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ABSTRACT

China's Great Leap: Forward or Backward? Anatomy of a Central Planning Disaster*

The Great Leap Forward (GLF) disaster, characterized by a collapse of grain output, and the associated famine in China between 1959 and 1961, can be attributed to a systemic failure in central planning. Encouraged by unrealistic expectations for agricultural productivity gains from collectivization, the government switched to an accelerated and infeasible timetable for industrialization. Consequently, it diverted massive amounts of agricultural resources to industry and imposed excessive grain procurement burdens on peasants, leaving them with insufficient food to sustain labour productivity. Grain output fell sharply at the onset of these policies and started to recover gradually when the policies were reversed. Official data and our supplementary survey data support the theoretical prediction regarding the dynamic progression of the disaster. They also show that over 80% of the decline in grain output is attributable to the policies of excessive procurement and resource diversion.

JEL Classification: N55, O14, P32, Q18
Keywords: agricultural crisis, central planning, grain procurement, industrialization, resource diversion, work capacity, China

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NON-TECHNICAL SUMMARY

In the world's most populous country, one that could barely feed itself, the unthinkable happened. In 1959, grain output in China fell precipitously by 15%. It declined by another 16% in 1960. The collapse in grain output was followed by a widespread famine with varying severity across provinces. What caused this disaster? Our theoretical and empirical analyses suggest that the grain output collapse can be attributed to a systematic failure in central planning.

We formulate a dynamic model of central planning to better understand the observed GLF policies during the crisis. Given the government's objective of rapid industrialization, the observed policies are consistent with a false premise ingrained in the dominant Soviet economic ideology. The premise is that collectivization would transform Chinese agriculture from small household farming into large-scale mechanized production, achieving a great leap in productivity. Our model predicts that the impatient central planner, believing in the magic effect of collectivization on agricultural productivity, would divert labour (and other resources) from agriculture to industry, and impose excessive grain procurement burdens on the rural population. The resource diversion reduces agricultural output directly. The excessive procurement, when combined with an actual reduction in productivity due to collectivization, significantly reduces food available in rural areas, leading to a severe nutritional deficiency in the peasants. The resulting reduction in work capacity would in turn reduce the quality of labour input in growing next year's crops, leading to an additional decline in production.

Using historical panel data at the provincial level, which were compiled from published sources and a retrospective survey that collected information from local data archives and agricultural experts, we adopt a production function approach to assess the role of various factors in determining changes in grain output over time. We find that the most important factor is the excessive procurement of grain that decimated the physical strength of the peasantry, contributing to 51.7% of the output collapse. Resource diversion is the next largest contributor, accounting for 28.6% of the output collapse. Other factors were less important. Radicalism associated with communal dining had a significant effect on grain output, contributing to 17.5% of the decline. Weather also played a role, accounting for 16.2% of the decline. The increased use of modern inputs helped partially to mitigate the effects of resource diversion and offset the decline by 15.8%. Organizational factors, such as the size of collective organization and the removal of exit rights, appear to have played a minor role in the crisis.

The dynamic progression of the GLF crisis is also consistent with our model's prediction. Research diversion led to an initial reduction in grain output. Then, the excessive grain procurement reduced food availability in rural areas to a dangerously low level. The resulting nutritional deficiency among peasants, compounded by severe weather and the implementation of other radical programmes (such as wasteful communal dining during harvesting seasons that further reduced food available for consumption during planting seasons), caused further declines in grain production. The lingering nutritional effects and bad weather continued in 1960, depressing national grain output to its lowest level. Starting in 1961, the grain output recovered gradually as labour and other resources were redirected to agriculture, and grain procurement was reduced to allow peasants to restore work capacity. Better weather conditions and the reversal of some radical programmes also contributed to the recovery.

Agricultural crises and the associated famines have long occupied the attention of scholars. While natural disaster is often the leading cause of crop failures, this study shows that erroneous judgements of production situations can also be fatal. During the GLF period, falsified information, combined with the central planner's fanciful vision (which encouraged data falsification), led to a massive diversion of resources from agriculture and an excessive procurement of grain. The resulting nutritional deficiency among peasants decimated the quality of agricultural labour input in growing the next year's crops. What makes the Chinese experience unique is that the GLF catastrophe was man-made, caused by a systemic failure in central planning, as Hayek (1935) had anticipated.

Abstract

The Great Leap Forward (GLF) disaster, characterized by a collapse of grain output, and the associated famine in China between 1959 and 1961, can be attributed to a systemic failure in central planning. Encouraged by unrealistic expectations for agricultural productivity gains from collectivization, the government switched to an accelerated and infeasible timetable for industrialization. Consequently, it diverted massive amounts of agricultural resources to industry and imposed excessive grain procurement burdens on peasants, leaving them with insufficient food to sustain labor productivity. Grain output fell sharply at the onset of these policies and started to recover gradually when the policies were reversed. Official data and our supplementary survey data support the theoretical prediction regarding the dynamic progression of the disaster. They also show that over 80 percent of the decline in grain output is attributable to the policies of excessive procurement and resource diversion.

JEL codes: O14, P32, N55, Q18.

Keywords: Industrialization, central planning, agricultural crisis, grain procurement, work capacity, resource diversion, China

"*Ten thousand years is too long, do it in one day.*"

Mao Zedong (*Mengjianghong - A reply to Comrade Guo Moruo*, 1963)

"*The people are hungry. It is because those above devour too much in taxes.*"

Lao Zhi (quoted from Becker, 1997, p. 47)

1 Introduction

In the world's most populous country, one that could barely feed itself, the unthinkable happened. In 1959, grain output in China fell precipitously by 15 percent. It declined by another 16 percent in 1960. Only three years earlier, China had launched the Great Leap Forward (GLF) movement that aimed at surpassing Great Britain in industrial output in fifteen years and the United States in twenty or thirty years. But the reality was bleak. The collapse in grain output was followed by a widespread famine with varying severity across provinces. Based on census data, demographers were able to infer from extrapolations of Chinese mortality trends that the total number of premature deaths between 1959-61 ranged from 18.48 to 30 million (see Ashton *et al.*, 1984; Peng, 1987; Yao, 1999). If these estimates were accurate in the order of magnitude, this famine would still be the worst in world history in terms of the loss of human life.[1] Since the release of official data in the late 1970s, this catastrophe has become a subject of increasing attention among social scientists.[2] Recent empirical research has concentrated on the causes of excess mortality during the famine, taking as given the shortage in food supply.[3] This paper departs from the literature by focusing attention instead on the fundamental issue: What caused the collapse in grain output?

The official explanation for the drop in grain output puts the blame mainly on bad weather (Communist Party of China, 1981), and refers to the period 1959-61 as the "three years of natural calamities." Using meteorological data collected independently, Kueh (1995) finds that bad weather contributed to the crisis. But he notes that bad weather of similar magnitude in the past had not produced such serious contractions in national grain output. Other factors, therefore, must have contributed significantly to the production collapse. These factors include reductions in agricultural labor and acreage sown with grain (*e.g.* Peng, 1987; Yao, 1999), implementation of radical programs such as communal dining (*e.g.* Yang, 1996; Chang and Wen, 1997), as well as reduced work incentives due to the formation of

[1] In comparison, the great Irish famine (1845-51) claimed 1.1 million lives, the Bengal famine (1943) 3 million, and the Ethiopian famine (1984-85) between 600,000 and 1 million (see Sen, 1981; Ravallion, 1997).

[2] Academic attention to this event includes a 1993 symposium issue of *Journal of Comparative Economics* and a 1998 special issue of *China Economic Review*.

[3] See, for instance, Yang (1996), Chang and Wen (1997), and Lin and Yang (2000). In addition to reduced food production, other causes of the famine include urban-biased food ration systems, the continued export of grain during the famine, the role of radical provincial leaders, and the waste of food resulting from communal dining.

large collectives which peaked during the crisis years (Perkins and Yusef, 1984). Another related explanation is advanced in a seminal paper by Justin Lin (1990), who argued that the deprivation of peasants' exit rights from the commune, which started in 1958, reduced their work incentive, and hence the total factor productivity in Chinese agriculture.[4] The reduction in productivity in turn contributed to the fall in grain output. To date, few studies have assessed the quantitative effects of these and possibly other factors on grain output, leaving a significant gap in our understanding of the GLF crisis. The paucity of empirical analysis is due in part to the lack of a consistent framework for analyzing the GLF policies and their implications.

In this paper, we formulate a dynamic model of central planning that "rationalizes" the observed GLF policies during the crisis and identifies additional factors that may have contributed to the output collapse. Given the government's objective of rapid industrialization, the observed policies are consistent with a false premise ingrained in the dominant Soviet economic ideology. The premise is that collectivization would transform Chinese agriculture from small household farming into large-scale mechanized production, achieving a great leap in productivity.[5] The leap in productivity is what the increasingly impatient central planner wants. With it, the central planner can extract more surplus (or taxes) from the peasantry to fund an ambitious industrialization drive. Our model predicts that the impatient central planner, believing in the magic effect of collectivization on agricultural productivity, would divert labor (and other resources) from agriculture to industry, and impose excessive grain procurement burdens on the rural population. The resource diversion reduces agricultural output directly. The excessive procurement, when combined with an actual reduction in productivity due to collectivization, significantly reduces food available in rural areas, leading to a severe nutritional deficiency in the peasants. The resulting reduction in work capacity would in turn reduce the quality of labor input in growing next year's crops, leading to an additional decline in production.

[4]According to Lin, the threat of withdrawal from harder working members in an agricultural collective helps discipline would-be shirkers. The removal of the exit rights destroyed the self-enforcing discipline, and therefore the work incentive of commune members. Lin's hypothesis is consistent with empirical observations that China's agricultural productivity collapsed during the GLF period and remained low until the decollectivization in the late 1970s (*e.g.*, Wen, 1993).

[5]To the government, this premise appeared to have passed the test in the Chinese countryside since the growth of China's agricultural production coincided with the collectivization movement between 1953 and 1957. It seemed to have been resoundingly reaffirmed when thousands of local cadres outdid one another in making wild claims about grain yields in 1958, the first year of the GLF.

Using historical panel data at the provincial level, which were compiled from published sources and a retrospective survey that collected information from local data archives and agricultural experts, we adopt a production function approach to assess the role of various factors in determining changes in grain output over time. One novelty of the present study is the inclusion of separate proxies—nutritional status of agricultural workers, the extent of resource diversions, climate conditions, participation in radical programs, scale of production, and exit rights—in the production function. We are, therefore, able to test both existing and new hypotheses under a unified framework, and decompose the sources of the collapse and the subsequent recovery.

Subject to qualifications, our findings suggest that the most important factor is the excessive procurement of grain that decimated the physical strength of the peasantry, contributing to 51.7 percent of the output collapse. Resource diversion is the next largest contributor, accounting for 28.6 percent of the output collapse. Radicalism associated with communal dining also had a significant effect on grain output, contributing to 17.5 percent of the decline. Weather did play a role, accounting for 16.2 percent of the decline. The increased use of modern inputs helped partially mitigate the effects of resource diversion and offset the decline by 15.8 percent. Other institutional factors, such as the size of collective organization and the removal of exit rights, appear to have played a minor role in the crisis.[6]

The dynamic progression of the GLF crisis is consistent with our model's prediction. The diversion of labor and other factors led to an initial reduction in grain output. Then, the excessive grain procurement reduced food availability in rural areas to a dangerously low level. The resulting nutritional deficiency among peasants, compounded by severe weather and the implementation of other radical programs (such as wasteful communal dining during harvesting seasons that further reduced food available for consumption during planting seasons), caused further declines in grain production. The lingering nutritional effects and bad weather continued in 1960, depressing national grain output to its lowest level. Starting in 1961, the grain output recovered gradually as labor and other resources were redirected to agriculture, and grain procurement was reduced to allow peasants to restore work capacity. Better weather conditions and the reversal of some radical programs also contributed to the recovery.

