bigger censure waiting?"

Even with the threat of purges and re-education, politician continued to criticize the Party's agenda. In Gansu province, even after the ousting of the Vice-Governor, it was reported that one-tenth of Party cadres

doubted the success of the Great Leap Forward ([Harvard University, 1962](#)). Cadres in Gansu province responded in writing that they would “reckon accounts with leaders after the fall [1958].” which referred to the censuring, or crisis, they expected following this leap. In section 4, I offer some ways to quantify heterogeneity at the provinces level for Mao, the speed of transition, and the GLF.

3 Conceptual Framework

3.1 Deciding to shirk the Great Leap Forward

A fundamental administration problem existed on the ground for the Party regarding GLF implementation. Cadres in the agricultural cooperative system need to make the peasants work harder for the benefit of others and turn over the harvest to the state. This choice of local level administrators between “localism” and “communalism” was a decisive problem for the Party leadership who wanted all local level administrators to choose “communalism”. This latent decision motivates my empirical study.

The formal model follows [Polinsky and Shavell \(1992\)](#) who model an individual’s willingness to commit a crime and the enforcement process. For this analysis, I redefine the “crime” a district leader shirking his duty to the Party of implementing the GLF at the level requested by his provincial First Party Secretary.² In other words, the district leader is choosing some level of “localism” below the level dictated by his superiors concerning the intensity with which he implements the GLF. The Party authorities punished district leaders who shirked their responsibility in implementing GLF policies, but detection was costly. A district leader will avoid implementing GLF policies to some degree if his benefit is greater than or equal to the expected punishment.

²The socialist ideals upheld in 1950s China advocated for gender equality but it likely that a vast majority of district authorities were male. For ease of discussion, I use the pronoun he when referring to these leaders.

The notation used in equation 2 is summarized as follows:

b = benefit to the district leader of shirking the GLF; b is positive.

$p(h)$ = punishment given to the district leader by the provincial government for shirking the GLF; p is positive for $h \geq 0$.

h = harm caused to the state if shirking the GLF is committed; h is positive.

$d(c)$ = probability of detection; d is negative for $c \geq 0$.

c = fixed enforcement costs; c is positive.

$$b \geq p(h)d(c) \tag{1}$$

Equation (2), however, is too simple and does not capture intricate details of the situation of interest. I propose two extensions that will end up driving my empirical investigation. First, historical studies have documented that the harm to the state, h , and the benefit to the district leader, b , may not be uniform across Chinese provinces but vary with the provincial leader's ideology. Second, the development literature has established that ruggedness of terrain, r_i , limits state capacity through increasing the costs of cooperation. Ruggedness hinders infrastructure development and restricts interactions among constituencies. [Jimenez-Ayora and Ulubaşoğlu \(2015\)](#) finds that terrain ruggedness presents challenges to the provision of public goods. [Numm and Puga \(2012\)](#) determines that topographic irregularities limited the scope of slave traders in Africa (1400-1900). And in a case study, [Osborne \(2013\)](#) reports that Southeast Asia groups living near one another but separated by highly rough surfaces rarely exchange or cooperate due to the insurmountable transportation costs they face.

I update the notation in the following ways:

m_j = degree of adventurism in provincial leader's ideology; $m \geq 0$ and j indicates the province.

$b(m_j)$ = benefit to the district leader of shirking the GLF; b is positive for $m \geq 0$.

$h(m_j)$ = harm caused to the state if shirking the GLF is committed; h are positive for $m \geq 0$.

r_i = measure of terrain ruggedness; $r \geq 0$.

$c(r_i)$ = fixed enforcement costs; c is positive for $r \geq 0$.

Conceptually, the inclusion of provincial ideology and local terrain ruggedness alters incentives to shirk. Ruggedness reduces the likely of detection. Adventurist provincial leaders increase both the punishment and benefit of shirking. Equation 2 can be rewritten as:

$$0 \geq b(m_j) - p(h(m_j))d(c(r_i)) \quad (2)$$

3.2 Shirking and famine mortality

Sen (1986) created the "Entitlement Approach" to explain how the determinants of food acquisition determine famine conditions. The approach does not conflate supply, which can fluctuate with natural forces, with command over food. A person has an *entitlement set* which is made up of an original bundle of ownership, the *endowment* and the ability to *acquire* additional bundles. The person experience famine through the loss of the original endowment, like land or labor power, and the loss the ability to acquire, like lower wages or higher prices.

A district leader's shirking decision altered the intensity with which GLF policies specifically affected both the entitlement and endowment set for his constituents. For example, shirking the GLF could result in relatively greater grain production between 1958 and 1961 because Soviet agricultural practices were not implemented or individual incentives for productivity remained in place. Additionally, districts that shirked the GLF may have relatively less overreported grain production estimates resulting in lower procurement rates. Shirking could also take the form of a less cooperation by community leaders with the national program including greater personal food supplies and less dependence on communal dining. There are many avenues

through which shirking the GLF positively impacted the endowment and entitlement sets for residents.

4 Data

4.1 Measuring Famine Severity (1959-61)

Excess mortality between 1959 and 1961 was primarily due to starvation (Meng et al., 2015). Therefore, famine mortality and famine conditions are highly correlated. I use excess death rate (EDR) data created by Cao (2005) to measure variation in famine mortality. EDR is the ratio of average unexpected deaths (1959-61) relative to the population in 1958. The aggregation of excess death according to Cao (2005) assessed the total number of famine-related casualties at 32.5 million. This estimation of the total death toll is far above the official estimate but below the highest estimate at 45 million (Dikotter, 2010).

Cao (2005) determined my basic unit of analysis is a historical sub-provincial administrative unit known as a fu. I align my other variables with this unit of observation. The fu is based on the zhou regions from early history and was a stable administrative unit for a millennium. The fu unit was chosen by Cao (2005) to bring together demographic information across the 1953, 1964, 1982 censuses for 223 fu across 17 provinces to calculate the average excess death rate for 1959, 1960, and 1961. Fu were only recently abandoned by the CCP (circa 1950). The 1820 boundaries of fu are published by Harvard's CHGIS department (CHGIS, 2010, Twitchett and Fairbanks, 1979). For ease of discussion, I will refer to the fu as a district for the rest of the paper.

4.2 Measuring Geographic Accessibility

To capture the accessibility of a community, we employ a relief intensity index constructed by Dijkshoorn et al. (2008) based on 90-meter digital elevation data (90m DEM) of the Shuttle Radar Topography Mission (SRTM) (CGIAR-CSI, 2004). I calculate the median terrain relief intensity, r_i , which I will call ruggedness for each sub-provincial district and use the natural log of it for ease of interpretation. TRI is defined as the median differences within one km² circle around the pixel in consideration and measures small-scale terrain irregularities such as caverns, caves, and cliffs. These topographic hurdles isolated communities from regional

administrators because transportation over irregular terrain is slower and more costly.

4.3 Outcome and control variables

I use two outcome variables in this study. First, I start with famine mortality which I have already described in section 4.1. In addition, I investigate the legacy of the GLF on contemporary income. I calculate GDP per capita in 2010 for each sub-provincial district which is equal to the mean county-level GDP weighted by the county population (Gooch, 2017, NBS, 2010).

I include two control variable in the baseline specifications. Ramankutty et al. (2002) calculates suitability for cultivation at a 5-minute resolution in both latitude and longitude based on mean-monthly climate conditions (temperature, precipitation, and potential sunshine hours) and soil properties. I calculate the average suitability for each sub-provincial district Cao (2005), in addition to excess death rate data, constructed population density for each sub-provincial district in 1958, just before the onset of the GLF. I present summary statistics in table 1.

