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AGRICULTURAL PLANNING IN CHINA: THE CASE OF LEE WILLOW TEAM NO. 4†

Economic agents usually operate in environments where their opportunities to make production decisions or engage in commercial exchange are in some way restricted. During the historical transition from a precapitalist to a capitalist economy, for example, commercial opportunities may be restricted simply because markets are underdeveloped. Restrictions can also be the consequence of government policies. In international markets governments impose quotas on imports, place controls on capital flows, and form restrictive bilateral trade agreements which constrain agents engaging in trade. Domestic agricultural programs in many countries limit producers by imposing area controls and setting maximum or minimum marketing orders for producers. Many socialist governments go even further, administratively planning much of agricultural production and distribution. Whether restrictions arise for historical reasons or due to government policies, microeconomic agents find their production and trading opportunities limited. In such environments, simple microeconomic profit-maximization at prevailing prices may no longer make sense from either an individual or social standpoint.

The object of this study is to analyze one example of a microeconomic agent operating in an environment where production and commercial choices are restricted. Specifically, this study examines the economic behavior of a collective farm in the People's Republic of China. In China restrictions on production and trade in rural areas exist not so much for historical reasons—many regions

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of China had highly developed urban and rural commercial networks well before the West—but as the result of conscious government policies. In the early 1950s the state began to plan distribution of farm products and intervene directly in production. Since that time, sales of modern inputs and consumer goods have to a greater or lesser extent been subject to planned supply, and producers have had to fulfill minimum quotas on their deliveries of farm products to the state. Furthermore, mandatory targets have been set for areas sown to certain crops, and occasionally additional targets have specified yield levels and production techniques. Finally, throughout most of the past three decades the exchange of land and labor has been severely curtailed. Although the specific levels and forms of these restrictions have varied from place to place and from time to time, all collective farms have faced such restrictions at most times.[1] Moreover, although they were reformulated and reduced in number after 1978, these restrictions continued to apply to household farms after the implementation of the household responsibility system in the early 1980s.

Planning restrictions, whether in the form of marketing quotas, trade prohibitions, or production targets, have affected the welfare and economic behavior of Chinese farms variously. In theory, if the basic objective of a farm, whether a collective farm or a farm household, is to maximize the welfare of its members, then in an unrestricted environment it would first maximize net income (profits) from production, and then trade to attain the welfare-maximizing consumption bundle. On the production side, output supplies and input demands would be decided purely on the basis of profitability considerations: the farm would choose output and input levels that maximize its profits. On the consumption side, profitability considerations would enter in the demand equation only through the budget constraint. Like any ordinary consumer, the collective or household farm would select the consumption levels that maximize its welfare subject to income derived from its production. [2]

In the presence of production restrictions such as sown area targets, a farm would simply maximize profits subject to the constraint that such targets were fulfilled. If the production constraints were binding, they would reduce net income and thus the farm's welfare. The reduction in income would, in turn, affect patterns of consumption. Thus the effects of production targets in China would be similar to the effects of certain agricultural production restrictions or allotments observed in the United States, Canada, or the European Economic Community.

Restrictions on marketing can have a somewhat different effect. By preventing the farm from trading to attain its utility-maximizing consumption bundle, marketing quotas can cause a farm not to behave as a simple profit maximizer. If the farm is unable to buy consumer goods that it can produce on

[1] For an excellent discussion of market restrictions and planning in Chinese agriculture during the 1950s and early 1960s, see Perkins, 1966.

[2] A thorough treatment of farm household behavior in an unrestricted environment can be found in Yotopoulos and Lau, 1974. See also Nakajima, 1969.

the farm, then consumption preferences may enter directly into the production decision. For example, suppose a restriction on purchases of grain prevented a farm from specializing in a commercial crop and then using the proceeds from the commercial crop's sale to buy grain for its own consumption. In the presence of such a quota, the scarcity or shadow value of grain to the farm would be raised above its external price. At this higher shadow price, the farm would be induced to produce more grain on its land. In this way marketing restrictions can eliminate the separability of production and consumption decisions. Furthermore, farm income and thus welfare can be affected adversely.[3]

This paper analyzes empirically the effects of production and marketing restrictions on Lee Willow Production Team No. 4, a collective farm in central China.[4] Although the particular experience of every collective farm is necessarily unique, analysis of the Lee Willow Team No. 4 can illustrate in concrete terms the way in which planning restrictions influence a farm's production and income. The effects of production targets and commercial quotas will vary depending on the level of those restrictions relative to each farm's population and resource endowment; nevertheless, the general nature of their impact is similar on all farms.

A linear programming approach is used to analyze the effects of production and commercial restrictions on Lee Willow Team No. 4.[5] Production targets and commercial quotas for producer goods are easily incorporated into a programming model as special row constraints. Commercial quotas on consumer goods require that consumer preferences be reflected in the model. This is accomplished by introducing additional row constraints representing minimum consumption levels for those consumer goods subject to such quotas. The specific form and justifications for the empirical model are presented in more detail below.

LEE WILLOW TEAM NO. 4

Lee Willow Team No. 4 is located in Mianyang County, a commercial cotton and grain-growing area in Hubei Province (Map 1). This central China region

[3] A detailed theoretical analysis of marketing restrictions' effect on a collective farm's behavior is given in Sicular, 1983.

[4] Lee Willow Team No. 4's name in Chinese is *Liuli sidui*. It was one of six production teams in the Lee Willow Production Brigade of the Tonghaikou People's Commune. The study was completed in 1980, before implementation of the household responsibility system. At that time the basic decision-making unit in Chinese agriculture was still the production team, a collective farm usually embracing the population of and land surrounding a natural village. In 1979 the average number of households in a team was 34 and population 157 (Chang and Luo, 1981, p. 5).

[5] The use of linear programming to analyze the effects of resource and other constraints on farm behavior is not new. See, for example, Gotsch et al., 1975, and Heyer, 1971.

has a moist, warm temperate climate, with temperatures averaging 16°C (60° F), and with 235 frost-free days annually. Water is abundant, as rainfall exceeds 1,000 millimeters a year and the county lies between two major rivers. For this reason, pumping machinery is used not only for periodic irrigation, but also to drain low-lying fields after heavy rains.

