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The microfoundations of mixed system of planning and markets: some theoretical considerations and an empirical analysis of the Chinese agriculture

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The microfoundations of mixed system of planning and markets: Some theoretical considerations and an empirical analysis of the Chinese agriculture

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1 INTRODUCTION

1.1 Background

China is a vast country with a population of over one billion people. The arable land in China is, however, only about 95.72 million hectares, or 0.087 hectares per capita on average (State Statistical Bureau, 1989). With the large population, limited arable land, poor infrastructure facilities, and restrained foreign exchange, agricultural development has always been the top priority in the Chinese economy.

Soon after the three year economic recovery following the foundation of the People's Republic of China in 1949, the collectivization characterized by Mutual Aid Team, and later on Cooperatives were initiated. Six years later, the Rural People's Commune system integrating both government administration and economic management was established. From then on, China had followed a highly centralized planned economic system. The major features of this system are: (1) the "three-level ownership, the People's Commune, the production brigade, and the production team, with the last as the basic production and accounting unit; (2) The state mandatory plan; and (3) the state monopoly for purchasing and marketing major farm products-grain, cotton, velvet, and oil-bearing crops and the state fixed purchasing over 70 farm products. Experienced over time, this system had been proved to be unfit for China.

Since late 1978, China has been in a course of transformation from a rigid centrally planned economic system to a mixed system of planning and markets. The process of reforming the Chinese agriculture can be characterized by three stages.

The first stage was from December 1978 to October 1984. The reforms in this stage aimed at improving management and providing incentives to raise productivity. The new policies have included introducing various production responsibility systems, allowing farmers to sell part of their surplus in local markets, and raising state purchasing prices. By 1983, the household responsibility system became a widely accepted form of organization. By the end of 1984, about 98 percent of rural households were converted into various types of production responsibility systems, 96.6 percent of them were involved in the household responsibility system (State Statistical Bureau, 1985, 1987).

The new policies brought about significant impacts on Chinese agricultural development. The nation's total agricultural output value increased at an average annual rate of 9 percent, or 6.7 percent after deducting the output value of village-run industries. Farmer income per capita, with price rises factored in, rose by a record rate of 14.8 percent per year (Duan, 1987). The total grain output increased from 304.8 million tons in 1978 to 402.3 million tons in 1984, at a record rate of 5.6 percent per annuam (Gao, 1990). It is of interest to note that the remarkable increase in grain production was realized as the areas sown to grain crops was reduced by 7.7 million hectares. This implies that rapid increase in grain production was achieved mainly from substantial rises in yields, as reflected in statistics that yields increased from 2,535 kg in 1978 to 3,615 kg in 1984. As land and labor shifted to other production activities, the non-grain production was flourised.

The second stage ran from October 1984 to December 1987. The main objectives are to adjust the rural economic structure through market machenism and take local comparative advantages to move from a self-sufficient rural economy to a planned commodity economy. While the reform measures initiated in the first stage continued in practice, the system of state monopoly for purchasing and marketing over the four major farm products was replaced by a system of contracted purchase. All products not purchased under the contract were allowed to be disposed of on free markets. The state fixed purchasing over 70 farm products was abolished and farmers could now deal with their outputs freely.

The factor markets were opened. Land could be leased out for rent, labor could be hired within limitation, and interest could be charged for credit. However, the extent of transactions was limited and the forms of transaction were restricted (Lin, 1988).

The positive results include the followings. First, crop planting structure has changed, namely the areas sown to grain and cotton were reduced and the areas of oil-bearing crop, suger-bearing crop, hemp, flax, other cash crop, and vegetables were expanded. The proportion of grain, cash crop, and other crops altered from 78:14:8 in 1984 to 75:16:9 in 1986 (Duan, 1987). Next, the livestock and fishery sectors developed dramatically. The outputs of meat including pork, beef, and mutton, milk, and aquatic products increased by 13.9 percent, 14.2 percent, and 12.5 percent in 1985, respectively; and 9 percent, 14.4 percent, and 15.3 percent in 1986, respectively (Duan, 1987). Finally, rural industry, construction, transportation, commerce have also been stimulated. The output of these sectors reached 348.2 billion yuan, a 50 percent growth over 1984 and accouting for 46.9 percent of total rural output value (Duan, 1987). As a result of overall development, total value of agricultural output increased by 15.6 percent in 1985 and 11.6 percent in 1986 and farmer's net income per capita rose by 8.4 percent in 1985 and 3.2 percent in 1986 (Duan, 1987).

The negative results were also observed. The outputs of grain and cotton fluctuated. Guo, Perkins, and Carter and Zhong, among others, argued that the reduction in grain and cotton were mainly attributed to low output prices relative to other farm outputs and increasing input prices. As a result, marginal revenue from grain or cotton production was lower than for other agricultural production. Consequently, investment in grain and cotton production were reduced leading the deduction in production.

The third stage ranges from October 1987 to the present. The necessity of political reform was recognized and added to the reform agenda. Since then China has been in the era of comprehensive reform involving all areas of the society. This in return has significant impacts on the agricultural development. The total agricultural output value in 1988 reached 561.8 billion yuan, 3.2 percent increase over 1987. Production of grain, cotton, and oil-bearing crops dropped by varying degrees. By contrast, other crop productions were continually increased. Livestock and aquatic production rose dramatically with meat, milk, and aquatic products up by 10.2, 11.7, and 9.5 percent over previous year, respectively. Farmer net income per capita was 545 yuan in 1988, 17.7 percent, or 6.3 percent higher after taking inflation into account, than that in 1987 (State Statistical Bureau, 1989).

Being aware of achievements and problems in agriculture, the government announced that the agricultural reforms will be kept moving in the same direction and the existing problems should be solved as the reforms are deepened. The reforms declared to remain unchanged comprise "(1) the policy regarding the contract responsibility system based on mainly on household management and linking remuneration with output will remain unchanged; (2) with common prosperity as the goal, the policy of allowing and encouraging some regions and people to prosper before others will not be altered; (3) the policy of 'never slacking our efforts to boost grain production, enthusiastically developing a diversified economy, steadily readjusting, and optimizing the rural production structure will not be changed; (4) the policy of encouraging and guiding the development of township enterprises will remain consistent; (5) the policy of developing a diversified economy under the prerequisite that the mainstay of public ownership is upheld will be kept unchanged; and (6) for the main agricultural and sideline products, the marketing and purchasing policy which combines a planned economy with regulation by the market will remain consistent" (Tian, 1990).

1.2 Problems

Most of the literature on the Chinese agricultural economy focuses on analysis of central planning issues. This is because Chinese economy followed a central planning system from the early 1950s to the late 1970s. Numerous works on these issues were developed in 1960s and 1970s. Most of them were, however, descriptive in nature, because of inavailability of adequate data and limited access to the economy by outside scholars.

To provide more information on Chinese agriculture, Liu and Yeh (1963), Perkins (1969), Chao (1970), and Eckstein (1980), among others, have interpolated various estimates of agricultural outputs, inputs, investments, and other indicators. However, since these estimates, made one way another outside

China, were based on the Chinese official statistical data or official media of reports, there is no evidence that these estimates reflect more accurate information than those published inside.

Early attempts to develop mathematical models representing Chinese agriculture included Schran's (1964) simultaneous equation model and Wang's (1966) single equation complete model. To evaluate the effects of the rural institutions on agricultural yields, Schran set up eight simultaneous equations. Since it is difficult to judge whether these functional forms are correct representation of Chinese agriculture, and since some of the variables were difficult to quantify, for instance, ideological awareness, the usefulness of the Schran's model in statistical analysis was limited.

Recognizing the shortcomings of Schran's model, Wang built a short run regression model for direct statistical analysis of the relationships between farm output and technical modernization, institutional change, farmer's income, and weather. Although a single-equation complete model served the purpose of testing the hypotheses involved, it is too simplistic to provide a basis for a full economic analysis of policy impacts on agricultural output.

In the early 1980s, it was accepted that, in the centrally planned economies, due to government promotional effects, certain essential economic variables interacted with one another in reflecting economicly rational process. These behavior patterns for economic variables can be formulated into model built with a consistent economic rational. Most of the last decade can be considered the period of pioneering work in terms of quantitative analysis of Chinese agriculture using descriptive and behavioral models.

Using the combined quadratic time trend and ARIMA (1,1) model, Noh (1983) studied and projected China's grain production and consumption. His time series models were suited to analyze and forecast the broad trend. However, without linking the grain production or consumption with policy variables, the economic determinants that the planner uses and that how the producers or consumers respond to changes in policy alternatives cannot be evaluated.

Ho (1982) modeled China's central planning process through the Leontief-type of input-output analysis to investigate the Chinese government's role in economic performance. Ho also developed an econometric model containing nine equations. Each of the nine equations including agricultural output and the rural labor force, was then estimated individually. Utilizing a piecewise linear regression approach, Tang (1984) also examined agricultural policy cycles, Cobb-Douglas function of labor productivity, and some other economic variables. Halbrendt et al. (1989) utilized fixed and stochastic coefficients regression techniques to analyze production, consumption, and trade of individual crops, namely corn and wheat. Halbrendt et al. (1989) also built a spatial equilibrium model of inter-provincial rice trade in China. Unfortunately, results of these efforts are partial in nature. These partial equilibrium analyses ignore the linkages either among the markets in the agricultural sector, resource markets, or between the agricultural sector to the remainder of the economy. As a result, the analyses of impacts of policy on agriculture is likely to be misleading. The contribution of these models to policy analysis was thus limited.

Chow (1985) is the first one to have more fully applied the basic tools of economic analysis, including macro- and microeconomic theory and econometric methods, to study the Chinese economy. Following a theoretical exploration, he used various quantitative approaches, such as Cobb-Douglas production function, linear regression, multiplier-accelerator models, systems of linear difference equations, etc., to conduct an economic analysis of agriculture, industry, consumption, national income, human capital, and foreign trade and investment, respectively. Although Chow's work provides a significant step in understanding the Chinese economy, the results are subjected to the same limitations of the partial equilibrium analysis. Also, his model of agricultural sector did not have commodity detail.

More recently, mathematical and econometric methods became more accepted as a technique for the analysis of economic effects of agricultural policies for central planning countries and some more sophisticated and elaborated models were constructed. The National Model for the Hungarian Food and Agriculture Sector (Csabki, 1981), among others, is a such good example. However, building mathematical and econometric national model for the Chinese economy has not been given wide attention in the literature on centally planned economy.

It is well known that a general equilibrium framework is the appropriate approach for evaluating the full economic consequences of policies affecting the farm sector. The Basic Linked System (Fischer et al., 1988), a global general equilibrium model developed at the International Institute for Applied Systems Analysis (IIASA), is one such approach for national and global agricultural policy evaluation. The China model in the Basic Linked System (Neunteufel, 1985), a country-specific model, follows the general equilibrium framework. However, there are two problems associated with the IIASA China national model. One is that it is incorporating the economic system prior to 1978 when China started the agricultural reform. It is now significantly out of date and not suitable for policy analysis of the current economic system. The other problem is that the model is too simple to be used as a tool for policy evaluation.

Some research results can be found in the literature on the current mixed system of planning and markets (Tang, 1980; Cheng, 1982; Hsu, 1982; Barker et al., 1982; Huan, 1985; Song, 1986; Xue, 1987) that can be used as a basis for a more elaborate model. Most of these describe the institutional changes and study the causes and effects of the shift from commune system to responsibility system. And majority of the results are descriptive. The exceptions can be observed in two categories. One category is to provide quantitative analysis of the causes and effects of the institutional transformation using econometric models. Another category is to incorporate the current economic system and agricultural policies in building theoretical and empirical models for the Chinese agricultural sector.

Of the first group researchers, Lin (1988) and McMillan et al. (1989) are noted worthy. Introducing the supervision and cost of supervision in his theoretical model, Lin drew three hypotheses and tested them with empirical data before and after the institutional reform. The accepted hypotheses include: (1) the rate of adopting the household responsibility system in an area was a function of the gains and costs of shifting to the new system in that area; (2) the effects of the institutional change in agricultural production from the production team system to the household responsibility system mainly involved the augmentation of effort supply, both in terms of quantity of work and quality of work; and (3) the change from the production team system to the household responsibility system should have a positive effect on agricultural production. Yet, its effects on household sideline production was indeterminate.

McMillan et al. employed a production function incorporating a method decomposing the effect of price increase and introduction of the responsibility system. The associated empirical results suggest that 22 percent of the increase in productivity in Chinese agriculture between 1978 and 1984 was due to higher prices and 78 percent to new production responsibility system.

Theoretical and empirical work on Chinese agriculture under the current mixed system of planning and markets can also be found. Of the authors who have investigated the model of current Chinese agriculture, mention should be made of Carter and Zhong (1988), Sicular (1989), and Pan and Johnson (1990a, 1990b). Carter and Zhong built and estimated a model for Chinese grain production reflecting the features of current system. They explicitly introduced average grain purchasing price index in the functions of grain sown area and grain yield. Total grain production is then equal to the product of these two functions.

Sicular developed a theoretical model in a general equilibrium framework. She showed that in the presence of state planning, economic agent's marginal decisions are guided only by market prices. State prices and quotas do not directly influence the production choice. She pointed out that the plan, however, affect levels of trade on the market and with the state, income distribution, and equilibrium market prices.

Pan and Johnson (1990a) have modeled Chinese grain production. Their model shows that the supply function possesses the features ascribed by the classical firm theory.

The complication is an additional shifter-equivalent income variation due to the interaction between the planned and market sectors. They found that farm marginal decisions are affected by the state prices and quotas only if market price is uncertain. If market price is known, profit maximization rules much like those for producers in market economics are directly applicable. They also showed how the planned and market sectors interacte with each other and how the plan affects producer net income.

Recently, Pan and Johnson (1990b) extended their analytical approach linking planned and market economic framework to evaluate policy alternatives for stimulating grain production in the mixed economic system. They showed thereticaly that the reform of Chinese grain marketing system has brought about positive impacts on the grain production. They concluded that, to ensure planning system and market system work together to achieve desired goals, it is important not to ignore the market equilibrium when formulating planning targets.

All of these results are, however, subject to the same drawbacks as the aforementioned; either partial equilibrium approaches or without associated empirical analysis for policy evaluation. The general equilibrium model with commodity detail for the current Chinese agricultural sector has not been given much attention in the literature on the current mixed system of planning and markets.

In the current mixed system of planning and markets, the state plans and certain economic variables interact with one another in such a way that together they generate economic process that can reflect economically rational behavior. These behaviors and interactions among them need to be formulated into a system to more fully reflect the economic process. Policy structure issues are especially essential in these mixed models due to the predominant roles of government.

It is very popular to incorporate the state plans in reduced form framework with the policy variables as explanatory variables (Carter and Zhong, 1988; Neunteufel, 1985; etc.). The common problems observed in this type of approach are incomplete specifications of policy variables, without explicitly specifying economic agent's objective, and not explicitly introducing policy variables in the objective.

Without fully specified policy representation, the conclutions drawm from the results derived from reduced form estimation may be misleading. For instance, some studies use average prices, weighted averages of state prices and market prices, in reduced form equations to analyze producer response to changes in output prices and of a positive response is reported. When state prices are raised the average prices are increased. Accordingly, output will go up as the conclusions have indicated. However, some other results (Sicular, 1989; Pan and Johnson, 1990a) showed that producer marginal decisions are affected only by market prices if market prices are certain and higher than state prices. Hence, it is important to complete specification of state prices and market prices in estimation.

If the producer objective is not explicitly and completely specified or policy parameters are not fully incorporated in the objective, unreliable results could also be generated. This is because producer optimal decisions are not only based on their objectives but also the structure of the economy in where they operate.

The structure of an economic model contains optimal decision rules of producers. The optimal decision rules vary systematically with changes in state plans. It is, therefore, obvious that adjustments in state plans will systematically alter the structure of econometric model. Thus, an econometric model for policy analysis must incorporate current economic system and the policy parameters. And evaluation of policy alternatives using currently developed models that include partial representaion of the policy and economic structure and an incomplete behavior hypothesis is problematic.

1.3 Objectives

This study explores the microfoundations of mixed system of planning and markets in China and develops an agricultural sector model for China. This model explicitly incorporates the major features of the current Chinese economy and selected key agricultural policy instruments. The farm level decisions on output supply and input demand are modeled in a theoretical framework. The structural equations at market level are then specified using the duality relationship between production function and variable profit function. The risk aversion is considered when the functional specification is formulated. The resulting expressions are estimated in a dual approach framework.

The theoretical restrictions imposed by profit maximization and risk aversion and the technical response relations assumed are maintained when the structural equations are specified and the model is estimated. This makes the model consistent with a general equilibrium framework for the agriculture as a whole.

The specific objectives of this study are:

(1) To describe the major features of current Chinese agricultural economic system and the key agricultural policy instruments.

(2) To build a theoretical model of the farm producer decisions on the supplies of outputs and demands for inputs incorporating current economic system and key agricultural policy instruments,

(3) To specify the structural equations for output supplies and input demands derived in a dual approach framework,

(4) To estimate the model maintaining all theoretical restrictions and examine the validity of the model, and

(5) To evaluate the implications from the empirical findings

and measure the impacts of selected Chinese agricultural policies on the Chinese farm sector using newly developed model.