Table 1: Summary statistics

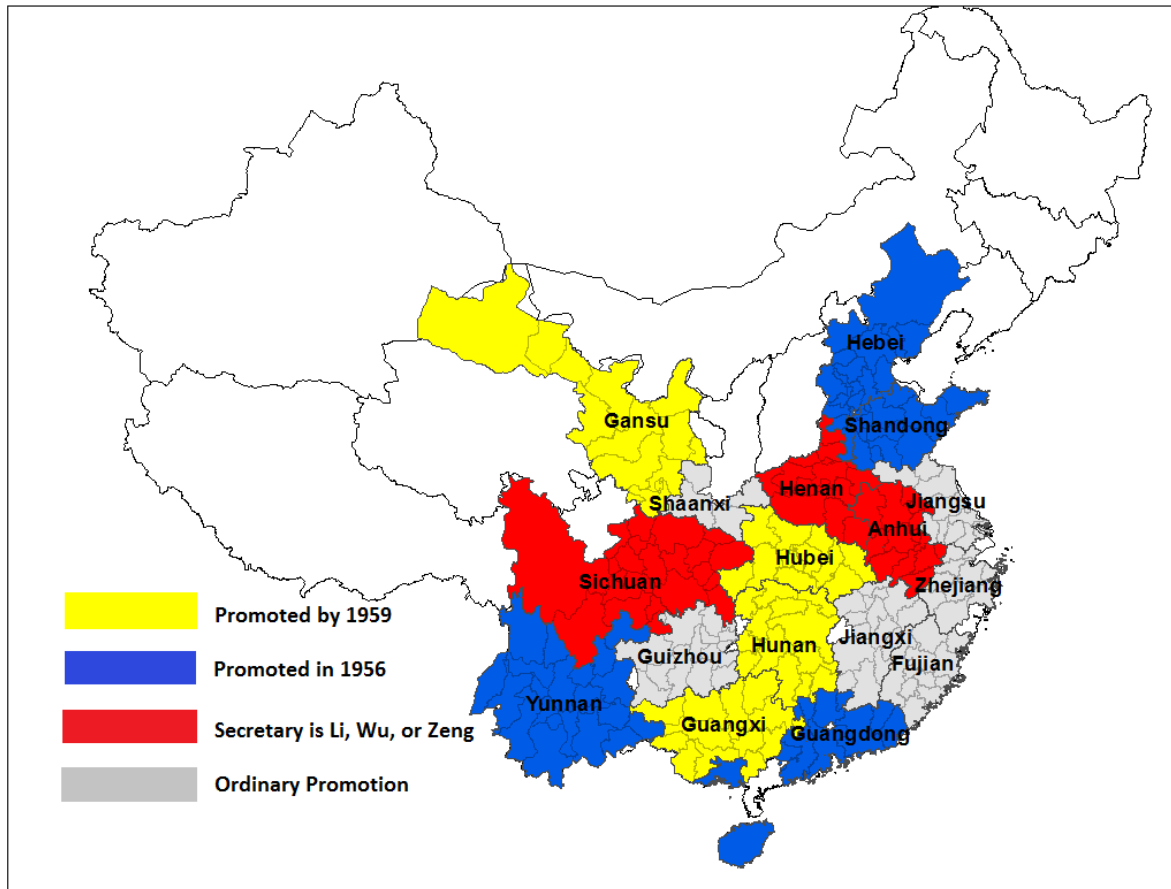
	(1)	
	mean	sd
ln(Ruggedness)	4.33	1.33
ln(Excess death rate)	1.13	1.22
ln(GDP per capita 2010)	0.60	0.65
ln(Average agricultural suitability)	-0.51	0.56
ln(Population density (1958))	-5.29	1.04
Observations	223	

4.4 Quantifying degree of provincial support for the GLF

Mao Zedong, the PRC prime minister, embraced the ideology of the far-left. In his view, the Chinese people could execute a rapid and aggressive transition, and his GLF development embodied these ideals. However, provincial leaders at the onset of the GLF varied in their viewpoint on the speed of China’s transition toward a socialist state and general agricultural and industry development trajectory.

The literature provides ways to measure provincial leaders’ support of the GLF. Two other ways to think

Figure 3: Provinces where the First Party Secretary received a special promotion in 1956 or by 1959



Source: Yang et al. (2014). Secretary Li of Sichuan province received a special promotion in 1956. Secretaries Wu of Henan and Zeng of Anhui received special promotions by 1959.

of this variation is the level of the leaders' commitment to a rapid transition to a socialist state or their allegiance to Mao. I have two measures set before the GLF and arguably determine provincial attitudes during the period of interest, 1) special versus ordinary promotion of the provincial First Party Secretary and 2) the degree to which grain procurement was censured following the Small Leap Forward. The provinces in which the Secretary received a special promotion map figure 3.

A Party Secretaries' job was to align the provincial government agenda with that of the Party. Special promotions for Secretaries and amount by which grain procurement declined (1955-56) both capture the possibility that the Secretary was purged and replaced by a person with less conservative ideology and willingness to implement policies for an abrupt transition. In Lui Shaoqi's May 1958 speech launching the

Great Leap Forward, he reiterates Mao's "militant call" and warns against allowing misgivings to interrupt progress [of abrupt change].

In the spring of 1958, provincial party secretaries conduct rectification campaigns were carried out by their respective governments and sixteen provinces outed the conservative opposition in the *People's Daily*. Specific purges of the Party (often including the Party secretary) were mentioned. For example, Pan Fusheng was deposed as Party Secretary of Henan for his strong element of "localism" and opposition to CCP policies since 1955. But what happened to Pan was not typical. The secretaries in other provinces reported that conservative-minded cadres, those who wanted to advance gradually and doubted the possibility of a leap forward, had been overcome. Cadres in Gansu province accepted Liu's challenge from his 1958 speech. They responded in writing that they would "reckon accounts with leaders after the fall.." which referred to the "censuring", or economic crisis, they expected following this leap. Even by the March of 1958, it was clear that opposition continued within the Party regarding the Great Leap Forward and would re-emerge if the policies began to create problems.

Yang et al. (2014) identifies First-party Secretaries who received their position in either 1956 or 1959 through a special promotion process was overseen by Mao himself. These specially promoted Secretaries more likely embraced similar ideals to Mao than their ordinarily promoted counterparts. However, for any Secretary to maintain his position at the start of the GLF period means that he had not supported "rightist" policies.

The 12-Year Agricultural Development Plan aimed to hasten rural development midway through the FFYP. As discussed in section 2.2, this plan was a touchstone for the political debate in the second-half of the 1950s, partly due to Mao personal investment in it. Three provincial First Party Secretaries merge from historical narratives as distinctly supportive of the 12-Year plan. First, Li Jingquan, the First Party Secretary of Sichuan, was the only one of 34 provincial leaders to reference the 12-Year Plan during the 8th Party Congress in 1956. Li spoke of the Plan in glowing terms. Again in 1957, Li extolled the virtues of the 12-Year plan at a provincial conference of 'progressive workers' (Goodman, 1986). Second, Zeng Xisheng, the First Party Secretary of Anhui province, wrote an essay for the New China Semimonthly promoting the 12-Year plan (Zeng, 1956). Additionally, after the unsuccessful *Small* Leap Forward, Zeng was the only

provincial First Party Secretary to suggest that the 12-Year Plan was still operative (Bachman, 1991).

Third, Wu Zhipu, First Party Secretary of Henan, who took the position after a successful effort to depose Pan Fansheng for “rightest” ideas. In 1958, Wu planned to adhere to the targets of the 12-Year plan and embrace of Mao’s call for “greater, faster, better, and more economical” (the slogan of the GLF) caught Mao’s attention. In August 1958, Mao endorsed Wu’s plans both at the August 1958 Beidaihe conference for Party leaders and in an August 17, 1958 issue of the People’s Daily, the official newspaper of the Communist Party (Cheek, 2015).