Map 1.—The Location of Mianyang County, Hubei Province

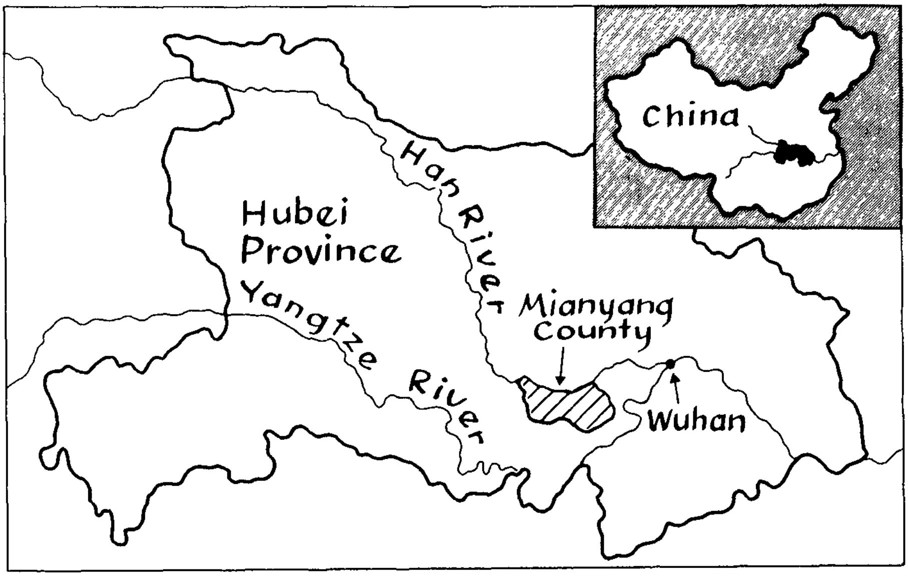
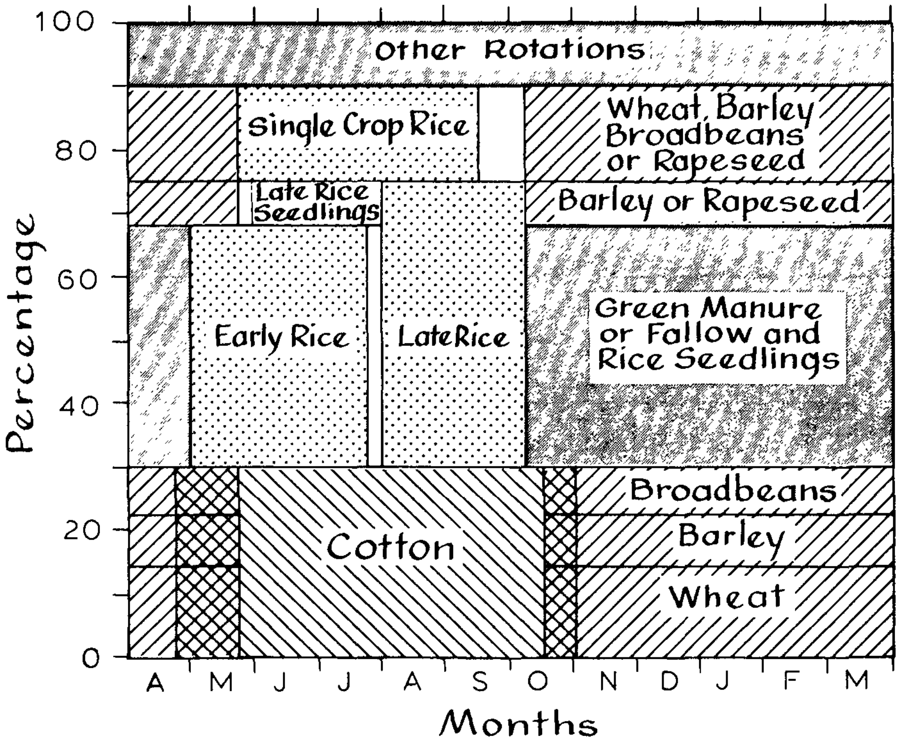


Chart 1 shows the cropping pattern and cropping calendar in Mianyang County during 1979. Crop cultivation was dominated by rotations that included a summer crop of either rice or cotton: in 1979, the time of this study, such rotations were planted on over 90 percent of the county's cultivated area. Rice was planted either as a double summer crop, in which case it was usually followed in the winter by a green manure crop, rape or barley, or as a single summer crop, in which case it was followed by barley, wheat, broadbeans, rape, or green manure crops. The dominance of double-cropped over single-cropped rice rotations during this period was in part due to government efforts to expand multiple cropping during the late 1960s and through most of the 1970s. This aim was largely accomplished by imposing mandatory sown area targets for the early crop of rice in the double-cropped rotation. Early rice sown area targets forced collectives to double-crop rice on land where the additional returns from the second crop did not adequately compensate the large increase in labor inputs required. Therefore, when these sown area targets were reduced in the late 1970s, farms gradually switched from double-cropped back to single-cropped rice on some of their land.

Chart 1.—Cropping Pattern and Calendar
in Mianyang County, Circa 1979*



*Except for early, late, and single-cropped rices, the periods shown are from sowing to harvesting. For early, late, and single-cropped rices, the periods are from transplanting to harvesting. Overlap between the cotton period and its following winter grains indicates intercropping.

Cotton rotations occupied about one-third of cultivated area. Cotton was usually planted with a winter crop of broadbeans, barley, or wheat. In order to fit the cotton and winter grain crop into one year, the grain and cotton were intercropped in the fall and spring. The winter grain was planted in rows between the cotton as it was harvested. In the spring cotton was sown on the strips of fallow land that had been left unplanted among the grain over the winter. After the grain was harvested, the cotton seedlings were transplanted so as to cover the whole field.

Other minor crops included sorghum, soybeans, hemp, peanuts, and sesame. Historically these crops had been cultivated more extensively, but after the 1950s they had slowly been replaced by expanding rice and cotton cultivation.

Examination of the crop calendar points to two important aspects of crop cultivation in this region: first, land was used very intensively throughout the year, especially during the summer. Multiple cropping, sometimes involving three crops in a year, was carried out on over 90 percent of county land, and the multiple cropping index exceeded 180. Second, labor was also used intensively, although labor use fluctuated widely during the year. The demand for labor was highest in late April through early May when winter crops were being harvested and early rice transplanted, and in late July through early August when early rice was being harvested and late rice transplanted. The demand for labor was lowest during the winter season. The pattern of intensive cultivation is not surprising given the high population density in this region. Local residents reported, however, that state policies promoting double-cropped rice cultivation caused farms to cultivate more intensively than they would have otherwise.