Agricultural crises and the associated famines have long occupied the attention of scholars.

[6]They probably contributed to the decline in productivity since the collectivization movement before the onset of the GLF disaster. See discussions in Section 6.

While natural disaster is often the leading cause of crop failures, Rosen (1999) and this study show that erroneous judgments of production situations can also be fatal. For the Irish famine, the erroneous expectation of the productivity of seed potatoes provoked "oversaving," which delayed possible substitution of other crops and led to a sharp reduction in next year's food supply. In the Chinese famine, falsified information, combined with the central planner's fanciful vision (which encouraged data falsification), led to a massive diversion of resources from agriculture and an excessive procurement of grain. The resulting nutritional deficiency among peasants decimated the quality of agricultural labor input in growing the next year's crops. What makes the Chinese experience unique is that the GLF catastrophe was man-made, caused by a systemic failure in central planning, as Hayek (1935) had anticipated.

2 China's Development Strategy and Rural Institutions

Devastated by nearly a century of turmoil and wars, China in 1949 was a desperately poor agrarian economy with nearly 90 percent of its population living in rural areas. As the economy recovered from the destruction of war, the government swiftly adopted a Soviet-style heavy-industry-oriented development strategy in 1952. To fund rapid industrialization, most investable surplus had to be extracted from the vast peasant population. Agricultural productivity had to be raised quickly in order to free up resources for industrial development, to feed a growing urban population, to increase the supply of raw materials for industry (*e.g.*, cotton and oil seeds), and to earn foreign exchange needed for importing capital goods.[7] In a speech on July 31 1955, Chairman Mao drew the link between industrialization, rural surpluses, and collectivization:

> "[Some] comrades fail to understand that socialist industrialization cannot be carried out in isolation from the cooperative transformation of agriculture. In the first place, as everyone knows, China's current level of production of commodity grain and raw materials for industry is low, whereas the state's need for them is growing year by year, and this presents a sharp contradiction. If we cannot basically solve the problem of agricultural cooperation within roughly three five-year plans, that is to say, if our agriculture cannot make a leap from small-scale

[7] The population in urban areas grew from 58 million in 1949 to 72 million in 1952, and to nearly 100 million in 1957. Until the mid-1970s, over 70 percent of China's exports were agricultural products and processed agricultural products, such as textiles (Lin, 1990).

> farming with animal-drawn implements to large-scale mechanized farming, along with extensive state-organized land reclamation by settlers using machinery ..., then we shall fail to resolve the contradiction between the ever-increasing need for commodity grain and industrial raw materials and the present generally low output of staple crops, and we shall run into formidable difficulties in our socialist industrialization and be unable to complete it. (Mao, 1977, pp. 196-7)

For the central planner, industrialization cannot proceed without a great leap forward in agriculture, which in turn cannot happen if the traditional household farms are not transformed into large-scale collectives.

At the urging of the central government, local cadres, eager to demonstrate their revolutionary zeal, rushed to create cooperatives in the fall of 1953.[8] By the end of 1954, 60.3 percent of all rural households were enrolled in collectives, ranging in size from "mutual-aid teams" consisting of less than 10 households to "high-level agricultural producers' cooperatives" consisting of more than 100 households.

On January 1, 1958, China launched the Great Leap Forward movement with a People's Daily editorial calling for China to catch up with Great Britain in fifteen years and the United States in twenty to thirty years. In its attempt to reach this untenable goal, the government mobilized massive amounts of investment funds and manpower. It raised the rate of accumulation from 24.9 percent of national income (or net material product) in 1957 to 43.8 percent in 1959, and directed most of the investment into heavy industries (Riskin, 1987, p. 142). In 1958, the government recruited 16.4 million rural workers to cities, about twice the size of the industrial labor force in 1957, to support the expansion of industry and construction. In the winter of 1957–58, it mobilized more than 100 million peasants to undertake large irrigation and land reclamation projects, and to build and operate "backyard iron furnaces."[9] The rural labor mobilization was greatly facilitated by the amalgamation of smaller cooperatives into 26,500 "people's communes," with each encompassing thousands of households.

[8] See Lin (1990) and Yang (1996) for detailed descriptions of the collectivization process.

[9] Those furnaces were constructed using mud and brick, burning wood and coal as fuel. Using scrub metal as raw materials, they produced iron blocks, which, by the government's own admission, were of low quality and could meet only "rural requirements." Yet their outputs were proudly included in the national statistics, which show that steel output rose more than three times between 1957 and 1960 before falling abruptly in 1961 to near pre-GLF levels.

Believing that these institutional changes significantly boosted agricultural productivity, the central government exhorted local cadres to "overcome reactionary conservatism" (*People's Daily*, September 10, 1958). Local cadres responded by outdoing each other in making wild claims about grain yield. In a hyper-euphoric atmosphere, *People's Daily* hailed that "agricultural production takes a Great Leap Forward with yields increasing by 100 percent, by several hundred percent, by 1000 percent and by several thousand percent . . .." Based on these wild claims, grain output was forecasted to grow to 525 million metric tons in 1958, or more than 2.6 times the grain output in 1957 (see column 1 in Table 1)! "Actual" production was estimated to be a more modest 375 million metric tons, still a great leap from the 1957 grain output of 195 million metric tons. The falsified output statistics were revised downward to 250 million metric tons on August 22, 1959, and again to 200 million metric tons in 1979.[10] Given the revision history, we suspect that the final figure of 200 million tons in 1958 is more of a guestimate than an estimate based on comparable statistical methodology used in other years.

Under the illusion that the collectivization drive had solved China's food problem permanently, the government diverted a large amount of rural labor from agriculture to industry. As shown in column 4 of Table 1, the agricultural labor force was reduced by 38 million between 1957 and 1958. These diverted laborers were likely the more productive, leaving the less productive peasants to man agricultural chores. The diversion resulted in a neglect of agricultural work, sometimes leaving grain to rot in the field.[11]

With attention being shifted to the seemingly insurmountable problem of grain storage, the government encouraged communes to allocate more arable land to cash crops so as to increase the supply of industrial raw materials.[12] Column 5 of Table 1 shows that the area sown with grain was reduced by more than 13 percent between 1957 and 1959. At the same time, fearing communalization without fair compensation, peasants significantly reduced their stock of draft animals—probably the most important piece of capital in Chinese agriculture in the 1950s. Column 6 shows that the stock of draft animals fell by 10 million heads between

[10] The 1959 revision was reported in the *New York Times* on August 27, 1959. The last revision was published in the 1980 edition of the *China Statistical Yearbook*.

[11] During an interview with one of the authors in 1999, a formal commune cadre in Henan province described 1958 as "a year of bumper crops without a bumper harvest." See also Becker's (1996) accounts.

[12] In 1959, Liu Shaoqi, the State President, envisioned a "three-three system" of cultivation under which only a third of the arable land would be needed for grain cultivation, a third could be allocated for cash cropping and tree-planting, and a third would lie fallow (Kueh, 1995). Fortunately, this system was never fully implemented.

1956 and 1958. Despite the rapid adoption of farm machines and chemical fertilizers in agriculture during this period (columns 7 and 8), the use of modern inputs remained low. The government also encouraged communes to establish communal kitchens that provided members with free meals, resulting in a great deal of wasted food (Yang, 1996).

Ecstatic about the sharp increase in grain yields, the government increased state procurement of grain.[13] Column 2 in Table 1 shows that grain procurement increased from 46 million metric tons in 1957 to 64 in 1959, even as grain output had actually fallen in 1959! Net exports of grain was raised from an average of 2.11 million tons between 1953 and 1957 to 3.95 million tons in 1959. Grain retained in rural areas fell sharply from 273 kg per capita in 1957 to 193 kg in 1959, and further down to 182 in 1960. Since grain was the primary source of food energy in China at the time, the drop in per capita food availability coincided with the onset of the worst famine in human history. Estimates of calorie intake by Ashton *et al.* (1984) show that daily per capita availability of food energy in China fell from over 2100 calories in 1957 to about 1500 calories in 1960, well below any estimates for other countries in 1980.

Reduction in calorie intake has been found to reduce a particular dimension of human capital—physical capacity to carry out manual work—and therefore adversely affect labor productivity (see Dasgupta, 1993; Strauss and Thomas, 1995). Becker (1996) reported that in villages a few miles from Beijing, peasants who survived the initial food shortage in 1959–60 were too weak to plant or harvest new crops. Indeed, grain output fell further in 1960 and remained low in 1961 even as the government dramatically reduced grain procurement (Table 1).

As the government gradually learned of the severity of the agricultural problems, it started to moderate its radical policies in early 1959.[14] In 1960, it reduced the procurement of grain in the countryside. Tens of millions of people were sent back to the countryside, raising the rural labor force by more than 50 million between 1958 and 1962 (Table 1). The government also reduced the size of rural collective organizations, making each production brigade (usually

[13]In Guangshan county, Henan province, "cadres reported a harvest of 239,280 tons when it was really only 88,392 tons, and fixed the grain levy at 75,500 tons. When [peasants] were unable to collect more than 62,500 tons, close to the entire harvest, the local cadres launched a brutal 'anti-hiding campaign"' (Becker, 1996, p. 113).

[14]In April 1959, Mao, who born the main responsibility for the GLF, stepped down as the Chairman of the People's Republic. In the Summer of 1959, at the Lushan conference of the Chinese Communist Party, Defense Minister Peng Dehuai openly criticised Mao and his GLF policies. Enraged by the criticism, Mao launched a counter attack, deposed Peng and his supporters, and temporarily reinvigorated the GLF.

less than 100 households) an independent accounting unit. Beginning in 1965, it instituted a procurement stabilization program. Actual grain procurement was set at just over 40 million metric tons per year. To meet the demand for grain in urban areas, the government reversed its grain export policy and imported on average 4.2 million metric tons of grain per year between 1961 and 1966, and 2.1 million metric tons per year between 1967 and 1976. Output began to recover in 1961, but did not surpass its pre-GLF level of 195 million metric tons recorded in 1957 until 1966, the first year of yet another political upheaval in China—the Cultural Revolution.

3 The Model

To better understand the nature of the GLF crisis, we set up a two-sector dynamic model of central planning. We show that the radical GLF policies documented above are consistent with an impatient government maximizing industrial production under the false premise that collectivization would dramatically raise agricultural productivity.