1.4 Organization of The Study

This study is organized as follows: Chapter 1 discusses the background, the problem setting, and the objectives of the study. Chapter 2 reviews and discusses various issues involved in the estimation of output supply and input demand equations. Chapter 3 decribes the Chinese agricultural economic system and the essential agricultural policy structure. The implications of these policies and the structure for farm behavior are then discussed. Chapter 4 constructs a theoretical model of farm level decisions on output supplies and input demands in the current mixed system of planning and markets. Chapter 5 outlines estimation procedure, describes the data used in the estimation, makes required assumptions for the analysis, and reviews appregation principles. Chapter 6 reports and interprets the empirical results and examines the validity of the model. Chapter 7 contains a summary of the results from the study, concluding remarks on the findings, and suggestions for further research.

2 MICROFOUNDATIONS OF ESTIMATION OF OUTPUT SUPPLY AND INPUT DEMAND

There is strong argument that specification of output supply and input demand equations should be carried out on the basis of a rigorous foundation of the theory of the firm. The development in duality theory and the associated computational or estimation methods have made it easier and more feasible to estimate simultaneously both the output supply and input demand equations derived from the theory of firm behavior. The view that risk plays an important role in economic decision making has been widely recoganized. Much attention has been focused on the impacts of uncertainty upon the results of the static, neoclassical theory of the firm and how comparative static methodology is enhanced powerful duality properties. The natural question is whether duality can be used successfully in the presence of uncertainty. Other issues such as flexible functional form, profit function specification, and aggregation from firm to market levels are also involved in empirical implematation. The aim of this chapter is to review and discuss the issues involved in developing the microfoundations for estimation of output supply and input demand equations.

2.1 Duality: Certainty Case

In a competitive world with regular technology, there is one-to-one correspondence between the production technology and the dual profit function (Chambers, 1988). Following Silberberg (1978), define the primal-dual Lagrange function as:

$$(2.1) \qquad L^{*} = F(\alpha) - f(X, \alpha) - \lambda G(X, \alpha)$$

where F is the indirect objective function, f is the direct objective function, λ is a Lagrange multiplier, G is an implicit constraint, X is a control vector, and α is a parameter vector. For the problem addressed in this study, F represents profit function and f profit equation for a firm, respectively. The profit is defined as:

$$(2.2) \qquad \Pi = PY(Z) - WZ - B$$

where P and Y are the vectors of price and quantity of output, respectively; Z and W are the vectors of quantity and price of input, respectively; and B is a vector of fixed cost. Technology is expressed implicitly by $G(Y, Z, B) = 0$.

The corresponding primal-dual Lagrange function is

$$(2.3) \qquad L^{*} = \Pi^{*}(P, W, B) - \Pi(Z, Y, P, W) - \lambda G(Y, Z, B).$$

First order conditions are

$$(2.4) \qquad \Pi_{X} - \lambda G_{X} = 0,$$

(2.5) $\partial \Pi^* / \partial \alpha - \partial \Pi / \partial \alpha = 0,$

(2.6) $G(X, B) = 0.$

where Π_X and G_X are vectors of derivatives with respect to the control vector X=(Z) and α represents the parameter set (P, W, B). It is worth noting that, by Samuelson's and Silberberg's interpretation, at the optimal value X^* the rate of change of profit with X^* adjusting to changing α is equal to the rate of change of profit with respect to α when profit is evaluated at X^* (treating X fixed at X^*).

Solving (2.4) for optimal output yields Y as a function of P and W:

(2.7) $Y^* = Y(P, W),$

which is the firm's supply function. Substituting (2.7) into (2.2) gives the profit function:

(2.8) $\Pi^* = PY(P, W) - WZ(P, W) - B = \Pi(P, W, B),$

which is the same as the first term in Equation (2.2).

The profit function possesses the following properties (Lau and Potopolous, 1972; Lau, 1978; Varian, 1984; Chambers, 1988): (1) It is a non-negative real valued function for all positive prices. (2) It is homogeneous of degree one in all prices. (3) It is convex and continuous in P and W for every fixed B. (4) It is nondecreasing in output prices and nonincreasing in input prices. And (5) it is differentiable only if there exists a unique profit maximizing supply and input demand.

If the function is differentiable then:

$$\partial \Pi \;/\; \partial W = Z^{*}, \tag{2.9}$$

$$\partial \Pi \;/\; \partial P = Y^{*}. \tag{2.10}$$

This property is referred to as Hotelling's lemma.

Two additional properties can be derived from (3) and (5). First, the matrix of second order derivatives of $\Pi(.)$ with respect P and W is positive semidefinite,

$$H = \begin{bmatrix} \partial^2\Pi/\partial P_i \partial P_j & \partial^2\Pi/\partial P_j \partial W_i \\ \\ \partial^2\Pi/\partial W_i \partial P_j & \partial^2\Pi/\partial W_i \partial W_j \end{bmatrix}. \tag{2.11}$$

Second, by Young's theorem, cross partial derivatives must be equal:

$$\begin{aligned} \partial^2\Pi/\partial P_i \partial P_j &= \partial Y_i/\partial P_j = \partial Y_j/\partial P_i = \partial^2\Pi/\partial P_j \partial P_i \\ -\partial^2\Pi/\partial W_i \partial W_j &= \partial Z_i/\partial W_j = \partial Z_j/\partial W_i = \partial^2\Pi/\partial W_j \partial W_i \\ \partial^2\Pi/\partial P_i \partial W_j &= \partial Y_i/\partial W_j = \partial Z_j/\partial P_i = \partial^2\Pi/\partial W_j \partial P_i. \end{aligned} \tag{2.12}$$

Equation (2.12) is generally referred to as the symmetric restriction. These imply that the matrix of H is symmetric.

The production technology can be examined directly using the primal approach or indirectly in a dual framework. The output supply and input demand relationships derived by the two approaches are identical.

The principal advantage of using the dual approach in the specification of system of supply and demand equations that is consistent with maximization behavior that allows the derivation of forms for supply and demand equations as the derivatives of a function rather than as the solution to a constrained maximization problem. Thus, the problem of production technologies giving rise to nonclosed-form solutions for demand equations is eliminated (Hallam et al., 1982).

The crux of this approach is that it is no more arbitrary to start the analysis by choosing a specification for a profit function than it is to choose a specification for a production function. Thus, specifying an arbitrary functional form for the indirect criterion function that satisfies the necessary regularity conditions guarantees that the resulting decision functions are derivable as the result of a maximization process for some well-behaved technology. Since these functions can be made quite flexible while allowing analytic derivation of implied supply and demand specification, fewer restrictions must be imposed on the underlying technology and preferences than in the primal approach (Hallam et al., 1982).

Furthermore, the coefficients in the system of supply and demand estimated in a dual framework, can be substituted directly back to profit function to analyze welfare levels under different prices or policy scenarios (Just et al., 1983).

Finally, it is easier to estimate output supply and input demand relationships in the dual framework, the dual approach does not reguire output specific input usage (Shumway, 1983; Lopez, 1982). Aggregate input use is sufficient for applying the dual approach while output specific input use is necessary in estimation in primal formulation. This has been a significant factor in the choice of which approach to be used, for in many cases, the data on output specific use are not available at market level.

2.2 Duality: Uncertainty Case

There is growing evidence that attitudes towards risk play an important role in economic decision making. Much effort has been made to examine how the firm theory performs when uncertainty is incorporated. Using the expected utility maximization farmework, McCall (1967) showed that output under uncertainty is less than, equal to, or higher than output under certainty for the risk-averse, risk-neutral, and risk-loving firm, respectively; since the optimal output is characterized by marginal cost being less than, equal to, or higher than the expected price for the risk-averse, risk-neutral, and risk-loving firm, respectively.

By examining the comparative statics of the firm under uncertainty, Sandmo (1971) found that simply assuming the existence of risk aversion is a very weak restriction on the firm's attitudes to risk. Sandmo (1971) and Batra and Ullah (1974) have shown that nonincreasing absolute risk aversion is a sufficient condition for an upward sloping supply curve. Unlike the results derived from the situation of certainty, Sandmo also verified that fixed inputs do matter in the sense that once a strictly positive output level has been chosen, this output is affected by a change in fixed input. Furthermore, competitive equilibrium under price uncertainty and risk aversion requires the existence of positive profits in order to choose a positive output level.

Ishii (1977) extended the Sandmo result to show that nonincreasing absolute risk aversion is a sufficient condition for output to decrease in response to an increase in price uncertainty, as defined by a mean preserving spread in the distribution of price.

The effects of output price uncertainty on factor demands have been investigated by Batra and Ullah (1974) who showed that under uncertainty the firm will choose input levels which minimize the cost of producing a given level of output. Based on this finding, along with Sandmo's conclusion that the presence of uncertainty reduces output, Hartman (1975) showed that the impacts of price uncertainty on factor demands depend on how the reduced level of output affects the cost minimizing level on inputs. The presence of uncertainty will reduce factor demands, except for inferior factors, for a risk averse firm. If the firm is risk neutral, the existing uncertainty has no effect on output supply and input demand. Hartman (1976) also invested the case where capital is a quasi-fixed factor, which means that capital input must be chosen ex ante--before the output price is observed. The labor input can, however, be adjusted ex post. Contrary to the case where all input are chosen ex ante, uncertainty plays an important role in determination of optimal input levels for a risk neutral firm.

Recently, much attention has been concentrated on how the comparative static methodology applies the powerful duality properties and whether duality approach can be used in the presence of uncertainty.

Assume that output price is randomly distributed as

$$(2.13) \qquad P_i = \bar{P}_i + e_i, \quad E(P_i) = P_i.$$

For the problem considered, let F and f in Equation (2.1) refer to the indirect and direct expected utility function of profit for a firm, respectively. The corresponding primal-dual Lagrange function is

$$(2.14) \qquad L^* = E\{U^*[\Pi^*(M,W,B)]\} - E\{U[\Pi(Y,Z,M,W)]\} - \lambda G(Y,Z,B)$$

where M denotes relevant moments of the distribution of P. First order conditions are:

$$(2.15) \qquad E[U'(\Pi)\Pi_X] - \lambda G_X = 0,$$

$$(2.16) \qquad \partial E[U^*(\Pi)] / \partial\alpha - \partial E[U(\Pi)] / \partial\alpha = 0,$$

$$G(X, B) = 0 \tag{2.17}$$

where $U'(\Pi) = dU/d\Pi$ and α represents the parameter set (M, W, B). All other notation is the same as defined for Equation (2.1). Equation (2.16) states that at the optimal value X^*, the rate of change of expected utility with X^* adjusting α is equal to the rate of change of expected utility with respect to α when expected utility is evaluated at X^* (treating X fixed at X^*).

Previous studies have shown (Sandmo, 1971; Aradhyula, 1988) that when prices are not known ex ante, the risk neutral producer behaves as if prices are known with certainty and equal to the expected value. Hence, a profit function for the certainty case is equivalent to the expected profit function for a risk neutral producer. In this case, conditions in (2.15) and (2.16) become

$$E[\Pi_X] - \lambda G_X = 0, \tag{2.18}$$

$$\partial E[\Pi^*] / \partial\alpha - \partial E[\Pi] / \partial\alpha = 0, \tag{2.19}$$

where * indicates optimal quantities. From Equations (2.19), (2.2), and (2.13), the results of McFadden are derived:

$$\partial E[\Pi^*] / \partial\bar{W}_i = - Z_i^*, \tag{2.20}$$

$$\partial E[\Pi^*] / \partial\bar{P}_j = Y_j^*. \tag{2.21}$$

When risk aversion is assumed for a firm, these primal-dual relations do not necessarily exist. Equation (2.15) leads to utility maximizing input demands:

$$(2.22)\quad Z_i^* = f(\bar{P},\ \bar{W},\ \alpha,\ \sigma)$$

and output supplies:

$$(2.23)\quad Y_i^* = f(\bar{P},\ \bar{W},\ \alpha,\ \sigma)$$

where σ is a vector of parameters characterizing the stochastic properties of prices other than their means such that $\partial e_i/\partial \bar{P}_i = 0$ for i = 1, ..., n and $\partial e_i/\partial \bar{W}_i = 0$.

Substituting Z^* and Y^* into the direct utility function gives the indirect utility function which specifies maximum expected utility as a function of the stochastic of prices:

$$(2.24)\quad E[V] = E\{U^*[X^*(\alpha),\ \alpha]\},$$

which is the indirect objective function, equivalent to $F(\alpha)$ in Equation (2.1). The concavity of direct utility function in X do dot necessarily imply convexity of the indirect utility function because $U^*_{\alpha\alpha}$ is nonzero, where $U^*_{\alpha\alpha} = \partial^2 U^*/\partial\alpha\partial\alpha$.

Application of the envelope theorem implies

$$(2.25)\qquad \partial E\{U^*(\Pi)]\ /\ \partial \bar{W}_i = -\ Z_i^* E[U'(\Pi)],$$

$$(2.26)\qquad \partial E[U^*(\Pi)]\ /\ \partial \bar{P}_j = Y_j^* E[U'(\Pi)].$$

Apparently, in the case of uncertain prices, the derivatives of the expected utility function no longer explicitly give factor demands or output supplies. The effects on the expected utility of profit function of a change in the mean of the price distribution is equal to the usual supply function or input demand function weighted by the expected marginal utility of profit (Roger and Lusky, 1977). Furthermore, because (2.25) and (2.26) are not generally separable in X, meaningfull comparative static results are not as easily derived as under certainty.

Differentiation of (2.24) with respect to α_j gives the envelope result:

$$(2.27) \quad E[V]_{\alpha j} = \partial E[V] \,/\, \partial\alpha_j = \partial E[U^*] \,/\, \partial\alpha_j \quad X^*.$$

Further diferentiating equation (2.27) with respect to α_k yields

$$(2.28) \quad E[V]_{\alpha j\alpha k} = \sum_{i=1}^{N} E[U^*]_{\alpha jxi} \,(\partial X^*_i \,/\, \partial\alpha_k) + E[U^*]_{\alpha j\alpha k} \quad X^*.$$

These results can be expressed compactly in matrix form as,

$$(2.29) \quad E[V]_{\alpha\alpha} = E[U^*]_{\alpha x*} \,(\partial X^* \,/\, \partial\alpha) + E[U^*]_{\alpha\alpha} \quad X^*.$$

Further derivation of an explicit representation of primal-dual relationships in terms of Hessian matrix can show the curvature of E[V]. Since optimal X^* is derived from $\partial E[U^*]/\partial X_i = 0$, i=1,...,n, comparative static analysis of the above equation gives in matrix form:

$$(2.30) \quad \partial X^* \,/\, \partial\alpha = -\, E[U^*]_{xx}{}^{-1} E[U^*]_{x\alpha}.$$

Substituting Equation (2.30) into (2.29) implies (dropping the asterisk on X for convenience):

$$(2.31)\quad E[V]_{\alpha\alpha} = - E[U^*]_{X\alpha}E[U^*]_{XX}{}^{-1}E[U^*]_{X\alpha} + E[U^*]_{\alpha\alpha}$$

where all functions are evaluated at X^*. The left-hand side of Equation (2.31) is the Hessian of the indirect utility function. Moving last term on the right-hand side of the equation yields

$$(2.32)\quad E[V]_{\alpha\alpha} - E[U^*]_{\alpha\alpha} = - E[U^*]_{X\alpha}E[U^*]_{XX}{}^{-1}E[U^*]_{X\alpha}.$$

Since $E[U^*]_{XX}$ is negative definite by assumption of risk aversion, so is $E[U^*]_{XX}{}^{-1}$. Thus, $E[V]_{\alpha\alpha} - E[U^*]_{\alpha\alpha}$ is positive semidefinite and must be positive semidefinite if $E[U^*]_{X\alpha}$ is of rank n because the left-hand side of Equation (2.32) is of full rank in this case.

Consider a special case of Equation (2.32) associated with certainty. The strict concavity of U^* in X is equivalent to convexity of V in normalized prices. When risk and risk aversion are introduced into the question, the concavity of $E[U^*]$ in X does not necessarily imply convexity of E[V] in normalized prices. However, under constant risk aversion, Hallam et al. (1982) showed that concavity of $E[U^*]$ in X is equivalent to convexity of E[V] in normalized prices since $E[U^*]_{\alpha\alpha} = 0$ in this case.

By explorating into the implications of convexity of L^* as implied by maximization of expected utility, Pope (1980) showed that with single product,

$$(2.33) \qquad L_{pp}^{*} = \sum_{i=1}^{M} (\partial E[U'(\Pi)Y^{*}] \;/\; \partial Z_i) * (\partial Z_i \;/\; \partial P) \geq 0.$$

This result is derivable in the general M input model given above as derived by direct differetiation of first order conditions by Sandmo. Thus, assuming nonincreasing absolute risk aversion, it is found that $\partial Y^{*}/\partial\bar{P} \geq 0$ and the supply curve is upward sloping.