Lee Willow Team No. 4's pattern of cultivation mirrored that of the region: of its 46 hectares of collectively cultivated land in 1979, 40 percent was planted in double-cropped rice, 10 percent in single-cropped rice, and 37 percent in cotton. The remaining collective land was usually planted in minor crops such as soybeans, sorghum, hemp, peanuts, and sesame. During the winter season barley, naked barley, wheat, broadbeans, and green manure crops completed the annual rotations. Lee Willow Team No. 4's collective cultivation practices were thus, like those of the county as a whole, quite land- and labor-intensive.

In addition to collective cultivation, production teams were permitted to devote a certain percentage of their land to private plots. In 1979 Lee Willow Team No. 4 set aside three hectares or 6 percent of its total land area, the maximum allowed, for private household plots. Each household in this team cultivated privately an average of .05 hectares. Vegetables and small amounts of cash crops were usually planted on these plots, as well as fodder for privately-owned hogs, on average, 2.5 hogs per household. In 1979 private cultivation and animal husbandry were reported to earn income of approximately 70 yuan per capita in addition to the income distributed by the collective, an amount equivalent to 30 percent of the per capita income distributed by the collective.[6]

The team population in 1979 was 365, and its labor force 135. Households numbered 63. With a total cultivatable land area of 49 hectares, the team's population density was 7.4 people per hectare (.14 hectares per person), about equal to the county average. The dependency ratio was high, with 1.7 dependents per working adult as compared to 1.4 for the county as a whole. As a result, the number of adult laborers per hectare was lower than average, which may have caused relatively fuller employment of its adult labor force and raised the level of wages paid per hour worked.

Due in part to the quality of its land, Lee Willow Team No. 4's yields were consistently higher than the county, provincial, and national averages. In 1979 the team's rice yields were 5.3 tons per hectare sown area, 10 percent higher than the county average and 25 percent higher than the national average.

[6] The official exchange rate in 1979 was 1.55 yuan to the U.S. dollar.

Cotton yields were 995 kilograms per hectare sown area, 14 percent above the county average and more than double the national average.[7]

As a result of these high yields, the team enjoyed high per capita output, which promoted high marketing rates and income. In 1979 the team sold 36 percent of its grain to the state, as compared to the county average of 23 percent and national average of 22 percent. The team's cotton marketing rate was 98 percent, equal to the national and slightly higher than the county average.[8] Team per capita distributed income from collective sources was 225 yuan, 57 percent above the county average of 143 yuan; the national average was 84 yuan.[9]

Lee Willow Team No. 4 was thus an above-average team by both county and national standards. It was not, however, a "model" team, that is, it did not receive preferential treatment in the form of superior access to markets, lower quota levels, or special financial and technical support from the state. Lee Willow Team No. 4 was subject to the same sorts of institutional arrangements and planning restrictions as other teams in the county. Thus an empirical case study of this team can usefully illustrate the general effects of such restrictions.

PLANNING RESTRICTIONS

As mentioned above, agricultural planning restrictions in China fall into two categories: (1) restrictions on production, and (2) restrictions on marketing. (Hereafter, restrictions on production are referred to as "targets," and restrictions on marketing and trade as "quotas.") Direct restrictions on production usually take the form of minimum crop area targets. In this part of China, area targets have applied in years past to grain and cotton and governed most of the farms' cultivated land area. Lee Willow Team No. 4's rice and cotton area targets together had covered more than 90 percent of the team's collectively cultivated area. In 1979, when rice area targets were eliminated throughout the country, Lee Willow Team No. 4's only remaining area target was for cotton, and it occupied 41 percent of collective land area.

The system of state marketing quotas faced by Lee Willow Team No. 4 and other collective farms was quite complex. Fixed minimum quotas were set on deliveries to the state of grain and oilseeds. These quotas were set in weight and did not specify type of grain or oil. In addition, variable quotas tied to production levels were set on deliveries of grain and cotton. For grain, in addition to the fixed quota a second, variable, "above-quota quota" was set annually on the basis of expected grain harvests. For cotton, teams with yields

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[7] Average national yields can be found in State Statistical Bureau, 1982, pp. 154-55.

[8] National marketing rates are given in Chang and Luo, 1981 pp. 393-94.

[9] Chang and Luo, 1980, p. 41. The income figures include both cash and in-kind income distributed by collectives to their members, but do not include income earned privately by households or individuals.

exceeding 750 kilograms per hectare were required to deliver all their output except one kilogram of ginned cotton per team member to the state; teams with lower yields had to deliver all but 0.75 kilograms per team member. Aside from these formal delivery quotas, in the late 1970s and early 1980s an informal maximum delivery quota applied to hog sales to the state. After the state raised hog prices in 1979, households in Mianyang County increased their production beyond the state's capacity to procure. The state responded by informally limiting the number of hogs it would buy from any particular household or team.

Fixed and variable quotas also applied to collective and household purchases of consumer and producer goods from the state. In general, the state did not sell grain or vegetable oils to the rural population. Before the relaxation of restrictions on private trade, then, collective farms could not purchase grain or vegetable oils, and so had to be self-sufficient in these items. Similar, although less stringent, restrictions applied to purchases of cloth: cotton cloth ration coupons were allocated to teams on a per capita basis. Since private trade in cotton and cotton cloth continued to be illegal until the early 1980s, and since collectives were required to deliver most of their cotton output to the state, cloth rationing essentially set an upper limit on the consumption of cotton products in rural areas.

Producer goods were also limited in supply, and the state allocated fixed quantities, usually on the basis of a team's sown areas or of its deliveries of farm products to the state. Chemical fertilizers, for example, were awarded on the basis of grain sown area, cotton deliveries, and vegetable oil or oilseed deliveries. Diesel fuel was allocated on the basis of team-owned machine horsepower. The team, of course, had to pay for any producer goods purchased.

For both consumer and producer goods, planned allocations per capita, per unit sown area, or per ton delivery to the state were set more or less uniformly for all teams within a county, but might vary from year to year depending on the county's total allocation for that year. After 1978 Mianyang County's total allocations of producer goods to most teams exceeded their demand. Lee Willow Team No. 4 reported that in 1979 it was able to buy as much of all important modern inputs as it desired.