3.1 Work Capacity and Production Technology

For simplicity, we assume that labor is the only factor input in agricultural production, and the economy's labor supply is normalized to be 1. The government allocates labor L_t to grain production and the remainder $1 - L_t$ to industrial production. Given $L_t < 1$ at time t, the effective agricultural labor is $L_t^* = L_t f(h_t)$, where h_t represents the physical work capacity of each worker—a specific form of human capital that is relevant here,[15] and $f(h_t)$ is an increasing and concave function in h_t. The work capacity h_t is assumed to depreciate at the rate $1 - \delta$ and increase with current investment—food consumption, c_t. More formally,

$$h_t = \delta h_{t-1} + c_t. \tag{1}$$

Assume that grain production exhibits constant returns to scale in effective labor. The aggregate grain output is thus $Q_t = aL_t f(h_t)$, where a is a productivity parameter, which depends in general on both technology and organizational form. Grain output per worker is

[15]The maximum work capacity of a laborer is often related to his anthropometric measurements—in particular, height and weight. For example, the body mass index (BMI), defined as weight divided by height squared (see Dasgupta, 1997; Strauss and Thomas, 1995), is frequently used to measure a person's nutritional status, and thus physical capacity.

then $q_t = af(h_t)$. When the government procures (*i.e.*, taxes) p_t from each agricultural worker after the harvest in period t, the retained grain $g_t = af(h_t) - p_t$ is saved for consumption during the subsequent period,[16]

$$c_{t+1} = g_t \equiv af(h_t) - p_t \tag{2}$$

The industrial sector uses labor and grain as an intermediate input. Assume that the technology for industrial production is Leontief: one unit of industrial output requires the use of one unit of labor and m units of grain in production. Therefore, with $1 - L_t$ units of labor in the industrial sector, the industrial output in time t is $1 - L_t$, if $m(1 - L_t)$ or more units of grain are used in production.

3.2 Preferences of the Central Planner

The government maximizes a discounted flow of industrial output, $\sum_{t=0}^{\infty} \beta^t (1 - L_t)$, subject to the constraint that there must be enough grain to feed the industrial work force and to use as an intermediate input for industrial production at each point in time. The parameter $\beta < 1$ is the government's discount factor. When the government extracts p_t amount of grain from each agricultural worker, the food constraint can be written as

$$p_t L_t \geq (m + n)(1 - L_t), \tag{3}$$

where n is the food entitlement for each urban industrial worker.[17]

Given its objective function, the government should allocate just enough labor to agricultural production so that the constraint (3) is binding at each time t. Thus an optimal labor allocated to agriculture at any time t should be $L_t = (m + n)/(p_t + m + n)$. By subsuming

[16]More generally, each crop cycle can be divided into two stages (Behrman, Foster and Rosenzweig, 1997): a planting stage and a harvesting stage. While food is usually plentiful during the harvesting stage, the supply of food during the planting stage depends on how much retained grain from last harvest was saved. Here we implicitly assume that the time period in the model matches the crop cycle.

[17]In China, each industrial worker (and each member of his immediate family) was entitled to receive a predetermined amount of food coupons from the government. The amount of food entitlement varied with job types. For example, in 1956, the national average of monthly ration of grain for unusually hard laborers was 25 kilogram (kg); for hard laborers, 20 kg; for light laborers, 16 kg; and for white-collar employees, the monthly average was 14 kg (Chen, 1982, p.206). Retail prices of staple food and industrial wages were both set by the government to ensure the affordability of the rationed food. Prices were not market clearing, and played little role in resource allocation.

this constraint and combining (1) and (2), the government objective can be rewritten as,

$$U = \sum_{t=0}^{\infty} \beta^t \frac{af(h_t) - h_{t+1} + \delta h_t}{af(h_t) - h_{t+1} + \delta h_t + m + n} \tag{4}$$

3.3 Equilibrium

The central planner's problem can now be reformulated using Bellman's equation:

$$V(h_t) = \max_{h_{t+1}} \left\{ \frac{a_t f(h_t) - h_{t+1} + \delta h_t}{a_t f(h_t) - h_{t+1} + \delta h_t + m + n} + \beta V(h_{t+1}) \right\} \tag{5}$$

for given h_0 and $t \geq 0$. Here $V(h_t)$ is the value function. Given that the industrial labor is bounded for all h_t (*i.e.*, $0 \leq 1 - L_t \leq 1$), it can be easily verified that there exists a continuous function g, such that $h_{t+1} = g(h_t)$ for $t \geq 0$ is the solution or the equilibrium policy rule. It contains the information needed to compute the optimal time path for work capacity h_t, grain procurement p_t and consumption c_t, for any given initial condition h_0.

Unfortunately, with the above specification, the dynamic equilibrium cannot be expressed analytically, even when we assume that the work capacity augmentation function is $f(h_t) = h_t^\alpha$ for $0 < \alpha < 1$. But its steady state equilibrium can be expressed analytically. By combining the first order and envelope conditions of (5), we obtain Euler's equation for the system,

$$\frac{(p_t + m + n)^2}{(p_{t-1} + m + n)^2} = \beta(af'(h_t) + \delta). \tag{6}$$

By substituting in $p_t = p_{t-1}$, we solve for the steady state h^s as

$$h^s = f'^{-1}\left(\frac{1 - \beta\delta}{\beta a}\right) \tag{7}$$

where f'^{-1}, as the inverse function of f', should be a decreasing function. The steady state work capacity, and hence, grain output per work, should therefore increase with grain productivity a and with the central planner's discount factor β – patience.

The derived results are consistent with Mao's statement about the link between agricultural productivity and industrial development. An increase in agricultural productivity raises grain output available for procurement and rural consumption, and therefore should in general increase procurement and investment in work capacity. The result would be a permanent increase in food availability in urban areas, allowing the government to reallocate some labor from agriculture to industry permanently. A more patient central planner would allow work capacity in rural areas to accumulate by procuring less aggressively, and therefore allow grain output per labor to rise to a permanently higher level than a less patient government would.

3.4 GLF policies

To show that the radical GLF policies can be formulated by an increasingly impatient central planner relying on the false promise of the productivity effect of collectivization, we solve the model numerically and simulate the dynamic setting of government policies and the economy's dynamic responses. The choice of parameter values characterizing the pre-GLF economy is discussed in Appdenix B.

Consider first the dynamic impact of acting on the false premise. Start with the post-war recovering economy at year $t = 1$ with a relatively low $h_1 = 0.9$. The government first pursues its optimal policy knowing the true agricultural productivity. Grain output rises as the peasants' work capacity recovers from its war-time low, as seen in Figure 1 from year 1 to year 4. Believing that collectivization would increase agricultural productivity permanently by, say, 40 percent, the government launches the Great Leap Forward movement in year 5. Assume that in actuality a falls by 5 percent permanently.

Based on the expected productivity, the government in year 5 "optimally" allocates "redundant" agriculture labor to industrial production (Panel A of Figure 1) and raises its procurement target per worker (Panel B). Because a actually falls in year 5, output per worker falls (Panel B). Aggregate output therefore falls (Panel D). The procurement turns out to be excessive for year 5 (Panel B). Consequently, retained grain in year 5 that will be consumed in year 6 falls sharply (Panel B), causing each peasant's work capacity to depreciate precipitously in year 6 (Panel C). The reduction in work capacity in turn results in a sharp reduction in grain output per agricultural labor in year 6 (Panel B).

Assume that in year 6 the government learns the true value of a and the much reduced work capacity of each agricultural worker.[18] Based on the new information, the government "optimally" reallocates labor back to agriculture in year 6 (Panel A), and simultaneously reduces the procurement (Panel B). But as h_t reaches it lowest point in year 6, it drags the

[18] This is a simplification. The history was more complicated; see footnote 14. If we simulate a delay by one year of the policy reversal, the output collapse would be even deeper and last longer.

aggregate grain output to fall to its lowest level (Panel D), despite the fact that there are now more agricultural workers. As food consumption (hence investment in work capacity) begins to recover from year 7 on (Panel B), work capacity, output, procurement and consumption all begin to recover and gradually converge to a lower level steady state equilibrium associated with the lower productivity under the collective institution.

The transition dynamics triggered by a spurt of impatience can be illustrated analogously. Figure 2 plots the dynamics of the system in response to an *ex ante* permanent reduction in the discount factor β by 10 percent in year 5 and is then restored to its original value from year 6 on, while a drops by 5 percent as a result of collectivization. Since a less patient central planner places a higher value on immediate increases in industrial output than future increases, he is willing to sacrifice future work capacity in order to divert more resources from agriculture today. In year 5, he diverts labor from agriculture to industry (Panel A) and increases grain procurement (Panel B). Retained grain in year 5 and hence grain consumption per worker in year 6 falls significantly, leading to a large reduction in work capacity in year 6 (Panel C). Aggregate grain output falls to its lowest level in year 6. As the government restores its patience in year 6, recovery starts in the following year and grain output gradually converges to a lower level steady state associated with a lower productivity under the collective institution.

The rush to industrialize would of course be infeasible *ex ante*, had agricultural productivity not been expected to take a great leap forward. It is therefore more instructive to see the combined effects of the false premise and increased impatience, which we plot in Figure 3. There we see the combined effects are much stronger.

The described dynamics are consistent with the aggregate data presented in Section 2. Our analysis here suggests that resource diversion and excessive procurement caused by unrealistic expectations about productivity and/or by heightened impatience are sufficient to generate the dynamic patterns observed in the data, if grain is considered an investment good which contributes to peasants work capacity when consumed. The implications of this hypothesis—that resource diversion and excessive procurement are important determinants of the grain output collapse—will be the subject of empirical testing in the remainder of the paper.

4 Data and Hypotheses

The GLF disaster is a complex phenomenon with perhaps multiple causes (Lin and Yang, 1998). In addition to the two testable hypotheses advanced by the preceding model, namely resource diversion and excessive procurement, other factors may have also contributed to the grain output collapse. These factors include weather conditions, the size of organization, exit rights within rural collectives, and radical programs such as communal dining.

In order to quantitatively evaluate the effects of these factors and to discriminate between alternative hypotheses, we have compiled from various published sources a panel dataset on grain production and procurement at the provincial level. To acquire unpublished data needed for this study, we conducted a retrospective survey in the provinces. The survey collected information on weather conditions, production scale, and the evolution of agricultural organizations from sources including provincial data archives and interviews with agricultural experts in each province. Appendix A provides more information on data sources, the design of the survey, and the definition of some of the variables.

Our analysis focuses on the period between 1954 and 1977 because 1954 was the first year in which systematic data collection began in many provinces and 1977 was the last year prior to the decollectivization reforms. Table 2 reports yearly averages of grain output and agricultural inputs from 25 provinces for each year between 1954 and 1977. Included in the table is a constructed variable, Farm Capital, which measures in equivalent power units (millions of KW) the sum of all farm machines and draft animals. A drawback of the Chinese agricultural statistics is that there are no activity-specific records that separate the uses of various inputs (except for sown area) between grain production and other lines of agricultural activities, such as the production of cash crops. The reported agricultural inputs in Table 2 are in general higher than those actually used in grain production. This is likely a minor measurement problem, however, since most agricultural inputs were actually used in the production of grain during our sample period. Column (9) of table 2 confirms that on average about 85 percent of sown areas were allocated to grain production. In the empirical analysis, we shall specify a procedure to control for possible measurement errors.