Pope also showed that

$$(2.34) \qquad L_{wiwi}^{*} = -\sum_{j=1}^{M} (\partial\{Z_i E[U'(\Pi)]\} \;/\; \partial Z_j) * (\partial Z_j \;/\; \partial W_i) \geq 0.$$

This nonnegative relation is obtained if the conditions of production concavity ($G_{ii} \langle 0$) and complementarity ($G_{ij} \rangle 0$) also hold under risk aversion such that $\partial Z_i^{*}/\partial\bar{W}_i \leq 0$ and $Y^{*}/\partial\bar{W}_i \leq 0$. The factor demand curves are then downward sloping.

Given nonincreasing risk aversion, Pope derived three sufficient conditions for symmetry of factor demand equations as the results under certainty:

[1] $E[U''(\Pi)(e - T)] = 0$ or

[2] $(\partial Y^{*}/\partial W_j) \;/\; (\partial Y^{*}/\partial W_i) = Z_j^{*} \;/\; Z_i^{*}$ or

[3] $f_{ci} = \partial E[U(\Pi)] \;/\; \partial W_i = Z_i$ for all i.

where $T = Cov[U'(\Pi), P]$. [1] describes the risk neutral or constant risk averse case and [3] the separability condition.

Risk neutrality implies conditions [1] and [3]. When risk preferences are nonlinear, there is no reason a priori to expect that the symmetry of factor demands, condition [2] will hold, it is so even under certainty. It follows immediatly that the symmetry condition hold only under constant risk aversion when risk preference is nonlinear. Condition [3] provides insight for the development of models guaranteeing the symmetry condition when risk aversion prevails.

Pope also showed that the symmetry for $-\partial Z_i^*/\partial \bar{P}=\partial Y^*/\partial \bar{W}_i$ is held only if conditions [1], [3], and

$$[4] \qquad (\partial Y^*/\partial W_i) \;/\; (\partial Y^*/\partial P) = -\, Z_i^* \;/\; Y^*.$$

When multiproduct case is considered, the term is ubiquitous in determination of comparative static results. However, by delinearing further restrictions on preferences, some usefull results can be obtained.

From Silberberg's theorem of the maximization hypothesis, $L_{\alpha i \alpha j}=L_{\alpha j \alpha i}$ and corollary, $\partial X_i/\partial \alpha_j=\partial X_j/\partial \alpha_i$ if objective function is additively separable in functions of the form $H_i(X_i,\ \alpha_i)$, Pope established following corollary: if $f\alpha_i=f\alpha_i(X_i,\ \alpha)$ for all i, then symmetry is preserved if $f\alpha_i x_i=\gamma_{ij} f\alpha_j x_j$, where γ_{ij} equals 1 or -1.

Given these conditions and results, one can define a class of utility functions which satisfy some or all of the assumptions and conditions needed to develop restrictions that are readily amenable to econometric analysis. This class is the set of expected utility functions, common in empirical work, of the form

$$(2.35)\qquad E[U(\Pi)] = \bar{\Pi} + \psi(\gamma,\ Y)$$

where $E(\Pi) = \bar{\Pi}$ and γ is defined as moments of P about $\bar{P}$ of order 2 and greater. If a class of utility functions exhibit the form in (2.35), the following theorem and corollary were stated and proved.

Consider a utility function of profits and the expected utility function is of form

$$(2.36)\quad E[U(\Pi)] = E[\Pi + \alpha_1(\Pi-\bar{\Pi}) + \ldots + \alpha_t(\Pi-\bar{\Pi})^t + \ldots + \alpha_T(\bar{\Pi}-\Pi)^T]$$

then, in case of uncertain output price, (2.36) can be written

$$(2.37)\qquad E[U(\Pi)] = \bar{\Pi} + \sum_{t=2}^{T} \alpha_t\sigma_t,$$

where σ_t is the t-th central moment of Π. Let $\sigma_t=\psi_t(\gamma_t,\ Y)$, where γ_t represents a vector of all relevant moments of price of order 2 and greater about mean. Equation (2.37) can be rewritten as

$$(2.38)\qquad E[U(\Pi)] = \bar{\Pi} + \sum_{t=2}^{T} \alpha_t\psi_t(\gamma_t,\ Y)$$

$$= \bar{\Pi} + \psi(\gamma,\ Y),$$

where ψ does not depend on $\overline{P}$. By Pope's corollary, following relations can be derived:

(2.39) $$\partial E[U(\Pi)] / \partial W_i = - Z_i^* \text{ for all i, and}$$

(2.40) $$\partial Z_i^* / \partial W_j = \partial Z_j^* / \partial W_i \text{ for all i and j.}$$

It is of interest to examine comparative static changes in particular moments of γ leaving others unchanged. Pope showed change in $\overline{P}$ holding other moments unchanged yields

(2.41) $$\partial E[U(\Pi)] / \partial \overline{P}_i = Y_i^*$$

and according to Pope's corollary all output symmetries and output supply and (negative) input demand symmetries are preserved when $\partial\psi / \partial\overline{P}=0$ is assumed. That is

(2.42) $$\partial Y_i^* / \partial \overline{P}_j = \partial Y_j^* / \partial \overline{P}_i \text{ for all i and j, and}$$

(2.43) $$\partial Y_k^* / \partial W_h = -\partial Z_h^* / \partial P_k \text{ for all k and h.}$$

When input prices are subject to uncertainty, the same logic is applicable and the comparative static results are derivable.

An apparent corollary is that the utility function need not be of the form in (2.36). That is, monotonically increasing transformations of (2.35) imply identical results. For example, the constant absolute risk aversion utility function of profits is negative exponential:

(2.44) $U(\Pi) = -be^{-R\Pi}$

where Π is profit which is assumed to be normally distributed with mean $\bar{\Pi}$ and variance σ^2, b is positive, and R is the measure of absolute risk aversion. Freund (1956) has shown that the producer's objective is to maximize

(2.45) $\Pi + a_2\sigma^2, \quad a_2 < 0.$

The theorem and corollary indicated in (2.39), (2.40), (2.41) (2.42), and (2.43) follow. The constant absolute risk aversion utility function has proved popular in pratical examples.

2.3 Producer Risk Preference

The microfoundations developed in 2.1 through 2.2 need to be specialized for empirical implementation for the present study. In particular, it is necessary to specify the nature of producer risk preferences.

To specify the supply and input demand functions, it is necessary to consider an explicit representation of producer risk preferences. The available methods have include (1) specifying a direct functional form of the utility function, (2) approximating the risk premium with a finite number of terms, and (3) using an indirect specification of the expected utility function. For detailed dicussion see Hallam et al.

Previous studies have shown (Sandmo, 1971; Aradhyula, 1988) that when prices are not known ex ante, the risk neutral producers behave as if prices are known with certainty and equal to the expected values. Thus, a profit function for a certainty case is equivalent to the expected profit function for a risk neutral producer. Many analyses suggest that, however, producers are not risk neutral but risk averse and maximize the expected utility of profits rather than simply profits (Young et al., 1979).

The Arrow-Pratt measure of absolute risk aversion, denoted by $R_A(\Pi)$, is known as:

$$R_A(\Pi) = - U''(\Pi)/U'(\Pi) \tag{2.46}$$

where the terms in the parentheses are the outcomes of concern to the individual in terms of one continuous variable, here is the profits of producers. The producer displays risk aversion, neutrality, or loving as $R_A(\Pi)$ greater than, equal to, or less than 0. If Π changes $R_A(\Pi)$ may be increased, constant, or decreased. Accordingly, the producer is increasing, constant, or decreasing absolute risk averse, respectively.

2.4 Profit Function

Making assumptions on the structure of technology is the first step in an econometric analysis. For smooth technologies, the empirical measurement of the economically relevant information, or generality in representing technology includes the value of the function, the gradient of the function, and the Hessian. For any primal or dual technology with n netputs (outputs and negative inputs), therefore, there are 0.5(n+1)(n+2) economically relevant effects. A functional form is flexible if it does not impose a priori values to any of these 0.5(n+1)(n+2) coefficients. These effects are determined by the data. Thus, it is not flexible functional form unless the functional form with n variables has at least 0.5(n+1)(n+2) parameters. However, flexible functional forms nevertheless impose some a priori restrictions, and not all flexible functional forms are equally suitable as dual representation of technology (Blackorby et al., 1977; Lopez, 1985).

The flexible functional forms have included generalized Leontief (Diewert, 1971), the translog (Christensen et al., 1973), normalized quadratic (Lau, 1978), generalized McFadden (Diewert and Wales, 1987), miniflex Laurent (Barnett, 1983), and Fourier (Gallant, 1981, 1982, 1984).

An algebraic functional form for a profit function $\Pi(P,W,\alpha)$ is of flexible functional form if at any given set of non-negative output and input prices (P and W), the parameter vector α can be chosen so that the profit function, the implied output supply and input demand functions, as well as their own and cross price elastisities can be assumed any arbitrary values at the given set of prices subject only to the theoretical consistency (Chambers, 1988). The present study uses a normalized quadratic variable profit function to represent the optimizing benavior of farm producers (Lau, 1976).

The normalized quadratic functional form represents a second order Taylor series approximation to the unknown profit function. Consider an agricultural producer with n outputs, m inputs (where n + m = q), and K fixed inputs or exogenous variables, market-level normalized (normalized by EP_q) quadratic profit function is

$$(2.47) \quad \Pi^*(P,B) = \alpha_0 + \sum_{i=1}^{q-1} \alpha_i EP_i + \sum_{i=1}^{q-1} \sum_{j=1}^{q-1} b_{ij} EP_i EP_j + \sum_{k=1}^{K} c_k B_k$$

$$+ \sum_{k=1}^{K} \sum_{l=1}^{K} d_{kl} B_{kl} + \sum_{i=1}^{q-1} \sum_{k=1}^{K} e_{ik} EP_i B_k$$

where Π^* is profit divided by the price of qth netput (netput including both output and input), EP_i is expected price of ith netput and P represents prices of both outputs and inputs, B_k is quantity of kth fixed input or exogenous variable, and α_0, α_i, b_{ij}, c_k, d_{kl} and e_{ik} are parameters to be estimated.

By Hotelling's lemma, the first derivatives of a normalized profit function with respect to normalized output prices and normalized input prices are the output supply and (negative) variable input demand equations. And these equations derived from the normalized quadratic profit function are linear in normalized output and variable input prices and fixed input quantities or exogenous variables. The numeraire netput is then calculated conditional on above estimations. These equations are given by

$$(2.48)\quad Y_i = \alpha_i + \sum_{j=1}^{q-1} b_{ij}EP_j + \sum_{k=1}^{K} e_{ik}B_k \qquad i=1,2,\ldots,n$$

$$(2.49)\quad -X_i = \alpha_i + \sum_{j=1}^{q-1} b_{ij}EP_j + \sum_{k=1}^{K} e_{ik}B_k \qquad i=1,2,\ldots,m-1,$$

$$(2.50)\quad -X_n = \alpha_o - 0.5\sum_{i=1}^{q-1}\sum_{j=1}^{q-1} b_{ij}EP_iEP_j + \sum_{k=1}^{K} e_kB_k + \sum_{k=1}^{K}\sum_{l=1}^{K} d_{kl}B_kB_l.$$

Because B_j represents an aggregate input level, consistent aggregation across firms requires that $\Pi^*(P,B)$ be affine in B. This implies that $\partial^2\Pi^*(P,B)/\partial B_k\partial B_l=d_{kl}=0$, a priori in the estimation. Equations (2.48), (2.49), and (2.50) are the complete system of equations to be estimated simultaneously in this study.

The linear output supply and input demand equations make it convenient in the estimation. This is one of the advantages of normalized quadratic profit function over other flexible functional forms. Furthermore, the matrix of second derivatives of a normalized quadratic profit function with respect to normalized prices is constant. This constant matrix allows us to check the convexity of profit function in prices by simply evaluation if the matrix is positive semi-definite. And this constant matrix implies that local convexity is also global convexity.

2.5 Aggregation

The preceding discussion on expected utility function, profit function, and the implied output supply and input demand equations are based on firm theory. However, firm level data are not always available, more offen the cross sectional or time series data at industry or national level are handy. Accordingly, industry functions, rather than firm-level functions, are estimated. As a result, firm level functions must be translated into market-level functions. This is refered in economics to "aggregation problem."

The aggregation problem involvs what functional forms for market-level functions are consistent with firm-level theory and what restrictions to be imposed on firm-level functions to ensure they are compatible with the rules of aggrgation.

Consider there are N firms. When all firms face the same output and input prices and no fixed variables are involved, then the aggregation problem become relative simple because there is no restriction to be imposed on either firm-level of market-level functions. Following equations explan the aggregation rule from firm-level to market-level.

$$(2.51) \qquad \pi(P,W) = \sum_{i=1}^{N} \Pi_i(P,W)$$

Adopting Hotelling's lemma one derive

$$(2.52)\quad \partial\pi(P,W)/\partial P_j = \sum_{i=1}^{N} \Pi_i(P,W)/\partial P_j = \sum_{i=1}^{N} Y_{ji}(P,W) = Y_j(P,W), \text{ and}$$

$$(2.53)\quad \partial\pi(P,W)/\partial W_h = \sum_{i=1}^{N} \Pi_i(P,W)/\partial W_h = \sum_{i=1}^{N} -Z_{hi}(P,W) = -Z_h(P,W).$$

These aggregation rules are often used in empirical studies. However, producer specific variables, for example, fixed inputs, specific prices, and specific policies imposed by government, may present. The presence of producer specific variables impose somse restrictions on the functional forms of both aggregate and firm-level profit functions. For detaied discussion see Gorman 1968, Blackorby and Schworm 1982, Chambers 1988, and Pope and Chambers 1988.

3 CHINESE AGRICULTURAL ECONOMIC SYSTEM AND IMPLICATIONS

To better incorporate the major features of the current Chinese agricultural economic system and the key agricultural policy instruments in building the model, this chapter would describe the Chinese agricultural economic system and essential agricultural policy structure. Then, the implications of these system and policy structure are discussed.

3.1 Agricultural Economic System

3.1.1 System prior to 1978

The rural collectivization characterized by Mutual Aid Teams and later on, Cooperatives were initiated soon after the three year recovery period following the foundation of the People's Republic of China in 1949.

Six years later, the system of the Rural People's Commune embodying both government administration and economic management was established in 1958. Experienced several changes over time, the "three-level ownership (the people's commune, the production brigade, and the production team) with the production team as the basic unit" ended up to be the major property of the commune system. According to the Chinese official statistics(Chinese statistical bureau, 1981), an average commune in 1978 had 13 production brigades, 91 production teams, 3,287 households, 15,218 persons.

As the basic production and accounting unit, the production teams managed land and other means of agricultural production, organized farm production activities, quantified and distributed incomes. However, all decisions, including the area and varieties of crops, dates of plowing, sowing, transplanting, applying fertilizers and insecticides, and harvesting, the techniques, etc., were made from higher level authorities. Some were made by governments at the county or higher level and transmitted by the commune or production brigade. Some were made by the commune or brigade themselves according to government policies. The commune and county governments were , however, not free in transmitting and making decisions. They had to follow orders from higher levels of governments (Carter and Zhong, 1988).

Farmers working under the supervision of a team leader were credited with work points for a day's work that they had done. At the end of a year, net team income was first distributed among team members according to basic needs, then the rest was distributed according to the work points that each member had accumulated during the year (Lin, 1988).

Agricultural products were marketed under three categories according to the nature of the products and the extent of importance to the economy. The products in the first category included grain, cotton, velvet, and vegetable oil crops and were classified as "state monopoly purchasing and marketing" goods. The government assinged a procurement quota to each group producers: Communes, brigades or teams, specifying how much must be sold to the state at what prices. The producers had an obligation to fulfill the quota requirements unless a serious disaster occurred. The government offered an above-quota price, for extra delivery. In the case of grain, this price was 30 percent higher than the quota price (Carter and Zhong, 1988). The government also set a total grain output target based on historical production figures. Both the procurement quota and output target were normally fixed for a three or five year period. If the actual output exceeded substantially the target, 30 percent of the above-target output was regulated to be sold to the state at the above-quota price. During the 1970s, the additional sale were purchased at a "negotiated price", which was also set by the government. It was 20 percent higher than the above-quota price (Carter and Zhong, 1988). In the case of cotton, all output must be sold to the state except a small amount left for the farmer's own use. This amount was also set by the government (Walker, 1984).

The second category comprised of over 70 farm and sideline products such as pork, beef, mutton, eggs, and tea (Duan, 1987). The products under this category were called "fixed quota purchasing" goods. The compulsory purchasing quotas and prices for these products were also set by the government. The remaining outputs were permitted to be sold in local markets.

The rest of the agricultural products belonged to the third category. There were no compulsory quotas or prices imposed on these products. Since long distance transportation and external marketing were prohibited, the state commerce agency was the main or even the sole buyer of products in both the second and the third categories. The state prices were thus dominant in the local markets.

The transactions in factor markets, such as land market, labor market, and private credit market, were all prohibited.