THE MODEL

The empirical model of Lee Willow Team No. 4 was designed to capture the specific farming system and planning environment of this team. The basic version of the model can be summarized as follows:

Maximize

$$Z = cy$$

subject to

$$Ay \leq b$$

$$Ry \leq k$$

$$y \geq 0.$$

where Z is team net income from production, A represents the team's production technology, and b gives initial endowments. $Ry \leq k$ contains the additional constraints due to planning and marketing restrictions, including consumption constraints. Altogether, the model contained approximately 180 rows and 4,000 nonslack columns.

The A Matrix

Coefficients of the A matrix were calculated using 1979 field data collected by the author. Activity columns in the A matrix represent Lee Willow Team No. 4's collective cultivation activities (where an activity is defined as an annual planting rotation), collective mechanical and processing activities, and also private household hog-raising and manure-collecting activities (see Table 1). Due to insufficient data, household private plot cultivation activities do not appear in the model. The exclusion of private plot cultivation is unfortunate, as these plots provided an additional source of household income and food and also probably competed with the collective for labor and other household resources. Nevertheless, in 1979 private plots accounted for only one-third of household private sideline income. Roughly 60 percent of household private sideline income was from hog raising, and this activity is included in the model.

Most of the columns in the matrix represent collective cultivation activities actually carried out in 1979. In addition, several collective cultivation activities that the team could have performed, but did not in the year of the study, also appear. These can be thought of as corner solution activities, and they were included so as to allow for the possibility that the team's observed choice of rotations was not the optimal choice. The input-output coefficients for these activities were obtained by questioning the team leaders about crops cultivated in the recent past and from neighboring teams that in fact did plant these rotations. Also, in some cases the model includes multiple activity columns producing the same items but with different technical coefficients. This permits some variation in relative factor proportions in the predominantly fixed coefficient model. For example, the model includes a cotton activity where the cotton is planted in rotation with broadbeans using less fertilizer, and a cotton activity where the cotton is planted with wheat using more fertilizer.

The decision to include corner solution activities and alternate activity columns for the same products increased the number of columns in the model. Efforts to improve the model's realism by allowing for differences in land quality

Table 1.—Activities Included in the Linear Programming Model of Lee Willow Team No. 4*

Activities
Cultivation: annual crop rotations
Cotton: with broadbeans, wheat, barley, *naked barley*
Ambary hemp: with barley, naked barley
Jute: with barley, naked barley
Sesame: with broadbeans, wheat, barley, naked barley
Single-cropped rice: with broadbeans, *wheat*, barley, naked barley
Double-cropped rice (second crop japonica): with barley, *naked barley*, green manure
Double-cropped rice (second crop glutinous): with barley, *naked barley*, green manure
Sorghum: with broadbeans, wheat, barley, naked barley
Soybeans: with broadbeans, wheat, barley, naked barley
Soybean/sorghum intercrop: *with broadbeans, wheat, barley, naked barley*
Animal husbandry and manure production
Collective cow-raising, and cow labor and manure production
Collective raising of breeding hogs, piglet production, and hog manure production
Household hog and hog manure production
Household human nightsoil manure production
Household chicken manure production
Mechanical and processing
Irrigation: using 10 hp diesel engine, 12 hp diesel engine, 12 hp diesel walking tractor, 10 kw electric engine, or 7.5 kw electric engine
Ploughing: using 12 hp diesel engine or 12 hp diesel walking tractor
Threshing: using 10 hp diesel engine, 12 hp diesel engine, 12 hp walking tractor, 10 kw electric engine, 7.5 kw electric engine, or paying a fee for brigade threshing
Transport: using 12 hp diesel walking tractor
Cotton ginning: paying a fee for brigade ginning
Oil pressing: paying a fee for brigade pressing

*Italicized crop rotations were not actually planted by Lee Willow Team No. 4 in 1979, but have been planted in other years or by neighboring teams.

and by permitting choice of timing in the planting and harvesting of most crop rotations also contributed to the large size of the model. The team had 17 plots, each with different soil characteristics and each calling for slightly different cultivation techniques. Land from each plot was therefore treated as a separate input. As a result, the model includes several activity columns for each rotation, with each activity using a different land input and having different coefficients. Similarly, in order to capture the seasonality of labor demand, labor was differentiated by the date of its use. The model therefore contains a number of activity columns for each rotation, each using different seasonal labor inputs. This permits choice in the timing of sowing and harvest.

The rows of the A matrix represent use of various inputs across production activities. Inputs include collectively cultivated land, human labor time, animal draft time, machine time, fuels, chemical fertilizers, organic fertilizers and pesticides. As mentioned above, land is differentiated by quality, and labor by time of use.

The right-hand side vector b associated with the A matrix gives the team's initial endowments of collective land, people, cattle, and machinery. Since the endowments of these items cannot be augmented by production or purchase in the short term (market restrictions prevent exchange of land or labor), initial endowments of these items reflect their maximum availabilities to the team.

The R Matrix

The matrix R and its associated right-hand side vector b contain additional planning and market restrictions and also minimum consumption constraints. These additional restrictions and constraints are summarized in Table 2. Planning and market restrictions include a minimum area target of 18.1 hectares for cotton; a minimum cotton sales quota of all output minus 1 kilogram per team member; a minimum grain sales quota of 55 tons husked grain equivalents; and a minimum vegetable oil and oilseeds sales quota of 1.4 tons oil equivalents.[10] Neither grain nor vegetable oils can be purchased by the team, only sold. Sales of hogs to the state are limited to 126 head, or two per household, the observed level of household hog sales in 1979. No formal maximum quota existed for hogs, but this constraint is necessary to capture the state's unwillingness to purchase as many hogs as team households wished to sell.

Consumption constraints are included in order to incorporate team preferences into the model. The production team is assumed to maximize collective utility subject to its income from production and subject to planning and marketing restrictions. If none of the market restrictions were binding, then utility maximization would have led the team to select a profit-maximizing production plan. In this case, profits could be used as the objective function in an empirical model of team production. If, however, one or more restrictions on the purchase of a consumed good is binding, then preferences may enter directly

[10] Consumption constraints do not specify type of grain or oil.

