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Marketing reforms, market development and agricultural production in China

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Abstract

Chinese agricultural reforms have consisted of two transitional stages; initially decollectivization in the late 1970s followed by market liberalization in the mid 1980s. While much research has been conducted on the initial stage of increasing the incentives for farmers in collective cultivation, little quantitative evidence exists on how marketing reforms and the development of rural markets has affected agricultural production decisions. Using more accurate and disaggregated measures of the reform and market development components of liberalization than previous research, this study examined the effects of these liberalization policies on the agricultural production decisions in Shaanxi province. Procurement quota levels were found to be positively associated with the area planted to grain crops. Thus, quotas represent an effective way of increasing grain production and thereby also a means of achieving food self sufficiency which remains an important policy objective for the Chinese government. The involvement of state grain stations in free market grain trade and the expansion of rural markets has increased the area planted to the two potential cash crops, soybeans and wheat, and reduced the sown area of the subsistence crop, corn reflecting the reduced need to plant corn as a self insurance mechanism for smoothing consumption. An increase in procurement quotas increases fertilizer use on grain crops, due to the policy of linking quotas to access to below-market priced fertilizer, but decreases the use of labor, which shifts to other more profitable enterprises. Market development has increased these off-farm employment opportunities and the earnings associated with them, thereby promoting the shift of labor out of crop production and increased the use of fertilizer which has also become more available. © 1997 Elsevier Science B.V.

1. Introduction

The impact of China's gradual reform policy has attracted the attention of scholars and policy makers interested in the performance of transitional economies. Unlike the Big Bang strategies used in Eastern and Central Europe and the Former Soviet Union, China's leaders have approached reform in a piecemeal manner, using the so-called 'crossing-the-stream-by-feeling-the-rocks' strategy. A core feature of this slow transition is the sequencing of reforms (Harrold, 1992; Perkins, 1992). Initially, the Chinese government adopted reforms targeted primarily at increasing incentives of the actors as a way of eliciting more effort in their economic activities, and did so initially without changing the basic institutional framework within which most actors operated (Lin et al., 1994). Reformers only incrementally pushed forward toward liberalization by decontrolling less important parts of the economy (both geographically and sectorally) and by slowly reducing the scope of planning in more strategic sectors (McMillan and Naughton, 1991).

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This two-stage transitional strategy also accurately characterizes Chinese agricultural reforms. The Chinese government began decollectivizing agriculture production in the late 1970s as a way of overcoming the serious disincentives for farmers to work hard in collective cultivation (Lin, 1992). However, unlike the perception portrayed by some scholars the regulatory framework governing agriculture production stayed mostly in place in the early 1980s as planners and their fellow procurement and marketing bureaucrats remained important players in the rural economy throughout the 1980s (Rozelle, 1996a). Pricing and marketing policy liberalization, including measures to reduce procurement quota levels, the management of resold grain and the development of marketing infrastructure, were steadily implemented in the first decade of reform but proceeded slowly and unevenly (Sicular, 1991). Geographically, leaders allowed reforms to advance more rapidly in the more mountainous and remote areas of the country, particularly the South and Far West. Sectorally, officials freed up non-staple crops such as fruits and vegetables before gradually liberalizing grain and oil seed markets.

While researchers have concentrated on evaluating the impact of the decollectivization stage of the agricultural reform (McMillan et al., 1989; Fan, 1991; Lin, 1992), less attention has focused on understanding agricultural growth during the market liberalization phase of the reforms in the mid- to late-1980s. A considerable body of work does describe the reforms and development of rural markets (Sicular, 1991; Watson, 1994; Rozelle et al., 1996a,b), illustrate the effect of liberalization policies on resource utilization and increasing responsiveness of economic agents to market signals (Carter and Zhong, 1991; Park et al., 1994), and document the deceleration in growth arising from the exhaustion of the one-time incentive impetus provided by the return to household farming (Fan and Pardey, 1995; Huang and Rozelle, 1996). Surprisingly little quantitative evidence, however, exists on how the various mechanisms of market reforms and the rise of rural markets have affected agricultural decision making and performance.

This paper attempts to fill part of the lacunae in the agricultural reform literature by exploring the different ways that market development and the nation's liberalization policies have affected decision making and productivity in rural China. Specifically, the study will document the marketing reforms and the steady expansion of markets in rural China. A framework is developed to test how the reforms and penetration of markets created by the reforms have influenced the cropping decisions of farmers. The idea that the emergence of markets for inputs, such as fertilizer and labor, themselves, are as important as the direct effects of rural marketing policy is examined in considerable detail.

To limit the scope of the study, the paper investigates the effects of liberalization reforms and the rise of rural markets on agricultural production decisions in one Chinese province, Shaanxi, from 1980 to 1990. Most previous research on marketing reforms has been done at provincial or national levels and deals with only general effects on agricultural productivity using relative price changes as a measure of the reforms (e.g., McMillan et al., 1989; Lin, 1992). In this study, decisions related to the production of three crops in Shaanxi (wheat, corn and soybeans) are examined at the county level and with a more disaggregated accounting of important aspects of marketing reform. Amounts of quota and negotiated price procurement, and cropping intensity measure the direct effects of marketing reforms, while the relative values of township enterprises and livestock production, the availability of fertilizer, and total area sown to cash crops measure the indirect effects of spreading markets and marketing opportunities. Not only are marketing reforms and market expansion measured more accurately and at a more disaggregated level than previous studies, this study also examines the effects of various explanatory variables on components of agricultural productivity such as crop area, input usage, yield and investment decisions in addition to output. As a consequence, the study provides a clearer picture of the impacts of marketing reforms on agricultural production decisions and can provide wider policy implications.

2. Background

2.1. Marketing reforms

Post-Mao leaders in China have recognized the role that free markets can play in increasing the

efficiency of resource allocation decisions. [2] In 1979, exchange of grains in rural markets was allowed for the first time since the 1950s. In 1983, long-distance private marketing of grain was legalized to promote greater regional specialization and trade. Initially farmers in many areas still produced primarily for family consumption but the percentage of grain marketed through non-planned channels did increase slowly, reaching 20% of total marketed grain by the late 1980s (Sicular, 1991).

The state also adopted other measures in order to improve rural economic performance through better resource utilization (Lardy, 1983). Central planning authorities eliminated control over many crops, relaxed control labor movement, eased restrictions on rural enterprise activities, and most importantly increased supplies allowing farmers more latitude in using fertilizer more efficiently (Ye and Rozelle, 1994). Since the mid-1980s, leaders also have gradually scaled back the proportion of the grain economy directly or indirectly subject to planning (Table 1). [3] Beginning in the mid-1980s mandatory delivery quotas, the main instrument which leaders used to influence production behavior, were reduced and fixed for a period of 3 years (Table 2, column 1). In this way, with a given quantity of land, there was more opportunity for decisions to be made by local producers. In combination with new trade opportunities, such measures were expected to lead to welfare gains as in many areas farmers and local leaders with superior knowledge of local resources could shift production to those crops in which they had a comparative advantage. In other cases, especially in poorer, less stable regions, farmers with new found choice might select to grow a mix of crops which met subsistence needs as a way to insure against the vagaries of weather and other natural and economic shocks.

Table 1
The development of rural periodic markets in China, 1980–1992

Year	Number of markets	Trade value (million yuan)
1980	37,890	21,170
1981	39,715	24,797
1982	41,184	27,639
1983	43,508	31,202
1984	50,356	33,321
1985	53,324	44,173
1986	57,909	54,448
1987	58,775	62,707
1988	59,178	71,072
1989	59,019	69,481
1990	59,473	71,644
1991	60,784	81,456
1992	64,678	98,932

Source: ZGGSXZGLNJ, 1992.