3.1.2 System between 1978-1984

In late 1978 when China started an agricultural reform, various production responsibility systems were introduced modifying the commune system. The production target was not compulsory any more. Production teams and individual farmers could make decisions regarding their own production measures. Production teams were allowed to allocate resources to diversified activities and to internally adopt various forms of responsibility systems as long as they could fulfill the quota and above-quota purchases and meet the social welfare requirements imposed by the commune and brigade. In the meantime, the prices of 18 major farm products increased by 24.8 percent on average, which resulted in a 22.1 percent increase in the agricultural price index. The grain quota price, among others, was raised by 20 percent on average. The former above-quota purchase and negotiated purchase was combined into new category which was also referred to as negotiated purchase. And the negotiated prices was set at 50 percent over the new quota price (Carter and Zhong, 1988).

By 1983, the "full responsibility system" turned out to be the most appropriate one. Under this system, a farm household was allocated a parcel of collective land to farm, a herd of livestock to raise, or a piece of machinery to provide service for other members in the team. In return, the household was obligated to fulfill the state quotas and meet the collective welfare requirements. The surplus was then within the farmer's discretion. They could use the surplus for their own consumption or dispose of in local markets or state negotiated purchases.

The transactions of factors, such as hiring labor, subleasing land, private lending money at high interest, were still explicitly forbidden in this period.

3.1.3 System after 1984

Begining in 1985, the state monopoly for purchasing and marketing of major farm products except for individual varieties, such as tobacco, was abolished. A system of purchasing under contracts and on the free markets for grain and cotton was introduced. Before the sowing season, the state and farmers signed purchase contracts specifying the quantity and price of grain or cotton to be delivered to the state. Both the quantity and price are set by the state with the price somewhat lower than that in the free markets (An, 1989). The new grain price equates the weighted quota and above-quota prices, with the former accounting for 30 percent and the latter 70 percent (Carter and Zhong, 1988). As for the price of cotton, 30 percent is purchased in north China at the state purchase price and the rest can be sold at the above-quota price. In the south, 60 percent of cotton is bought at the state price and 40 percent at the above-quota purchase price (Duan, 1987).

All products not purchased under the contract were disposed of in free markets. The state could buy this surplus in the free markets at the market prices. If the market prices are lower than the state purchase price, the state has an obligation to buy the entire quantity at state prices (Cheng, 1985). Table 3.1 describes the data on total grain production and different grain marketing channels.

The fixed quota purchase system for pigs, aquatic products, beef, mutton, poultry, eggs, vegetable and other non-staple foods was also abolished. Selling prices are decontrolled, free markets are opened and prices are determined by supply and demand.

The system of state monopoly for purchasing timber was replaced by the system of state negotiated purchase at the negotiated price. The system of state monopoly for purchasing Chinese medical herbs was also removed and free purchase and

Table 3.1. Grain production and marketing channels[a]

Year	Grain[b] Production	Total[c] Sale	Average[c] Price	Negotiated[d] Sale	Negotiated[d] Price
1978	304.765	50.73	0.263	1.33	0.520
1979	332.115	60.10	0.331	4.77	0.518
1980	320.555	61.29	0.361	8.40	0.510
1981	325.020	68.46	0.382	9.77	0.520
1982	354.500	78.06	0.392	14.64	0.501
1983	387.275	102.49	0.393	16.36	0.509
1984	407.305	117.25	0.395	19.83	0.561
1985	379.108	107.63	0.416	22.86	0.511
1986	391.512	115.16	0.466	25.99	0.520
1987	402.977	120.92	0.509	29.02	0.620
1988	394.081	119.95	0.564	32.05	0.707

[a]Quantities in million tons and prices in Yuan/kg.

[b]Raw grain and collected from Statistical Yearbook of China, 1988 and 1989.

[c]Collected from China Trade and Price Statistics, 1988.

[d]Collected from China Trade and Price Statistics, 1952-1983. The quantities from 1984 to 1988 are estimated by regression and the prices for years 1984 to 1988 are set equal to market prices.

Table 3.1. (continued)

Year	Quota[e] Sale	Quota[f] Sale	Market[g] Sale	Market[g] Price
1978	48.20	0.256	1.20	0.692
1979	53.33	0.300	2.00	0.625
1980	49.79	0.304	3.10	0.581
1981	55.09	0.316	3.60	0.581
1982	59.17	0.358	4.25	0.581
1983	81.63	0.329	4.50	0.587
1984	92.67	0.319	4.75	0.561
1985	79.27	0.388	5.50	0.511
1986	82.87	0.454	6.30	0.520
1987	85.29	0.506	6.61	0.620
1988	81.18	0.580	6.72	0.707

[e]Calculated by the formula:
Quota Sale = Total Sale - Negotiated Sale - Market Sale.

[f]Prices for year from 1978 to 1984 are collected from China Trade and Price Statistics, 1988. Prices of 1985 to 1988 are calculated by the formula:
Quota Price = (Total Sale * Average Price - Negotiated Sale * Negotiated Price - Market Sale * Market Price) / Quota Sale.

[g]Collected from various issues of Statistical Yearbook of China.

marketing become legal except for those products under strict control for protecting natural resources. The state monopoly in trade tobacco are kept in effect. Tobacco is treated differently according different varieties. A mandatory purchase plan is drawn up by the state and transactions in tobacco is handled by designated state commercial companies, but the purchase price has been raised somewhat.

All other farm products are no longer subject to state monopolies. The farmers can sell their products freely and all commercial agencies are allowed to buy farm products directly from farmers. The state is not the sole buyer and seller of farm products any more.

To promote grain production, as sufficient grain supply has been the major concern of the policy makers, the state uses input subsidies. These have included preferential supplies of chemical fertilizers, improved seed varieties, and other means of production at lower prices. State loans at low interest rate are also available for the grain producers.

Factor transactions, namely land, labor, and private credit, were legalized but in limited extent and restrict forms. Land can not be bought or sold as before. Land transactions are in fact to shift the right to use the land and take place in two forms. The first form is the one without compensation. In this case, farmers can either give their land back to collective (former production team which is altered to village) or give it to relatives or friends. Households still hold their claim over the right to use the land. This means that they can take land back whenever they desire. The transactions can be compensated if the land is leased out. Rent or sharecropping are the two common ways to be compensated.

Labor transactions are also legal now. But the up limit to hire labor is set at eight workers. As other output and factor markets are open, credit with high interest rate is no longer prohibited (Chen, 1987).

3.2 Economic Implications

As the household responsibility system restored the individul household as the basic unit of production and accounting and the new system brings the decision making power back to the farmers, the farmers are now responsible for profits and losses from their own performance. Maximum attainable profits become farmers' objectives.

In the environment of mixed system of planning and markets, the farmers must behave in accordance with the rules of the markets because the marginal decisions involve whether to purchase or sell on the markets upon the relative prices on the markets given the government intervention.

Although the state prices and quotas do not affect producer marginal decisions, they do matter in determining producer maximum attainable profits. Because producer profits will turn to zero in a competitive and certainty world, the state prices and quotas and production expenditures together determine if the producers desire to produce more than the quotas. Thus, state prices and quotas do have indirect impacts on production. Furthermore, if producers are subject to uncertainty, the state prices and quotas, in addition to the market prices, do have effects on marginal decision making. Since the real world is, more or less, characterized by uncertainty either in production or price, especially the agricultural production is subject to uncertain factors such as weather, the state prices and quotas do influence agricultural production.

Transactions in land, labor, and credit, even if it is limited somewhat, give rise to allocate resources efficiently. If the transactions are costless, certain, unconstrained, and enforceable, then marginal products will be brought into equality by market transactions. Production specialization and diversification are encouraged in line with local comparative advantages. The economy as a whole is thus running more efficiently.

4 THEORETICAL SUPPLY MODEL

This chapter will develop a theoretical supply side model incorporating the current Chinese economic system and major agricultural policy instruments. The chapter begins with the description of a theoretical profit function for the Chinese farmers. The producer risk preferences are then introduced into the model. Finally, the implied output supply and input demanad equations are derived and discussed.

4.1 Decision Rules Under Certainty

4.1.1 A primal approach

Consider a price-taking farm producing n outputs with m inputs and k fixed inputs and exogenous variables. The production function in implicit form is given by

$$(4.1) \qquad F(y_1,\ldots,y_n,x_1,\ldots,x_m) = 0.$$

The implicit production function is assumed to have continuous first and second order partial derivatives that are different from zero for all its nontrivial solutions. It is assumed that (4.1) is an increasing function of the y's and a decreasing function of the x's. Finally, it is assumed that (4.1) is regular strictly quasi-convex over a relevant domain.

Under the current mixed system of planning and markets, the Chinese farmers are presumed to maximize profit

$$(4.2)\quad \Pi = P'*Y_f + P_s'*Y_s - W'*X$$

where Π is profit; P and P_s are nx1 vectors of market prices and state prices of outputs, respectively; W is a mx1 vector of variable input prices; Y_f and Y_s are nx1 vectors of outputs sold in free markets and to the state, respectively; and X is a mx1 vector of variable inputs. The producer maximization of profit is subject to its technology characterized by the implicit production function, output quotas Y_s, sold to the state at the state prices, and input constraints.

Since $Y_s + Y_f = Y$, where Y is a nx1 vector of total output, let assume that $Y_f > 0$, $Y_s = Y_s$, and inputs are not binding. Substituting these assumptions into Equation (4.2), the profit can be rewritten as:

$$(4.3)\quad \Pi = P'*Y - (P - P_s)'*Y_s - W'*X.$$

The question is what is $(P - P_s)*Y_s$? In Figure 4.1, S represents the supply curve of output and D the demand curve of the output. P and Y are the observed market equilibrium price and quantity. In line with the state price P_s producers are required to supply Y_s, and $Y_f = Y - Y_s$, the output sold in the free markets. The shaded area, $(P - P_s)*Y_s$ is thus the change in producer surplus due to mandatory selling Y_s to the state at

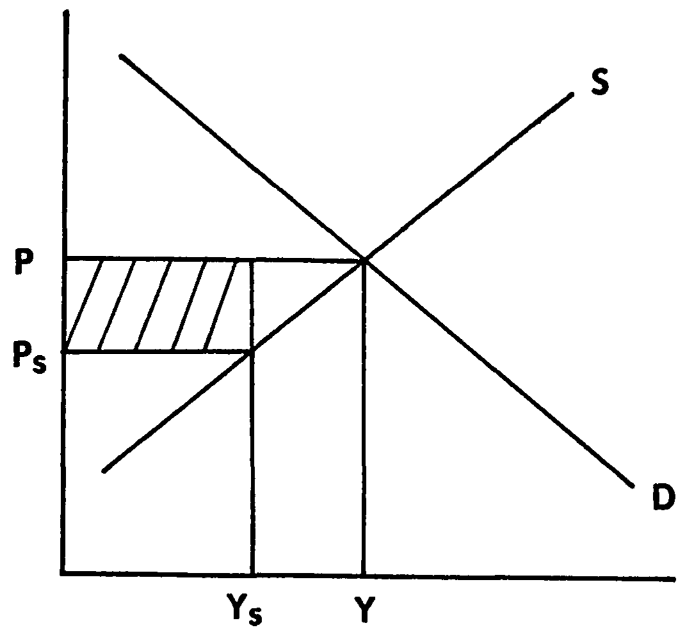

Figure 4.1. Producer equivalent income variation

price P_s, lower than the market price P. To better interpret this model, we could define $(P - P_s)*Y_s$ as equivalent income variation for output Y denoted by EIV. As long as the supply curve is observable, EIV is measurable. The level of EIV is negatively related to maximum attainable producer profits. Thus, EIV works like producer tax dispensing with producer equivalent income variation. Based on the discussion, Equation (4.3) can be modified as:

$$(4.4) \quad \Pi = P'*Y - W'X - EIV',$$

and apart from including the surplus measure, is of standard form.

The Lagrange function for this problem is given by

$$(4.5) \quad L = P'*Y - W'*X - EIV' + \lambda F(y_1,\ldots,y_n,x_1,\ldots,x_m).$$

Take the first order partial derivatives and set each of them equal to zero:

$$(4.6) \quad \begin{aligned} &\partial L / \partial y_i = p_i + \lambda F_i = 0 && i = 1,\ldots,n \\ &\partial L / \partial x_j = - w_j + \lambda F_j = 0 && j = 1,\ldots,m \\ &\partial L / \partial \lambda = F(y_1,\ldots,y_n,x_1,\ldots,x_m) = 0 && \end{aligned}$$

where F_i and F_j are the partial derivatives of (4.1) with respect to its respective argument. The second order conditions for the maximization of profit require that the relevant bordered Hession determinants alternative in sign. Then, the following relations can be derived from these first order conditions:

$$p_i / p_k = F_i / F_k = - \partial y_k / \partial y_i \qquad j, k = 1,\ldots,n$$

$$(4.7) \quad w_j / p_k = - F_j / F_k = \partial y_k / \partial x_j \quad \text{or} \quad w_j = p_k (\partial y_k / \partial x_j)$$

$$j = 1,\ldots,m \text{ and } k = 1,\ldots,n$$

$$w_j / w_k = - \partial x_k / \partial x_j \qquad j, k = 1,\ldots,m.$$

Equation (4.7) states that the necessary conditions for profit maximization require that: (1) the rate of product transformation between every pair of outputs equals their price ratio, (2) the value of the marginal product of each input with respect to each output equals the input price, and (3) the rate of technical substitution between every pair of inputs equals their price ratio.

It is of interest to note that because market prices are higher than state prices for outputs, producer's marginal decisions do not involve the state prices and quotas, that is, state prices and quotas have no impacts on the marginal decision making. It is only market prices that matter in making marginal decision for output supply and input demand if $Y > Y_s$.

Assuming the second order conditions are satisfied, the output supply and input demand functions can be derived from (4.6):

$$Y^* = f(P,\ W)$$

(4.8)

$$X^* = f(P,\ W)$$

and the profit function is

$$(4.9)\quad \Pi(P,W,EIV) = P'{*}\ Y^* - W'{*}X^* - EIV'.$$

It is clear that profit at the maximum is related to not only market prices but also the state prices and quotas reflected in the term of EIV. It is in this way that state prices and quotas matter in determining maximum attainable profit.

The profit maximizing producer will respond to changes in input and output prices by varying his or her input and output level in order to continue to satisfy the necessary conditions. An increase of the jth output price, with other prices constant, will always increase the production of the jth output. An increase of the ith input price, with other prices unchanged, will always decrease the use of the ith input. Most of the cross effect may be of either sign depending upon the particular form of the implicit production function. Nevertheless, these cross effects are symmetry in nature. Furthermore, once a strictly positive output and variable input level have been chosen, they are unaffected by any changes in fixed inputs and exogenous variables (Henderson and Quandt, 1980), here are state prices and state quotas in question.

4.1.2 A dual approach

It is known that in a competitive world with regular technology, there is one-to-one correspondence between the production technology and the dual profit function. The production technology can be examined directly in a primal framework or indirectly by a dual approach. The output supply and input demand relationships derived using the two approaches are identical. Consider the same farm with n outputs, m inputs, and k fixed inputs and exogenous variables. The variable, or restricted profit function is given by

$$(4.10)\quad \Pi(P,W,F) = \max_{Y_f,X} [P'*Y_f + P_s'*Y_s - W'*X;\ (Y,X,F)\epsilon T]$$

where F is a kx1 vector of fixed inputs or exogenous variables, and T is the farm's production possibility set. All other variable definations are the same as those in (4.2). Given the assumptions made for Equation (4.3), the profit function can be rewritten as:

$$(4.11)\quad \Pi(P,W,EIV,F) = P'*Y - W'*X - EIV',$$

and again, it is of standard form except for including an additional term of the surplus measure.

The profit function possesses the properties described in Chapter 2.1: (1) It is a non-negative real valued function for all positive prices; (2) it is homogeneous of degree one in all prices; (3) it is convex and continuous in P and W for every fixed input; (4) it is nondecreasing in output prices and nonincreasing in input prices; and (5) it is differentiable only if there exists a unique profit maximizing supply and input demand.

If the function is differentiable then

$$\partial\Pi \,/\, \partial W = -\, X^*,$$

$$\partial\Pi \,/\, \partial P = Y_f^*,$$

(4.12)
$$\partial\Pi \,/\, \partial P_s = Y_s, \text{ and}$$

$$Y^* = Y_s + Y_f^*,$$

where X^* is optimal input demand, Y_f^* is optimal output supply in free markets, and Y^* is optimal total output supply. This property is referred to as Hotelling's lemma. These supply and input demand equations are the derivatives of profit function rather than the solution to a constrained profit maximization problem. However, these equations are consistent with maximization behaviors.

Two additional properties are observed. One is that the matrix of second order derivatives of $\Pi(.)$ with respect to P and W is positive semidefinite. Another one is that, by Young's theorem in calculus, cross partial derivatives are equal (see (2.11) and (2.12)). These two properties imply that the comparative static results derived using a dual approach are the same as those derived in a primal framework. An increase of the ith output price, with other prices unchanged, will always increase the supply of the ith output. An increase of the jth input price, holding other prices constant, will always decrease the use of jth input. Although the cross effects may be either sign, they must be symmetry. And changes in fixed inputs or exogenous variables do not have effects on the optimal output supply and input demand levels.