Table 2.—Price and Planning Regime:
The Basic Model

	Level
Output prices	1979 state above-quota procurement prices
Input prices	1979 state retail sales prices
Marketing restrictions	
Minimum grain sales quota	55 tons husked grain equivalents
Minimum vegetable oil sales quota	1.4 tons oil equivalents
Maximum hog sales limit	126 head (2 head per household)
Minimum cotton sales requirement	All output produced except 365 kilograms (1 kilogram per team member)
Self-sufficiency restrictions	Grain, vegetable oils, and cotton cannot be purchased by the team.
Production planning restrictions	
Minimum cotton area target	18.07 hectares
Consumption constraints	
Grain	116 tons unhusked grain (317 kg/capita)
Vegetable oil	0.9 tons (2.5 kg/capita)
Ginned cotton	365 kg (1 kg/capita)
Labor-leisure constraints	
Maximum labor availability	1.4 work units per laborer per day ($6\frac{3}{4}$ hours per laborer per day, labor cannot be hired in)
Minimum leisure consumption	$17\frac{1}{4}$ hours per laborer per day

into the production decision and must be specified as elements in either the objective function or body of the model.

Due to insufficient data, the latter approach is used. The empirical model maximizes team profits conditional on consumption at optimal levels. Optimal consumption levels appear in R as a set of minimum consumption constraint rows for important consumer goods, specifically, for grains, vegetable oils, and leisure.[11] Consumption constraints are set equal to observed 1979 consumption levels, which are assumed to be the optimal consumption levels at 1979 prices given 1979 planning and market restrictions. The leisure consumption constraint is set equal to the minimum level of leisure time observed during

[11] "Leisure" refers to all time not spent in collective work and private hog raising and manure collection. The labor-leisure choice depicted by the empirical model, therefore, is not strictly a choice between labor and leisure, but a choice between collective or hog-raising activities and time spent in leisure or other household sidelines.

peak seasons in 1979. When binding, the shadow prices associated with these consumption constraints give the marginal value of team consumption in terms of foregone profit income. Observed consumption levels can only be assumed optimal under the conditions actually faced by the team in 1979; therefore, it would be inappropriate to use these consumption constraints for simulations of alternative price or planning regimes.

The Objective Function

The empirical model's objective function $Z = cy$ is defined as team short-run profits: the value of collectively produced output plus privately raised hogs minus the cost of purchased variable inputs. Outputs in the objective function comprise products marketed and retained for team consumption, but not products used as intermediate inputs in the production process. Inputs that appear in the objective function include only those that are purchased and variable in the short-run, such as chemical fertilizers, fuels, and pesticides. Land, human labor time, animal draft time, and machinery—inputs of which the team has an endowment but which cannot be purchased or sold, or which are fixed in the short-run—do not appear in the objective function. The scarcity values of these inputs to the team, however, appear in the model solution as shadow prices.

Prices used to value inputs and outputs in the objective function are chosen to reflect the team's expected marginal prices. Since in 1979 rural free markets were not fully developed in Mianyang County, and since the production team did not participate in those markets, state prices are used. Team output is valued at 1979 above-quota state prices.[12] Commercial inputs like chemical fertilizers and pesticides are valued at 1979 state retail sales prices.

FINDINGS

Solutions of the linear programming model described above provide insights into the way that state planning restrictions affect team income, cultivation patterns, and labor allocation. First, the solution of a basic model version that replicates the team's price and planning environment in 1979 indicates which restrictions are binding and gives an approximation of their shadow prices. Comparison of the basic model solution to the team's observed behavior in 1979 serves as a check on the accuracy of the model and its underlying assumptions. Second, solutions of an unrestricted version of the model, where the team faces no state-imposed planning or market constraints, suggests how the team's behavior and income might change if state planning restrictions were removed.

[12] The state pricing system was multitiered, with quota sales receiving a basic quota price, and above-quota sales receiving a price 30 to 50 percent higher than the quota price. Since the team had to fulfill the quota, the relevant price for an additional unit output was the above-quota price.

The Basic Model Solution

Before discussing the impact of planning restrictions, it is important to compare the basic model solution with the team's observed behavior in 1979 in order to confirm that the model and its underlying assumptions are sufficiently realistic. The model solution predicts patterns of land use, levels of production and input use, and a level of team profits similar to observed values. Moreover, most differences between the model solution and actual team behavior have a straightforward explanation.

Examination of Tables 3, 4, and 5 shows that the model's basic solution is, for the most part, consistent with observed team behavior. Major differences between predicted and actual land use are (1) the model solution substitutes single-cropped rice for double-cropped rice on roughly 10 percent of cultivated land area in the summer season, and (2) it substitutes barley for naked barley, wheat, and green manure crops on roughly 45 percent of cultivated area in the winter season. These differences in land use explain differences in levels of production and input use. For example, expansion of barley onto land planted in green manure crops causes winter and total grain output to exceed their observed levels, and also is responsible for higher applications of animal manure.

Table 3.—Predicted and Observed Land Use
(Percent of collective land area)

	Observed, 1979	Predicted, basic model	Predicted, unrestricted model
Summer crops			
Cotton	41.3	41.3	33.7
Double-cropped rice	44.2	35.1	23.9
Single-cropped rice	12.2	23.6	42.4
Other crops	2.3	0	0
Winter crops			
Broadbeans	13.7	15.4	18.4
Naked barley	13.0	0	0
Wheat	10.5	6.3	0
Barley	20.4	66.6	75.8
Green manure	42.4	11.6	5.8

The model's substitution of single-cropped for double-cropped rice can be attributed to recent changes in Lee Willow Team No. 4's production targets. Through 1978 the team had faced a sown area target for double-cropped rice which forced the team to plant double-cropped rice on portions of its land where single cropping would have been more profitable. When this target was eliminated in 1979, the team began to shift its cropping pattern, but full adjustment

Table 4.—Predicted and Observed Levels of Production
(Tons, except as indicated)

	Observed, 1979	Predicted, basic model	Predicted, unrestricted model
All grain and pulses	267.6	311.2	344.0
Rice, total	214.6	218.5	241.6
Early	87.5	69.4	50.1
Late nonglutinous	75.8	66.2	46.0
Late glutinous	10.6	0	0
Single-cropped	40.7	82.9	145.5
Winter grains, total	50.8	92.7	102.3
Broadbeans[a]	9.4	9.1	12.1
Barley	22.9	78.8	90.2
Naked barley	8.4	0	0
Wheat	10.0	4.8	0
Other grains	2.3	0	0
Cotton	17.8	19.6	18.0
Oilseed and oil			
Oilseed (not pressed)	25.7	27.8	25.3
Pressed oil[b]	0.9	0.9	0
Hogs (number)[c]	126	126	351

[a]Considered a grain in China.
[b]Cottonseed yields 12 percent its weight in oil.
[c]Does not include team-breeding stocks and immature hogs.

required several years. The model does not allow for gradual adjustment, but assumes that the team moved instantly to its new profit-maximizing equilibrium. Evidence from 1980 indicates that, in fact, the team's rice cultivation pattern continued to move toward the model solution over time.