Reflecting concerns for equity (Travers, 1992), the Chinese government used the grain management system to affect the distribution of resources both between rural and urban populations and among geographic regions. Procurement prices were raised partially to increase stagnating rural incomes and thereby reduce rural–urban inequity (Table 2, column 4). China's planners also redistributed resources among administrative regions through procurement and transfer policies. Prior to 1993, annual and seasonal plans directed individual counties to transfer specified amounts of grain to other counties at low procurement prices. In the 1980s, these in- or out-transfer decisions were based on grain supply requirements for estimated state sales obligations. [4] Officials claim that procurement obligations passed down to each level reflect differences in relative productivity among regions, with productive areas bearing a larger procurement burden.

The grain management system also ran a program during the 1980s to sell subsidized grain to poor rural households (Park, 1996). Although programs in parts of China had provided subsidized grain sales to

[2] Chen Yun was an early proponent of this view, but has opposed rapid and comprehensive reform.

[3] Although nationally the area sown to grain has not been systematically allocated by central planners since the 1960s, there are many methods (both rules and incentive mechanisms) used to ensure localities produce grain (Rozelle, 1994). Examples include 'subsidized inputs for grain delivery' programs; above quota sales requirements; marketing restrictions; etc. Also, through the early 1980s, official tried to influence cropping decisions by raising quota levels when production rose as is evident in Table 1.

[4] Although the urban rationing system was officially abolished as a national program in the early 1990s, most provincial and sub-provincial government bodies are still running urban subsidy programs.

Table 2
State and non-state procurement, marketing, and prices of grain in China, 1978–1990

Year	State grain trade			Prices of quota and negotiated grain*		Free market trade	
	(1) Planned Quota of Contract (MMT)	(2) State Procurement (MMT)	(3) Proportion of State Procurement at Planned Prices (2)(1)	(4) Quota Procurement Price	(5) Negotiated Procurement Price	(6) Grain Procured by Non-State Traders (MMT)	(7) Proportion to Market (%)
1978	47.8	51.1	94	291	n.a.	4	7
1979	54.0	59.2	91	339	540	5	8
1980	50.1	58.7	85	328	528	6	9
1981	52.0	62.6	83	319	509	6	9
1982	56.2	73.6	76	318	507	6	8
1983	91.2	98.8	92	315	479	7	7
1984	102.3	111.7	92	301	422	8	6
1985	59.6	79.3	75	372	373	7	8
1986	62.2	94.6	66	359	398	9	8
1987	56.9	99.3	57	334	420	10	9
1988	50.5	94.3	54	318	446	11	10
1989	48.9	100.4	49	312	572	12	10
1990	50.2	93.9	53	301	522	12	12

Source: all figures computed by authors based on ZGSYNJ, ZGTJNJ, and MOA.
* Yuan per ton, 1980 Yuan (price given is for wheat).

farmers specializing in cash crop production and livestock activities, most public grain sales to farmers are in the form of 'resold grain' (*fanxiaoliang*) which are subsidized relief sales to farmers whose grain availability falls short of consumption needs. The proportion of 'resold grain' (of all state grain sales to the countryside) rose from less than 35% in 1980 to over 60% in 1989 (SXLSHB, 1981–1990). These sales are targeted at two general groups of households: (a) those that chronically fall below the poverty line; and (b) those that suffer some catastrophic event and incur a temporary grain shortfall. [5] These programs might help farmers make decisions based on comparative advantage rather than subsistence crops.

Other changes instituted in 1985 were designed to directly involve the local grain management system in evolving markets (Sicular, 1991). In addition to their traditional activities, state grain stations began to engage in trade at locally-set negotiated prices designed to reflect local market conditions (Table 2, column 5). The proportion of state-procured grain purchased at these negotiated prices was allowed to increase over time in order to provide better production incentives for farmers (Table 2, column 3). Leaders hoped that profits from this grain trade would help offset the budgetary burden of the increasingly expensive procurement/rationing system and provide higher prices to farmers increasing their incentive to produce (Park, 1993). Such changes have been shown to result in more integrated mar-

[5] As such, resold grain sales are not restricted to poor areas. Richer counties in Shaanxi also have access to resold grain for distribution to both target groups. Unlike in more developed areas that have significant urban populations and prosperous rural economies, however, the volume of resold grain to farmers in poor counties can often match or surpass that of subsidized rationed sales to urban residents and commercial enterprises. In one county in southern Shaanxi, the average amount of subsidized grain sales to farmers has been about equal to that of rationed sales to non-farmers, though much more variable. The variability in the provision of resold grain is related to its use as a disaster relief tool. For instance, in 1987 floods crippled production in a large number of Shaanxi counties. Resold grain sales were a record 9.8 million tons in that year, amounting to nearly 9% of total grain production. In the following year when yields returned to normal, resold grain amounted to only 2.0 million tons.

kets in some cropping sectors and in some regions of the country including Shaanxi Province (Carter and Zhong, 1991; Park et al., 1994). [6]

2.2. Expansion of rural markets

Relaxation of marketing restrictions, operational reforms in the grain procurement and sales bureaus, and general reform policies triggered the expansion of markets in the 1980s (Table 1). The number of agricultural markets grew by 7% per year and the transaction value by more than 15% during the early 1980s but growth slowed in both areas during the latter part of the decade. After the market liberalization reforms, the growth of rural markets resumed. Between 1990 and 1992, the number of markets increased by nearly 10% and value of the goods traded rose by more than 25%.

Rising standards of living and liberalization measures also stimulated the development of industrial product markets (Byrd and Lin, 1990) as well as factor markets for labor, fertilizer and other key inputs into the agricultural production process (Lin et al., 1991). The rise of township and village enterprises (TVEs) can in part be explained by the market opportunities exiting in the newly liberalized consumer product markets (Byrd and Lin, 1990). The flow of labor in and out of rural areas rose from almost nothing in the early 1980s to a level in the early 1990s which by some estimates reached 50 to 100 million labor migrants (Solinger, 1995). China's producers and importers increased the availability of chemical fertilizer to such an extent in the 1980s, that domestically supplied fertilizer overcame most of the chronic shortages that had plagued the nation's farmers for decades (Huang and Rozelle, 1996).

This expansion of economic exchange, however, does not mean that markets were perfect. A number of others have pointed to remaining barriers and fragmentation, and sources of imperfect competition (Lyons, 1992; Putterman, 1993; Rozelle, 1994, 1996b). However, rises in domestic trade volume, increases in the scope, sophistication and size of physical markets, and the degree of integration, especially compared to the early 1980s, make it difficult to dispute the role of market development in the decision making by Chinese farmers, including both their short run and longer term investment behavior.

In summary, when considering the impact of marketing reforms on agricultural performance, there are two types of forces to consider. Marketing reforms, such as changes to crop management marketing, procurement quotas, and redistribution policies, directly affect production decisions. These direct policies and other more general reforms create a second force associated with more pervasive and efficient rural markets. Both forces may influence the cropping choices of farmers.