4.2 Decision Rules Under Uncertainty

The existence of guaranteed minimum price alters the original market price distribution to a truncated one. If a random price received by farmers for output over state quota, FP is defined such that:

$$(4.13) \qquad FP = \begin{cases} P_m & \text{if } P \le P_m \\ P & \text{if } P \ge P_m \end{cases}$$

then the truncated cumulative propability density function, G(FP) is defined as:

$$(4.14) \qquad G(FP) = \begin{cases} F(P_m) & \text{if } P \ge P_m \\ F(P) & \text{if } P \le P_m \end{cases}$$

and the expected price received by farmers, E(FP) can be expressed as:

$$(4.15) \quad E(FP) = F(P_m) * P_m + \int_{P_m}^{\infty} Pf(P)dP,$$

where P_m is the minimum price guaranteed by the state, P is random unknown market price, $F(P_m)$ is subjective cumulative function of P_m, F(P) is subjective cumulative function of P, f(P) is subjective probability density function of P.

This system is illustrated in Fiqure 4.2. The minimum price is the truncated point for the original price distribution. The cumulative probability that the price will fall below P_m is represented by the hatched area. The probability equal to $F(P_m)$ is assigned at $P = P_m$ in the truncated process. It is clear that the minimum price changes the first moment of the price distribution, the expected price, and the higher order moments of the unknown price.

When producers are subject to uncertainty, it is assumed that the objective of the farm is to maximize the expected utility of profits and the producer obeys the von Neumann-Morgenstern axioms. The utility function of the farm is concave, continuous, and differentiable function of profits, such that

$$(4.16) \quad \partial U / \partial \Pi > 0 \quad \text{and} \quad \partial^2 U / \partial \Pi^2 < 0.$$

Thus, the producer is assumed to be risk averse. Furthermore, it is assumed that production is certain while price is

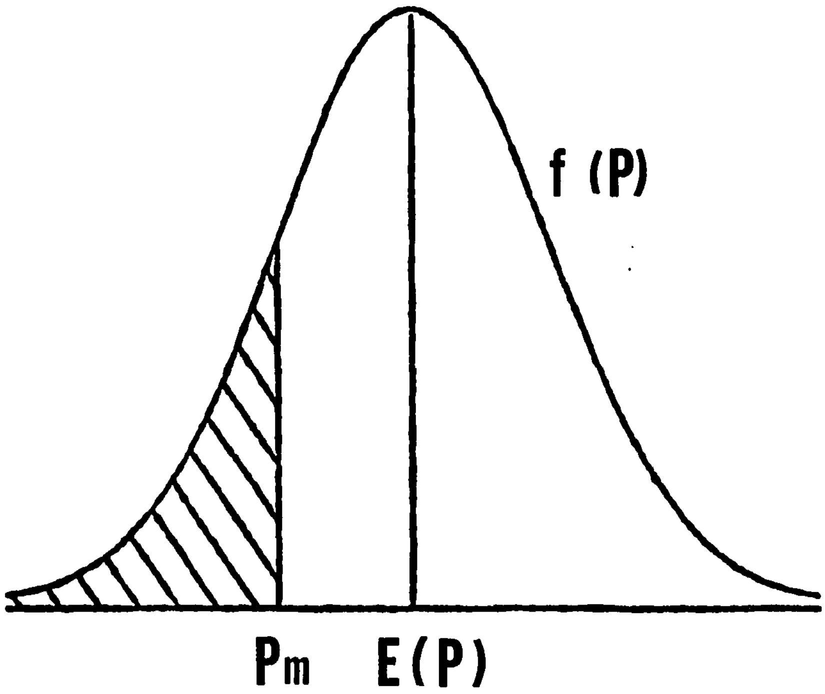

Figure 4.2. Truncation of a hypothetical probability distribution of market price

uncertainty. The producer's profit is given in Equations (4.2), (4.3), and (4.4).

4.2.1 A primal approach

Consider a price taking and risk averse farm producing n outputs with m variable inputs, and k fixed inputs and exogenous variables. The producer implicit expected utility function of profit is defined as:

$$(4.17)\quad E[U(\Pi)] = U[P_m'{*}Y - (P_m - P_s)'{*}Y_s - W'{*}X]F(P_m) + \int_{P_m}^{\infty} U[P'{*}Y - (P - P_s)'{*}Y_s - W'X]f(P)dP,$$

where U denotes a strictly concave von Neumann-Mergenstern utility function, Π is profit, P and P_s are nx1 vectors of market prices and state prices of outputs, respectively, Y and Y_s are nx1 vectors of total outputs and outputs sold to the state at the state prices, respectively, W is a mx1 vector of input prices, X is a mx1 vector of variable inputs, P_m is a nx1 vector of minimum prices of outputs, $F(P_m)$ is subjective cumulative probability function of P_m, and f(P) is subjective probability density function of P.

The first order conditions for this optimization problem are:

$$(4.18)\quad dE[U(\Pi)]/dY = E[U]'_{pm}P_mF(P_m) + \int_{pm}^{\infty} U'Pf(P)dP$$

$$(4.19)\quad dE[U(\Pi)]/dX = E[U]'_{pm}WF(P_m) + \int_{pm}^{\infty} U'Wf(P)dP$$

where the subscript P_m behind E[U]' means the derivative is evaluated at the profit level corresponding to the guaranteed minimum price.

Equations (4.18) and (4.19) show that producer decisions involve not only expected market prices, but also the state prices, minimum prices, the state quotas, and some terms that characterize the stochastic properties of prices other than their means, say ψ. Setting these first order conditions equal to zero and solving them simultaneously, we derive the optimal output supply and input demand functions as:

$$(4.20)\quad \begin{aligned} Y^* &= f(\overline{P}, W, P_s, X_s, P_m, \psi) \\ X^* &= f(\overline{P}, W, P_s, X_s, P_m, \psi) \end{aligned}$$

and the implicit expected utility function of profit is

$$(4.21)\quad E[U(\Pi)] = f(\overline{P}, W, P_s, X_s, P_m, \psi).$$

4.2.2 A dual approach

In the framework of a dual approach, we can specify a specific direct expected utility functional form

$$(4.22)\quad E[V(\Pi)] = \overline{\Pi} + \sum_{t=2}^{T} \alpha_t \sigma_t$$

where V denotes the indirect utility function, Π stands for profit, σ_t represents the t-th central moment of Π. Note that Π is random because prices are random. Assuming that the second term in Equation (4.22) contains only the second central moment of Π, then the variance of Π, σ_Π is given by

$$(4.23)\quad \sigma_\Pi = Y^2\sigma_p{}^2 + X^2\sigma_w{}^2 + 2YXCov(P,W)$$

where $\sigma_p{}^2$ is variance of output price, $\sigma_w{}^2$ is variance of input price, and Cov(P,W) is covariance of P and W. Substituting expected profit in Equation (4.3) and (4.23) into (4.22) yields

$$(4.24)\quad E[V(\Pi)] = E(P)Y - E(W)X - E(EIV) + \alpha^2\sigma^2.$$

In this study, producers are assumed to be risk averse and display nonincreasing absolute risk averse. The expected direct utility function given in Equation (4.24) satisfies all the conditions [1] to [4] and assumptions developed in Chapter 2. These conditions and assumptions imply that producers are constant risk averse. If producers are constant risk averse, then following functions can be arrived by Pope's corollary:

$$(4.25)\quad \begin{aligned} \partial E[U(\Pi)] \,/\, \partial\overline{W} &= -\,X^*, \\ \partial E[U(\Pi)] \,/\, \partial\overline{P} &= Y_f{}^*, \end{aligned}$$

$$\partial E[U(\Pi)] \; / \; \partial P_s = Y_s, \text{ and}$$

$$Y^* = Y_f^* + Y_s.$$

and the symmetry conditions remain. These results are held when changes in expected prices has no impacts on other t-th central moments of prices. X^* is input demand function and Y^* is output supply function.

4.3 Comparative Static Analysis

The producer desires to maximize profit subject to technology possibility set. The neccesary conditions for profit maximization require that: (1) the rate of product transformation between every pair of outputs equals their price ratio, (2) the value of the marginal product of each input with respect to each output equal the input price, and (3) the rate of technical substitution between every pair of inputs equal their price ratio (Henderson and Quandt, 1980).

The profit maximizing producer will respond to changes in input and output prices by varying his or her input and output level in order to continue to satisfy the neccesary conditions. An increase of the jth output price, with other prices constant, will always increase the production of the jth output. An increase of the ith input price, with other prices unchanged, will always decrease the use of the ith input. Most of the cross effect may be of either sign depending upon the particular form of the implicit production function. Nevertheless, these cross effects are symmetric in nature. Furthermore, once a strictly positive output and variable input level have been chosen, they are unaffected by any changes in fixed inputs and exogenous variables.

When producers are subject to uncertainty, however, meaningfull comparative static results are not as easily derived as under certainty. Previous studies (Sandmo, 1971; Batra and Ullah, 1974) have shown that simply assuming risk aversion is a very weak restriction on the farm's attitudes to risk. Sandmo (1971) and Batra and Ullah (1974) verified that nonincreasing absolute risk aversion is a sufficient condition for an upward sloping supply curve and downward sloping input demand curve. Sandmo and Ullah also showed that unlike under certainty, changes in fixed input do have impacts on the positive optimal output and input levels. Employing envelope theorem, Pope (1980) found that if producer is constant absolute risk aversion, the expected utility function is separable, and the ratio of the effects of changes of input price to the effect of changes of output price on optimal output is equal to the ratio of optimal input level to optimal output level (see [1], [2], and [4] in Chapter 2.2), the symmetry conditions will hold when risk aversion prevails.

For the comparative static analysis of present study, let start with one output case. The results are then needed to be extended to multiple product analysis. It is assumed that the producer produce one single output with capital, K, and labor, L, as inputs. The capital input is assumed to be quasi fixed while the labor input is assumed to be completely variable. By this, we mean that the capital input is purchased before the output price uncertainty is resolved, but the labor input is chosen until after it is resolved. It is also assumed that the producer has a subjective probability distribution for output price, P, before it is actually observed. Finally, it is assumed that capital price, Z, and wage rate, W, are known with certainty.

Since the labor input is chosen after the capital input has been determined and after the output price is known, labor will be chosen to maximize short-run profits,

$$(4.26) \quad \Pi = PY(K,L) - WL - EIV.$$

where EIV is the equivalent income variation of the output. The first-order condition for this optimization is

$$(4.27) \quad \partial\Pi / \partial L = P\, \partial Y / \partial L - W = 0,$$

which can be solved for the optimal labor input demand,

$$(4.28) \quad L^* = f(K, P, W).$$

Substituting L^* into (4.26) yields the short-run profit function,

$$(4.29)\quad \Pi(K,P,W,EIV) = PY(K,L^*(K,P,W)) - WL^*(K,P,W) - EIV$$
$$= G(K,P,W) - EIV.$$

If the producer uses labor optimally in the short-run, long-run profits are

$$(4.30)\quad \Pi = G(K,P,W) - ZK - EIV.$$

At the time the capital input is chosen, Π is clearly a random function because P is a subjective random variable. The producer is assumed to be risk averse. In the long run, the producer will choose capital input to maximize the expected utility function of profits,

$$(4.31)\quad EU(\Pi) = EU[G(K,P,W) - ZK - EIV],$$

where U is a strictly concave von Neumann-Morgenstern utility function.

The first order condition with respect to K gives

$$(4.32)\quad \partial EU / \partial K = E[U'(\Pi)(P\ \partial G / \partial K - Z)] = 0.$$

The capital input demand function is then derived by solving (4.32),

$$(4.33)\quad K^* = f(\overline{P},\ W,\ Z,\ EIV,\ \psi),$$

where $\overline{P}$ is expected output price, and ψ is the terms of other moments of output price distribution. The output supply function is given by

(4.34) $Y^* = f(\bar{P}, W, Z, EIV, \psi)$.

Above analyses give rise to the fact that under current mixed planning and market system with uncertainty output price, not only the market prices but also the state prices and quotas affect the marginal decision for output supply and input demand for capital through their impacts on producer income--equivalent income variation if $Y^* > Y_s$.

The following comparative static results can be derived from Equation (4.32):

$$\partial K^* / \partial P_s = - EU_{kps} / EU_{kk} \geq 0$$

$$\partial K^* / \partial Y_s = - EU_{kys} / EU_{kk} \leq 0$$

(4.35)
$$\partial K^* / \partial Z = - EU_{kz} / EU_{kk} \leq 0$$

$$\partial K^* / \partial W = - EU_{kw} / EU_{kk} \ ? \ 0$$

$$\partial K^* / \partial \bar{P} = - EU_{k\bar{p}} / EU_{kk} \geq 0.$$

Since EU_{kk} is negative for maximization, the signs in (4.35) are the same for the numerators. The derivatives of EU_k with respect to P_s, Y_s, Z, W, and $\bar{P}$ are shown below:

$$EU_{kps} = E[U''(\Pi)(P\ \partial G / \partial K - Z)(\partial \Pi / \partial EIV)$$
$$(\partial EIV / \partial P_s)] \geq 0$$

$$EU_{kys} = E[U''(\Pi)(P\,\partial G / \partial K - Z)(\partial\Pi / \partial EIV)$$

$$(\partial EIV / \partial Y_s)] \leq 0$$

$$(4.36) \qquad EU_{kz} = E[U''(\partial)(P\,\partial G / \partial K - Z)K + U'(\partial)(-1)] \leq 0$$

$$EU_{kw} = E[U''(\partial)(P\,\partial G / \partial K - Z)\partial G / \partial W$$

$$+ U'(\partial)P\,\partial^2 G / \partial K\partial W] \;?\; 0$$

$$EU_{kp} = E[U''(\Pi)(P\,\partial G / \partial K - Z)\;\partial\Pi / \partial\bar{P}$$

$$+ U'(\Pi)(\,\partial G / \partial K + P\,\partial^2 G / \partial K\partial\bar{P})] \geq 0.$$

Note that nonincreasing absolute risk aversion is a necessary and sufficient condition for these signs. For the proof and discussion of these results see Sandmo (1971) and Batra and Ullah (1974). Because the production function is assumed to have positive marginal product of its input, same comparative static results can be derived for the output supply.

The relation between capital input demanded and expected output price can also be expressed explicitly,

$$(4.37) \qquad \partial K^* / \partial\bar{P} = \partial K^* / \partial\bar{P} + (\partial K^* / \partial EIV)(\partial EIV / \partial\bar{P}),$$

that is changes in expected output price have two effects, direct and indirect. The indirect effect through equivalent income variation shows how the producers respond to the changes in expected market price as a result of anticipated income effect. Note that the indirect effect will vanish if the state and expected market prices change by the same amount, given the state quota Y_s. This is because the negative effects of changes in the state price and positive effects of changes in expected market price are cancelled.

There are many ways in which this analysis can be extended and generalized over the farm with multiple outputs and multiple inputs. Because producers are able to spread risks by output diversification, it is particular interest to explore the comparative static analysis under uncertainty.

The mathematical derivation of the comparative static results in the case of multiple outputs and multiple inputs must be very complicated. However, by explorting into the implication of convexity of utility function of profits as implied by maximization of expected utility and imposing condition of nonincreasing absolute risk aversion, the supply curves are upward sloping and input demand curves are downward sloping. This implies that an increase of the ith output price, giving other prices constant, will always increase the supply of ith output. An increase of jth input price, with other prices unchanged, will always decrease the use of the jth input. The cross effects are indeterminant depending on the particular production possibility set and the way the producer to spread the risks over the multiple outputs and multiple inputs. Under the assumption of constant absolute risk aversion, the symmetry cross signs are preserved.

4.4 Supply and Input Demand Equations

The present study assumes that the producer is risk averse and displays constant absolute risk aversion. To be consistent with these assumptions, an expected utility function of profits in (2.27) is employed to represent the producer risk preference and a normalized quadratic functional form is used to represent variable profit function. The profit function is assumed to be normally distributed with mean μ and variance σ^2. And the mean is equal to the expected value of profits.

The expected utility function of profit which is of normalized quadratic form is as follows:

$$
\begin{aligned}
(4.38)\quad E[U(\Pi)] = {} & \alpha_o + \sum_{i=1}^{q-1} \alpha_i EP_i + \sum_{k=1}^{K} c_k Z_k + \sum_{g=1}^{G} d_g EIV_g \\
& + \sum_{i=1}^{q-1} \sum_{l=1}^{q-1} b_{ij} EP_i EP_j + \sum_{k=1}^{K} \sum_{l=1}^{L} e_{kl} Z_k Z_l \\
& + \sum_{g=1}^{G} \sum_{h=1}^{H} f_{gh} EIV_g EIV_h + \sum_{i=1}^{q-1} \sum_{k=1}^{K} g_{ik} EP_i Z_k \\
& + \sum_{i=1}^{q-1} \sum_{g=1}^{G} h_{ig} EP_i EIV_g + \sum_{k=1}^{K} \sum_{g=1}^{G} l_{kg} Z_k EIV_g + \sum_{t=2}^{T} \alpha_t \sigma_t
\end{aligned}
$$

where EP_i's are the expected prices of outputs and inputs, Z_i's are fixed inputs and exogenous variables, σ_t represents the t-th central moment of profit distribution, and α, β, c, d, e, f, g, h, and l are parameters to be estimated. All others are the same as defined in previous discussion.