The expanded barley cultivation during the winter season predicted by the model arises because the model does not fully capture seasonal labor constraints. As mentioned above, labor inputs in the model are differentiated by time of year, and each cultivation activity uses time-specific labor inputs consistent with the timing of that rotation's land preparation, sowing, transplanting and harvesting. These time frames are set equal to the ranges of dates during which the different labor applications had usually occurred over the previous few years. In any particular year, however, weather and growing conditions may have permitted less time for labor applications than is specified in the model, so the model permits more flexibility in the timing of labor use than the team actually experienced in 1979.

Table 5.—Predicted and Observed Use of Inputs

		Predicted			
	Observed, 1979 (kg)	Basic model (kg)	Unrestricted model (kg)	Basic model (percent of observed)	Unrestricted (percent of basic)
Labor					
Total[a]	40,000	40,818	42,326	102.0	103.7
Per adult[a,b]	296	302	314	—	—
Chemical fertilizers					
Urea	9,562	9,353	8,374	97.8	89.5
Ammonium nitrate	155	155	155	100.0	100.0
Ammonium bicarbonate	11,300	11,253	11,987	99.6	106.5
Calcium superphosphate	4,150	3,964	3,737	95.5	94.3
Compound fertilizer	1,350	1,350	1,067	100.0	79.0
Organic fertilizers					
Oilcake	12,301	11,794	16.997	95.9	144.1
Hog manure[a]	4,066	5,003	4,127	123.0	82.5
Cow manure[a]	804	1,190	1,025	148.0	86.1
Nightsoil	451	414	314	91.8	75.8
Fuels					
Diesel oil	4,144[c]	3,028	2,904	73.1	95.9
Electricity (kilowatt-hours)	13,000[c]	11,977	13,822	92.1	115.4

[a]Measured in work units, each equivalent to approximately 4.8 hours labor time.
[b]The team had 135 adult laborers in 1979.
[c]Includes inputs used for nonagricultural and indirectly agricultural activities not included in the model.

The model's extra flexibility in the timing of labor use explains why it predicts expanded barley cultivation. The additional barley is planted in rotation with double-cropped rice. This rice-rice-barley rotation requires large applications of labor in the short period when barley is being harvested and early rice is transplanted. The model's additional flexibility in labor timing permits expansion of this rotation. In reality, however, the team's seasonal labor constraints caused it to plant more of the rice-rice-green manure, rice-wheat, and rice-barley rotations which used less peak season labor.

Despite these differences between predicted and observed team production, the model gives team profits close to their observed level. Predicted profits are

170,000 yuan, only slightly more than the observed 164,000 yuan.[13] Together with the basic consistency between predicted and observed land use, production levels, and input applications, the similarity between predicted and observed profits suggests that the linear programming model captures essential aspects of Lee Willow Team No. 4's economic environment. The model thus can be usefully employed to analyze the effects of planning restrictions on the team.

Binding Planning Restrictions

The planning and market restrictions faced by Lee Willow Team No. 4 appear in the linear programming model as row constraints on team production, sales, and consumption. A positive shadow price for one or more of these constraints in the basic model solution indicates that the corresponding restrictions are binding. Of the planning and market constraints in the basic model, four show positive shadow prices: the cotton area target, the hog marketing limit, the vegetable oil self-sufficiency constraint, and the leisure consumption (labor availability) constraint for the period May 11 to 15. Binding planning and market restrictions and their shadow prices are shown in Table 6.

Table 6.—Planning and Marketing Restrictions
That Are Binding in the Basic Model Solution

Constraint	Level	Shadow price (yuan)
Minimum cotton area target	18.07 ha	1,385.26
Maximum hog marketing limit	126 head	38.50
Minimum vegetable oil self-sufficient consumption constraint	0.9 tons	90.00
May 11–15 minimum leisure/maximum labor constraint	11,640 hours leisure/ 4,560 hours (950 work units) labor	4.18[a]

[a]Shadow price per work unit.

Before discussing the four binding constraints, it is useful to consider those that are not binding in the basic model solution. Neither the minimum grain sales quota nor the minimum grain consumption constraint is binding. The basic model predicts team grain production more than adequate to meet the team's livestock feed-grain requirements, the grain sales quota, and desired

[13] Note that these figures for predicted and observed profits are calculated valuing all output at above-quota prices. Both predicted and observed profits would be lower if quota sales were valued at quota prices.

consumption. The team's vegetable oil sales quota and cotton sales requirement are also nonbinding. The levels at which these quotas were set are also consistent with profit maximization. Leisure consumption constraints are not binding except during the period May 11 to 15. During all other periods adult workers have as much or more free time (time not spent raising hogs or working for the collective) than their minimum observed level of 17 hours per person per day. In other words, labor required for production is less than or equal to the 1.4 work units (7 hours) per laborer per day maximum implied by this level of leisure, and the shadow price of human time is zero.

Of the four binding constraints, two—the cotton area target and the hog marketing limit—do not involve team consumption preferences. The minimum cotton area target of 18.1 hectares is binding with a shadow price of 1,385 yuan. In other words, this target forced the team to plant cotton on land for which net revenues per hectare would have been 1,385 yuan higher if the team were able to plant on the basis of profitability. The maximum hog sales limit of 126 head is binding with a shadow price of 38.5 yuan. (The average hog procurement price in 1979 was 102 yuan per head.) Both these constraints reduce team profits and influence team behavior, but since they do not involve consumed items, they do not bring preferences directly into the production decision.

The binding vegetable oil consumption constraint and the May 11 to 15 labor-leisure constraint involve items consumed by team members and therefore make the team's production and consumption decisions interdependent. The vegetable oil minimum consumption constraint is binding at 0.9 tons with a shadow price of 90 yuan. This constraint is binding even though the team produces enough cottonseed to overfulfill the state oilseed quota, feed its livestock, and feed team members. The reason it is binding is that at 1979 state prices it would cost the team less to sell raw cottonseed to the state and buy back pressed oil than to press the oil itself. If the team were permitted to buy pressed oil at state prices and eliminate its own oil-pressing activity, it would save 90 yuan per ton of oil consumed.