The statistics in Table 2 offer a description of agricultural production in China consistent with the aggregate statistics in Table 1. During the GLF period, there was a sharp reduction in grain output as well as in the use of traditional inputs—labor, land, and draft animals—in production. The provincial data also reveal rapid increases in fertilizer use throughout the sample period. However, the rapid increase in the use of farm machines could not fully compensate for the decline in draft animals during the GLF, since aggregate farm capital fell steadily during the GLF period.

Table 3 presents summary statistics of weather and policy variables. Below we give a brief description of these variables and testable hypotheses associated with them.

Weather. To assess the impact of weather on grain output, we obtained from our survey an index of annual weather conditions for each province on a scale of 1 to 5 with 5 being the best.[19] Consistent with Kueh (1995), Column (2) of Table 3 shows that bad weather coincided with the collapse of grain output during 1959–60.

Size of Organization. To assess the incentive effect of collectivization on agricultural labor productivity, we also collected information on the size of basic production units that had independent accounting. Column (4) indicates that the average production unit grew from a size of 22 households in 1954 to 2675 households in 1958; then declined sharply to 41 households in 1962.

Exit Rights. To investigate the extent to which the official removal of exit rights reduced peasants' incentives and contributed to the collapse of grain output, we interviewed knowledgeable experts in each province, collecting information on when compulsory participation became an official policy. Column (3) reports the proportion of sample provinces that did not allow exit rights in each year. It is worth noting that the percentage of provinces with no exit rights increased from 20 percent in 1955 to 60 percent in 1957, consistent with the reports by Kung and Putterman (1997). Compulsory participation, which was believed to have been implemented widely after 1958, was actually not an official policy in about one-third of the sample provinces.

Communal Dining and Radicalism. Regional innovations in radicalism, as epitomized by the establishment of communal kitchens, may have wasted a substantial amount of already scarce food and hence compounded the nutritional effects of excess procurement on peasants' work capacity. In the fall of 1958, more than 2.65 million communal kitchens were established (see Chang and Wen, 1997). By the end of 1959, the participation rate of peasants in communal kitchens reached an average of 64.7 percent with a range from 16.7 percent to

[19] We choose not to use the official weather index that measures the percentage of sown acreage experiencing 30 percent or more reduction in yield due to flood, drought, frost, or hail. Given the party line explanation of the GLF disaster, it is quite possible that crop failures caused by other factors, such as bad policies, may have been attributed to bad weather.

97.8 percent across provinces. Yang (1996) argues that the cross-province variation reflected in large part the variation in the degree of radicalism between provincial leaders. While communal kitchens operated between 1958 and 1960, data on the participation rates are available only for 1959.

Resource Diversions. Diversion of agricultural inputs has both quantitative and qualitative dimensions. The declines in sown area, labor and farm power during the GLF, as documented in Table 2, directly measure the extent of the quantitative diversion of inputs. What is not apparent in the data is that more productive agricultural workers were often assigned to large irrigation and land reclamation projects and to backyard steel mills, leaving the less productive to perform agricultural chores. Since we have data only on steel and iron production in each province, we use the cumulative change in steel and iron output from 1956 to 1964 as a proxy for diversion of rural labor to non-grain production activities. Column (5) in Table 3 indicates that there was a surge in steel output during the GLF between 1957-61.

Procurement and Nutrition Effects. While we don't observe peasant food consumption directly, we do have data on procurement for each province in each year. Since grain consumed during the current planting season must have come from retained grain—total grain output minus total procurement—from previous harvesting seasons, we use lagged values of retained grain to approximate food availability for the current year.

5 Empirical Specification

The joint significance of the factors discussed in determining grain output in China can be estimated with a properly specified production function. For province i in year t, given *effective* inputs of labor (L^*_{it}), land (A^*_{it}), farm capital (K^*_{it}), and chemical fertilizers (M^*_{it}), the grain output Q_{it} can be written in a Cobb-Douglas specification as

$$\ln Q_{it} = \sum_{X=L,A,K,M} \alpha_X \ln X^*_{it} + \sum_{j=1}^{3} \omega_j W^j_{it} + u_i + \epsilon_{it}, \tag{8}$$

where W^1_{it}, W^2_{it}, and W^3_{it} are three weather dummy variables, u_i measures province-specific fixed effects that capture geographical and political factors that affect grain production, and ϵ_{it} is an idiosyncratic random error term. Obtained from our survey, the weather dummies W^1_{it}, W^2_{it} and W^3_{it} indicate if the weather conditions in year t are "average", "bad", and "very bad" respectively. With weather dummies indicating better-than-average weather conditions excluded, the coefficients ω_j measure the extent of output loss under average or below-average weather conditions relative to the output under better-than-average weather conditions. We expect $\omega_3 < \omega_2 < \omega_1 < 0$.

Effective inputs are inputs used for grain production that are adjusted for quality or efficiency differences. Such adjustments are important to this study since we are interested in testing, among other hypotheses, whether nutritional deficiencies caused by excessive procurement of grain have a significant impact on lowering peasants' work capacity and hence their productivity, and whether collective institutions reduced peasants' incentive to work. Since effective inputs are not directly observed, we embed (8) empirical specifications for making needed quality adjustments using available data.

But first we need a specification for measuring inputs used in grain production. The observed inputs are the total number of agricultural workers (L_{it}), total sown area (A_{it}), farm capital (K_{it}), and fertilizers (M_{it}), available for agricultural production. Naturally, a small portion of these inputs should have been devoted to the production of other agricultural products. Since the proportion of sown area allocated to grain (G_{it}) is observed, a flexible specification for measuring inputs used in grain production, X_{it}^G, may be written as

$$\ln X_{it}^G = \ln X_{it} + \gamma_X \ln G_{it} + c_{Xi}, \quad X = L, A, K, M; \tag{9}$$

where X_{it} are the inputs reported for agricultural production, γ_X is the adjustment parameter to be estimated, and c_{Xi} captures input- and province-specific factors that affect the allocation of available inputs between grain and non-grain production. If all inputs are used in the same proportion as sown acreage for the production of grain, we should have $\gamma_X = 1$ and $c_{Xi} = 0$. In general, one expects that the proportion of labor (and other inputs) allocated to grain production would be related to G_{it}.

During the GLF, not all labor available for grain production was actually used in grain production or was used to its productive potential. Many factors have contributed to the reduction in effective labor input. Their combined effects on the quantity and quality of effective labor can be written in the following flexible specification,

$$\ln L_{it}^* = \ln L_{it}^G + \gamma_h \ln h_{it} + \gamma_R \ln R_{it} + \gamma_S \ln S_{it} + \gamma_Z \ln Z_{it} + \gamma_E E_{it}. \tag{10}$$

We now discuss the adjustment terms.

As discussed in Section 3, h_{it} represents the average peasant's work capacity, a special form of human capital that depends on nutrition. Unfortunately, h_{it} is not observable. But analytically (from (1)) and intuitively, it is simply a discounted flow of past and present food intakes (*i.e.*, investments in work capacity), $h_{it} = \sum_{s=0}^{\infty} \delta^s c_{i,t-s}$. If δ is low, *i.e.*, if the depreciation rate is as high as one would expect, h_t is determined mostly by food consumption in the present and the immediate past. In what follows, we use the first order approximation $h_{it} = c_{it} + \delta c_{i,t-1}$ and ignore all second or higher order terms in δ. In Section 4, we proposed to use retained grain per capita in rural areas from the previous harvest as a proxy for the unobserved per capita food consumption in the current year (Recall the crop cycle discussed in footnote 16). Accordingly, the work capacity of each peasant in year t can thus be reexpressed using lagged values of retained grain per capita, $g_{i,t-1}$ and $g_{i,t-2}$, or

$$h_{it} = g_{i,t-1} + \delta g_{i,t-2} \tag{11}$$

From the discussion in Section 4, the size of the production team (Z_{it}) and the removal of exit rights (E_{it}) may negatively influence the supply of work effort by encouraging free-riding. Here E_{it} is a dummy variable with $E_{it} = 1$ indicating the absence of exit rights. We expect $\gamma_Z \leq 0$ and $\gamma_E \leq 0$ so both of the institutional factors should contribute negatively to grain output. Also as discussed, the cumulative changes in steel output (S_{it}) between GLF years and 1956 can be used as a proxy to indicate the extent of unobserved labor diversion. Additionally, radical programs (R_{it}), as represented by the communal dining system, may cause food waste and other negative effects on production. Both γ_S and γ_R are expected to be negative.

Quality adjustment can also be made to land input. Since land is usually more productive with irrigation than without, the quality of land input should increase with the proportion of sown area that is irrigated. We thus specify a flexible adjustment for the efficiency units of land as:

$$\ln A^*_{it} = \ln A^G_{it} + \gamma_I \ln I_{it} \tag{12}$$

where I_{it} is the proportion of sown area under irrigation. Because quality variations in chemical fertilizers and farm capital are unobserved and are presumably small, we make no quality adjustment to M_{Git} and K_{Git}.

Finally, we suspect that the 1958 grain output was compiled using methods significantly different from other years (see Section 2). To test and control for possible statistical discrepancies in the reported 1958 grain output figure, we include in the regression a dummy variable $D_{t,58}$ with $D_{t,58} = 1$ for $t = 1958$ and 0 for other years. If grain output in 1958 is exaggerated by a significant margin, it would lead to one additional complication concerning the measurement of the retained grain per capita. This is because we need to adjust 1958 grain output before we compute the per capita food availability in that year. Therefore, for each year t, the retained grain per capita in province i should be measured as

$$g_{it}^{*} = (Q_{it}/e^{\mu D_{t,58}} - \text{procurement}_{it})/\text{rural population}_{it}, \tag{13}$$

where μ is the coefficient on $D_{t,58}$ in the regression equation that measures the extent of grain output over-reporting in 1958.

Substituting (9)-(13) into (8), we derive the following empirical model in terms of observed quantities:

$$\begin{aligned} \ln Q_{it} \quad = \quad & \alpha_A \ln A_{it} + \gamma_I lnI_{it} + \alpha_M lnM_{it} + \alpha_K \ln K_{it} + \alpha_L lnL_{it} + \gamma_G \ln G_{it} \\ & + \gamma_h ln(g_{t-1}^{*} + \delta g_{t-2}^{*}) + \gamma_R ln(R_{it}) + \gamma_S ln(S_{it}) + \gamma_Z lnZ_{it} + \gamma_E E \\ & + \sum_{j=1}^{3} \omega_j W_{it}^{j} + \mu D_{t,58} + u_i^{*} + \epsilon_{it}, \end{aligned} \tag{14}$$

where $\gamma_G = \sum_X \gamma_X \alpha_X$, $g_{i,t-1}^{*}$ and $g_{i,t-2}^{*}$ are defined in (13), and u_i^{*} collects c_{Xi} for all inputs X and u_i.

Equation (14) can be estimated using a non-linear fixed-effects panel data regression. The estimated coefficients would be consistent and asymptotically normal if the included regressors are uncorrelated with the idiosyncratic error ϵ_{it}. For the period between 1954 and 1977, the government controlled the allocation of agricultural inputs and policies. While it was possible that actions taken by the government were related to each individual province's specific features (*e.g.*, comparative advantage) that were observed, it would be more difficult for the government to get up-to-date information on the idiosyncratic shock ϵ_{it} and to act on it promptly. The fact that the government exported more than 3.95 million tons of grain in 1960 while millions of peasants were starving to death suggests that the government either didn't have access to up-to-date information from local levels or couldn't act on the information quickly. As long as the government didn't adjust the allocation of inputs in response to idiosyncratic shocks ϵ_{it}, our estimates should be consistent. The parameters estimated from (14) will provide the basis for testing hypotheses concerning the causes of the grain output collapse.