Li, Zeng, and Wu made efforts to broadcast their adventurism before the onset of the GLF. Their uniqueness is supported by many qualitative historical accounts. In table 2, I point out provincial leaders for which historians have suggested showed considerable support for the GLF.

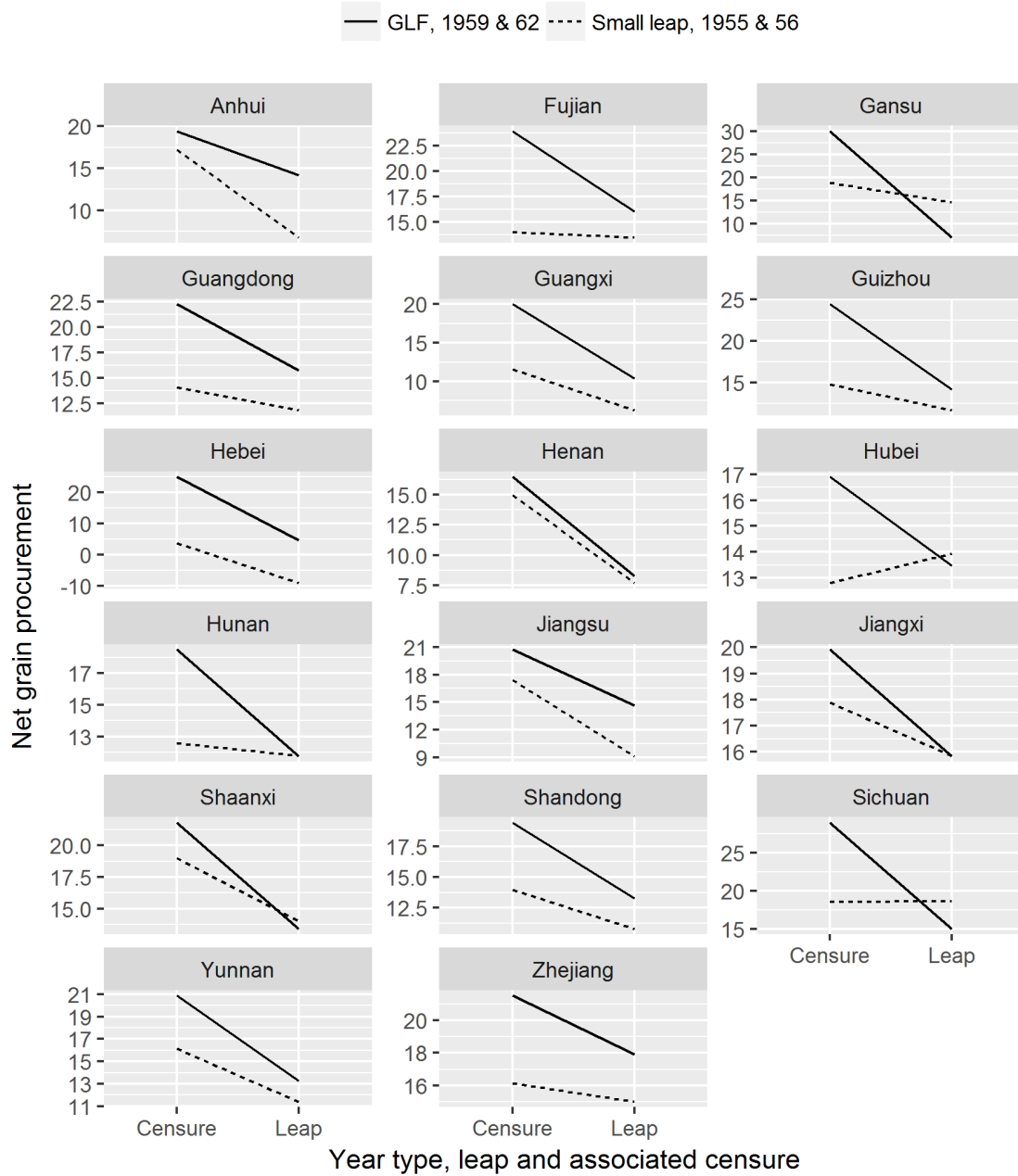
Reference	Anhui	Fujian	Gansu	Guizhou	Guangdong	Guangxi	Henan	Hebei	Hunan	Hubei	Jiangsu	Jiangxi	Shandong	Shanxi	Sichuan	Yunnan	Zhejiang
Bramall (2011)	X						X								X		
Chang and Wen (1998)	X		X	X			X						X		X		
Chen (2011)	X																
Goodman (1980)															X		
Li (1994)	X																
Rzanna (2010)							X										
Walker (1998)															X		
Yang (1996)	X														X		
Yang and Su (1998)	X			X			X						X		X		

Table 2: Evidence of Extremely Radical Political Ideology of First Party Secretaries’ Li Jingquan, Wu Zhipu, and Zeng Xisheng

Decisions by provincial leaders to censure grain procurement, allow free-market trading, criticize the Party, among other rightest activities in response to the unsuccessful Small Leap Forward in 1957 lead to purges and self-criticism campaigns that affected provincial support for the GLF. I measure the change in provincial grain procurement between the “leap forward” in 1955 and the censure in 1956 and suggest that a greater change signals greater scrutiny for rightest tendencies in the provincial leader by the Party. The relative censure in net grain procurement following the Small and Great Leaps Forward is presented in figure 4. The data on procurement amounts in each year was collected by Yang et al. (2014).

I also use three are measures taken in 1959 during the height of the GLF. This variation accurately captures GLF implementation but may also include variation in the reach of the state which is the interest

Figure 4: Difference in net grain procurement amount between “leap” year and following censure year for the Small and Great leaps forward



Source: Yang et al. (2014)

of this study. The in-time GLF measures are 1) the communal dining hall participation rate in 1959 (Yang and Su, 1998), 2) the agricultural output inflation rate by local officials in 1958 published at the provincial reported by Fan et al. (2016), and 3) the grain procurement rate in 1959 (Yang et al., 2014). It is assumed in the literature that the greater the participation rate, inflation rate, and procurement rate the more likely the provincial leader supported an abrupt transition and the greater degree to which the GLF was implemented in their jurisdiction. The relative intensity of grain procurement in 1959, communal dining in 1959, and output inflation in 1959 are depicted in figure 5

The dining hall participation rate captures the shift from private households to commune living in a province, a central intention of the GLF. The output inflation rate in 1958 shows the extent to which local cadres were willing to exaggerate production to meet Party ideals. This inflation, though publically denounced by Mao, aligns with the political eagerness rewarded at the time. And the grain procurement rate captures the willingness of the provincial leaders to remove grain from their rural communities to meet national goals.