The May 11 to 15 labor-leisure constraint is binding at 950 work units (4,560 hours labor and 11,640 hours leisure) for the five-day period. This constraint is binding because at this time in the double-crop rice barley rotation, barley must be harvested and early rice transplanted immediately after so as to minimize delay in the early and late rice crops that follow. The binding May 11 to 15 labor constraint effectively limits team cultivation of this triple-grain rotation. An additional work unit of labor would enable the team to expand double-cropped rice-barley cultivation, and so increase team profits by 4.18 yuan. This shadow price is considerably higher than the average wage of 1.35 yuan paid by the team per work unit in 1979. The model implies, then, that team members forego this income in order to maintain free time for leisure or profitable private sidelines.

The Unrestricted Model

Comparing the basic model solution to the solution of an unrestricted version of the model further clarifies the overall effect of the four binding constraints on team behavior. In the unrestricted version of the model, the team faces no quotas or area targets and can purchase any amounts of grain and oil from the state at their above-quota procurement prices. In addition, the team has access to additional labor that is supplied by team members at a reservation wage of 1.35 yuan per workpoint. The unrestricted model thus assumes that team members are unwilling to work for the collective unless the marginal return on their labor exceeds 1.35 yuan per workpoint. Since no market wage existed and information on the marginal returns to labor in private sideline activities was unavailable, the choice of a reservation wage is necessarily somewhat arbitrary. For lack of a better alternative, the reservation wage was simply set equal to the wage per workpoint actually distributed by the collective to its members in 1979. In light of this arbitrariness, some discussion of how production levels in the unrestricted model solution respond to changes in the wage level is included below.

The unrestricted version of the model does not, of course, predict team behavior in a free market environment. The unrestricted model resembles the free market situation in that the production team faces no planning restrictions; however, the prices used are not market prices but state-planned prices. Comparison of the basic and unrestricted model solutions therefore simply indicates how planning restrictions influence the team's production behavior when prices are held fixed.

As shown in Table 3, the unrestricted model solution predicts substantial reductions in cotton and double-cropped rice cultivation. Cotton and double-cropped rice are replaced by single-cropped rice, which increases from the basic model level of 24 percent to 42 percent of team land. In the winter season barley and broadbean cultivation expands, while wheat and green manure cultivation contracts. These shifts reflect substitution of the single-cropped rice-barley rotation for single-cropped rice-wheat, cotton-barley and double-cropped rice-barley, as well as a switch from barley to broadbeans as the winter crop planted with single-cropped rice on one plot of land. Predicted levels of crop production reflect these substitutions (Table 4).

The changes in cultivation patterns described above in part reflect the removal of planning restrictions, and in part reflect the introduction of a reservation wage for labor. Cotton production declines because the cotton sown area target is eliminated: this area target forced the team to plant cotton on land better suited for rice cultivation. With the removal of this target, then, cotton-barley is replaced by single-cropped rice-barley on 1.33 hectares.

The remaining shifts in cultivation are due to the introduction of a reservation wage. In the basic model, labor is essentially free except during peak seasons when the labor constraint is binding. In the unconstrained model, labor has a positive price regardless of when it is used. For this reason, certain relatively labor-intensive crop rotations are replaced by less labor-intensive rotations in the unrestricted model solution: double-cropped rice-barley is replaced by single-cropped rice-barley, wheat is replaced by barley in the winter season following single-cropped rice on one plot of land, and barley is replaced by broadbeans in the winter season following single-cropped rice on another plot of land. These substitutions reduce labor use in cultivation activities by 2,665 work units, or 7.4 percent. Total labor use in the unrestricted model, however, still exceeds that in the basic model because the additional employment generated by expanded hog-raising activities more than offsets reduced employment in cultivation (see below).

The cropping pattern predicted by the unrestricted model is, not surprisingly, sensitive to the price of labor. This is illustrated by examining how the unrestricted model solution changes with parametric variation in the reservation wage. At a zero reservation wage, double-cropped rice cultivation actually exceeds that in the basic model solution. As the reservation wage increases, single-cropped rice gradually replaces double-cropped rice. If the reservation wage is raised high enough, an even less labor-intensive sesame-broadbeans rotation begins to replace single-cropped rice. Thus the extent and intensity of rice cultivation is inversely related to the price of labor. A higher wage reduces rice production and encourages diversification into less labor-intensive commercial crops.

Perhaps the most dramatic change in production predicted by the unrestricted model solution is in hog raising. With the removal of the maximum hog marketing limit, the number of hogs raised and marketed more than doubles. Households now raise an average of 5.6 hogs for market, as compared to 2 per household in the basic model (Table 4). All barley produced now goes to feed livestock, while rice and broadbean output continues to be sold to the state. It is more profitable for the team to use the barley to raise hogs than to sell it directly to the state. Moreover, the expansion of livestock activities requires an additional 4,173 units of labor, and so causes an increase in total labor use.

With the elimination of the vegetable oil minimum consumption constraint, oil-pressing activities drop to zero. In the unrestricted model solution, all cottonseed is sold to the state in raw form. Any vegetable oil consumed would be purchased.

The above changes in production influence the team's employment of labor. Since market restrictions limited labor-intensive hog production, once the restrictions are removed the team's total labor use rises. The unrestricted model solution requires roughly 1,500 additional work units of labor, a 4 percent increase over the basic model solution. Work units per adult laborer increase accordingly from 302 to 314 per year, so that hours worked per laborer per day in collective cultivation and hog-raising activities increase about 10 minutes a day, but the proportion of labor time spent raising hogs almost doubles from 12 percent in the basic solution to 22 percent in the unrestricted solution (Table 5).

The above changes in production and employment raise the team's net income somewhat. Net income in the unrestricted model rises to 181,225 yuan, an increase of roughly 11,200 yuan, or 6.6 percent over the basic model solution. (As no labor charges are subtracted from team net income in the basic model, they are not subtracted from net income here in order to make the two figures comparable.) Division of the increase in team profits by the increase in labor use gives an average return of 7.43 yuan for each extra work unit of labor, much higher than the the 1.35 yuan per work unit actually paid by the team to its members in 1979. It therefore seems reasonable to expect that team members would be willing to devote extra labor to hog-raising activities if planning and market restrictions were indeed removed.