6 Estimation Results

Table 4 reports results of estimating equation (14) and two variant specifications. Regression (1) is a baseline case that includes basic agricultural inputs as explanatory variables. Regression (2) adds variables adjusting for weather conditions, the quality of land (*i.e.* irrigation), and incentive effects of institutions (*i.e.* exit rights and scale of production). This specification allows for a preliminary testing of the conventional hypotheses on the causes of the output collapse. Regression (3) is based on equation (14) that incorporates the following new variables emphasized in this paper: the nutritional status of agricultural workers, the changes in steel output during the GLF, and a year 1958 dummy. We estimate the first two specifications using ordinary least squares with provincial dummies, and the last specification using non-linear OLS with provincial dummies.

The estimates in regression (1) indicate that all conventional inputs contribute positively and significantly to grain output, with labor accounting for the largest input share. The estimated coefficient for the proportion of acreage sown with grain ($\ln G_{it}$) is small and statistically indistinguishable from zero, implying that on the margin, available labor, capital, and fertilizers were allocated mostly to grain production. It is worth noting that the estimated returns to scale – the sum of factor input coefficients – is 1.18 with a t-value of 4.29, which is statistically significant at the 1 percent level for rejecting the null hypothesis of constant returns to scale. A standard explanation would be that grain production at the provincial level exhibits increasing returns to scale. This claim would seem to support the official ideological claim that collective farming reaps the benefits of scale economies. However, this inference is probably premature because the regression is likely affected by omitted-variable biases because many variables in (14) are excluded.

In regression (2), we add three dummy variables for weather, the proportion of sown area under irrigation for land quality, and three policy variables—a no-exit dummy, the scale of production, and the communal dining participation rate. As expected, the inclusion of these variables affects the estimates of the coefficients on factor inputs. The estimated returns to scale are reduced to 1.11 with a t-value of 1.16, which is no longer statistically significant for rejecting the null hypothesis of constant returns to scale. Consistent with expectations, the estimates show that irrigation raises the productivity of land, and bad weather does reduce grain output. Relative to above-average weather conditions, the realization of average, bad or very bad weather conditions would reduce grain output by 5.6, 9.3, or 16.7 percent respectively. Similar to the results for regression (1), the estimated coefficient for the percentage of land sown with grain is small and statistically indistinguishable from zero. This result remains valid for all specifications.

The estimated coefficients on the three institutional variables merit discussion. Consider first the "no-exit" dummy variable. The game theoretical explanation proposed by Lin (1990) suggests that the removal of the peasants' right to withdraw from the communes in 1958 sharply reduced their work incentives, thus causing a collapse of agricultural productivity.[20] By including the "no-exit" variable in the regression, we hope to find whether the change in the official policy on voluntary participation is an important determinant of labor effort, and thus grain output. Consistent with the hypothesis, the estimated coefficient is negative and statistically significant, implying a sizeable 6.3 percent drop in output once exit rights are removed.

Turn next to the scale of production. While there may be some economies of scale in grain production from utilizing modern inputs, collective farming faces serious incentive problems due to high costs of monitoring work effort in agriculture and the egalitarian income sharing rule. The lack of managerial abilities in operating large size organizations may also result in poor performance. While the net effect of increasing the size of production units cannot be ascertained theoretically, it is generally thought to be negative on grain output since labor intensive farming in China did not favor large scale operations. Regression (2) reports a positive but statistically insignificant coefficient. This result suggests that the large scale of production per se did not reduce labor quality.

Finally, with regard to radical programs and communal dining, we find that grain output is significantly lower in provinces with a higher rate of participation in communal dining, and thus higher degree of radicalism. This result is consistent with the findings of earlier research that deeper involvement in radical projects may result in more serious waste of food

[20] Lin's hypothesis is at variance with another branch of theory that emphasizes the role of exit costs in punishing slackers and inducing effort (see MacLeod, 1993). However, there has been a convergence in views on both theoretical and empirical fronts that the elimination of exit rights caused a decline in the productivity of collective farms during the entire commune period of 1958-77 (Putterman and Skillman, 1993; Wen, 1993).

and other destructive effects on production.

The estimates of the parameters in (14), the complete empirical specification that incorporates the intertemporal effects of nutrition and the effect of labor diversion due to rural steel production (and other large projects), are reported in column (3). Inspection of the signs of the estimated coefficients reveals that all variables operate as predicted. But the inclusion of new variables in the regression leads to some changes in the coefficient estimates for factor inputs. For instance, the output elasticity of labor is reduced to 0.364 from 0.580 and 0.399 in specifications (1) and (2). This result is consistent with the view that nutritional status is an important element of labor input. The coefficient on fertilizer is more precisely estimated than in the first two regressions, and there is an increase in the size of the estimated value. Overall, parameter estimates are rather robust to changes in specifications.

The results of regression (3) suggest that the grain output figure for 1958, which had been revised downward a few times, is still likely to be biased since this particular statistic was collected rather differently. The estimate of the coefficient on the year 1958 dummy is positive and statistically significant, implying that the 1958 grain output may still be overstated by about 6 percent relative the estimated input-output relationships.

The results also indicate a negative and significant coefficient on communal dining, confirming the view that radicalism during the GLF had been disruptive to grain production. The parameter estimates for scale of production remains small and statistically insignificant. This finding suggests that, despite its theoretical plausibility, the increase in the size of organization during the GLF was, in itself, not an important factor contributing to the collapse in grain output.

The estimate of the coefficient on the no-exit dummy is still negative as expected, but statistically insignificant. This finding should not be surprising, however. In fact, it is not inconsistent with previous findings (Lin (1990) and Wen (1993)) that the removal of exit rights or more generally the collectization movement reduced agricultural productivity from the mid-1950s to 1977, when compared with productivity in the early 1950 and the productivity since decollectivization reforms began in 1978. Given the purpose of this paper, we have limited our analysis to the collective farming period between 1954 and 1977, and therefore cannot take advantage of the decollectivization event to measure the negative effect of compulsive collective institutions. In regression (3), due to the use of lagged values of retained grain per capita, the actual sample period is further shortened to between 1956 and 1977, during which the variation in institutions is even smaller than that between 1954 and 1977 (see column (3) in Table 3). This change in sample period helps explain why the estimate of the coefficient on the no-exit dummy is statistically insignificant, and smaller in size in regression (3) than regression (2).

Two important findings in regression (3) are related to the newly added labor quality variables. First, the estimated coefficient on the proxy for work capacity of rural workers is positive and statistically significant, implying that better nutrition enhances labor quality. The estimate for the depreciation rate $(1 - \delta)$ implies that nutritional intake in the previous year has a rapidly diminishing effect on physical work capacity in the current year. According to the estimate, work capacity would depreciate at the rate of 71 percent (or $1-0.29$) per year. This is consistent with the assumption we made in Section 3 for deriving the proxy for work capacity (11). Based on these results and the actual changes in food availability during the GLF, we can infer the negative effects of nutritional factors on grain output. The estimates imply that, *ceteris paribus*, a 10 percent reduction in retained grain from the sample average would substantially lower the work capacity of peasants, causing an approximately 4 percent drop in grain output. Therefore, severe nutritional deficiency among agricultural workers, caused by excessive procurement, was an important cause of the grain output collapse.

Second, the coefficient on steel production, a proxy for labor diversions, is negative and statistically significant, confirming the view that, for a given rural labor force, expansions in non-agricultural activities reduced effective labor input in grain production. Based on the estimates in column (3), an increase in steel output by 10 thousand tons, *ceteris paribus*, is associated with a significant reduction in effective agricultural labor, leading to a grain output contraction by about 2.7 percent. Given that on average the steel output for a province increased by 15.7 thousand tons between 1959 and 1960 (see Table 3), this variable should explain a good part of the decline in grain output. Therefore, at the peak of the GLF, backyard steel smelters and large land reclamation and irrigation projects represented an important dimension of resource diversion. Combined with the fact that the government also directed productive inputs out of the rural sector during the GLF (see Table 2), resource diversion should be a major causal factor for the grain output collapse.

To summarize the estimation results, we group various causal factors into five broad categories: (1) excessive procurement and nutritional effects, as measured by lagged values of per capita retained grain; (2) diversion of resources away from grain production, relating to changes in sown area, labor, capital, and steel output—a proxy for wasteful use of rural labor in unproductive activities; (3)weather conditions; (4) institutional factors, including communal dining/radicalism, exit rights and the scale of production; and (5) modern inputs, consisting of the use of fertility and irrigation. Given the yearly changes in the variables presented in Tables (1)-(3) and the estimates of their effects on grain output in Column (3) of Table (4), we provide an outline below for the causes and the dynamic changes in grain output for the years surrounding the GLF catastrophe:

1958: At the onset of the GLF movement, the government diverted resources to industrial production by reducing sown acreage, agricultural labor and capital, as well as increased participation in non-agricultural activities, such as backyard steel production. Implementation of radical programs, such as communal dining, also had negative effects on production. However, grain output in 1958 by our estimates stayed about the same as in 1957, because of superior weather conditions.

1959: At the peak of the GLF euphoria, more resources were diverted from grain production, as indicated by large increases in steel and iron output (Table 3). Moreover, weather conditions deteriorated dramatically, which combined with reduced inputs resulted in declines in grain production. The most alarming event in 1959 was that, despite sharp reductions in output, grain procurement reached the highest level. This in turn caused drastic declines in food availability in rural areas for the following year.

1960: The three sets of conditions - nutrition, input diversions, and weather - generally deteriorated to their worst levels, causing the largest single-year percentage decline in grain production and sending national output to its lowest level.

1961: The government's effort to rectify erroneous GLF policies started to be felt as resources were reallocated back to agriculture, radical programs (such as communal kitchens) were shut down, and backyard furnaces were dismantled. However, the lingering nutritional effects among rural workers and severe weather conditions continued to suppress grain production. At the national level, output only registered a modest increase.

1962-66: 1962 marked the first year of a sizeable recovery in grain supplies. All determinants of production either had already started or began turning in a positive direction. This recovery continued in the following years, and, in 1966, the national output finally exceeded the pre-crisis level of 1957.

To assess quantitatively the contribution of each of the discussed factors to the grain output collapse and the consequent recovery, we estimate the effects on grain output of the observed changes in each of the right-hand side variables in (14) using the estimates reported in column (3) of Table 4. The results are presented in Table 5. Columns (1) and (3) report the magnitude of each factor's estimated contribution to the change in log(grain output), while columns (2) and (4) report each of the contributions as a proportion of the observed change in log(grain output).

The results indicate that the empirical model fits the data very well: the estimated changes account for 91 and 88.2 percent of the observed changes in grain output for the two periods, respectively. An interesting finding is that the intertemporal effect of excessive procurement and nutrition was the largest contributor to the collapse in grain output, accounting for 51.7 percent of the observed output decline between 1957 and 1960. Resource diversion was the second largest contributor, accounting for 28.6 percent of the observed output decline between 1957 and 1960. Other institutional or policy factors, including communal dining and other radical practices, was also important, accounting for 17.5 percent of the observed output decline. Adverse weather conditions played a significant role as well, accounting for 16.2 percent of the output decline. The increased usage of fertilizer and irrigation helped mitigate some of the negative effects of policies by erasing 15.8 percent of the output decline. And finally, the increase in the scale of production and the official removal of exit rights appear to have played a limited role in affecting grain output during the entire period. But as discussed, our estimate of the effect of no-exit policy may have understated its true contribution to the reduction in agricultural productivity for our entire sample period.