Assuming that changes in expected market prices have no impacts on the second- and higher-order central moments, by Pope's corollary, the derivative of E[U] with respect to normalized expected output price gives optimal supply and derivative of E[U] with respect to normalized expected input price yields optimal (negative) input demand as follows,

$$(4.39) \quad Y_i = Y_{si} + Y_{fi}$$

$$= \alpha_i + \sum_{j=1}^{q-1} b_{ij}EP_j + \sum_{g=1}^{G} h_{ig}EIV_g + \sum_{k=1}^{K} g_{ik}Z_k \qquad i=1,\ldots,n$$

$$(4.40) \quad -X_i = \alpha_i + \sum_{j=1}^{q-1} b_{ij}EP_j + \sum_{g=1}^{G} h_{ig}EIV_g + \sum_{k=1}^{K} g_{ik}Z_k \qquad i=1,\ldots,m-1$$

$$(4.41) \quad -X_n = \alpha_o - 0.5 \sum_{i=1}^{q-1} \sum_{j=1}^{q-1} c_{ij}EP_iEP_j + \sum_{k=1}^{K} g_kZ_k.$$

Equations (4.39) through (4.41) are the system of supply and input demand equations to be estimated subject to all the theoretical restrictions of monotonicity, homogeneity, symmetry, and convexity.

5 DATA AND ESTIMATION

This chapter describes the data set used for the estimation. This description is followed by a discussion of the aggregation procedures used for the data aggregates. Finally, the procedure of estimation of the empirical analysis of the supply module for the Chinese agriculture is expressed.

5.1 Data

Aggregate annual agricultural data for China were used in the estimation. The sample period covers years from 1978 to 1988. Endogenous variables consist of seven outputs (n=7): grain protein feed, other food products, nonfood agricultural products, bovine and ovine meat, dairy products, and other meat; two variable inputs: fertilizer and feed. Thirteen exogenous variables include prices of outputs and inputs, two fixed inputs --land and animal inventory, equivalent income variation of grain, and a time variable representing technological changes over time (m=13). Table 5.1 gives the variable definitions, units, and sources of data.

Data for grain, fertilizer, animal inventory, and land were collected from various issues of Statistical Yearbook of China and China Trade and Price Statistics. Since these data are directly available, aggregation of data over commodities is not necessary. The remaining data on outputs and inputs, however,

Table 5.1. Variable definitions, units, and sources of data

Name	Explanation	Units	Sources
GRAIN	Grain, production	Million tons	SYC[a]
PFDFC	Protein feed from crops, production	Million ton protein	Derived[b]
OFDFC	Other food from crops, production	Million 1000 Yuan[c]	Derived[b]
NFDAG	Nonfood agriculture, production	Million 1000 Yuan	Derived[b]
BOMET	Bovine and ovine meat, production	Million ton carcass weight	Derived[b]
DAIRY	Dairy product, production	Million ton milk	Derived[b]
OTHEM	Other meat, production	Million ton protein	Derived[b]
LNDUS	Land use	Million hecter	SYC
FERUS	Fertilizer use	Million ton	SYC
FEDUS	Feed use	Quantity index	Derived[d]
NANIN	Number of livestock inventory	Million head	SYC
EIVGN	Equivalent income variation of grain	Million Yuan	Derived[e]
GRANP	Grain, market price	Yuan/ton	SYC, CPTS[f]
PFFCP	Protein feed from crops, price	Yuan/unit	Derived[b]
OFFCP	Other food from crops, price	Yuan/unit	Derived[b]
NFDAP	Nonfood agriculture, price	Yuan/unit	Derived[b]
BOMTP	Bovine and ovine meat, price	Yuan/ton	Derived[b]
DAIRP	Dairy product, price	Yuan/ton	Derived[b]
OTHMP	Other meat, price	Yuan/ton	Derived[b]
FERTP	Fertilizer, price	Yuan/ton	SYC, CPTS
FEEDP	Feed, price	Price index	Derived[d]

[a]<u>Statistical Yearbook of China, 1983, 1984, 1985, 1986, 1987, 1988, and 1989.</u>

[b]These data are derived by aggregating various FAO (Food and Agricultural Organization, Rome) and World Bank data series. A more detailed description of data are available with the author.

Table 5.1. (continued)

[c]Chinese currency.

[d]These data derived from data reported in Table A.4.

[e]These data are derived from data series collected from SYC and CPTS and presented in Table 3.1.

[f]*China Trade and Price Statistics, 1952-1983 and 1988.*

are aggregate in nature and data are not available at this level of aggregation. It is thus necessary to arrive the quantity and price aggregates for these groups.

This study follows the aggregation logic and compilation procedure developed by Fischer and Sichra (Fischer and Sichra, 1983). The Supply Utilization Accounts on agricultural products (SUA), the original data published by the Food and Agricultural Organization (FAO) of the United Nations, has been the starting point for the aggregation. Time series about 500 agricultural commodities are covered in the aggregation to arrive at nine target commodities. Six of them are used as remaining outputs in our estimation. They are protein feed from crop, other food from crop, nonfood agricultural products, bovine meat, dairy products, and other meats.

The target commodities represent three types of products. The first one is characterized by alternative derived products. This situation occurs when the higher level commodity is processed in different ways to give various derived products. The second type is called joint derived products. They represent the case when the processing of a commodity results in several derived products simultaneously. The last type is the general case where a commodity A has M jointly derived products and N alternative derived products. The aggregation procedures for different type products are accordingly formulated. For the complete commodity list and detailed aggregation description see Fischer and Sichra.

The group of aggregated grains includes rice, wheat, corn, sorghum, barley, rye, and oats. Soybeans and tubers which are accounted as grain in the Chinese statistics are taken away from the total grain production. The share of soybeans and tubers in total grain is calculated first. Then same share is taken out of the quantities of total supply, sale to the state, and sale in the free market when the model is estimated. By doing so, double accounting of tubers and soybeans is eliminated, since Fischer and Sichra's aggregates include tuber and soybeans already. Table A.1 in Appendix gives the productions of total grain (including tubers and soybeans), tubers, and soybeans as well as the percentage of tubers and soybeans in total grain production.

The grain output sold to the state is set equal to the quota plus above quota levels for the years before 1985, and to the contracted quota thereafter to reflect the policy situation as described in Chapter 3. Similarly, the state price is set equal to the weighted average of quota price and above quota price for the period before 1985, and to the contracted price after that. The market quantity is the sum of the negotiated sale to the state and the sale in free markets. Accordingly, the market price is equal to the weighted average of state negotiated price and free market price. The equivalent income variation is, then, equal to the difference of state price and market price times the state quota. Because the data are not complete, some estimates are used to be the proxy of the missing data. For the complete data used for estimation and calculation formulas see Table A.2 in Appendix.

Fertilizer is one of the important variable inputs in crop production. The elemental nutrients contained in fertilizer are nitrogen (N), phosphoric acid (P_2O_5), and potash (K_2O). Since only the nutrients contained in fertilizer contribute to crop production and different mixed grade fertilizers contain different nutrients or different combination of the nutrients, the quantity of fertilizer use is calculated on the basis of 100 percent effectiveness. This means the total fertilizer input use is the summation of the quantities of actual nutrients. Data of fertilizer consumption calculated on the basis of actual nutrients are collected directly from Statistical Yearbook of China, various issues.

Feed is the most important variable input in livestock production. Various farm products and by products are used as livestock feeds in China. To keep the model manageable, it is desirable treat all kinds of feeds as a composite one. The procedure used to aggregate these feeds into one group will described later on in this chapter.

Land utilization is under restrictive control of the government in China. Land transaction is allowed only recently in limited form and extent so there is no systematic and complete data on the land transaction. As arable land is a critical factor in the Chinese agricultural production, land is treated as a fixed input in the present study. Data on total sown areas of land were collected from the various issues of Statistical Yearbook of China and presented in Table A.2 in Appendix.

Animal inventory at the end of previous year has significant impacts on the livestock production in the following year. The lagged animal inventory is, thus, used as a fixed input in this model. The total animal inventory is the summation of year-end figures of cattle, buffalo, hog, goat, and sheep and were collected from various issues of the Statistical Yearbook of China. Data on the total inventory can be found in Table A.2 in Appendix.

Various technological progress have improved the Chinese crop and livestock productivity. To capture the impacts of such technical advancement on the Chinese agriculture, a time variable is used in all supply and input demand equations to be estimated.

The data of quantities and prices of other six groups of outputs derived using Fischer and Sichra's aggregation procedure are presented in Table A.3 in Appendix. Output and input quantities and their respective prices are scaled such that the units of gross revenues, production times output price, and expenditures, input usage times input price, are always million yuan at current prices. Unlike grain data, the FAO aggregates for these six target commodities are available only for the years prior to 1987. To increase the number of observations, thus add degree of freedom in estimation, the quantities in 1987 and 1988 and prices in 1987 are estimated using time trend method. The estimates are then used as the proxy of these data.

Note that the FAO nine target commodities are arrived from about 500 primary agricultural products. It is not necessary to list all time series of 500 products in Appendix in this study. Interested readers can find these time series data in the Supply Utilization Accounts on agricultural products, the original data published by the Food and Agricultural Organization.

Given these aggregate data, the Tornquist approximation to Divisia index (Tornquist, 1936; Diewert, 1976; Trivedi, 1981) was used as necessary to aggregate price and quantity for feeds which involve most of agricultural products. The Tornquist approximation to Divisia index is as follows:

$$(5.1)\quad D_t = \sum_{i=1}^{N} (1/2)(P_{it}*Y_{it}/E_t + P_{it-1}*Y_{it-1}/E_{t-1})*\mathrm{Log}(P_{it}/P_{it-1})$$

$$(5.2)\quad P_t = P_{t-1} * \exp(D_t),$$

where $E_t = \sum_{i=1}^{N} P_{it} * Y_{it}$, P_{it} is price of ith good in time t, Y_{it} is production of ith good, and P_t is Divisia price index. The implicit quantity index, Y_t is derived by formula:

(5.3) $Y_t = E_t / P_t$.

For the data used to derive Divisia index as well as derived Divisia price index and quantity index are presented in Table A.4 in Appendix.

5.2 Estimation Procedure

Because the model is specified for the current Chinese economy, only observations after 1977 are relevant. Thus, the sample is restricted to years 1978 through 1988. This small sample of observations is a critical and constraining issue in the present study. To accommodate reasonable degrees of freedom in the estimation, simplifying assumptions are made to reduce the number of parameters to be estimated. More specifically, nonjointness between crop and livestock sectors has been assumed and imposed in the estimation.

Because the Chinese government ensures that if market grain price is lower than the state quota price, the government has an obligation to buy all quantities of grains provided by farmers, the state price is, in fact, the floor price. Thus, market grain price distribution has low bound. The expected market price of grain is assumed to be of form:

$$(5.4) \quad E(P_t) = \text{Max}\ (P_{t-1}, P_{st}),$$

that is, farmers' expectated market price of grain is equal to lagged market price if it is higher than what is announced for this year's state price. If the state price which is known when farmers are making production decisions is higher than the market price of last year, farmers are sure that the market price of grain in this year will at least as high as the state price.

The market price distributions for other commodities are quite different because there are no lower bound for these market prices. For these commodities, naive adaptive price expectations are assumed in the present study, that is,

$$(5.5) \quad E(P_t) = P_{t-1}.$$

All prices in crop sector are normalized by the price of nonfood agriculture and all prices in livestock sector are by feed price index. And, hence these equations are homogeneous of degree zero in all prices. This functional form ensures that the profit function is homogeneous of degree one in all output and input prices.

Symmetry of expected utility function in cross partials requires that equations (4.39) to (4.41) are to be estimated subject to the symmetry constraint:

(5.6) $b_{ij} = b_{ji}$ $\forall\ i,j \in [1,\ldots,7]$.

Monotonicity of the profit function implies that the indirect expected utility function is also monotonic when the utility function is of a special form described in Equation (2.36). Monotonicity requires that predicted Y_i and X_i must be nonnegative for all prices. This property can be evaluated at each sample point after the estimated parameters are obtained. There is no need to impose this restriction in priori to the model.

The convexity of indirect utility function is satisfied if the matrix of b_{ij} coefficients in equations to be estimated is positive semidefinite. Thus, supply and input demand equations must be estimated subject to

(5.7) $[b_{ij}]$ is positive semidefinite.

The convexity of the utility function can be checked by evaluation if the matrix of estimated parameters b_{ij}^* is indeed positive semidefinite. This procedure can, however, not impose the property of convexity in the model when it is estimated.

There are two approaches that reparameterize b_{ij} in the equation system subject to condition (5.7) while the system is estimated. One is Cholesky factorization. Another one is eigenvalue decomposition. This study will use eigenvalue decomposition method to impose the restriction of convexity.

The eigenvalue decomposition methodology relies on the property that a real symmetric matrix is positive semidefinite if and only if all its eigenvalues are nonnegative. Following this protocol, the convexity is imposed by restricting the smallest eigenvalue to be nonnegative when matrix $[b_{ij}]$ is reparameterized and implied eigenvalues of the matrix are calculated. Although this procedure requires a lot computation work, the modern computer can handle this job. The parameter estimates subject to all theoretical restrictions are obtained using Fortran-GQ-OPT, version 5.0.

6 EMPIRICAL ANALYSIS AND MODEL EXAMINATION

This chapter provides the empirical estimation results of the theoretical model developed in the previous chapters. The validation of the model is examined following the analysis of the empirical results.

6.1 Output Supply and Input Demand Equations

6.1.1 Output supply and input demand equations of full model

Joint generalized least squares estimates of output supply and input demand equations maintaining homogeneity, symmetry, and convexity are presented in Table 6.1 and Table 2. The t-ratios reported in the parentheses must be interpreted with caution since the sample size is small. These t-ratios may only give us approximations of significance of these estimates.

In the restricted model, all of the own price coefficients of outputs and inputs are positive indicating that an increase of the ith output price will always increase the production of the ith output and an increase of the jth input price wll always decrease the use of the jth input, with other prices constant. This means that the estimated output supply curves are upward sloping and the estimated input demand curves are downward sloping.

Table 6.1. Estimation of output supply and input demand equations of crop model

$$
\begin{aligned}
GRAIN_t = & -14219.00616 + 92.12804 * GRANP_t + 1.33165 * PFFCP_t \\
& \quad (100.969)^{a} \qquad (0.592) \qquad\qquad (0.139) \\
& - 12.57475 * NFAGP_t - 37.30718 * FERTP_t \\
& \quad (0.896) \qquad\qquad (1.934) \\
& - 7.33405 * LNDUS_t + 7.84528 * YEAR_t \\
& \quad (0.859) \qquad\qquad (13.016) \\
& - 2.01601D\text{-}9 * EIVGN_t \\
& \quad (6.917D\text{-}10)
\end{aligned}
$$

R-square = 0.89

$$
\begin{aligned}
PFDFC_t = & -901.71481 + 1.33165 * GRANP_t + 2.28120 * PFFCP_t \\
& \quad (2.224) \qquad (0.139) \qquad\qquad (0.765) \\
& + 0.30490 * NFAGP_t - 12.73605 * FERTP_t \\
& \quad (0.292) \qquad\qquad (1.463) \\
& + 0.10182 * LNDUS_t + 0.45011 * YEAR_t \\
& \quad (0.250) \qquad\qquad (2.176) \\
& - 0.04071 * EIVGN_t \\
& \quad (0.299)
\end{aligned}
$$

R-square = 0.99

[a]Figures in parentheses are approximate and absolute values of t-ratios.

Table 6.1. (continued)

$$NFDAG_t = \underset{(4.777)}{-823.98508} - \underset{(0.896)}{12.57475} * GRANP_t + \underset{(0.292)}{0.30490} * PFFCP_t$$

$$+ \underset{(0.979)}{2.03715} * NFAGP_t + \underset{(0.933)}{2.28610} * FERTP_t$$

$$+ \underset{(0.339)}{0.20682} * LNDUS_t + \underset{(4.246)}{0.40298} * YEAR_t$$

$$+ \underset{(0.648)}{0.15960} * EIVGN_t$$

R-square = 0.86

$$FERUS_t = \underset{(79.274)}{3791.61883} - \underset{(1.934)}{37.30718} * GRANP_t - \underset{(1.463)}{12.73605} * PFFCP_t$$

$$+ \underset{(0.933)}{2.28610} * NFAGP_t + \underset{(2.436)}{87.90501} * FERTP_t$$

$$+ \underset{(0.191)}{0.16029} * LNDUS_t - \underset{(31.646)}{1.93210} * YEAR_t$$

$$+ \underset{(0.528)}{0.19448} * EIVGN_t$$

R-square = 0.98

Table 6.1. (continued)

$$OFDFC_t^{b} = \underset{(5.848)}{-2171.66752} + \underset{(3.086)}{0.64929} * LNDUS_t + \underset{(5.903)}{1.06829} * YEAR_t$$

$$+ \underset{(2.515)}{0.36632} * EIVGN_t - 0.5 \sum_{i=1}^{N-1} \sum_{j=1}^{N-1} b_{ij}\ EP_{it}\ EP_{jt}$$

R-square = 0.86

System statistics:

Log-likelihood value: - 1.839 $R^{2*} = 0.99$[c]

[b]This equation was estimated conditional on the rest of the crop system. Thus, N-1 includes all other netputs in crop sector.