2.3. Production decisions in Shaanxi province

Located in northwest China, Shaanxi province has a population of approximately 32 million. In 1989, farmers cultivated a total of 53.12 million mu of which 43.56 million mu was devoted to grain. [7] The province is one of great extremes, containing rich

[6] There are many reasons to believe that the implementation of commercialization reforms and progress in market integration may not have proceeded unimpeded throughout the reforms. While the efficiency gains from greater commercialization have been striking in some cases (Lyons, 1992), giving farmers freedom in production and marketing decisions requires a relinquishing of controls that might otherwise be used to pursue other grain policy objectives. Greater commercialization can be inconsistent with the achievement of procurement targets as well as food self-sufficiency strategies. In fact, when planners are faced with tight markets that result in high prices and potential grain shortages, they have not hesitated to take action to reverse market liberalization policies. In many areas, markets are closed during the harvest season until procurement has been completed (see, for example, Rozelle, 1996a). In 1988 after several successive years of poor harvests, grain markets were prohibited nationally by decree. In many area, leaders sharply curtailed all marketing of grain. Thus, while the importance of efficient production to overall growth is appreciated by Chinese planners, it is only one among several competing objectives. In this regard, it is interesting to consider the relative impact of increasing grain commercialization on more and less developed areas. Because developed areas are relatively more important to the achievement of sectoral objectives, it might be expected that regional leaders would exercise more caution when executing policy changes. When markets are tight, market restrictions may show up first in richer areas since their contribution to procurement quota deliveries are much more important relative to poor regions (Park et al., 1994).

[7] 1 ha = 15 mu.

Table 3
Fertilizer and labor use by crop in Shaanxi, 1980–1990

Fertilizer (kg/mu)				Labor (days/mu)		
Year	Wheat	Corn	Soybean	Wheat	Corn	Soybean
1980	32	30	6	25	25	10
1981	31	28	4	24	23	10
1982	34	32	10	20	24	11
1983	39	39	9	18	18	11
1984	49	39	12	18	20	12
1985	47	36	12	15	19	12
1986	50	41	23	14	16	11
1987	47	46	24	17	17	13
1988	58	50	26	17	17	13
1989	69	57	16	16	18	13
1990	80	69	6	17	17	11

Source: all figures compiled by authors based on ZGSYNJ and ZGTJNJ.

and poor income counties; fertile and barren land; mountains and desert-like topography. Its climate is also one of the most variable in all of China (Stone and Rozelle, 1995).

During 1980–1990, wheat, corn, and soybeans accounted for about 60% of cropped area in Shaanxi with the relative share of wheat and soybeans increasing slightly over the period. Total output of these crops increased dramatically over the decade, rising by 120% for wheat, 25% for corn, and 65% for soybeans with the increase due almost exclusively to the increase in yields. Some of the yield increase certainly arose from increasing fertilizer use on all three crops (Table 3). In contrast, labor use in wheat and corn production decreased from 25 work days per mu to 17 work days from 1980 to 1990 while remaining relatively constant for soybean production (Table 3, columns 1–3).

Since the climate allows only single cropping in most parts of the province, there is competition among the crops for land, labor, fertilizer and other scarce inputs. Limited family labor and tight financial resources can be expected to affect the farmer's cropping mix. Wheat requires more intense management than corn, its closest substitute, and hence in areas where labor is relatively scarce, corn is more likely to be grown. Wheat is more fertilizer responsive than the other crops (given that some Shaanxi corn farmers do not use modern hybrid varieties); when fertilizer and other chemical inputs are in short supply (due to general shortages or household cash shortfalls), farmers likely would use more fertilizer on wheat than other crops. Moving into more intensive and profitable cash cropping (for crops such as soybeans in Shaanxi), also involves investment in terracing, water control, soil improvement, and other cash- and labor-dependent inputs.

The role that each of these crops plays in the household's livelihood strategy also may affect production decisions. In the 1980s, poor residents in Shaanxi still considered corn as their primary subsistence food, a historical legacy arising from corn's greater tolerance to the region's weather stresses. Interviews with farmers clearly revealed that poorer farmers plant corn as a source of insurance (Park, 1996). As consumers, however, most households prefer wheat-based food products over corn. When incomes rise or risk falls to a point where farmers do not face threats of food shortages (or trade possibilities allow for the sale of cash crops and purchase of fine grains), farmers eagerly switch out of subsistence corn production and into crops that they prefer eating (Huang et al., 1996). Thus, in the short, harsh growing seasons in most of Shaanxi, wheat and corn compete for own area in farmers' rotations.

In contrast, soybeans, the other main crop in Shaanxi often compliments the economic activities of wheat and corn. Moreover, while farmers do sell part of their wheat crop to satisfy both their quota and as a cash earning enterprise, almost all soybeans are sold in markets. The rising demand in Xian, the provincial capital, and other urban centers for edible oils and other processed soy products rose sharply during the 1980s and became an important cropping activity for Shaanxi farm households.

Mandatory delivery quotas in Shaanxi province for wheat and corn increased in the early 1980s, but since the middle of the decade have declined substantially in many regions. The changes in wheat and corn procurement quotas, however, must be viewed in the context of changes in total crop quota. After an initial increase in the early 1980s, soybean quota has been steadily cut during the 1980s. The government also reduced or eliminated quotas for coarse grain such as sorghum and millet. Decreases in wheat and corn quotas in the middle of the decade coincided with changes in national grain policy re-

forms designed to gradually reduce state-sector domination of the grain sector, the implementation of national poor area policies, and increase the role of market procurements in the activities of the state's grain system.

3. Conceptual model

Agricultural output is determined generally by input allocation, which depends on the economic decisions made by farmers in response to factors such as relative prices, access to inputs and output markets and policy constraints. Marketing reforms and the rise of economic exchange have altered both prices and policy constraints faced by Chinese farmers and such changes would be expected to influence output. In order to understand the relationship between marketing reforms, market development, and agricultural production decisions, a conceptual framework is developed which divides the producer's decisions into short run and long run optimization stages similar to that of McGuirk and Mundlak (1992). In the first stage, farmers choose variable input usage levels for each crop and the allocation of quasi-fixed inputs between crops given the level of quasi-fixed inputs such as total land and capital investment. In the final stage, producers may adjust total quasi-fixed input levels.

The Chinese agricultural producer under study is assumed to grow only crops. Output of crop j, Y_j, is produced through the following process:

$$Y_j = F_j(\boldsymbol{v}_j, \boldsymbol{k}_j, I, \mathrm{E}) \tag{1}$$

where F_j is the production function for crop j; $\boldsymbol{v}_j$ and $\boldsymbol{k}_j$ are respectively vectors of variable inputs and quasi-fixed inputs allocated to crop j; I is gross investment in quasi-fixed inputs which acts to reduce output due to costs of adjusting capital stock; and E represents environmental and policy considerations. Inclusion of investment in the production function requires the allocation decision to be examined under a dynamic framework (Berndt et al., 1981).