It is interesting to observe that the recovery is brought about mainly by allocating massive amount of resources back to the agricultural sector, something that a central planner knows how to do well. The procurement stabilization program implemented after the GLF helped restore peasants' nutrition and work capacity, which in turn, contributed to the recovery in grain output.

7 Summary and Conclusions

Throughout history and in different parts of the world, natural disasters have often been blamed as the leading cause of massive crop failures. The Chinese experience was special because the dramatic grain output collapse coincided with the inception of the Great Leap Forward movement and adverse weather conditions. Despite the official story that bad weather was the main cause, our theoretical and empirical analysis suggests that the main culprit was the GLF policies, which were in turn the result of a systemic central planning failure. The disaster could have been avoided *if* the central planner could have obtained reliable information on agricultural productivity and local conditions, an impossibility according to Hayek (1935).

The dynamic model of central planning formulated in this paper seeks to explain the behavior of the central planner. Upon switching to an accelerated and infeasible timetable for industrialization, which was encouraged by unrealistic expectations for agricultural productivity gains from collectivization, the government diverted massive amounts of agricultural resources to industry and imposed an excessive grain procurement burden on peasants, leaving them with insufficient food to maintain labor productivity. Grain output fell sharply at the onset of these policies and started to recover gradually when the policies were reversed.

Using data from published sources and a recent survey, we are able to construct variables needed for testing various hypotheses, including the implications of our theory. By estimating a production function that incorporates both quantitative and qualitative adjustments made to factor inputs, we find that excessive procurement, resource diversion, bad weather, and radical programs are all contributors to the output collapse. The most important factor, however, is excessive procurement that decimated the physical strength of the peasantry, contributing to 51.7 percent of the output collapse. Resource diversion is the next largest contributor, accounting for 28.6 percent of the output collapse.

The dynamic progression of the crisis observed in the data is consistent with the theory's predictions. Massive diversion of agricultural resources to industry in 1958-59 caused a large reduction in grain output in 1959. The excessive extraction of food grain from peasants in 1958 and again in 1959 severely reduced food available for consumption in rural areas, igniting a famine in some parts of the Chinese countryside in the spring of 1959, which spread to much of the countryside in the spring of 1960. Weakened by malnutrition, peasants could not exert sufficient labor input into planting or harvesting crops, leading to sharp declines in grain output. Adverse weather conditions and radical projects and programs exacerbated the output collapse.

This study is significant not only in its insights into China's Great Leap Forward tragedy, but also in its general implications on the relationship between economic systems and economic performance. Our research confirms Hayek's (1935) analysis of the inherent flaws of central planning. The dilemma of a central planned system, as Nelson and Winter (1982, p. 365) put it, "is that the information flow overwhelms a centralized system if it is open to new ideas and data, [while] closing the system and forcing the plan to work forecloses alternatives and risks unhedged mistakes." The GLF disaster has all the earmarks of an unhedged mistake.

References

[1] Ashton, B., Hill, H., Piazza A., and Zeitz, R. "Famine in China: 1958–61." *Population and Development Review*, 10 (1984): 613–45.

[2] Becker, Jasper. *Hungry Ghosts: Mao's Secret Famine.* New York: Henry Holt and Compan, 1996.

[3] Behrman, Jere R.; Foster, Andrew D.; and Rosenzweig, Mark R. "The Dynamics of Agricultural Production and the Calorie-Income Relationship: Evidence from Pakistan." *Journal of Econometrics*, 77: 187–207.

[4] Chang, Gene Hsin and Wen, Guangzhong, James. "Communal Dining and the Chinese Famine of 1958-1961," *Economic Development and Cultural Change,* 46 (no.1, 1997): 1-34.

[5] Chen, Chu-yuan. *China's Economic Development: Growth and Structural Change.* Boulder, CO: Westview, 1982.

[6] Communist Party of China, Central Committee. *Decisions on Several Historical Issues of the Communist Party of China since the Founding of the Republic.* Beijing: People's Press, 1981.

[7] Dasgupta, Partha. *An Inquiry into Well-being and Destitution.* Oxford: Oxford University Press, 1993.

[8] Dasgupta, Partha. "Nutritional Status, the Capacity for Work, and Poverty Traps," *Journal of Econometrics*, 77 (1997): 5-37.

[9] Hayek, F. A. "The Present State of the Debate," in F. A. Hayek (eds) *Collectivist Economic Planning: Critical Studies on the Possibilities of Socialism*, pp. 210–243. London: Routledge& Kegan Paul, 1935.

[10] Kueh, Y. Y. *Agricultural Instability in China, 1931–1991.* Oxford: Clarendon Press, 1995.

[11] Kung, James and Putterman, Louis. "China's Collectivization Puzzle: A New Resolution," *Journal of Development Studies*, 33 (1997): 741–763.

[12] Lin, Justin Yifu. "Collectivization and China's Agricultural Crisis in 1959–61," *Journal of Political Economy*, 98 (1990): 1228–52.

[13] Lin, Justin Yifu and Yang, Dennis Tao. "On the Causes of China's Agricultural Crisis and the Great Leap Famine," *China Economic Review*, 9 (1998): 125–40.

[14] Lin, Justin Yifu and Yang, Dennis Tao. "Food Availability, Entitlements, and the Chinese Famine of 1959-61, " *The Economic Journal*, 110 (2000): 136-158.

[15] MacLeod, W. B. "The Role of Exit Costs in the Theory of Cooperative Teams: A Theoretical Perspective, " *Journal of Comparative Economics*, 17 (1993): 540–59.

[16] Mao, Zedong. *Selected Work, Vol. V.* Beijing: Foreign Language Press, 1977.

[17] Ministry of Agriculture. *Compilation of China's Rural Economic Statistics: 1949-86.* Beijing: Agricultural Publishing House, 1989.

[18] Nelson, Richard and Sidney Winter. *An Evolutionary Theory of Economic Change.* Cambridge: Harvard University Press, 1982.

[19] Peng, X. Z. "Demographic Consequences of the Great Leap Forward in China's Provinces," *Population and Development Review,* 13 (no.4, 1987): 639-670.

[20] Perkins, Dwight H. and Yusuf, Shahid. *Rural Development in China.* Baltimore: Johns Hopkin's University Press, 1984.

[21] Putterman, L. and Skillman, G. L. "Collectivization and China's Agricultural Crisis," *Journal of Comparative Economics*, 17 (1993): 530-39.

[22] Ravallion, Martin. "Famines and Economics," *Journal of Economic Literature*, 35 (1997): 1205-1242.

[23] Riskin, Carl. *China's Political Economy.* Oxford: Oxford University Press, 1987.

[24] Rosen, Sherwin "Potato Paradoxes," *Journal of Political Economy*, 107 (1999): s294-s313.

[25] Sen, Amartya K. *Poverty and Famines: An Essay on Entitlement and Deprivation.* Oxford: Clarendon, 1981.

[26] Strauss, John and Thomas, Duncan. "Human Resources: Empirical Modeling of Household and Family Decisions," in *Handbook of Development Economics, Vol. 3*, eds. J. Behrman and T. N. Srinivasan. Amsterdam: North Holland, 1995.

[27] Walker, Kenneth R. *Food Grain Procurement and Consumption in China.* Cambridge: Cambridge University Press, 1984.

[28] Wen, Guanzhong James "Total Factor Productivity Change in China's Farming Sector: 1952-1989," *Economic Development and Cultural Change*, 42 (1993): 1-41.

[29] Yang, Dali L. *Calamity and Reform in China: State, Rural Society, and Institutional Change Since the Great Leap Famine*. Stanford: Stanford University Press, 1996.

[30] Yao, Shujie "A Note on the Causal Factors of China's Famine in 1959-1961," *Journal of Political Economy*, 107 (1999): 1365-1369.

A Description of the Survey and Data

A.1 The Survey

The retrospective survey was conducted by the authors during the summer of 1999 in cooperation with the General Organization of Rural Socio-Economic Survey (GORSES), a division of the State Statistical Bureau of China. Members of GORSES' branch offices in each province implemented the survey plan. The survey team filled out the questionnaires by first using available historical and statistical records. When archived historical records were incomplete, the team would then conduct an interview meeting to assess, estimate and supplement the missing data. The interviewees were selected in each province from a pool of local agricultural experts and local academic researchers who were knowledgeable about the history of agricultural production in that province. To ensure that we collected first-hand information, we required that at least two of the interviewees be older than 55. For variables concerning weather, scale of production, and the evolution of rural institutions, we requested answers to the following questions for each year between 1954 and 1989.

1. Name of the basic accounting unit for agricultural production:

   (a) elementary team; (b) advanced team; (c) commune; (d) production brigade; (e)production team; (f) household.

2. According to official provincial regulations, are farmers permitted to withdraw from their collective production units (e.g. withdraw from elementary collectives)?

   (a) Yes; (b) No.

3. What is the average scale of the basic production accounting units in this province? Please give your estimate on the number of households in an unit.

4. Please rate the overall weather conditions for agricultural production.

   (a) very good; (b) good; (c) average; (d) bad; (e) very bad.

A.2 Variable Descriptions

The main data source for agricultural input and output information at the province-level was the *Compilation of China's Rural Economic Statistics: 1949–86* by the Ministry of Agriculture (1989). When there were missing data, we then searched for information from various volumes of *Statistical Yearbooks* and *Agricultural Statistical Yearbooks* published by individual provinces in various years. Using multiple sources allowed us to cross-check the data. Most variables we use are standard variables with units noted in Tables 2 and 3. The following variables merit additional explanations.

Grain Output is the simple arithmetic sum of the gross physical output of eight kinds of grain: rice, wheat, corn, potato, sorghum, millet, soybeans, and other coarse grains. Output by type of grain is not available from published data.

Sown Area is land on which crops are planted and from which a harvest is expected. Since land is frequently sown two or more times a year (*multiple cropping*), sown area is substantially larger than cultivated area.

Draft Animals. The available numbers are end-of-year heads of draft animals. We compute the simple arithmetic mean of the two end-of-year numbers for a more accurate proxy for draft animals for the corresponding calendar year.

Capital is the sum, in equivalent power units, of all farm machines and draft animals in a given year. Measured in millions of kilowatt (KW), the formulae for aggregation recommended by the State Statistical Bureau is: Capital in million KW = Machine power in million HP/0.745 + Draft Animal in million heads*0.7.

B Choice of Model Parameters

Model parameters that characterize the pre-GLF economy are chosen as follows. We choose $\beta = 9/10$, a relatively small discount factor to reflect the government's desire for a speedy industrialization. We set the work capacity augmentation function parameter $\alpha = 31/63$, and the depreciation rate of work capacity $1 - \delta = 3/4$ or $\delta = 1/4$, values that are close to their estimates reported later (Table 4). For the productivity parameter, we set $a = 7/4$ so that the steady state equilibrium value of $h^s = 1$. To make sure that in the steady state 90 percent of labor is allocated to agriculture, we set the urban grain requirement at $m + n = 9$.