[c]Baxter-Craigg R-square, see text for details.

Table 6.2. Estimation of output supply and input demand equations of livestock model

$$BOMET_t = \underset{(208.544)^a}{-208.67020} + \underset{(2.267)}{0.00017} * BOMTP_t + \underset{(1.044)}{0.00031} * DAIRP_t$$

$$- \underset{(1.000)}{0.000004} * OTHMP_t + \underset{(1.711)}{0.00135} * NANIN_t$$

$$+ \underset{(187.787)}{0.10551} * YEAR_t$$

R-square = 0.99

$$DAIRY_t = \underset{(572.973)}{-573.000} + \underset{(1.044)}{0.00031} * BOMTP_t + \underset{(0.398)}{0.00072} * DAIRP_t$$

$$- \underset{(0.138)}{0.00002} * OTHMP_t - \underset{(0.136)}{0.00044} * NANIN_t + \underset{(272.598)}{0.29106} * YEAR_t$$

R-square = 0.99

$$OTHEM_t = \underset{(395.434)}{-418.31963} - \underset{(1.000)}{0.000004} * BOMTP_t - \underset{(1.384)}{0.00002} * DAIRP_t$$

$$+ \underset{(0.230)}{0.000004} * OTHMT_t - \underset{(0.192)}{0.00071} * NANIN_t$$

$$+ \underset{(170.099)}{0.21248} * YEAR_t$$

R-square = 0.97

[a]Figures in parentheses are approximate and absolute values of t-ratios.

Table 6.2. (continued)

$$FEDUS_t^{b} = \underset{(7.917)}{1893396.87} + \underset{(0.782)}{13.65500} * NANIN_t$$

$$- \underset{(7.768)}{1964.17200} * YEAR_t - 0.5 \sum_{i=1}^{N-1} \sum_{j=1}^{N-1} b_{ij}\ EP_{it}\ EP_{jt}$$

R-square = 0.93

System statistics:

Log-likelihood value: -2.28297 $R^{2*} = 0.99$[c]

[b]This equation was estimated conditional on the rest of the livestock system. Thus N-1 includes all other netputs in livestock sector.

[c]Baxter-Craigg R-square, see text for details.

Changes in market price of grain will have two effects: direct and indirect. The indirect effect through equivalent income variation indicates how producers respond to the changes as a result of anticipated income effects. Note that the indirect effect will vanish if the state price changes by the same amount as the market price given the state quota constant.

The equivalent income variation of grain is negatively related to grain production, protein feed from crops, and fertilizer use while positively related to other crop production. This implies that the impacts of equivalent income variation of grain are not necessary to be negative for all production for a utility maximizer under constant risk aversion. Same results can be derived for a profit maximizer under certainty.

All the parameters for time trend are positive for output supplies and negative for (negative) input demands indicating progressive technical change in Chinese agriculture. However, by the approximations of t-ratios one is not able to determine if it is global indirect Hicks neutral technical progress or technical changes of some other forms.

Monotonicity of expected indirect utility function ($\partial E(U^*)/\partial P_i \geq 0$) implies that estimated output supplies and (negative) input demands must be nonnegative. Model simulation with estimated parameters proved that monotonicity was not violated at the sample points.

While homogeneity in prices is ensured in normalized quadratic profit functional form, the symmetry property is not tested in the present study due to following considerations. The first one is to save degrees of freedom so that the empirical estimation can be carried out in this study. Estimation of the model without symmetry restriction needs nine more parameters. However, the sample size is small because the model incorporates the current Chinese economic system. This means that only observations for the years 1978 through 1988 are relevant. Furthermore, eigenvalue decomposition method has already made the model highly parameterized. The second one is that maintaining symmetry is necessary to test convexity when eigenvalue decomposition methodology is employed.

To test for the convexity, unrestricted model maintaining homogeneity and symmetry without imposing convex restriction needs to be estimated. The coefficients of own prices and the associated t-ratios from restricted and unrestricted models are presented in Table 6.3. Again, because of small sample size, these t-ratios can only give approximations of significance of these estimates. The estimates show that one out of seven own price parameters estimated without imposing convex restriction is negative. This indicates a negatively sloped output supply function which violates the convex property of the expected indirect utility function under the assumption of constant risk aversion.

Table 6.3. Comparision of own price coefficients of restricted and unrestricted models

	Unrestricted Model[a]		Restricted Model[b]	
	Estimates	t-ratios	Estimates	t-ratios
GRANP	106.78646	0.703	92.12804	0.592
PFFCP	-6.87124	0.223	2.28120	0.765
NFAGP	2.02632	0.781	2.03715	0.979
FERTP	258.45847	1.238	87.90501	2.436
BOMTP	0.00016	1.480	0.00017	2.267
DAIRP	0.00038	0.076	0.00072	0.390
OTHMP	0.000003	0.010	0.000004	0.230

[a]Convexity not imposed.

[b]Convexity imposed.

The convexity restriction can be imposed by the eigenvalue decomposition method. This methodology relies on the ground that a real symmetric matrix is positive semidefinite if and only if all its eigenvalues are nonnegative. Based on this property, the convexity is imposed by restricting the smallest eigenvalue to be nonnegative when matrix $[b_{ij}]$ is reparameterized and implied eigenvalues are calculated.

Estimated model maintaining all theoretical restrictions fits the data reasonably well. R-square coefficients ranged from 0.85 for other food from crop output supply equation to 0.99 for protein feed suuply, bovine and ovine meat supply, and dairy product supply equations (see Table 6.1 and Table 6.2). Six out of nine R-square coefficients are at or higher than 0.90, accounting for 67 percent of the total. Five out of nine R-square coefficients are higher than 0.95, about 56 percent of the total R-square coefficients.

An overall indication of explanatory power of the entire model can be measured by the "generalized R-square", R^{2*}, developed by Baxter and Cragg (1970). The generalized R-square is defined as:

$$(6.1) \quad R^{2*} = 1 - \exp[2(L_0 - L_{max})/T],$$

where L_0 is the value of the log-likelihood function when all parameters but intercepts were constrainted to zero; L_{max} is the maximized value of the log likelihood when all parameters are allowed to vary; and T is the total number of observations. The R^{2*} coefficient for the estimated crop model in Table 6.1 is 0.99 and livestock model in Table 6.2 is 0.99, indicating that the overall goodness fits are high.

There is, however, a problem associated with the coefficient of equivalent income variation in the grain supply equation. The theoretical model developed in Chapter 2 and Chapter 4 shows that equivalent income variation has effects on output supply and input demand. The empirical evidence obtained using general linear model does not support that economic hypothesis. Even the sign of the coefficient of equivalent income variation in grain supply is desireble, the magnitude is so small (- 0.000000002) that it can be approximated to zero. This leads a conclusion that equivalent income variation due to the state grain quota and the state grain price has almost no effects on grain supply. This obviously does not reflect the economic situation in China. Hence, further effort is needed to explore the problem.

6.1.2 Multicollinearity

The general linear model is an extremely powerful and widely used statistical tool. As in all statistical applications, however, the power of the method depends on the underlying assumptions being fulfilled for the particular application in question.

One of the basic assumptions of the general linear model is that the data matrix X, which is of order n x k, has rank k. This implies that no linear dependence exists between the explanatory variables. The reason for this assumption is that the least-square estimator $B^* = (X'X)^{-1}Y$ reqires the inversion of X'X, which is impossible if the rank of X, and hence the rank of X'X, is less than k. This is the case of extreme multicollinearity which exists when some or all of the explanatory variables are perfectly collinear. A less extreme but still very serious case arises when the assumption is only just satisfied, that is when some or all of the explanatory variables are highly but not perfectly collinear (Johnson, 1984).

Multicollinearity is associated with the fact that economists observe, but not set or control, the values of the explanatory variables that produce or condition values of the dependent variables. More specifically, economic variables are often related in general ways, and when the statistical results are ambiguous because of interrelationships among the explanatory variables, a multicollinearity problem is said to exist. The statistical ambiguity arises because, when explanatory variables have linear associations, their coefficients' estimates tend to have large sampling errors, and thus the actual estimates may be far from the true parameter values. This is because a variable coefficient is interpreted as the effect of a one-unit changes in an explanatory variable on the dependent variable, all other things held constant. If in a sample, the variation in an explanatory variable is persistently related to variation in one or more other explanatory variables, the resulting variation in the dependent variable can not be accurately attributed to a specific source.

The multicollinearity can result in following main negative consequences (Johnson, 1984; Judge et al., 1982). First, the precision of estimation falls so that it becomes very difficult, if not impossible, to disentangle the relative influences of the various explanatory variables. Second, coefficients may not appear significantly from zero and may be excluded from the analysis, not because the associated variable has no effect but because the set of sample data has not enabled us to pick it up. Third, estimates of coefficients become very sensitive to particular sets of sample data, and the addition of a few more observations can sometimes produce dramatic shifts in some of the coefficients. These situation may occur despite possibly high R-square or F values, indicating a model that fits the data well.

There are some ways to detect multicollinearity (Judge et al., 1984). The first one is to check simple correlations among regressors. A commonly used rule is that if the correlation between the values of two regressors is greater than 0.8 or 0.9, then multicollinearity is a serious problem. A modification of this rule compares the simple correlation coefficients to R-square, multicollinearity is then interpreted as harmful if the simple correlation is greater than R-square.

The second method is to evaluate determinant of X'X. If the regressor variables are standardized so that they have a mean of zero and a standard deviation of unity, then X'X contains element that are simple correlation coefficients between the regressors. In that case the determinant of X'X falls in the interval [0,1]. If det (X'X) = 0, then one or more exact linear dependencies exist among the columns of X. If det (X'X) = 1, then the columns of X are orthogonal.

The third approach is called auxiliary regressions. It is to regress each of the independent variables on the other (K - 1) regressors. If the value of R-square is high, a near-exact linear dependence among the columns of X is indicated. Also, if the multicollinearity involves only a few variables so that the auxiliary regressions do not suffer from extensive multicollinearity, the estimated coefficients may reveal the nature of the linear dependence among the regreesors.

The last method is named as matrix decompositions. The analysis of the characteristic roots and vectors of the X'X matrix can reveal much about the presence and nature of multicollinearity. The number of relative small characteristic roots (relative to the largest) indicates the number of near-linear dependencies among the columns of X. Whether or not the multicollinearity is harmful depends on whether the small characteristic roots contribute a large amount to the variance of estimates.

To see if multicollinearity exists in the data used in the estimation, the first and the second methods are employed to analyze the data used in the crop model. The correlation matrix for the regressors is presented in Table 6.4. The determinant of the correlation matrix, which is the standardized X'X matrix, is 0.003. This value falls at the low end of the interval [0,1] indicating the existing of multicollinearity in the data of crop equivalent income variation of grain is 0.853, which is greater than 0.8 indicating that multicollinearity is a serious problem. Because all other correlation coefficients are small than 0.8, multicollinearity is obviously due to high correlation between grain price and equivalent income variation of grain. Since equivalent income variation is defined as the product of the state grain quota and the differenc between grain price and the state grain price, that is, equivalent income variation is related the level of grain price, this must cause the problem of multicollinearity in the data set of crop sector.

Once multicollinearity has been detected and deemed serious enough to warrant further effort to mitigate its ill effects, a variety of alternative stratigies should be pursued. Several

Table 6.4. Regressor correlation matrix for crop model

	GRANP	PFFCP	NFAGP	FERTP	EIVGN
GRANP	1.000				
PFFCP	-0.336	1.000			
NFAGP	0.354	0.377	1.000		
FERTP	0.480	0.210	0.205	1.000	
EIVGN	0.853	-0.540	0.214	0.068	1.000

methods have been proposed for coping with multicollinearity. These include obtaining additional sample data, applying exact linear restrictions, applying stochastic linear restrictions, and finding a slightly biased estimator with a much smaller variance using ridge regression. Since additional sample data are not available and linear restrictions may result in adverse consequences, ridge regression approach is used in this study to deal with the serious problem of multicollinearity.

6.1.3 Ridge regression

Ridge regression as developed by Hoerl and Kennard (1970) is a biased estimation procedure which generally arrives coefficient estimates with lower variances than ordinary least squares regression (OLS). In general

(6.2) $\quad MSE = VARIANCE + BIAS$

Ridge regression increases bias but reduces variance so that with small amounts of bias an overall reduction in MSE is possible.

The ridge regression estimator is

(6.3) $\quad B_r = [X'X + KI]^{-1}X'Y,$

where the scalar K is chosen arbitrarily with a value usually between zero and one. If $K = 0$ the ridge estimates reduce to ordinary least squares. In application, K is to be chosen in such a way that the resulting estimates are "stable," presumably with respect to small variations in K. It is easily shown that although the ridge estimator is biased,

$$(6.4) \qquad E[B_r] = [X'X + KI]^{-1}X'X\beta,$$

its variance

$$(6.5) \qquad Var[B_r] = \sigma^2[X'X + KI]^{-1}(X'X)[X'X + KI]^{-1},$$

where σ^2 is the variance of the disturbance, is smaller than that of the ordinary least squares estimator. As a result the ridge estimators often have a smaller mean square error than their ordinary least square counterparts particularly when a high degree of multicollinearity is present.

Hoerl and Kennard (1970), Brown and Beattie (1975), Watson and White (1976), and others have attempted to find an optimal value of K through iterative procedures. Watson and White found that a simple graphical device called the "ridge trace" is sometimes more useful as it shows the behavior of the coefficients under changing values of K. The estimated ridge coefficients are plotted against their respective value of K so that the ridge trace reveals the sensitivity of the coefficients. A coefficient insensitive to changes in the data will not change very much under changing values of K.

Let ridge regression model of grain supply be

(6.6) GRAIN = f(GRANP, PFFCP, NFAGP, FERTP, LNDUS, YEAR, EIVGN).

Table 6.5 summarizes the ridge results for eleven models at different K values. Note that because the sample size is small, t-ratios may provide only approximations of the significance of coefficients. Theil (1970) and Watson and White (1976) have proposed two measures to test the predictability of the ridge regression model. One is called the forecast root mean square error. The other one is named as Theil's inequality coefficient. Unfortunaly, the present study can not perform these two tests because of small sample size. Watson and White, among others, have approved that ridge forecast is superior to ordinary least squares forecast when multicollinearity exists and the intercorrelations among explanatory variables are changing.

The results indicate that the positive coefficient on GRANP, grain price under ordinary least squares stabilized at negative sign when estimated using ridge regression. The positive coefficient on EIVGN, equivalent income variation of grain under ordinary least squares stabilized at negative sign when K values are higher than 0.4 in ridge regression. All other coefficients show same sign under the two different regression procedures. These results imply that coefficients of GRANP and EIVGN are sensitive to changes in the data while others not. These

Table 6.5. Estimated coefficients and t-ratios of ridge regression

K-value/ Variable	K=0[a]	K=0.1	K=0.2	K=0.3	K=0.4	K=0.5	K=0.6	K=0.7	K=0.8	K=0.9
CONSTANT	-20411	-9835	-7542	-6362	-5621	-5102	-4711	-4403	-4150	-3938
	(1.93)[b]	(2.96)	(2.66)	(2.54)	(2.50)	(2.47)	(2.46)	(2.45)	(2.44)	(2.42)
GRANP	24.99	-16.14	-58.75	-56.67	-54.91	-53.38	-51.98	-50.70	-49.51	-48.38
	(0.10)	(2.08)	(2.68)	(2.97)	(3.12)	(3.20)	(3.24)	(3.25)	(3.24)	(3.23)
PFFCP	220.22	125.11	98.07	84.15	75.47	69.45	64.96	61.45	58.60	56.20
	(1.90)	(1.19)	(0.97)	(0.88)	(0.84)	(0.82)	(0.81)	(0.80)	(0.80)	(0.79)
NFAGP	-32.55	-24.12	-21.31	-19.44	-18.04	-16.92	-15.98	-15.18	-14.49	-13.87
	(2.02)	(1.43)	(1.23)	(1.15)	(1.11)	(1.09)	(1.07)	(1.06)	(1.05)	(1.04)
FERTP	-317.41	-62.65	-58.38	-60.08	-61.99	-63.46	-64.47	-65.09	-65.42	-65.52
	(0.62)	(0.34)	(0.34)	(0.36)	(0.38)	(0.41)	(0.43)	(0.44)	(0.46)	(0.47)
YEAR	10.51	5.31	4.17	3.57	3.19	2.93	2.73	2.57	2.44	2.33
	(1.97)	(3.28)	(2.98)	(2.89)	(2.86)	(2.85)	(2.85)	(2.85)	(2.85)	(2.85)
LNDUS	-1.48	-2.93	-2.99	-2.94	-2.87	-2.80	-2.73	-2.67	-2.61	-2.56
	(0.27)	(1.02)	(1.35)	(1.57)	(1.73)	(1.85)	(1.94)	(2.01)	(2.07)	(2.11)
EIVGN	4.11	2.03	0.95	0.40	0.07	-0.15	-0.30	-0.40	-0.48	-0.53
	(1.45)	(1.35)	(0.74)	(0.36)	(0.07)	(0.16)	(0.35)	(0.51)	(0.65)	(0.76)

[a]The coefficients and t-ratios of ordinary least squares regression when K=0.