Reflecting the reality of Chinese agriculture, the producer must sell a portion of the total crop j produced according to Eq. (1) at a government determined price P_{jQ}. The difference between total production, F_j, and the procurement or quota level, Q_j, can be sold at the market price of P_{jM}. From these two sources of gross revenue is subtracted the costs of variable and quasi-fixed inputs which can be purchased at the price vector $\boldsymbol{w}$ and the rental rate vector $\boldsymbol{q}$ respectively. The problem facing the producer is to maximize the present value of net returns over time which can be written formally as:

$$J(V,K,I,E) = \mathrm{Max} \int e^{-rt} \{ \Sigma P_{jM} [F_j(\cdot) - Q_j] + \Sigma P_{jQ} Q_j - \Sigma \boldsymbol{w} \boldsymbol{v}_j - \Sigma \boldsymbol{q} \boldsymbol{k}_j \}$$

subject to:

$$V - \Sigma \boldsymbol{v}_j = 0 \tag{3}$$

$$K - \Sigma \boldsymbol{k}_j = 0 \tag{4}$$

$$\dot{K} = I - \delta K \tag{5}$$

$$K(0) = K_0,\ V(t), I(t) \geq 0 \tag{6}$$

where $J(\cdot)$ is the value function representing the discounted future stream of rents accruing to the quasi-fixed inputs and r is the discount rate. The first and second constraints (Eqs. (3) and (4)) restrict the sum of an input allocated to each individual crop j to equal the total amount available. The restriction also allows for the possibility, which may exist in certain areas for some inputs, that the aggregate level of variable inputs, V, and quasi-fixed inputs, K, may be constrained. Eq. (5) describes the change in the level of the quasi-fixed inputs, $\dot{K}$ as the difference between gross investment (I) and the level of depreciation where δ is the constant depreciation rate. The final constraints (Eq. (6)) give an initial endowment of K, K_0, and ensures the choices on variable inputs and gross investment are non-negative.

Optimal input allocation for the above problem is where the marginal value product of an input is equal to its price provided constraints on the total amount available are not binding. These first order equations show that along the optimal path, the quantity of an input allocated to each crop in each time period does not affect revenue in subsequent periods implying the optimization problem can be solved recursively (McGuirk and Mundlak, 1992). Thus, variable input usage and the allocation of the quasi-fixed inputs can be determined in the short run

given the total levels of quasi-fixed inputs which become choice variables in the long run.

The first stage of the optimization process determines the optimal input levels, $\boldsymbol{v}_j^*$ and $\boldsymbol{k}_j^*$, by simultaneously solving the first order conditions. The resulting input demand functions are: $\boldsymbol{v}_j^* = \boldsymbol{v}_j(\boldsymbol{s}(t))$ and $\boldsymbol{k}_j^* = \boldsymbol{k}_j(\boldsymbol{s}(t))$, where:

$$\boldsymbol{s}(t) = \{P_{jM}(t), P_{jQ}(t), \boldsymbol{w}(t), \boldsymbol{q}(t), Q(t), V(t), K(t), E\} \quad (7)$$

is the vector of state variables. The farmer's input choices thus depend on prices, policy constraints on output sales or input availability, and environmental conditions. This first stage of the production process can be further sub-divided into two steps; area allocation and yield determination (Mundlak, 1963; Antle, 1983). Rather than making decisions on $\boldsymbol{v}$ and $\boldsymbol{k}$ simultaneously, farmers generally decide initially how to allocate their given land base, one of their quasi-fixed inputs K, among different crops given the available information at planting time. Area sown to crop j, a_j, is thus:

$$a_j^* = a_j(\boldsymbol{s}(t)) \quad (8)$$

After cropping patterns have been chosen, farmers then can change output only by influencing yield through the selection of variable inputs and the allocation of other quasi-fixed inputs. The demand for these other inputs depends on optimal area allocations, a^*, and updated expectations of the state variables given by Eq. (7);

$$\boldsymbol{v}_j^* = \boldsymbol{v}_j(\boldsymbol{s}'(t)) \quad (9)$$

$$\boldsymbol{k}_j'^* = \boldsymbol{k}_j'(\boldsymbol{s}'(t)) \quad (10)$$

where $\boldsymbol{s}'$ denotes the updated vector of state variables including the crop area decisions and $\boldsymbol{k}'$ identifies that the vector of quasi-fixed inputs allocation between the crops no longer includes land. Substituting crop area (Eq. (8)), variable input use for each crop (Eq. (9)) and the allocation of other quasi-fixed inputs not including land (Eq. (10)) into the production function (Eq. (1)) indicates the optimal level of output for crop j is:

$$Y_j^* = F_j(a_j(\boldsymbol{s}), \boldsymbol{v}_j(\boldsymbol{s}'), \boldsymbol{k}_j'(\boldsymbol{s}')) \quad (11)$$

Eq. (11) can then be rewritten as a product of area and yield:

$$Y_j^* = a_j(\boldsymbol{s}) f_j(a_j(\boldsymbol{s}), \boldsymbol{v}_j(\boldsymbol{s}'), \boldsymbol{k}_j'(\boldsymbol{s}')) = a_j(\boldsymbol{s})\, y_j(\boldsymbol{s}, \boldsymbol{s}') \quad (12)$$

where yield for crop j is:

$$y_j^* = y_j(\boldsymbol{s}, \boldsymbol{s}') = f_j(a_j(\boldsymbol{s}), \boldsymbol{v}_j(\boldsymbol{s}'), \boldsymbol{k}_j'(\boldsymbol{s}')) \quad (13)$$

The inclusion of crop area in the yield function implies that productivity may vary depending upon land allocation. The two components of total crop output, area and yield, can be estimated separately.

In the first stage of the optimization, the levels of the quasi-fixed inputs, including total cropped area, are fixed and thus are part of the state variable influencing input choice in the short run. In the second stage of the optimization, quasi-fixed input levels are optimally chosen. These investment decisions can be determined by substituting the restricted profit function, which is the solution to the short run profit maximization problem, into the value function (Eq. (1)), and then maximizing the resulting value function through the appropriate choice of K. The lone control variable is investment in the quasi-fixed inputs since the restricted profit function allows for calculation of the optimal variable input demand and allocation of quasi-fixed inputs among crops conditional on the stock and investment in K. The time path of investment to the quasi-fixed input is detailed further in Epstein (1981) but the general form has actual investment, $\dot{K}$, proportional to the difference between the desired level (K^*) and its actual level.

$$\dot{K} = \tau(K^* - K) \quad (14)$$

where τ is the adjustment rate to the desired level ($0 \leq \tau \leq 1$). Thus, quasi-fixed input demand is a function of the state variables (s) that determine K^* and lagged K.

4. Empirical model specification

Based on the foregoing discussion, short-run decisions involving crop area allocation (Eq. (8)), variable inputs (Eq. (9)) and yield (Eq. (13)), and the

long-run decisions on quasi-fixed inputs (Eq. (14)) all depend on the state variables (Eq. (7)). Marketing reforms and the existence of markets may affect each component of the state variable vector. This section presents the empirical specification of the model including how market reforms and market development are measured. The model contains three major crops, wheat, corn and soybean, which are produced through variable inputs, labor and fertilizer, and quasi-fixed inputs of net cropped area and capital.

4.1. Crop area

The area allocation (Eq. (8)) indicates net cropped area allocated to each crop. Incentive to plant a given crop will increase with expected average revenue as determined by price and yield. Following Lin (1995) and Huang et al. (1996), expected average price in year t is measured as the average of the state procurement price, P_{jQ}, as announced prior to planting and market (or negotiated) price, P_{jM}, lagged one period with the weights determined by the proportion of production used for satisfying the procurement quota and for all other uses. Similarly, lagged yield is used to proxy expected crop yield. Price and yield of all three crops are included in each area equation.

Marketing reforms not only affect returns through the state procurement price but also through restrictions on the amount that must be sold to the government, Q. Because procurement prices for a crop produced under such a quota are depressed to levels lower than prevailing market prices, higher quota levels lower farmer profits. However, if the quota is binding, an increase in the procurement quota of a certain crop would be expected to increase that crop's sown area and decrease the area of competing crops.