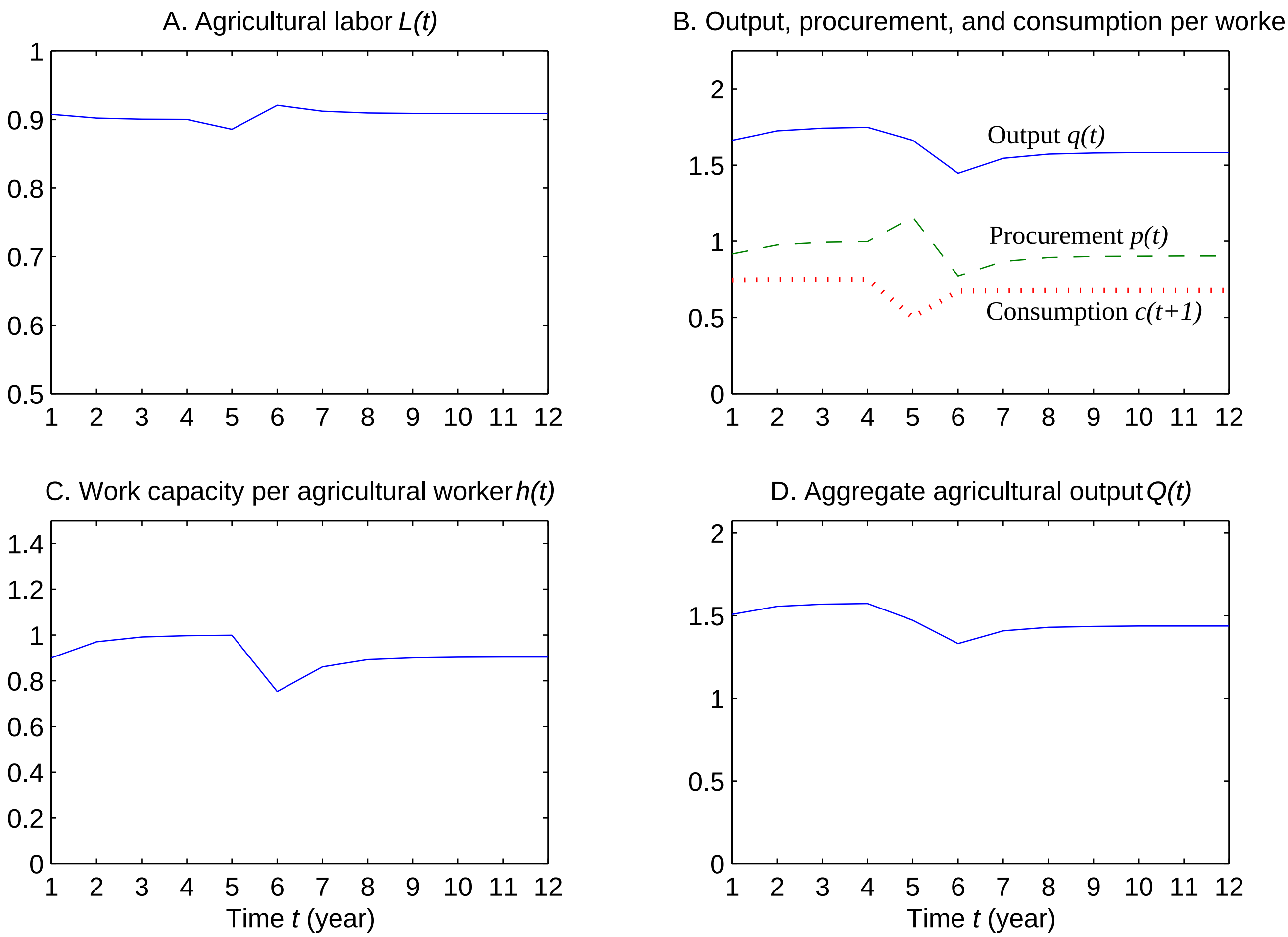

Figure 1: Simulated impact of GLF: the effects of over-optimistic expectations.

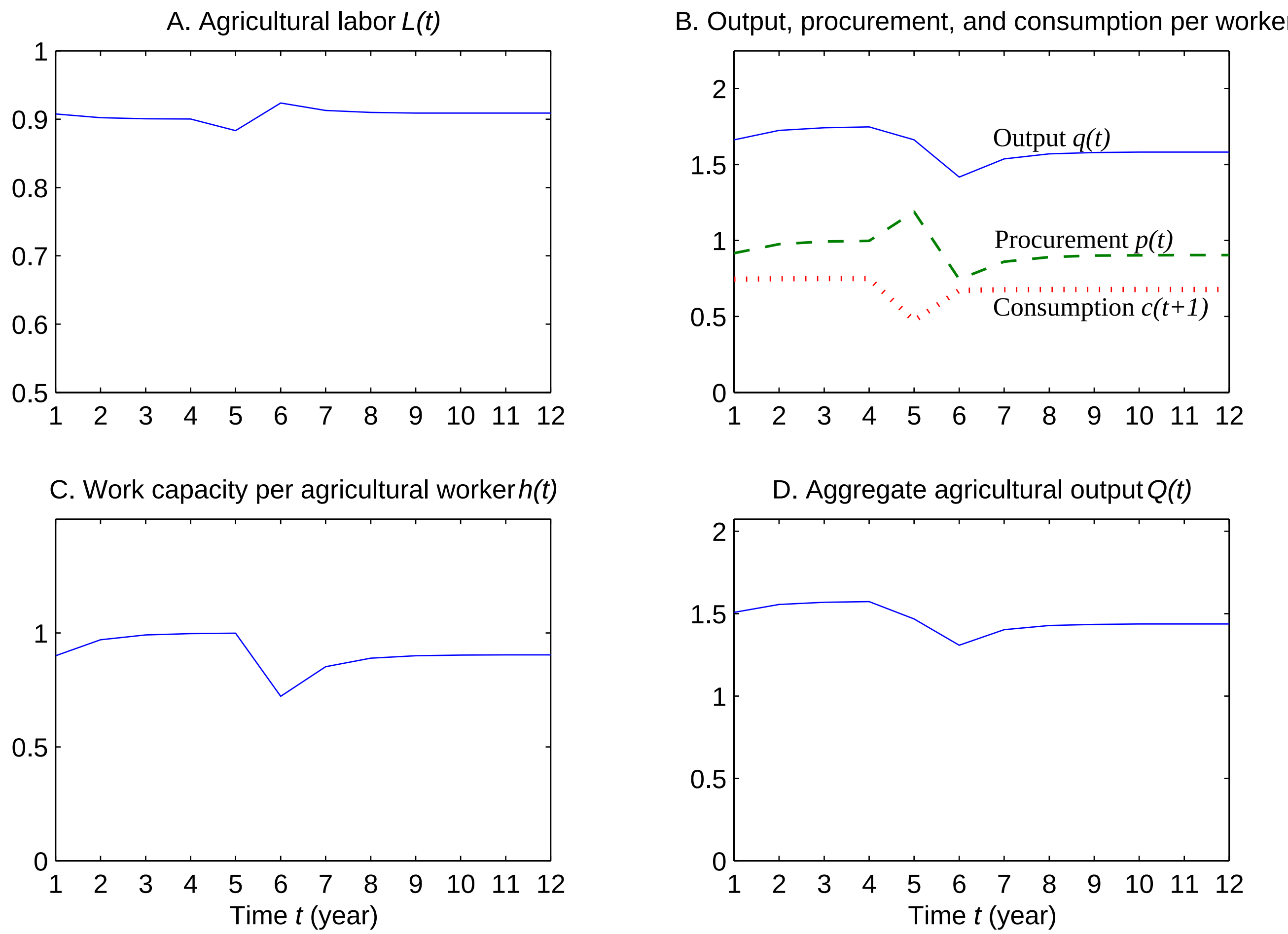

Figure 2: Simulated impact of GLF: the effects of increased impatience

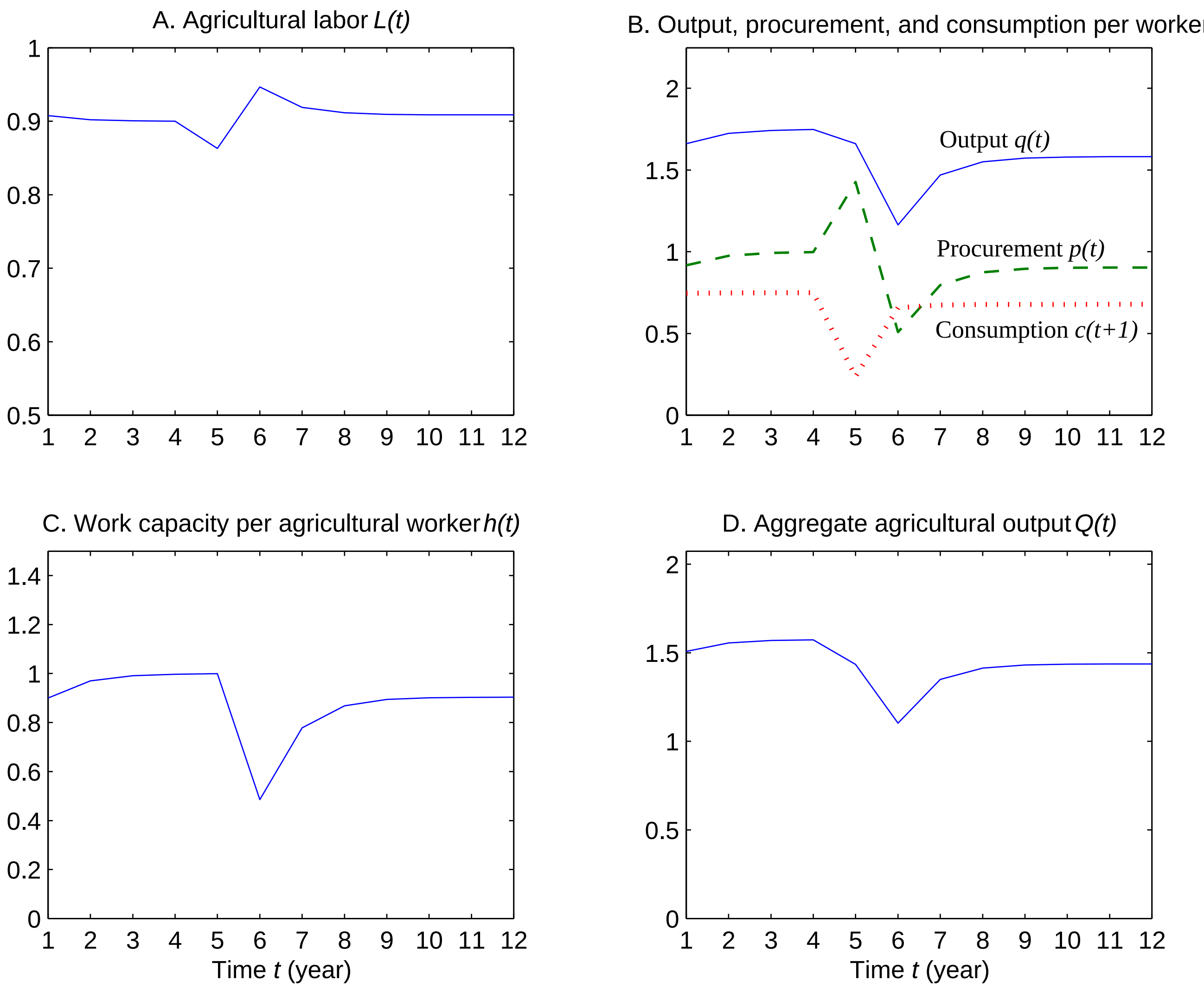

Figure 3: Simulated impact of GLF: the combined effects of over-optimistic expectations and increased impatience.