5 Empirical Framework

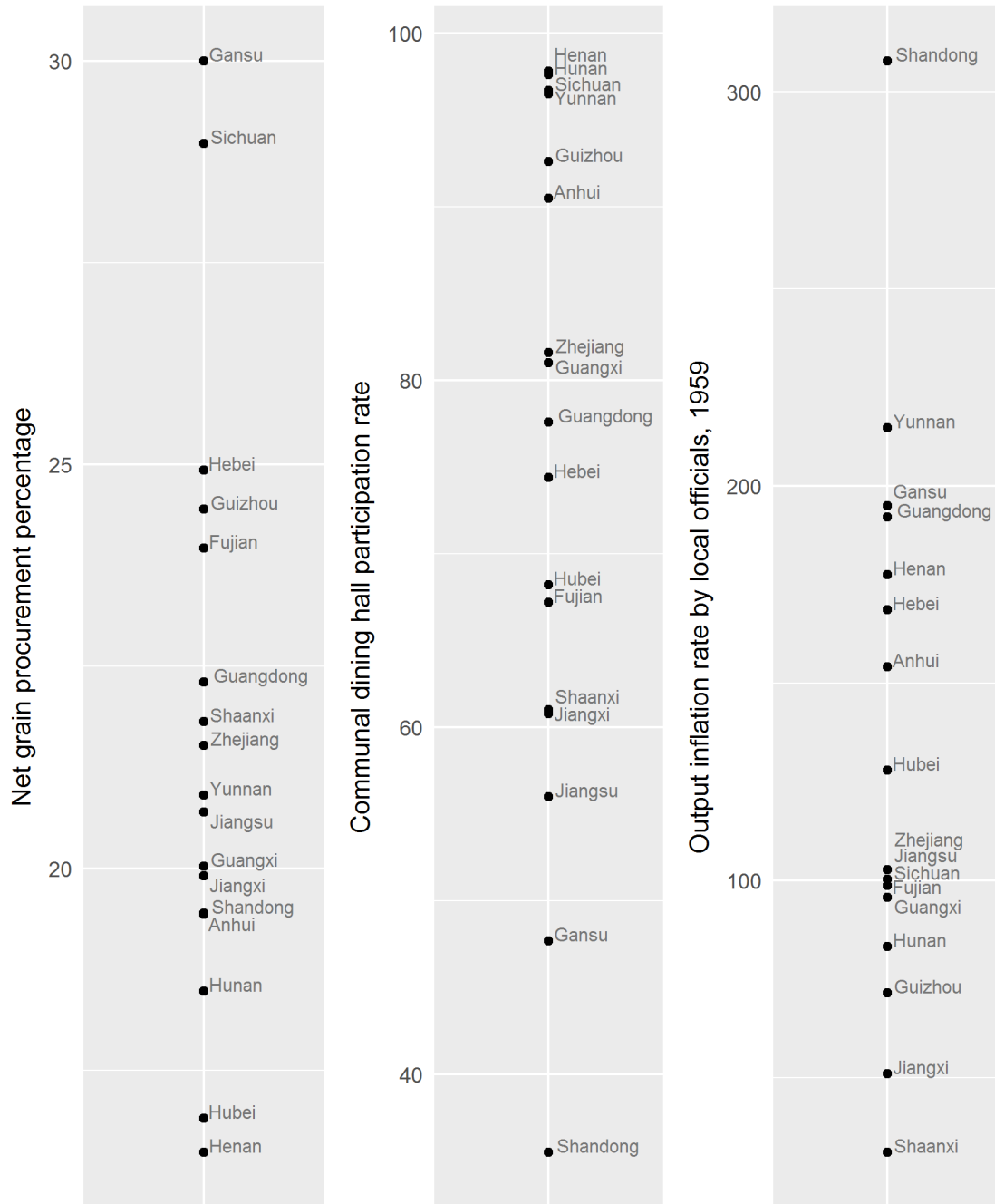
5.1 Core Relationships Regarding Famine Mortality

The microfoundations in section 3 state that a district leader will shirk when the benefit is greater than the punishment times the probability of detection. To conduct an empirical analysis I linearize benefit, punishment, and detection such that $b(m_j) = \kappa_1 + \alpha m_j + e1_i$, $p(m_j) = \kappa_2 + \gamma m_j + e2_i$, and $d(c(r_i)) = \kappa_3 - \delta r_i + e3_i$. I also omit the expected outcome nature of probability of detection such that the cost of detection c varies directly with terrain ruggedness, r_i and assume both that every district leader will shirk at some level. Finally, I assume that shirking intensity s_i varies with the ratio of benefit to cost. Taken together, 2 to motivate a reduced form

$$s_i = \kappa_4 - \kappa_5 m_j + \kappa_2 \delta r_i + \delta \gamma m_j r_i + e_i \text{ if equation (2) is satisfied} \quad (3)$$

where $\kappa_4 \equiv \kappa_1 - \kappa_2 \kappa_3$ and $\kappa_5 \equiv \kappa_3 \gamma - \alpha$.

Figure 5: Variation in the implementation of specific GLF policies and GLF attitudes in 1959 at provincial level



Source: Dining hall participation rate in 1959 (Yang and Su, 1998), grain output inflation rate in 1959 (Fan et al., 2016), and net grain procurement rate in 1959 (Yang et al., 2014).

I also follow the conceptual framework in section 3 which suggests that shirking affects food acquisition which affects famine mortality. I linearize the determinants of food acquisition with the following linear equation:

$$a(s, r, m) = \kappa_6 + \tau s_i - \pi r_i - \rho m_j + u_i \quad (4)$$

I model famine mortality as inversely related to food acquisition, formalized in the following way

$$f(a) = \kappa_7 - \lambda a_i + \xi_i \quad (5)$$

Famine conditions for a district i are a function of the district leader's shirking choice, the ruggedness of the terrain, and the ideology of the provincial authorities. I combine (3), (4) and (5) as follows:

$$f_i = \kappa_8 + \lambda \kappa_9 m_j + \lambda \kappa_{10} r_i - (\lambda \tau \gamma \delta) m_j \times r_i + \zeta_i$$

where $\kappa_8 \equiv \kappa_7 - \lambda(\kappa_6 + \tau \kappa_4)$, $\kappa_9 \equiv \tau \kappa_5 + \rho$, $\kappa_{10} \equiv \pi - \tau \delta \kappa_2$ and $\zeta_i \equiv \xi_i - \lambda(\tau e_i + u_i)$. This relationship leads to the motivating equation of this research:

$$f(m, r) = \beta_0 + \beta_1 m_j + \beta_2 r_i + \beta_3 m_j r_i + \epsilon_i \quad (7)$$

for each fu, i , in province, j . The outcome variable, f_i , is the natural log of average excess death rate (1959-61). I capture variation in the ideology of first party secretary, m_j using a few different measures described in section 4.³ Terrain ruggedness, r_i , captures the accessibility. ϵ_i is a classical error term.

Equation (7) yield the initial hypotheses of my paper:

Hypothesis 1 The more radically GLF policies were implemented the more famine mortality occurred;

$$\beta_1 > 0.$$

Hypothesis 2 Rugged regions are prone to underdevelopment; therefore ruggedness exacerbates famine conditions resulting in greater mortality rates; $\beta_2 > 0$.

³As discussed in section 4, m_j for province, j , was chosen to represent ideological alignment with Mao Zedong which can also be viewed as support of a rapid transition towards a socialist state.

Hypothesis 3 Under the jurisdiction of radical provincial leaders, rugged terrain protected communities from the reach of the state limiting GLF policies, $\beta_3 < 0$.

5.2 The Legacy of the GLF on Economic Development

Following [Nunn and Puga \(2012\)](#), I develop an estimation strategy for investigating the relationship among ruggedness, famine, and income. Starting with an inverse relationship between ruggedness and development. The relationship can be written as

$$y_i = \kappa_{11} - \theta r_i + \psi q_i + u_i \quad (8)$$

Historical studies and the empirical work of [Gooch \(2017\)](#) have documented that famine mortality adversely affected society. I capture this effect of the Great Famine with

$$q_i = \kappa_{12} - \omega f_i + v_i \quad (9)$$

Substituting equation (7) into equation (9) and then into (8) yields

$$y_i = \kappa_{13} - \kappa_9 \kappa_{14} m_j - \kappa_{14} (\kappa_{10} - \theta) r_i + \kappa_{14} \tau \gamma \delta m_j r_i - \eta_i \quad (10)$$

where $\kappa_{13} \equiv \kappa_{11} + \psi(\kappa_{12} - \omega \kappa_8)$, $\kappa_{14} \equiv \psi \omega \lambda$ and $\eta_i \equiv u_i + \psi(v_i - \omega \zeta_i)$.