Marketing reforms also allowed state grain stations to become involved in local grain trade and to do so by negotiating prices that reflected local market conditions. Grain market size, or the ease at which crops may be sold, is proxied by the negotiated price procurement level which measures how much of a crop farmers can sell to state grain stations at the market price. Increases in the free market activity of the grain bureau as measured by negotiated procurement lagged 1 year should lead to an increase in sown area provided the crop is a normal good.

A final market reform variable is an index of cropping intensity (MCI). In some area during the pre- and early reform era, local officials have forced farmers to plant second and third crops, usually grain, even when that crop was unprofitable. Under such a situation, a decrease in MCI would be expected with market reforms, and would likely increase the area planted to cash crops and decrease grain area.

Relaxation of the above market restrictions and other general reform policies spurred the development of rural markets. The influence of market development on crop area allocation decisions are captured by total sown area in cash crops (CA_t) which reflects the competition for land area between grain crops and cash crops. Increases of CA reflect the relaxation of the government's control on sown acreage. A time trend is also included in the sown area equation to reflect effects of other liberalization policies and the rise of markets and opportunities to specialize along with technological and other policy changes.

The other elements of the state variables affecting crop area are input availability, K, and environmental effects, E. Input restrictions on land, irrigation and capital influence area allocation decisions. Land availability is measured by net cropped area (A_t). Irrigation and capital capacity are respectively proxied by total effective irrigated area and total power of agricultural machinery. County dummy variables are included to account for environmental effects, E (e.g. soil quantity, rainfall, temperature, etc.). Cropping area in the previous time period is another constraint measured to reflect the adjustment costs of changing rotations.

4.2. Input demand

After crop area decisions are made, the amount of the two variable inputs, fertilizer and labor, applied to each crop is subsequently determined (Eq. (9)). The allocation of variable inputs among the three crops is influenced by the same vector of state variables except for the inclusion of individual crop area. An increase in area planted to a given crop, ceteris paribus, would be expected to increase input

use on that crop. Predicted values of sown area are employed to avoid simultaneity bias. Variable input use would be further enhanced with an increase in crop price that raises the marginal productivity value for a given input amount.

Marketing reforms influence the amount of input use indirectly through the area allocation decision and directly through the amount used on the given area. Once the area effect of the quota is accounted for, the impact of China's procurement policy on production behavior depends on several factors. Lin (1995) shows that if the quota is proportional to output, farmers will reduce input use to keep down yields and minimize future quota increases. If, on the other hand, the quota is fixed, there is no reason to believe that it will affect behavior because it has no marginal effect. If farmers are cash short and unable to purchase all of the fertilizer they require under normal market conditions, a policy linking access to below-market priced fertilizer to the mandatory delivery quota (the '3 links' policy) could increase fertilizer use.

Households facing higher risk may choose to produce more of the staple grain by allocating more fertilizer to that crop and away from cash crops. With the breakdown of the commune system, farmers, especially in poor area, may respond by moving into less risky, staple crops which use less fertilizer. Several facets of grain policy, however, may affect producer input decisions through the means in which risk is increased or decreased. Regardless of how quotas vary with output and yield levels, the quota will act as an income-decreasing tax which may increase the risk faced by households (Sicular, 1988; Park, 1996). In contrast, the government's resold grain policy reduces risk because it sets a floor on income, and ceteris paribus, may allow farmers to concentrate input use on riskier cash crops.

The expansion of rural market effects on input use are captured by the total value of products of township enterprises over total value of crop products (TV), total value of livestock products over total value of crop products (LV) and a time trend. These variables potentially have a complex relationship with input use. On the one hand, as market activities become more prevalent, farmers will allocate their resources to the sectors with highest returns and also provide them with greater purchasing power. On the other hand, greater participation in the cash economy may break constraints in the agricultural sector allowing expansion in farming operations. For example, Huang et al. (1996) shows that increases in TV decreased the labor used in crop production clearly an inter-sector competition effect. However, Ye and Rozelle (1994) show that as markets developed in China as a whole in the 1980s, and labor flowed out of agriculture, farmers used their higher earnings to purchase chemical fertilizers as a partial substitute for their labor inputs. Hence, as TVE, livestock and other markets developed, both competitive and complementary effects should be expected on crop input use.

Land availability, cropping pattern, the multiple cropping index and capital levels are also included as constraints to the use of fertilizer and labor. Regional dummy variables are incorporated to reflect regional environmental differences that may influence crop input use.

4.3. Yield

Once the level of variable input use is determined, crop yield can be calculated as determined by the production function given by Eq. (13). Crop yield thus depends on the area planted to that particular crop and on the usage of the variable and quasi-fixed inputs. To avoid simultaneity bias, the predicted values for crop area and the variable inputs are used in estimation of the yield equations for each of the three crops. In long run equilibrium under perfect market regimes, increases in individual crop area will expand output but most likely decrease yields as the newly cultivated area in a given crop may be less suitable than the base area. If cropping decisions were not based on marginal, profit-oriented criteria, however, expansion (contraction) of the constrained (over-planted) area may increase (reduce) yields. In the case of this study, increases in individual crop areas are expected to have negative effects on yield for a staple crop (since pre-reform policies had encouraged grain cultivation) while increasing yield for higher returning cash crops (which were typically constrained under previous policies). As with any production function, higher input use should increase crop yield.

4.4. Quasi-fixed inputs

The short run decisions on cropping area, variable input demand and yield modeled previously have assumed the levels of the quasi-fixed inputs of land area and capital as given. However, over time the producer can modify the level of these variables through investment. Investment demand, as shown earlier, depends on the state variables influencing the short-run decisions along with lagged levels of the quasi-fixed inputs (Eq. (14)). In addition to market reform and market development variables, investment in land and capital is assumed to be influenced by resource availability as measured by lagged total rural income. Expected demand for the quasi-fixed inputs also is expected to increase with an increase in population density of the county.

5. Data

The data on agricultural production in Shaanxi province used in this study primarily come from three sources: (a) a data base of the Chinese Ministry of Agriculture, (b) grain procurement data and other secondary data from Shaanxi province grain bureau, and (c) the Shaanxi province price bureau.

The Chinese Ministry of Agriculture collects annual data on basic information of the rural economy at the provincial, the prefecture and the county level. Data used in this study are at the county level from 1980 to 1990. The data base includes sown area, yield and production for all crops for each of the 93 counties within Shaanxi. There is also county level information available on income level agricultural labor use, fertilizer use, capital levels, and irrigation capacity.

Data on grain procurement and price are from the Grain Bureau of Shaanxi province. Data include quota price procurement, negotiated price procurement, quantity of grain procured and resold grain to farmers by crop through the state grain departments.

Production cost data in selected counties for various crops were obtained from the Price Bureau of the province. The Price Bureau conducts annual household surveys in selected regions to get information on the amount and cost of every input for the production of the main crops. Inputs by crop include chemical fertilizer, labor, and quasi-fixed inputs such as total cropped area and capital. Data are available for all the prefectures of the province from 1980 to 1990. Variable inputs used on each crop are constructed based on these data as are prices for crops and variable inputs.

6. Results

When using a data base that has both time series (1980–1990) and cross-sectional (93 counties) elements, a model needs to be specified that will adequately allow for differences in behavior over cross-sectional units as well as any differences in behavior over time for a given cross-sectional unit (Judge et al., 1985). A common formulation assumes that differences across units can be captured by differences in the constant terms (fixed effects). However, it might also be appropriate to view individual specific constant terms as randomly distributed across cross-sectional units (random effects) (Greene, 1993). The Hausman specification test is used to select the appropriate model. For the sown area equation (Table 4), the fixed effects model is presented since the Hausman test strongly suggested that the null hypothesis of no correlation between the intercept and explanatory variables should be rejected. The random effects model was generally deemed appropriate for the input use and yield equations but not for the quasi-fixed inputs.