Table 1. China's Grain Output and Agricultural Inputs: 1954-77

Year	Grain output (million tons) (1)	Grain procurement (million tons) (2)	Retained grain per capita (kg/person) (3)	Rural labor (million) (4)	Area sown to grain (million hectares) (5)	Draft animals (million heads) (6)	Farm machinery (million HPs) (7)	Chemical fertilizer (million tons) (8)
1954	170	51	228	182	129	85	0.5	0.16
1955	184	48	256	186	130	88	0.8	0.24
1956	193	40	284	185	136	88	1.1	0.33
1957	195	46	273	193	134	84	1.7	0.37
1958	200	52	268	155	128	78	2.4	0.55
1959	170	64	193	163	116	79	3.4	0.54
1960	143	47	182	170	122	73	5.0	0.66
1961	148	37	209	197	121	69	7.1	0.45
1962	160	32	229	213	122	70	10	0.63
1963	170	37	231	220	121	75	12	1.0
1964	188	40	256	228	122	79	13	1.3
1965	195	39	261	234	120	84	15	1.9
1966	214	41	282	243	121	87	17	2.3
1967	218	41	281	252	119	90	20	2.4
1968	209	40	261	261	116	92	22	2.7
1969	211	38	259	271	118	92	26	3.1
1970	240	46	282	278	119	94	29	3.4
1971	250	44	293	284	121	95	38	3.8
1972	241	39	298	283	121	96	50	4.3
1973	265	48	293	289	121	97	65	4.8
1974	275	47	303	292	121	98	81	5.4
1975	285	53	304	295	121	97	102	6.0
1976	286	49	306	294	121	95	117	6.8
1977	283	48	300	293	120	94	140	7.6

Data source: Columns (1)-(2) and (4)-(6) are from the Ministry of Agriculture (1989); (3)=(1)-(2) divided by rural population; and (7)-(8) are from Wen (1993).

Table 2. Provincial Averages of Grain Output and Agricultural Inputs: 1954-77

Year	Grain output (million tons) (1)	Rural labor (million) (2)	Area sown with grain (million hectares) (3)	Capital (million HPs) (4)	Draft animals (million heads) (5)	Machine power (million HPs) (6)	Chemical fertilizer (million tons) (7)	% of irri-gated area (8)	% of acreage sown with grain (9)
1954	6.49	8.17	76.8	…	…	0.02	0.03	22.5	87.8
1955	7.05	8.31	77.3	1.72	2.38	0.04	0.04	23.2	86.7
1956	7.24	8.47	81.1	1.72	2.35	0.06	0.05	24.3	87.0
1957	6.96	8.53	79.6	1.71	2.30	0.08	0.07	24.8	86.7
1958	7.42	8.45	76.1	1.69	2.21	0.10	0.10	31.5	85.5
1959	6.36	8.34	69.2	1.64	2.07	0.15	0.11	28.4	82.8
1960	5.41	8.26	72.7	1.59	1.90	0.19	0.14	28.8	83.7
1961	5.16	8.33	72.3	1.56	1.77	0.25	0.14	29.7	86.9
1962	5.84	8.57	72.3	1.59	1.72	0.29	0.16	30.8	87.9
1963	6.28	8.79	71.8	1.70	1.77	0.34	0.22	31.5	87.5
1964	6.99	8.96	72.5	1.83	1.85	0.40	0.26	32.2	86.9
1965	7.89	9.13	71.1	1.95	1.91	0.46	0.34	33.2	85.2
1966	8.34	9.34	71.7	2.11	1.98	0.54	0.43	34.0	84.5
1967	8.45	9.53	70.7	2.30	2.06	0.64	0.48	35.1	84.3
1968	8.17	9.75	68.9	2.47	2.12	0.74	0.50	36.0	84.4
1969	8.15	10.02	69.7	2.66	2.17	0.85	0.58	36.9	84.5
1970	9.43	10.27	70.6	2.97	2.22	1.05	0.67	38.3	84.8
1971	9.94	10.44	71.5	3.36	2.22	1.35	0.76	39.2	84.6
1972	9.63	10.56	71.8	3.78	2.21	1.67	0.84	40.0	83.6
1973	10.63	10.72	71.5	4.26	2.23	2.02	0.94	41.0	82.9
1974	10.95	10.90	71.4	4.79	2.23	2.41	0.99	42.2	82.6
1975	11.43	11.03	71.4	5.35	2.22	2.83	1.09	44.1	82.2
1976	11.39	11.12	71.3	5.94	2.20	3.28	1.24	45.4	81.5
1977	11.25	11.20	71.1	6.57	2.18	3.77	1.43	49.1	81.5

Data Source: Data are from various published sources for 25 Chinese provinces (see Appendix A). The three largely urban municipalities (Beijing, Shanghai and Tianjing) and the two autonomous regions (Tibet and Xinjiang) are not in the sample.

Table 3. Provincial Averages of Rural per Capita Grain, Weather Index, and Institutional Variables: 1954-77

Year	Retained grain per capita in rural areas (kg/person) (1)	Weather conditions (1=very bad, 3=average, 5=very good) (2)	% of provinces that removed exit rights (3)	Size of production units (households) (4)	Steel and iron output (10k tons) (5)
1954	251	1.72	20	22	7.9
1955	271	2.44	20	33	10.2
1956	306	1.84	44	162	16.0
1957	257	1.60	60	179	19.1
1958	280	2.28	60	2675	30.4
1959	210	1.48	64	1696	46.9
1960	179	1.08	64	1751	62.6
1961	186	1.12	64	354	31.0
1962	214	1.62	64	41	23.8
1963	230	1.92	64	30	27.2
1964	244	2.33	64	31	34.4
1965	278	2.29	64	33	43.7
1966	284	2.44	68	31	54.7
1967	289	2.44	68	31	36.8
1968	260	2.20	72	35	32.6
1969	249	2.20	72	36	47.5
1970	278	2.32	68	37	63.3
1971	297	2.94	68	49	76.0
1972	276	1.64	68	50	83.5
1973	293	1.21	68	39	90.0
1974	314	2.54	68	40	72.2
1975	314	2.12	68	40	85.4
1976	300	2.04	68	41	73.1
1977	296	2.17	64	42	84.8
# of provinces	19	25	25	23	25

Data Source: Columns (1) and (5) are from published sources, and (2)-(4) are from the retrospective survey. Some provinces have missing data: six do not have information on retained grain per capita, and two do not have data on the size of production units. Therefore, seventeen provinces have complete data on all variables.

Table 4. Fixed-Effect Estimates of Grain Production in China

Independent Variables	Dependant Variable=Log(grain output)		
	OLS (1)	OLS (2)	Nonlinear (3)
Sown area	0.323***	0.473***	0.434***
	(4.49)	(6.08)	(4.18)
Irrigation	…	0.117***	0.104***
		(4.73)	(4.22)
Fertilizer	0.010**	0.007	0.023***
	(2.08)	(1.44)	(3.52)
Capital	0.270***	0.233***	0.119***
	(14.17)	(12.09)	(5.61)
Labor	0.580***	0.399***	0.364***
	(6.67)	(4.78)	(4.02)
Food consumption	…	…	0.406***
			(9.71)
1 - depreciation rate (=delta)	…	…	0.286*
			(1.88)
Steel production*100	…	…	-0.027***
			(2.72)
Communal dining/radicalism	…	-0.075**	-0.065*
		(2.42)	(1.91)
Scale*100	…	0.009	0.357
		(1.54)	(0.67)
No-exit	…	-0.063**	-0.027
		(2.16)	(0.84)
Average weather	…	-0.056***	-0.051***
		(3.74)	(3.22)
Bad weather	…	-0.093***	-0.077***
		(5.44)	(4.28)
Very bad weather	…	-0.167***	-0.156***
		(8.47)	(7.93)
Year 1958 dummy	…	…	0.060**
			(2.42)
Grain area (%)	0.034	-0.050	-0.026
	(0.48)	(0.72)	(0.39)
Provincial dummy	yes	yes	yes
R-square	0.974	0.980	0.981
# of provinces	25	23	17
# of observations	574	517	374

Note: Absolute values of t-ratios are in parentheses. ***, ** and * indicate statistical significance at 1, 5, and 10 percent levels, respectively. The reductions in number of observations from (1) to (3) reflect data availability (see note for Table 3) and reduced data points due to the inclusion of lagged variables.

Table 5. Decomposition on the Sources of Grain Output Collapse and Recovery

Contributing Factors	The Collapse (1957-60) Changes in log(output) (1)	The Collapse (1957-60) % contribution to total change (2)	The Recovery (1960-66) Changes in log(output) (3)	The Recovery (1960-66) % contribution to total change (4)
Observed total change	-0.234	**-100.0**	0.442	**100.0**
Estimated total change	-0.213***	**-91.0**	0.390***	**88.2**
	(9.16)		(15.77)	
1. Procurement/nutrition	-0.121***	**-51.7**	0.090***	**20.4**
	(8.72)		(6.81)	
2. Resource diversions	-0.067***	**-28.6**	0.114***	**25.8**
	(4.61)		(6.11)	
Sown acreage	-0.018***	-7.7	-0.010***	-2.3
	(4.21)		(4.21)	
Capital	-0.006***	-2.6	0.036***	8.1
	(5.71)		(5.71)	
Labor	-0.012***	-5.1	0.051***	11.5
	(4.03)		(4.03)	
Steel production	-0.032***	-13.7	0.037***	8.4
	(2.23)		(2.23)	
3. Weather conditions	-0.038***	**-16.2**	0.080***	**18.1**
	(7.19)		(7.80)	
4. Institutional factors	-0.041*	**-17.5**	0.041*	**9.3**
	(1.86)		(1.86)	
Dining/radicalism	-0.041*	-17.5	0.041*	9.3
	(1.86)		(1.86)	
Exit rights	[-0.003]	…	[-0.002]	…
	(0.82)		(0.82)	
Scale of production	[0.010]	…	[-0.024]	…
	(1.52)		(1.52)	
5. Modern inputs	0.037***	**15.8**	0.066***	**14.9**
	(6.19)		(5.87)	
Fertilizer	0.018***	7.7	0.038***	8.6
	(3.54)		(3.54)	
Irrigation	0.020***	8.5	0.028***	6.3
	(4.17)		(4.17)	
6. Residuals	-0.021*	**-9.0**	0.052***	**11.8**
	(1.90)		(11.61)	

Note: Absolute values of t-ratios are in parentheses. *** and * indicate statistical significance at 1 and 10 percent level. The effects of exit rights and scale of production are not included for estimating the total change because their estimated coefficients are not statistically significant.