Guided by equation (10), I estimate the following relationship between ruggedness, political ideology, and income:

$$y_i = \beta_4 + \beta_5 m_j + \beta_6 r_i + \beta_7 m_j r_i + \epsilon_i \quad (11)$$

Equation (11) illustrates the relationship between income and ruggedness and yields these additional hypotheses:⁴

Hypothesis 4 Under the jurisdiction of radical provincial leaders, rugged terrain protected communities from the reach of the state, limiting both GLF policies and their detrimental effect, $\beta_7 > 0$.

⁴The error term ϵ_i in equations (11) and (7) are not the same variable. I use the letter ϵ in both because there are only so many letters available.

When I bring the Great Famine to the foreground by substituting equation (9) into (8). This gives me a relationship between income and famine mortality.

$$y_i = \kappa_{15} - \theta r_i - \psi \omega f_i + \iota_i \quad (12)$$

where $\kappa_{15} \equiv \kappa_{11} - \psi \kappa_{12}$. I test this relationship by estimating

$$y_i = \beta_8 + \beta_9 m_j + \beta_{10} r_i + \beta_{11} m_j r_i + \beta_{12} f_i + \epsilon_i \quad (13)$$

Estimating equation 13 allows me to test an additional hypothesis:

Hypothesis 5 $\beta_{11} = 0$ (once famine mortality is taken into account, the effect of ruggedness is no different conditional on the ideology of provincial leaders in 1958.)

Hypothesis 5 provides a way of testing whether famine mortality can account for the positive effect of ruggedness within more radically governed provinces circa 1958. If the relationship between ruggedness and income differs relative to ideology in 1958 only because of famine mortality, then once I control for the effect of Great Famine on income, there should be no longer a differential effect of ruggedness.

6 Results

6.1 Terrain protected communities from famine, 1959-61

As the first step in my empirical analysis, I estimate the effect of ruggedness and political ideology in 1958 and their differential effect on famine mortality (1959-61). My estimates of equation (7) are given in table 3 for pre-GLF determinants of ideological radicalness that may indicate a rapid transition: whether or not the Provincial First Secretary received a special promotion from Mao by 1959 (columns 1 and 2), whether or not the Provincial First Secretary was the notoriously radical Li, Wu, or Zeng (columns 3 and 4), and the magnitude of the net grain procurement censure following the Small Leap Forward for each province (columns 5 and 6). For each indicator of a rapid transition, I estimate a simple specification which only includes province fixed effects (the odd-numbered column) and a more conservative estimate which includes

province fixed effects, the natural log of average agricultural suitability and the natural log of population density in 1958 as covariates (even-numbered columns.)

Table 3: The Differential Effect of Terrain Relief on Famine Mortality (1959-61)

	Dependent variable: ln(Excess death rate (1959-61))					
	Special promotion in 1956 or 59		Li, Wu or Zeng governed province		Grain procurement censure, 1955-56	
	(1)	(2)	(3)	(4)	(5)	(6)
Rapid transition indicator	4.747*** (1.287)	4.820*** (1.118)	4.940*** (0.670)	5.926*** (1.265)	0.429*** (0.0688)	0.442*** (0.137)
ln(Ruggedness)	0.284 (0.255)	0.384* (0.200)	0.108 (0.100)	0.0565 (0.103)	0.0909 (0.107)	0.0413 (0.118)
Rapid transition indicator \times ln(Ruggedness)	-0.408 (0.271)	-0.532** (0.222)	-0.519*** (0.166)	-0.460** (0.184)	-0.0282* (0.0166)	-0.0242 (0.0186)
ln(Population Density (1958))		-0.212 (0.157)		-0.197** (0.0940)		-0.126 (0.156)
Rapid transition indicator \times ln(Population Density (1958))		0.128 (0.199)		0.317 (0.277)		0.00911 (0.0296)
ln(Average Agricultural Suitability)		2.005** (0.863)		0.328** (0.148)		0.281 (0.294)
Rapid transition indicator \times ln(Average Agricultural Suitability)		-1.746** (0.878)		-0.665* (0.339)		0.00547 (0.0777)
Obs.	223	223	223	223	223	223
Adj. R ²	0.523	0.532	0.542	0.546	0.522	0.521

Notes: Coefficients are reported with robust standard errors in brackets.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Looking first at column 2, when I estimate equation (7) by regressing the natural log of the average excess death rate (1959-61) on ruggedness while allowing for a differential effect via the indicator of a rapid GLF transition at the province-level, I find that the coefficient for the rapid transition indicator (in this case: whether or not the Provincial First Secretary received a special promotion from Mao by 1959): $\beta_1 > 0$ in (7). This indicates that, generally, these provinces had greater famine mortality. This is consistent with the findings of Yang et al. (2014) and my hypothesis 1. Additionally, I find that the coefficient for the ruggedness is positive and statistically significant: $\beta_2 > 0$ in (7). This indicates that across China, ruggedness exacerbates famine conditions causing greater mortality. This is consistent with ruggedness' positive association with underdevelopment and my hypothesis 2.

The coefficient estimate for ruggedness interacted with the rapid transition indicator is negative and statistically significant: $\beta_3 < 0$ in (7). This differential effect for provinces with more radical leadership is

consistent with hypothesis 3. For the other two rapid transition indicators presented in columns 4 and 5, the results are more or less the same but with less statistical significance.

In addition to pre-GLF indicators of the potential for a rapid transition, variation in actual GLF outcomes at the province level provide measures for the intensity of GLF policies. Similarly to table 3, I estimate the effect of ruggedness and political ideology in 1958 and their differential effect on famine mortality (1959-61). My estimates of equation (7) are given in table 4. I use five in-time indicators: grain output inflation rate in 1959 (columns 1 and 2), communal dining participation rate in 1959 (columns 3 and 4), net grain procurement censure between 1959 and 1962 (columns 5 and 6), net grain procurement at the height of the GLF in 1959 (column 7 and 8), and average excess death rate (1959-61) (columns 9 and 10).

I order these indicators in table 4 from left to the right in terms of how much the proxy measure capture the GLF vigor within the province while at the same time not already taking into the reach of the state. For example, a high average grain procurement rate during the GLF means not only that the provincial authorities embraced the GLF, but also that their procurement initiative could access a large amount of grain around their province. While reported output inflation means that the GLF was embraced but does not capture information about the reach of the state.

In columns 2 and 4 of table 4, the coefficients resemble those in table 3 and reconfirm hypotheses 1, 2, and 3. Grain output inflation and the communal dining participation rate are both self-reported measures of provincial support of a rapid GLF transition. On the contrary, the following three indicators of a rapid transition with conservative estimates reported in columns 6, 8, and 10 are more likely to already to account for the impact of my hypothesis 3, that rugged terrain limited the reach of the state.