6.1. Short-run decisions

The conceptual framework presented earlier divides the producer's decisions into two stages: the short-run and the long-run decisions. In the short run, crop area allocation is first decided, followed by the determination of variable input usage and thus expected yield.

6.1.1. Crop Area

Results of the sown area equations for wheat, corn and soybean are given in Table 4. Coefficients on both own expected price and yield have the expected positive sign in the wheat and corn equations, although the estimates of expected wheat price and corn yield are not statistically significant. For

Table 4
Estimates of wheat, corn and soybean area equations

Explanatory variables	Dependent variable		
	Wheat area	Corn area	Soybean area
Expected returns			
Expected crop price			
Wheat	2.18 (0.67)	12.65 (3.85)	−1.48 (−0.77)
Corn	−16.12 (−3.97)	9.59 (2.34)	3.50 (1.64)
Soybean	3.99 (2.75)	3.14 (2.17)	−0.29 (−0.35)
Expected crop yield			
Wheat	0.00062 (1.13)	−0.00080 (−1.42)	0.00014 (1.07)
Corn	0.00031 (0.48)	0.00005 (0.07)	0.00001 (0.02)
Soybean	−0.00070 (−0.40)	0.00130 (0.72)	−0.0004 (−0.30)
Marketing reforms			
Procurement quota			
Wheat	0.00007 (5.78)	0.00001 (0.45)	−0.00001 (−1.30)
Corn	−0.00001 (0.38)	0.00017 (7.34)	0.00002 (1.49)
Soybean	0.00029 (1.77)	−0.0054 (−3.27)	−0.00013 (−1.40)
Negotiated procurement			
Wheat	0.00010 (2.45)	...	...
Corn	...	−0.00004 (−1.99)	...
Soybean	...	...	0.00018 (3.08)
Multiple cropping index	−3.37 (−8.30)	−5.71 (−13.75)	0.05 (0.21)
Market development			
Cash crop area	−0.242 (−12.70)	−0.262 (−13.60)	−0.002 (−0.23)
Time trend (T)	0.191 (3.53)	−0.255 (−4.62)	0.084 (2.62)
Constraints			
Total area	0.186 (11.05)	0.298 (17.32)	0.373 (3.84)
Irrigation	0.026 (1.61)	−0.029 (−1.78)	0.019 (2.04)
Capital	−0.000001 (−0.35)	0.000002 (1.18)	0.000002 (2.29)
Lagged area	0.395 (19.89)	0.158 (7.39)	0.435 (16.82)
Adjusted R^2	0.91	0.44	0.44
Hausman test FE vs.RE	587.25	671.64	196.42

soybean, coefficients on both price and yield are unexpectedly negative but not significant. The estimated signs on the cross-price variables are generally consistent with the cropping pattern in Shaanxi where farmers always select crop rotations of wheat interplanted with soybean and corn interplanted with soybean. Wheat and corn are shown to be substitute crops while soybean is a compliment to both wheat and corn. The positive and significant influence of wheat price on corn area, which is inconsistent with a substitute relationship, may reflect the fact that corn has been the most important crop to insure for farmers' own food consumption in Shaanxi where half of the farmers produce barely enough grain for their own consumption. As wheat price increases, farmers want to sell more of this crop for cash purposes but these same farmers then need to produce more corn to meet their own consumption needs.

Market reform effects are captured through changes in procurement quota and the increases in market size. The positive sign on the quota level shows that the quota system has been an effective way of increasing wheat and corn production in Shaanxi; with lower or quotas, area sown to either wheat or corn would fall. The insignificant sign on the soybean variable likely reflects the small size of the soybean quota, since it is so small that the impact on farmer behavior is not noticeable. The results may also explain why China's government has not given

up the procurement quota during the more than 10 years of market oriented reforms, given that food self-sufficiency is still an important objective of China's agricultural policy.

The level of negotiated price procurement (NPC) measures how much grain farmers sold to state grain stations at market prices during the previous year and proxies market size. The positive and significant influence of NPC for wheat and soybean in their own area equations suggests that the state grain station's involvement in the free market grain trade does increase the sown area of these two cash crops. The negative and significant coefficient on NPC for corn reflects the fact that the farmers produce corn mainly for their own consumption and shows, that as markets develop, corn area, which may have been planted for self insurance purposes to smooth consumption when markets are restricted, can be reduced.

Cropping intensity (MCI) declines with marketing reforms as directives decline to farmers to plant second and third crops of low-valued buckwheat, sorghum and rye. Since MCI reduces total cropped area, it might be expected to reduce the sown area of all three crops. The positive and significant influence of MCI on the area of wheat and corn suggests reducing cropping intensity has allowed more area to be concentrated in the production of main crops such as wheat and corn.

Increases in total sown area to cash crops reflects the relaxation of government control on area allocation and the development of markets for these crops. The significant, negative sign on this variable in the wheat and corn area equations confirms the expectation that cash crops compete in area with grain crops. Finally, significant positive coefficients in the wheat and soybean equations on the time trend, a proxy for among other things a rise in free markets, suggest that reform policy changes during the 1980–1990 period (not incorporated into the other explanatory variables) have had positive effects on sown area. Over the decade, the area sown to wheat and soybean has increased 6% and 17% respectively in Shaanxi. However, these changes have had negative effects on the area sown to corn which decreased 8% during the reform period, an expected result if the rise of free markets would encourage farmers to move away from their subsistence crops.

Constraints on quasi-fixed input levels have the expected effects. A decrease in total cropped area causes a decrease in the sown area of all three crops as expected. Irrigation capacity is important for increasing wheat area which is expected because wheat requires considerably more water per unit of land than corn or soybean. Since area sown to wheat is interplanted with soybean, and wheat and corn are substitutes, increases in irrigation capacity also have the expected positive effects on the sown area of soybean, and negative influence on the corn area. Except for the soybean area equation, capital levels, which is expected to have a positive effect on the area of all three crops, is insignificant.

As expected, all coefficients on the crop's own lagged area are between 0 and 1. Soybean area responds quickest to changes followed by wheat and that desired levels for both crops are planted within 3 years of changes to dependent variables. In contrast, corn area takes approximately twice as long to adjust to changes in its explanatory variables. These results on adjustment response are consistent with the observation that corn is generally produced for consumption while wheat and, particularly, soybeans are produced mostly for market.

6.1.2. Variable input usage

6.1.2.1. Fertilizer. Estimated coefficients for the variables used to explain the aggregate amount of fertilizer used on wheat, corn and soybean are reported in Table 5. Estimates of predicted own crop area have the expected positive sign in each fertilizer equation and are all statistically significant. Similarly all coefficients on expected crop price are positive and significant as expected. Increases in crop price, increase the marginal value product of a unit of fertilizer and thus increase the amount of fertilizer applied.