The impact of planning and market restrictions in Lee Willow Team No. 4 as illustrated by the basic and unrestricted linear programming model solutions is consistent with expectations. Binding restrictions lower team net income and alter levels of production and labor use. Although due to insufficient data on team preferences the linear programming models cannot demonstrate the impact of binding restrictions on team consumption, theoretically one would expect different levels of consumption between the restricted and unrestricted cases. First, removal of restrictions would have a positive income effect on consumption. Since team net income is higher when planning restrictions are removed, team consumption of grain, oil, and other normal goods should increase. Second, since the implicit price of oil declines, its consumption should experience an additional positive substitution effect. The planning restrictions imposed on Lee Willow Team No. 4 therefore probably depressed team consumption, especially of oil.

In addition to altering team net income, production, and consumption, planning restrictions eliminated the separability of Lee Willow Team No. 4's production and consumption decisions. Binding self-sufficiency constraints on oil, labor, and leisure forced the team to choose its production plan not just on the basis of profitability, but also on the basis of its consumption preferences. Due to consumption preferences, the team maintained unprofitable oil-pressing activities and reduced cultivation of the double-cropped rice-barley rotation in the basic model solution.

CONCLUSIONS

The empirical analysis discussed above demonstrates that Chinese state policies restricting production and commercial exchange have influenced rural production, consumption, and income. As illustrated by the experience of Lee Willow Team No. 4, production targets forced the team to plant cotton on land better suited for rice. Commercial quotas and suppression of markets caused it to reduce cultivation of labor-intensive crop rotations, maintain unprofitable oil-pressing activities, and raise fewer hogs. Total and peak season labor use were reduced, as was team net income. Although the empirical model does not estimate team consumption, in theory such restrictions could reduce consumption of normal goods and cause substitution in consumption because restricted goods' shadow prices differ from their external prices.

The analysis suggests further that planning restrictions have influenced not only the levels of team production, consumption, and income, but also the mix between collective and household employment. For Lee Willow Team No. 4, restrictions on hog sales effectively suppressed a profitable household production activity, thus reducing the amount of labor devoted to private production and causing collective activities to employ an artificially high proportion of team labor time. In the past, Chinese planning restrictions have proscribed not only hog raising but also private plot cultivation and a wide range of other household production and marketing activities. Recent reforms have lifted many of these restrictions. To the extent that household enterprise is more profitable than collective enterprise, these reforms should lead to a shift in labor allocation away from collective and toward household employment.

Policies restricting trade also undermined the separability of production and consumption decisions. When a collective farm is unable to trade items both produced and consumed, consumption preferences may enter directly into its production decisions. In Lee Willow Team No. 4, this was demonstrated by the reduction of peak season labor activities in order to maintain desired leisure consumption, and by continued oil-pressing in order to satisfy team vegetable oil demand. When consumption preferences enter into production decisions, farms may become less sensitive to external market signals and the price elasticities of both supply and demand reduced. In such an environment state pricing policy may be ineffective as a means to guide resource allocation. Rural production and consumption may be very responsive, however, to adjustments in quantity restrictions. Current research on Chinese agriculture supports this conclusion: in recent years agricultural production has apparently been quite sensitive to reforms in production targets and commercial quotas.[14]

Although Lee Willow Team No. 4 provides a useful case study, the specific impact of market restrictions on levels of production, consumption, and income, on the mix between collective and private employment, and on the interrelation between consumption and production decisions could be quite different for a production team in another region, or even for another production team in the same region. A team poorly endowed for grain production, for example, would be more severely affected by grain self-sufficiency constraints than a team like Lee Willow No. 4 that enjoyed a comparative advantage in grain and was able to produce large quantities of grain per team member. Thus during the Cultural Revolution when self-sufficiency was strictly enforced, regions of China traditionally known for their production of cotton, sugar, or other commercial crops had no choice but to plant grain on land better suited to those other crops, and so experienced reduced incomes and living standards (Lardy, 1983). Variations in population density and dependency ratios can also influence the particular effect of labor market restrictions on the labor-leisure choice: a team with relatively abundant labor would have a low shadow value for human time,

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[14] See Sicular, 1983, and Sicular, forthcoming, for discussion of supply responses to price and planning reforms.

and so would consume more leisure and use more labor in production than a team where labor was in short supply. Labor market prohibitions thus would cause the marginal product of labor to differ among teams. In general, variation in the impact of market restrictions among farms would be caused by differences in the levels of restrictions relative to local resource endowments. Since China is a large and agriculturally diverse country, the effect of market restrictions has not been uniform.

The effect of market restrictions has varied not only among teams, but also has changed over time with shifts in economic policy. In recent years the Chinese government has instituted a number of reforms, including increased tolerance of private exchange in rural free markets, reformulation of planning policies, and implementation of the household responsibility system.[15] Increased opportunities for private exchange and reformulation of quota policies have in general reduced restrictions on trade and so have softened the impact of commercial quotas. The household responsibility system reforms replaced collectives with households as the basic farm unit. Households, however, continued to face market constraints similar to those that formerly applied to collectives. The above analysis of market restrictions would therefore apply to households as well as to a collective farm unit.

Analysis of Chinese agriculture contains lessons for other developing countries. First, it highlights some potential difficulties of state commercial planning in the agricultural sector. In countries where farmers consume a significant portion of their output, for example, the use of marketing quotas to promote national production objectives may have unanticipated effects. In such countries, marketing quotas will affect not only the quantity of farm output produced and marketed, but also consumption levels and the relationship between consumption and production decisions. Second, incomplete or fragmented rural markets affect microeconomic agents in more or less the same way as commercial quotas: they restrict opportunities for exchange, and so maintain the interrelation between production and consumption behavior (Bardhan, 1980; McKinnon, 1973). Incomplete markets and market fragmentation are commonly observed in rural sectors of developing countries. Efforts to eliminate such obstacles to trade may promote rural employment, welfare, and the efficiency of agricultural production.

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[15] Since 1980 the Chinese government has instituted reforms that significantly reduce the role of collective farms and shift decision-making responsibility to households. The new household farming arrangements are usually referred to as the household responsibility or contracting system. For more information about these reforms, see Nolan, 1983.

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