I find that the amount by which grain procurement was censured following the GLF and Great Famine, column 6 of 4 provides no conclusive evidence to support the core hypotheses of this paper. Furthermore, when I use variation in net grain procurement in 1959 as a measure of provincial authorities' commitment to the GLF, the signs of the coefficients of interest oppose hypotheses 1, 2, and 3. Finally, I include the excess death rate at the provincial-level as a measure of a rapid transition as a type of falsification test. Using famine rates as the rapid transition proxy already fully captures the demographic disaster which is related to GLF policies but may not be caused by them. Therefore, the coefficients in column 10 are inconclusive

Table 4: The Differential Effect of Terrain Relief on Famine Mortality (1959-61)

	Dependent variable: $\ln(\text{Excess death rate (1959-61)})$									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Grain output inflation, 1959	Communal dining rate	Grain procurement censure, 1959-62	Grain procurement rate, 1959	Average Excess death rate, province					
Rapid transition indicator	0.0767*** (0.00973)	0.0726*** (0.0111)	0.367*** (0.0444)	0.401*** (0.0536)	0.487*** (0.0768)	0.517*** (0.0880)	-1.549*** (0.186)	-1.293*** (0.248)	0.274*** (0.0575)	0.430*** (0.0979)
$\ln(\text{Ruggedness})$	0.571*** (0.207)	0.671*** (0.215)	0.760** (0.383)	0.689 (0.441)	-0.0555 (0.150)	-0.140 (0.172)	-0.974** (0.413)	-1.258*** (0.427)	0.0270 (0.126)	-0.0537 (0.130)
Rapid transition indicator $\times \ln(\text{Ruggedness})$	-0.00428*** (0.00132)	-0.00494*** (0.00137)	-0.0106** (0.00483)	-0.0102* (0.00550)	-0.000701 (0.00916)	0.00146 (0.0100)	0.0408** (0.0175)	0.0508*** (0.0180)	-0.0192 (0.0159)	-0.00591 (0.0174)
$\ln(\text{Population Density (1958)})$		0.0456 (0.199)		-0.876*** (0.306)		-0.272 (0.192)		-1.210* (0.647)		-0.376** (0.150)
Rapid transition indicator $\times \ln(\text{Population Density (1958)})$		-0.000700 (0.00115)		0.00935** (0.00398)		0.0124 (0.0127)		0.0469* (0.0282)		0.0482** (0.0207)
$\ln(\text{Average Agricultural Suitability})$		0.620 (0.890)		1.150*** (0.410)		-0.0363 (0.829)		-0.0346 (1.731)		0.534 (0.361)
Rapid transition indicator $\times \ln(\text{Average Agricultural Suitability})$		-0.00130 (0.00489)		-0.0145** (0.00617)		0.0241 (0.0566)		0.00140 (0.0595)		-0.0503 (0.0515)
Obs.	223	223	223	223	223	223	223	223	223	223
Adj. R ²	0.536	0.541	0.529	0.541	0.513	0.516	0.529	0.535	0.518	0.530

Notes: Coefficients are reported with robust standard errors in brackets.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

as per my hypotheses.

6.2 At what point was terrain rugged enough?

The OLS estimates derived from equation (7) are based on the mean ruggedness in a district. However, it is possible that either less rugged terrain was sufficient or more rugged terrain was necessary to alter the trajectory for inaccessible regions significantly. I am posing the following question to the data: when was the terrain inaccessible enough to limit the reach of the state?

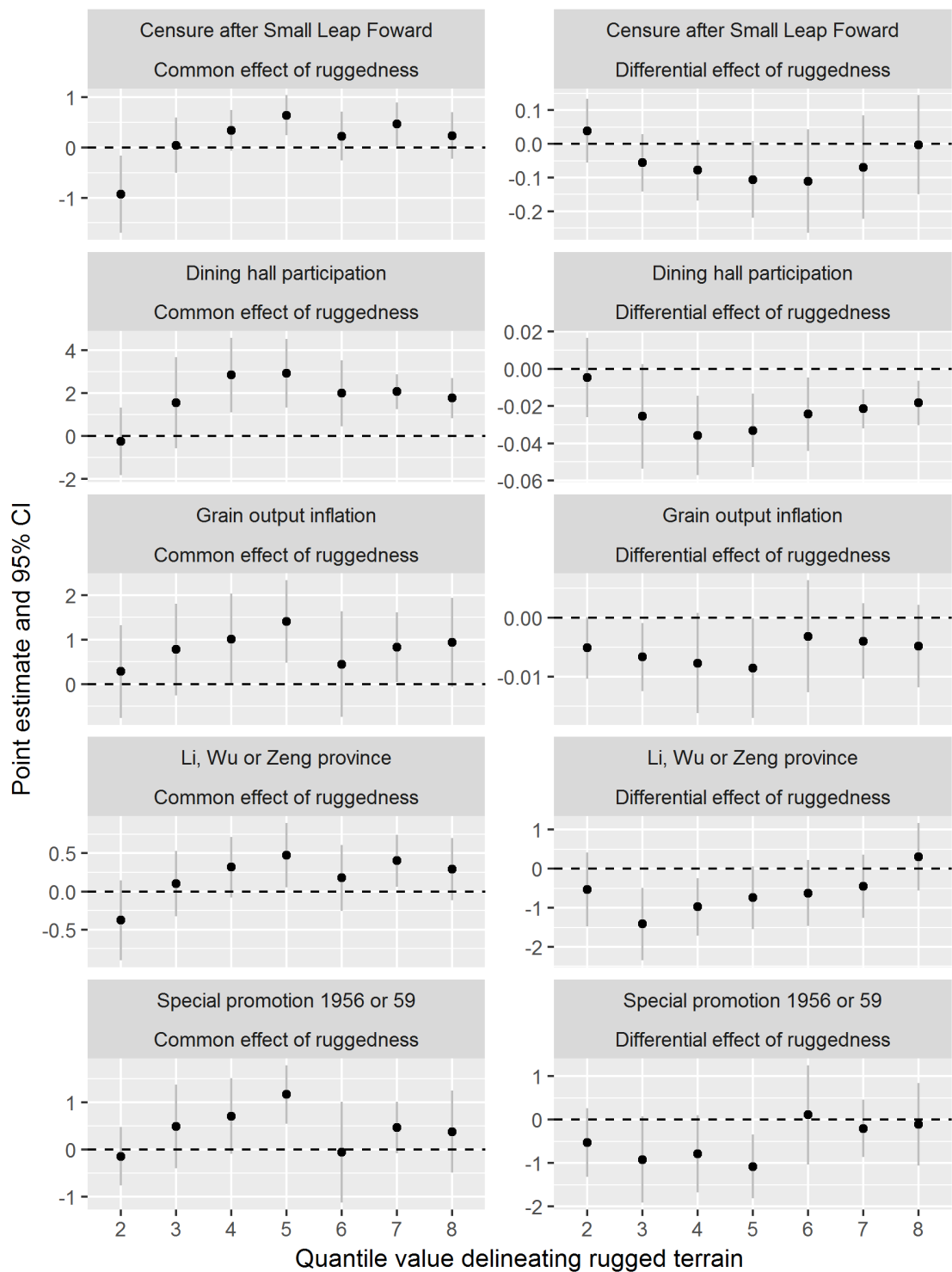
To investigate this pivotal point, I create binary measures ruggedness where below a certain threshold the indicator equals zero and equals one above. The threshold value ranges from the second decile to the eighth decile, thereby creating seven binary measures of ruggedness which I substitute for the continuous version of ruggedness used earlier analyses.

My estimates of equation (7) are given in figure 6. Each row of graphs corresponds to one type of rapid transition indicator: grain procurement censure after Small Leap Forward (row 1), communal dining hall participation rate in 1959 (row 2), grain output rate in 1959 (row 3), whether or not the province was headed by Li, Wu, or Zeng (row 4), and whether or not the province was headed by a Secretary that received a special promotion by 1959 (row 5). The left-hand side column of graphs depicts the point estimate β_2 , the common effect of ruggedness on the excess death rate, for the seven binary measures of ruggedness. The right-hand side column of graphs depicts the point estimate β_3 , the differential effect of ruggedness on the excess death rate, for the seven binary measures of ruggedness. The x-axis of each graph indicates which threshold level is used to delineate rugged from the not rugged terrain.