The policy of linking grain delivery quotas to access to below-market priced inputs and credit suggests increases in procurement quotas for grain crops should increase fertilizer use. Coefficients on wheat and corn quotas are significantly positive as expected. Apparently, there is little evidence of Lin's yield-quota ratchet effect whereby input use is reduced to minimize future quota increases. As shown in Rozelle et al. (1996a,b), local officials in the

Table 5
Estimates of fertilizer use in wheat, corn and soybean production

Explanatory variable	Fertilizer use in		
	Wheat	Corn	Soybean
Predicted Crop Area			
Wheat	893.0 (3.89)	...	...
Corn	...	346.2 (10.14)	...
Soybean	...	...	214.4 (11.74)
Expected crop price			
Wheat	43,945.4 (4.07)	...	...
Corn	...	24,414.5 (3.73)	...
Soybean	...	...	776.2 (1.39)
Marketing reforms			
Procurement quota			
Wheat	0.090 (1.56)	...	...
Corn	...	0.165 (3.49)	...
Soybean	...	...	−0.385 (−5.65)
Resold grain	−0.086 (−0.65)	−0.131 (−2.12)	0.056 (4.54)
Multiple cropping index	−3177.5 (−1.58)	−230.4 (−0.61)	−230.0 (−3.17)
Market development			
TV[a]	584.9 (1.31)	510.3 (2.47)	1.6 (0.04)
LV[b]	−3367.9 (−1.76)	−841.8 (−0.98)	659.1 (3.81)
Cash crop area	−179.7 (−1.57)	−12.3 (−0.37)	5.8 (0.96)
Time trend	385.4 (1.96)	247.2 (2.77)	−10.6 (0.83)
Constraints			
Total area	172.5 (1.89)	15.1 (1.37)	−3.9 (−2.05)
Capital	0.022 (2.71)	0.009 (2.55)	−0.0002 (−0.38)
Regional dummies	Yes	No	No
Adjusted R^2	0.45	0.32	0.15
Hausman test FE vs. RE	59.30	22.96	17.51

The numbers in parentheses are t-statistics. The estimated coefficients of 93 county dummies are not reported.
[a]TV: Total value of products of township enterprises over total value of crop products.
[b]LV: Total value of livestock products over total value of crop products.

post-reform era seldom link quota allocations to present or past productivity. In contrast, the coefficient on soybean fertilizer usage is negative. Increases in soybean quota act to reduce both sown area and fertilizer usage. Given the relative importance of soybean quotas in the 1980s, the sign is what the model of Park (1996) would predict. Imposing a quota on poor farmers increases their risk. While they may be getting access to more inputs, perhaps in response to risk, farmer do not use extra fertilizer on soybeans and apply lower levels of fertilizers to cash crops. Increases in resold grain, on the other hand, has the opposite risk-reducing effect. In areas, with high resold grain activity, which is mostly corn, farmers reduced fertilizer used on that crop since an increase in resold grain reduces the amount of corn that farmers must produce for their own consumption. Farmers shifted their production from corn to soybeans, the area's cash crop, and increased soybean fertilizer usage as reflected by the positive and significant coefficient on resold grain in the soybean fertilizer equation.

The final market reform variable, the multiple cropping index, had the expected negative effect on fertilizer usage on all three crops but particularly on wheat which is the most fertilizer-intensive crop. An increase in the number of crops decreases the amount of fertilizer available for use on any single one.

The rise in fertilizer use requires increases in cash holdings to afford the purchase of the input. With poor financial markets (few farmers in Shaanxi have access to credit), one of the major sources of fertilizer financing is through wage earnings from local township and village enterprises. A major element in the development of rural markets was the expansion of fertilizer markets. And indeed, increases in TV (the ratio of total value of township enterprises products to the total value of crop products) increase fertilizer use on each crop. An increase in the level of livestock activity (LV), however, decreases fertilizer used for wheat and corn production. An increase in livestock will increase production and subsequently the usage of organic fertilizer. Farmers frequently told interviewers one of the main reasons for raising livestock is for the organic manure. The negative sign may reflect a substitution effect between organic and chemical fertilizer on grain crops. The same substitution effect between organic and inorganic fertilizer, however, is not seen on soybeans. In addition, an increase in livestock production requires an increase in soybean production to meet livestock feed requirements. Therefore, an increase in the relative value of livestock increases the amount of fertilizer used in soybean production.

Total cropped area is positively related to crop area for all three crops and thus should be directly related to aggregate fertilizer use on each crop. The expected positive influence was found on fertilizer

Table 6
Estimates of labor use in wheat, corn and soybean production

Explanatory variable	Labor use in		
	Wheat	Corn	Soybean
Predicted crop area			
Wheat	9.45 (2.08)	...	...
Corn	...	22.55 (3.23)	...
Soybean	...	...	11.59 (53.63)
Expected crop price			
Wheat	304.9 (1.34)	...	...
Corn	...	−526.5 (−1.98)	...
Soybean	...	...	3.98 (0.35)
Marketing reforms			
Procurement quota			
Wheat	−0.0035 (−2.86)	...	...
Corn	...	−0.0046 (−2.28)	...
Soybean	...	...	−0.0004 (−0.28)
Multiple cropping index	−101.93 (−2.41)	−25.04 (−0.51)	0.20 (0.17)
Market development			
TV[a]	−20.73 (−2.19)	−8.43 (−1.28)	−0.38 (−0.48)
LV[b]	55.14 (1.37)	13.26 (0.47)	9.56 (3.09)
Cash crop area	9.33 (3.85)	11.96 (5.30)	0.069 (0.81)
Time trend	−18.58 (−4.48)	−2.95 (−0.92)	0.25 (0.99)
Constraints			
Total area	6.91 (3.58)	1.75 (0.72)	−0.04 (−1.64)
Capital	0.00060 (3.52)	0.00002 (0.15)	0.00003 (2.38)
Regional dummies	Yes	Yes	No
Adjusted R^2	0.13	0.15	0.82
Hausman test FE vs. RE	27.88	85.17	2.27

The numbers in parentheses are *t*-statistics. The estimated coefficients of 93 county dummies are not reported.
[a]TV: Total value of products of township enterprise over total value of crop products.
[b]LV: Total value of livestock products over total value of crop products.

used for wheat and corn, but not for soybean. The latter result probably reflects the fact that chemical fertilizer supplies in Shaanxi were constrained in some places and some times in 1980s (Ye, 1992). However, a relaxation on fertilizer constraints in China during the 1980s is also reflected by the significantly positive coefficients on the time trend in wheat and corn equations indicating fertilizer used on these two staple food crops has increased over time. An increase in capital increases fertilizer use suggesting capital may increase the marginal value product of fertilizer.

6.1.2.2. Labor. Regression results for the amount of labor used in wheat, corn and soybean production are presented in Table 6. As with fertilizer, the amount of labor used in production of each crop is generally positively associated with area sown and own crop price (except for corn). Unlike the fertilizer equations, all coefficients on quotas are negative suggesting that an increase in procurement quotas causes a shift in labor from agriculture to non-agriculture. Apparently due to the decrease in relative returns in crop production associated with increased government taxation, farmers leave the sector allocating their labor to more profitable enterprises. This response coupled with the positive response of fertilizers to quota levels, means that farmers use fertilizer to help assure their quota is met but allocate their labor to uses out of the cropping sector.

A related result is also found in the expected negative effects of labor market development on labor use in crop production. An increase in the relative value of products from township enterprises (TV) has a negative influence on the amount of labor used in crop production. An increase in TV, as with an increase in procurement quotas, reduces relative returns in agriculture and thus reduces the amount of labor in crop production. The result that farmers apply more fertilizer and less labor to crop production as labor markets liberalize and TV employment opportunities increase is consistent with the substitution between fertilizer and labor found by Ye and Rozelle (1994). It is also consistent with Huang et al.