The point estimate and confidence interval at the 5th decile is equivalent to the coefficient and standard errors presented in tables 3 and 4. Graphs in row 2 and 4 offer additional insight into the role of ruggedness. When dining hall participation is used to capture the provincial authorities' commitment to a rapid GLF transition (row 2), ruggedness below the mean was sufficient for protecting communities from famine conditions: $\beta_3 < 0$ in equation (7) and statistically significant.

Likewise, when the provinces administered by Li, Wu, and Zeng are used to capture the transition the differentially negative effect of ruggedness is apparent at a lower threshold level. Specifically, when deciles

Figure 6: Plotting coefficients of the common and differential effect of ruggedness on famine mortality when the definition of ruggedness varies



1-3 of ruggedness are coded as not rugged and deciles 4-10 are coded as rugged, $\beta_2 = 0$ while $\beta_3 < 0$ in equation (7). This indicates that this definition of ruggedness does not exacerbate famine in general but does protect communities from famine mortality. This pattern of relatively lower ruggedness deterring famine is discernible in rows 3 and 5 as well, grain output inflation and special promotions. It seems that the rapid transition indicator, grain procurement censure after Small Leap Forward, yields limited evidence of the opposite effect.

6.3 Legacy of the Great Leap Famine on contemporary income

As the next step in my empirical analysis, I estimate the common effect of ruggedness on income per person and its differential effect for provinces that experience a more rapid transition towards a socialist state with the GLF. My baseline estimates of equation (11) are given in the even-numbered columns of table 5. Each set of two column corresponds to a different measure of the rapid transition specified in the column title. Across the even-numbers columns, when I estimate equation (11) by regressing income per person on ruggedness while allowing for a differential effect in provinces with a authorities the supported a rapid transition via the GLF, I find that the coefficient for the rapid transition indicator is negative and significant: $\beta_5 < 0$ in equation (11) and hypothesis 4. This indicates a negative effect of political radicalism during the late 1950s in China, generally. I also find that the coefficient for ruggedness is negative and statistically significant: $\beta_6 < 0$ in equation (11). This indicates negative common effect for ruggedness in China as a whole. This is consistent with ruggedness negatively affecting income by increasing costs of trade, construction, and agriculture.

The coefficient estimate for ruggedness interacted with the rapid transition indicator is positive and statistically significant: $\beta_7 > 0$ in equation (11). This differential effect for provinces with authorities who supported a more rapid transition towards a social China. Within these provinces, an additional positive effect of ruggedness on income exists as provincial authorities become more radical in the late 1950s.

Table 5: Great Famine as transition mechanism

	Dependent variable: ln(GDP per capita, 2010)														
	Special promotion in 1956 or 59	Li, Wu or Zeng governed province	Grain procurement censure, 1955-56	Grain output inflation, 1959	Communal dining rate	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Rapid transition indicator	-1.483*** (0.384)	-0.749* (0.417)	-1.863*** (0.378)	-0.629 (0.457)	-0.195*** (0.0383)	-0.138*** (0.0427)	-0.0269*** (0.00453)	-0.0150*** (0.00573)	-0.132*** (0.0229)	-0.0778*** (0.0270)					
ln(Ruggedness)	-0.176** (0.0741)	-0.145* (0.0750)	-0.168*** (0.0545)	-0.156*** (0.0540)	-0.210*** (0.0651)	-0.195*** (0.0616)	-0.291*** (0.110)	-0.199* (0.119)	-0.340 (0.237)	-0.225 (0.224)					
Rapid transition indicator \times ln(Ruggedness)	0.0890 (0.0895)	0.0352 (0.0887)	0.203** (0.0844)	0.0718 (0.0856)	0.0198** (0.00836)	0.0160* (0.00829)	0.00128 (0.000777)	0.000582 (0.000853)	0.00310 (0.00289)	0.00151 (0.00269)					
ln(Excess death rate)		-0.109** (0.0518)		-0.111** (0.0449)		-0.175*** (0.0603)		-0.126 (0.0847)		-0.205* (0.115)					
Rapid transition indicator \times ln(Excess death rate)		-0.0760 (0.0747)		-0.179** (0.0752)		0.00509 (0.0110)		-0.000196 (0.000645)		0.000637 (0.00146)					
Obs.	223	223	223	223	223	223	223	223	223	223	223	223	223	223	223
Adj. R ²	0.447	0.487	0.461	0.499	0.462	0.495	0.453	0.487	0.450	0.486					

Notes: Coefficients are reported with robust standard errors in brackets. Each specification is estimated with the following control variables: province fixed effects, ln(average agricultural suitability), and ln(population density in 1958).
 * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

6.4 Does famine mortality account for the GLF’s detrimental legacy on economic development?

In the jurisdictions where GLF policies were implemented intensely, the empirical evidence suggests that ruggedness limited famine mortality and supported economic development. Now, I turn to showing that famine mortality is negatively related to current economic outcomes and that this accounts for the differential effect of ruggedness within radical provinces in some specifications. In the odd-numbered columns of table 5, I estimate equation (11) and in the even-number columns, I estimate equation (13). Equation (13) is identical to equation (11), except that the excess death rate is also included in the estimating equation. The measure of a rapid transition used in the specification is listed above the model.

With the full set of controls, when famine mortality is controlled for, the differential effect of ruggedness in more radical provinces decreases in magnitude across all specifications. The rapid transition indicator, whether or not the province was administered by Li, Wu, or Zeng (columns 3 and 4) provides a particularly clear example. In columns 4, the estimated coefficient on *Rapid transition indicator* \times *ruggedness* is close to zero and insignificant, while in the corresponding columns 3, the interaction was significantly different from zero: $\beta_{11} = 0$ in equation (13). It provides support for the explanation that the differential effect of ruggedness arises because of the direct link between the GLF and the Great Famine. Other measures of a provinces’ transition speed during the GLF offer weaker evidence.

6.5 Economic magnitude of results

To this point, I have been focusing on the statistical significance of my estimated coefficients, ignoring the magnitude of their effects. Using the estimates from column 4 of table 3, I calculate some counterfactuals to show the economic magnitude of the results concerning the impact of the GLF on famine mortality. Examining the differential relationship between provinces administered by Li Jingquan, Wu Zhipu, and Zeng Xisheng and other provinces offers an exceptionally simple example because of the binary nature of this rapid transition indicator.

Using estimates from column 4 of table 3, I calculate the change in the excess death rate for a counterfactual district with mean level ruggedness and mean level excess death rate. Within the group of provinces

administered by Li, Wu, and Zeng, the counterfactual district's excess death rate would be $f'_i = 4.7$ as opposed to the actual mean excess death rate of $f_i = 8.17$. For these provinces, a one standard deviation increase in ruggedness translates to a 1.18 standard deviation decrease in the excess death rate. If I conduct a similar analysis for a counterfactual district in another province under more politically moderate leadership (1959-61) the counterfactual excess death rate would be greater than the actual excess death rate: $f'_i = 2.49 > f_i = 2.32$. In the other provinces, a one standard deviation increase in ruggedness translates to a 0.06 standard deviation increase in the excess death rate.

Using estimates from column 3 of table 5, I calculate the change in the excess death rate for a counterfactual district with mean level ruggedness and mean level ruggedness. Within the group of provinces administered by Li, Wu, or Zeng, the counterfactual district's GDP per capita in 2010 would be $y'_i = 17124.93$ as opposed to the actual GDP per capita in 2010 of $y_i = 16323.16$. For these radical provinces, a one standard deviation increase in ruggedness translates to a 0.13 standard deviation increase in income in 2010. If I conduct a similar analysis for a counterfactual district in another province under more politically moderate leadership (1959-61) the hypothetical district's GDP per capita in 2010 would be $y'_i = 15218.4$ as opposed to the actual GDP per capita in 2010 of $y_i = 18964.81$. For these other provinces, a one standard deviation increase in ruggedness translates to a 0.75 standard deviation decrease in income in 2010.