Table 7
Estimates of wheat, corn and soybean yield equations

Explanatory variable	Crop yield		
	Wheat	Corn	Soybean
Predicted crop area			
Wheat	−1.23 (−1.77)	...	...
Corn	...	−2.50 (−2.51)	...
Soybean	...	...	2.36 (0.56)
Predicted fertilizer use			
Wheat	0.0028 (3.05)	...	...
Corn	...	0.0047 (3.16)	...
Soybean	...	...	−0.0098 (−3.58)
Predicted labor use			
Wheat	0.130 (4.18)	...	...
Corn	...	0.014 (0.40)	...
Soybean	...	...	−0.399 (−1.09)
Time trend	0.23 (0.16)	4.93 (4.80)	5.65 (18.44)
Constraints			
Total area	−0.506 (−2.63)	−0.089 (−0.65)	0.001 (0.02)
Capital	−0.00002 (−0.17)	0.00003 (0.56)	0.00005 (1.93)
Regional dummies	No	No	No
Adjusted R^2	0.04	0.10	0.22
Hausman test FE vs. RE	18.64	26.55	17.20

Numbers in parentheses are *t*-statistics.

(1995) who show a significant part of the slow down in Chinese agricultural productivity growth in the late 1980s is associated with the growth of off-farm labor opportunities which then compete for labor in agriculture.

An increase in the relative value of livestock to crop production was found to increase labor use on all three crops which suggests livestock and crops are jointly produced. Full-time farmers may be willing to allocate additional labor to raise livestock and forego other off-farm activities which may then also be available for crop production. Labor use on wheat and corn decreased with time ceteris paribus, but increased on soybean. This result may reflect the influence of the increases in other non-agricultural activities during the 1980s. An increase in capital increases the amount of labor used on all three crops suggesting capital and labor are complements in crop production.

6.1.3. Yield

Results of yield responses for wheat, corn and soybean with the random effects model are reported in Table 7. Wheat and corn yields decrease as their areas increase suggesting that less productive land is used as the area sown to these crops increase. In contrast, the coefficient on area in the soybean equation is significantly positive suggesting increasing returns as possibly more fertile land is planted to this cash crop as its returns and subsequently sown area increase. Apparently, early patterns of crop allocation were inefficient and sown areas adjusted with the marketing reforms. The same results were found by Park et al. (1994) in Shaanxi and Carter and Zhong (1991) in Central China.

The estimated coefficients for fertilizer and labor in the wheat and corn yield equations have the expected positive effect with a higher marginal effect found for fertilizer use on wheat. The unexpected inverse relationship between fertilizer use and soybean yield may be due to the low relative volume of fertilizer necessary for soybean production and the possibility of more productive land being used to grow soybeans, as suggested above. In contrast, the level of capital input used had a significantly positive effect on soybean yield and not on the productivity of the other two crops. The result is expected given the low stage of development for soybeans; farmers must invest in land and new equipment as they move into the production of cash crops. The large, significant positive time trend during the 1980–1990 period suggests that marketing reforms, such as the Household Responsibility System and market liberalization effects, (and perhaps technological change) may have increased the efficiency of producing all three crops.

6.2. Long-run response

The short-run results have shown the positive influence of quasi-fixed inputs, total cropped area and capital, area allocation and variable input usage. In this section, the factors affecting the levels of those two quasi-fixed inputs are examined (see Table 8).

6.2.1. Total cropped area

Marketing reforms and market development variables, while all having the expected sign, have an insignificant effect on total cropped area which has

Table 8
Estimates from total cropped area and capital equations

Explanatory variable	Dependent variable	
	Total area	Capital
Marketing reforms		
Total procurement quota	0.00001 (0.17)	0.115 (0.78)
Market development		
TV[a]	0.42 ()	175.326 ()
LV[b]	−3.76 (−1.65)	1360.62 (0.17)
Time trend	−0.01 (−0.02)	449.5 (0.89)
Demand		
Land area/population	0.42 (0.92)	−190.67 (−0.12)
Total rural income	0.00009 (1.02)	1.077 (3.30)
Lagged endogenous		
Total cropped area	0.04 (1.38)	...
Capital level	...	−0.08 (−2.25)
Regional dummies	Yes	Yes
Adjusted R^2	0.11	0.13
Hausman test FE vs. RE	547.85	173.09

The numbers in parentheses are t-statistics.
The estimated coefficients of 93 county dummies are not reported.
[a]TV: Total value of products of township enterprises over total value of crop products.
[b]LV: Total value of livestock products over total value of crop products.

not exhibited a significant trend over the reform period. Similarly, the demand variables as measured by population density and total rural income also have a positive but insignificant effect on total cropped area. The only significant variable influencing crop area was the relative value of livestock to crop production. The estimated negative sign indicates that an increase in livestock products will shift some cultivated area to pasture land. The statistically significant coefficient on lagged crop area of 0.04 indicates that it takes total cropped area approximately 25 years to adjust its long-run equilibrium value.

6.2.2. Capital

Agriculture in Shaanxi has become more capital intensive over time. The increase in capital use can be partially explained by the development of markets during the reform period. The increase in rural industrial market activity as measured by the relative value of township enterprises to crop production increased capital use in agriculture. Enhanced nonfarm market activity also an indirect effect on capital intensity in agriculture through its effect on rural incomes. Some of the additional funds earned by the farm household is expected to be spent on agriculture as verified by the significant positive effect total rural income has on the level of capital. Despite poor credit markets, farmers in Shaanxi displayed a propensity to invest during the reforms in response to higher incomes. The other demand variable, population density, has a positive but insignificant influence on capital use.

7. Conclusions

Chinese agricultural reforms have consisted of two transitional stages; initially decollectivization in the late 1970s followed by market liberalization in the mid 1980s. While much research has been conducted on the initial stage of increasing the incentives for farmers in collective cultivation, little quantitative evidence exists on how marketing reforms and the development of rural markets has affected agricultural production decisions. Market reform measures include the scaling back of mandatory delivery quotas on crop output and an increase in the extent of state grain station trading at locally negotiated prices. The increased flexibility combined with new, more profitable trade opportunities enlarged the set of decision making choices by producers and permitted those choices to be based on comparative advantage rather than self insurance concerns. Opportunities were enhanced further through the expansion of markets triggered by the relaxation of market restrictions and reform policies.

Using more accurate and disaggregated measures of the reform and market development components of liberalization than previous research, this study examined the effects of these liberalization policies on the agricultural production decisions in Shaanxi province. Procurement quota levels were found to be positively associated with the area planted to grain crops. Thus, quotas represent an effective way of increasing grain production and thereby also a means of achieving food self sufficiency which remains an important policy objective for the Chinese government. The involvement of state grain stations in free market grain trade and the expansion of rural markets has increased the area planted to the two potential cash crops, soybeans and wheat, and reduced the sown area of the subsistence crop, corn. The change in crop area allocation reflects the reduced need to plant corn as a self insurance mechanism for smoothing consumption. Input use on these crops has been significantly affected by the liberalization policies. An increase in procurement quotas increases fertilizer use on grain crops, due to the policy of linking quotas to access to below-market priced fertilizer, but decreases the use of labor, which shifts to other more profitable enterprises. Market development has increased these off-farm employment opportunities and the earnings associated with them, thereby promoting the shift of labor out of crop production and increased the use of fertilizer which has also become more available. Total cropped area has been unaffected by the liberalization policies but the level of capital investment, the other quasi-fixed input examined, has increased due to the reforms.

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