When the famine mortality (1959-61), however, is taken into account in the specification, column 4 of table 5 then the impact of a one standard deviation increase in ruggedness translates to a 0.7 decrease in income in 2010 for provinces with more politically moderate leadership during the GLF period and a 0.28 decrease in income for Anhui (Zeng), Henan (Wu), and Sichuan (Li). Once famine mortality is taken into account, a one standard deviation increase in ruggedness produces lower GDP per capita in 2010 which is not significantly different from the other provinces. Therefore, the differential benefit from ruggedness is due to its limiting effect on famine mortality during the Great Famine.

7 Regression discontinuity analysis at the border of rapid and gradual provinces

I conduct the regression discontinuity analysis using equations (7), (11), and (13) on three samples of districts along the boundary between three types of provinces: provinces administered by Li, Wu, or Zeng and other provinces (table 6), provinces administered by a First Party Secretary who received a special promotion in 1956 and other provinces (table 7), and provinces administered by a First Party Secretary who received a special promotion by 1959 and other provinces (table 8). Each analysis only includes the subset of districts either touching the boundary of interest or one district removed from that boundary. This type of geographic regression discontinuity analysis provides a sharpened look at the protection topological irregularities provided communities in radical provinces by removing potential unobservable confounding factors.

Table 6: Discontinuity at boundary of Li, Wu, and Zeng provinces

	ln(Excess Death Rate)	ln(GDP per capita in 2010)	
	(1)	(2)	(3)
Li, Wu, and Zeng provinces	5.341*** (1.449)	-1.964** (0.830)	-0.652 (0.769)
ln(Ruggedness)	0.0493 (0.171)	-0.00657 (0.0820)	-0.000824 (0.0811)
Li, Wu, and Zeng provinces \times ln(Ruggedness)	-0.467** (0.233)	0.108 (0.109)	-0.0118 (0.104)
ln(Excess death rate)			-0.117 (0.0930)
Li, Wu, and Zeng provinces \times ln(Excess death rate)			-0.157 (0.109)
Obs.	122	122	122
Adj. R ²	0.651	0.522	0.569

Notes: The sample of districts used in this analysis reside either on the boundary or one district away from the boundary of Li, Wu, and Zeng provinces. Coefficients are reported with robust standard errors in brackets. Each specification is estimated with the following control variables: province fixed effects, ln(average agricultural suitability), and ln(population density in 1958).
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

First, I estimate the effects of ruggedness and transition speed and their differential effect on famine mortality (1959-61). My estimates of equation (7) are given in column 1 of each table 6, 7, and 8. Like

the baseline estimates presented in section 6.1, I find that the first column of each table yields a negative and statistically significant coefficient on the interaction between the rapid transition indicator and ruggedness, $\beta_3 < 0$ in equation (7). This differential effect for provinces with more radical leadership from each discontinuity analysis is consistent with hypothesis 3.

Table 7: Discontinuity analysis at boundary of provinces with a First Party Secretary who received a special promotion in 1956

	ln(Excess Death Rate)	ln(GDP per capita in 2010)	
	(1)	(2)	(3)
Special promotion in 1956 provinces	5.924*** (1.196)	-2.033*** (0.708)	-0.675 (0.716)
ln(Ruggedness)	0.143 (0.144)	-0.0396 (0.0753)	-0.0186 (0.0765)
Special promotion in 1956 provinces \times ln(Ruggedness)	-0.616*** (0.209)	0.165 (0.107)	0.0115 (0.107)
ln(Excess death rate)			-0.147** (0.0646)
Special promotion in 1956 provinces \times ln(Excess death rate)			-0.133 (0.110)
Obs.	150	150	150
Adj. R ²			
r2_a	0.578	0.520	0.585

Notes: The sample of districts used in this analysis reside either on the boundary or one district away from the boundary of provinces with a First Party Secretary who received a special promotion in 1956. Coefficients are reported with robust standard errors in brackets. Each specification is estimated with the following control variables: province fixed effects, ln(average agricultural suitability), and ln(population density in 1958).

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Next, I estimate the effect of ruggedness on income per person and its differential effect for provinces that experiences a more rapid transition. My baseline estimates of equation (11) are given in column 2 of tables 6, 6, and 6. The coefficient estimate for ruggedness interacted with the rapid transition indicator is positive in magnitude but not statistically significant: $\beta_7 \geq 0$ in equation (11); weak evidence that an additional positive effect of ruggedness on income exists.

Finally, in column 3 of tables 6, 6, and 6, I estimate equation (13). The coefficient on the interaction between ruggedness and the rapid transition indicator is close to zero in magnitude and statistically insignificant. This provides weak evidence that famine mortality is negatively related to current economic outcomes and that this accounts for the differential effect of ruggedness within radical provinces.

Table 8: Discontinuity analysis at boundary of provinces with a First Party Secretary who received a special promotion by 1959

	ln(Excess Death Rate)	ln(GDP per capita in 2010)	
	(1)	(2)	(3)
Special promotion by 1959 provinces	4.748*** (1.159)	-1.987*** (0.623)	-1.065 (0.669)
ln(Ruggedness)	0.277 (0.204)	-0.0907 (0.0926)	-0.0614 (0.100)
Special promotion by 1959 provinces \times ln(Ruggedness)	-0.567** (0.251)	0.169 (0.116)	0.0615 (0.119)
ln(Excess death rate)			-0.106 (0.0835)
Special promotion by 1959 provinces \times ln(Excess death rate)			-0.163 (0.110)
Obs.	138	138	138
Adj. R ²	0.617	0.554	0.608

Notes: The sample of districts used in this analysis reside either on the boundary or one district away from the boundary of provinces with a First Party Secretary who received a special promotion by 1959. Coefficients are reported with robust standard errors in brackets. Each specification is estimated with the following control variables: province fixed effects, ln(average agricultural suitability), and ln(population density in 1958).

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

8 Conclusion

Terrain ruggedness has been linked to underdevelopment because of the higher associated costs for trade and cultivation. However, ruggedness also limits the reach the state which may have benefitted remote communities between 1958 and 1961 when Chinese central leadership enacted Chairman Mao Zedong's radical agenda, the Second Five-Year Development Plan or more commonly known as the Great Leap Forward (GLF). Variation in the enthusiasm with which provincial authorities implemented the new policies, together with variation in terrain irregularities, allows me to estimate the differential effect of terrain ruggedness had on famine mortality during the Great Famine (1959-61). According to some of my estimates, a one standard deviation increase in ruggedness in provinces with the most radical administrators reduced the excess death rate by more than half. This finding provides the first causal evidence of a systematic pattern of famine mortality highlighting both the anthropogenic origin of the Great Famine and relationship between Mao's GLF program and the demographic disaster.

Within the jurisdiction of a GLF-supporting provincial administrator, I also found that communities in rugged terrain had greater income today than their accessible counterparts. Following the empirical

framework of Nunn and Puga (2012), I assess that a portion of the positive impact of ruggedness on economic development arises from terrain's bounding effect on the legacy of the Great Famine. Additional evidence from three regression discontinuity designs conducted at the boundaries between provinces administered by Mao supporter and Mao antagonist confirm my baseline findings.

My findings contribute to the historical debates about the importance of GLF policies in explaining part of the famine mortality between 1959-61. They provide evidence that Mao Zedong through the reach of the state was influential in the magnitude of the disaster. Furthermore, because the GLF also impacted income today, my results suggest that historical policies continued to play a role in economic growth over the next half-century.

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