[b]Figures in parenthesis are approximate and absolute values of t-ratios.

results indicate that the multicollinearity problem does exist in the model and the problem is due to the high correlation between the independent variables of grain market price and equivalent income variation.

A desirable procedure to search the best value of K is to find optimal K from the estimated data and use it to forecast into the unknown region. This procedure is done by means of the ridge trace. Figure 6.1 to 6.7 give the ridge traces for seven explanatory variables. These figures describe the path of each coefficient as K increases. The ordinary least squares coefficients (when K = 0) are signified by the left axis.

Figure 6.1 and Figure 6.7 presenting the traces for GRANP and EIVGN, respectively, show the severe multicollinearity problem. The coefficient of GRANP estimated using ordinary least squares method was positive. This positive sign turned to negative as K increased above zero. The coefficient of EIVGN followed the same pattern except that change in sign occured as K increased above 0.4. More significantly, the pathes of the two explanatory variables converge as K value increases indicating that these two variables are highly correlated.

The procedure of finding an optimal K from the ridge trace is to search values of K greater than zero until the major instabilities of the coefficients have disappeared. Figure

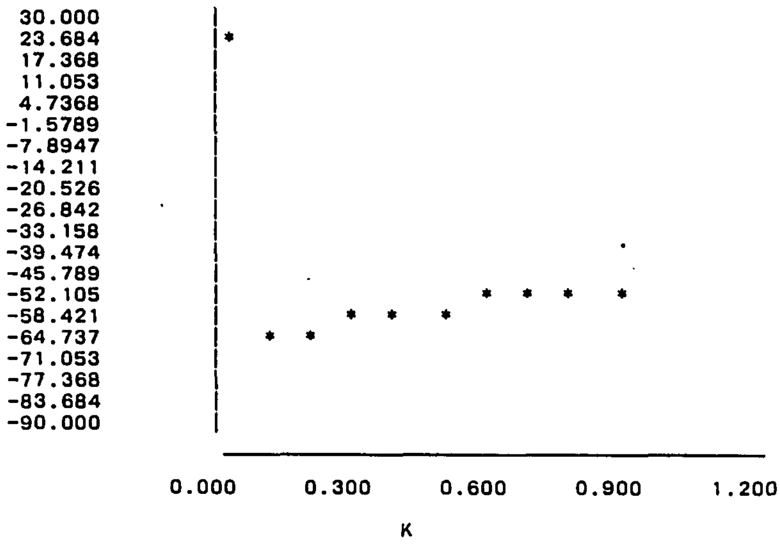

Figure 6.1. Ridge trace for coefficient of GRANP

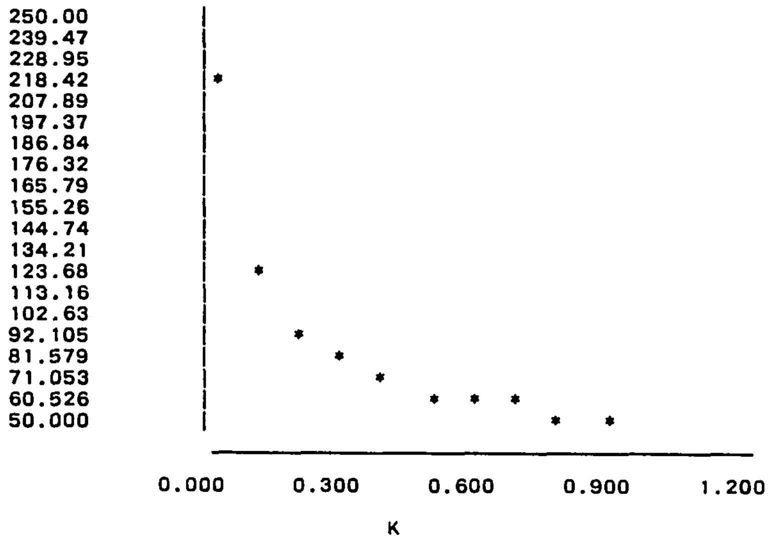

Figure 6.2. Ridge trace for coefficient of PFFCP

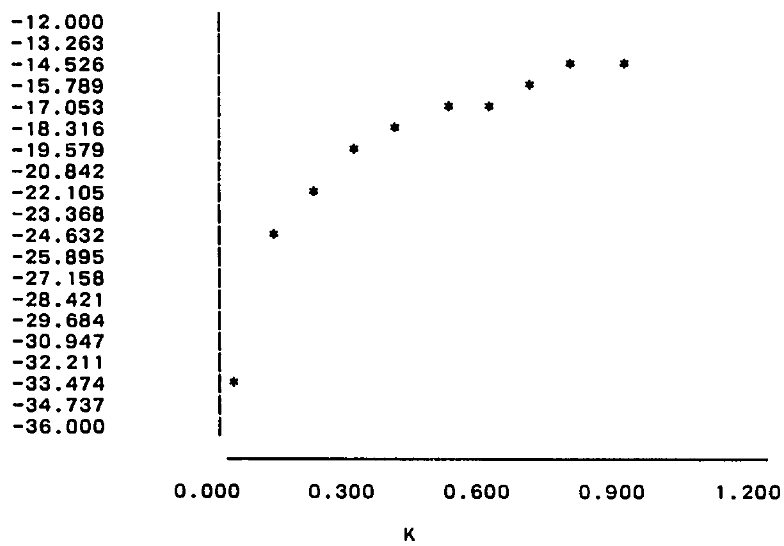

Figure 6.3. Ridge trace for coefficient of NFAGP

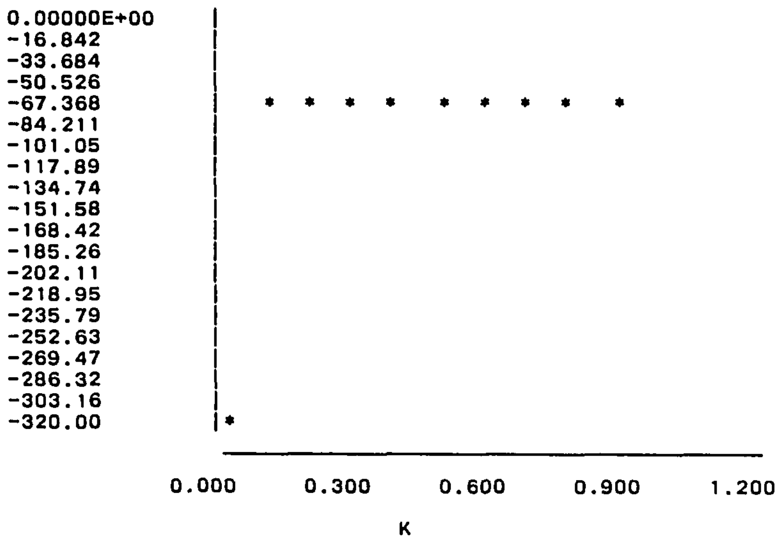

Figure 6.4. Ridge trace for coefficient of FERTP

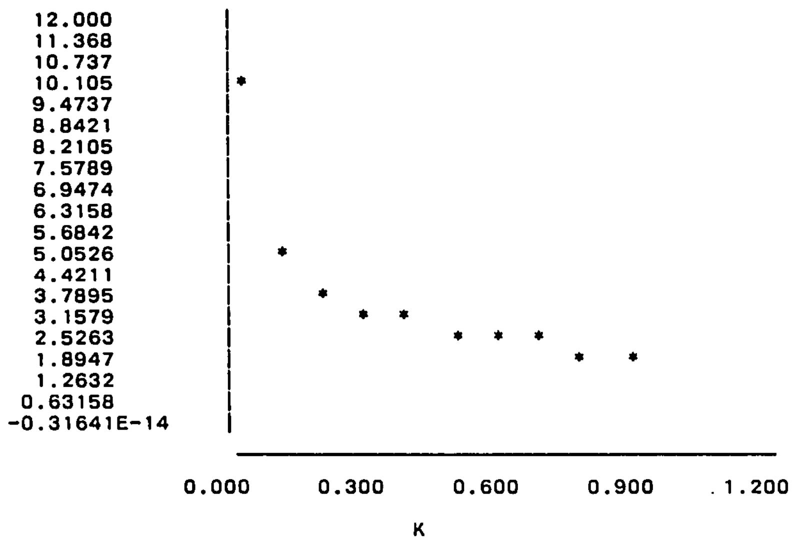

Figure 6.5. Ridge trace for coefficient of YEAR

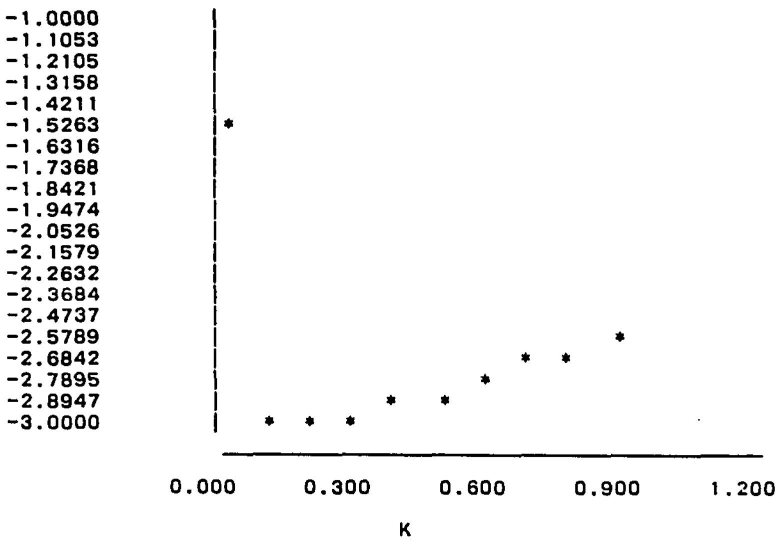

Figure 6.6. Ridge trace for coefficient of LNDUS

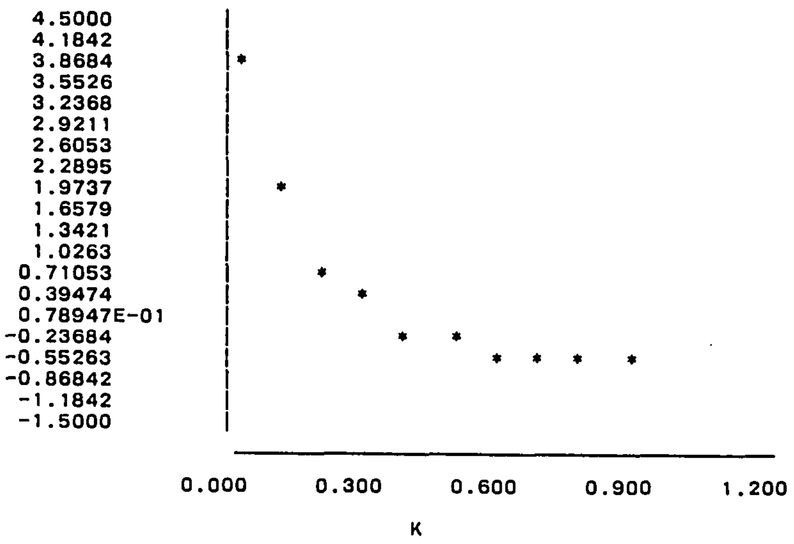

Figure 6.7. Ridge trace for coefficient of EIVGN

6.1 and Figure 6.7 show that the unstable coefficients have settled down in the neighborhood of K = 0.7 (see Table 6.5). The previous studies (Watson and White, 1976) show that this value corresponds with the optimal K from the forecast period as measured by the root of mean square error and Theil's inequality coefficient statistics.

At k = 0.7 the coefficient of EIVGN is 0.4002 which is used as predetermined value in the estimation using Fortran -GQ-OPT maitaining all theoretical restrictions as discussed in the previous chapers. The model using fixed coefficient of equivalent income variation is refered to as ridge model. In the following study the model means this ridge model except otherwise indicated. The model before using ridge regression is called original model accordingly.

6.1.4 Output supply and input demand equations of ridge model

Given the coefficient of equivalent income variation estimated using ridge regression as predetermined, crop model was estimated again applying joint generalized least squares. The empirical results of output supply and input demand equations maintaining homogeneity, symmetry, and convexity are presented in Table 6.6. Onec again, the t-ratios reported in the paranthesis must be interpreted with caution since the

Table 6.6. Ridge model of output supply and input demand equations of crop sector

$$GRAIN_t = \underset{(11981.731)^{a}}{-13298.05109} + \underset{(11.677)}{114.70518} * GRANP_t + \underset{(0.009)}{0.19249} * PFFCP_t$$

$$- \underset{(1.244)}{18.13339} * NFAGP_t - \underset{(0.338)}{10.26466} * FERTP_t$$

$$- \underset{(2.430)}{8.53604} * LNDUS_t + \underset{(29.184)}{7.46991} * YEAR_t$$

$$- 0.40020 * EIVGN_t$$

R-square = 0.89

$$PFDFC_t = \underset{(763.479)}{-932.75325} + \underset{(0.009)}{0.19249} * GRANP_t + \underset{(0.612)}{7.39059} * PFFCP_t$$

$$+ \underset{(0.151)}{0.45128} * NFAGP_t - \underset{(0.759)}{8.17295} * FERTP_t$$

$$+ \underset{(0.060)}{0.05686} * LNDUS_t + \underset{(6.815)}{0.46736} * YEAR_t$$

$$+ \underset{(0.213)}{0.07649} * EIVGN_t$$

R-square = 0.96

[a]Figures in parentheses are approximate and absolute values of t-ratios.

Table 6.6. (continued)

$$NFDAG_t = \underset{(174.735)}{-599.18039} - \underset{(1.245)}{18.13339} * GRANP_t + \underset{(0.151)}{0.45128} * PFFCP_t$$

$$+ \underset{(0.642)}{3.01131} * NFAGP_t + \underset{(0.431)}{1.79914} * FERTP_t$$

$$+ \underset{(0.382)}{0.42508} * LNDUS_t + \underset{(3.389)}{0.27429} * YEAR_t$$

$$+ \underset{(0.158)}{0.08876} * EIVGN_t$$

R-square = 0.82

$$FERUS_t = \underset{(2204.693)}{2554.34987} - \underset{(0.338)}{10.26466} * GRANP_t - \underset{(0.759)}{8.17295} * PFFCP_t$$

$$+ \underset{(0.431)}{1.79914} * NFAGP_t + \underset{(1.715)}{15.95033} * FERTP_t$$

$$+ \underset{(0.325)}{0.42298} * LNDUS_t - \underset{(14.239)}{1.32534} * YEAR_t$$

$$- \underset{(0.188)}{0.09905} * EIVGN_t$$

R-square = 0.99

Table 6.6. (continued)

$$OFDFC_{tb} = \underset{(5.443)}{-2258.44153} + \underset{(3.283)}{0.77201} * LNDUS_t + \underset{(5.455)}{1.10301} * YEAR_t$$

$$+ \underset{(2.530)}{0.41175} * EIVGN_t - 0.5 \sum_{i=1}^{N-1} \sum_{j=1}^{N-1} b_{ij}\, EP_{it}\, EP_{jt}$$

R-square = 0.83

System statistics:

Log-likelihood value: - 1.982 $R^{2*} = 0.99$[c]

[b]This equation was estimated conditional on the rest of the crop system. Thus, N-1 includes all other netputs in crop sector.

[c]Baxter-Craigg R-square, see text for details.

sample size is small. These t-ratios may only give us only approximations of significance of these estimates.

In the restricted model, all of the own price coefficients of outputs and inputs are positive indicating that an increase of the ith output price will always increase the production of the ith output and an increase of the jth input price wll always decrease the use of the jth input, with other prices constant. This means that the estimated output supply curves are upward sloping and the estimated input demand curves are downward sloping.

Changes in market price of grain will have two effects: direct and indirect. The indirect effect through equivalent income variation indicates how producers respond to the changes as a result of anticipated income effects. Note that the indirect effect will vanish if the state price changes by the same amount as the market price given the state quota constant.

Given the negative effect of equivalent income variation on grain production as predetermined using ridge regression, equivalent income variation is positively related to all other agricultural supplies. This implies that if the government taxes grain production by either decreasing the state price of grain or increasing the state quota of grain, nongrain productions and fertilizer use will increase. This also indicates that the impacts of equivalent income variation of grain are not necessary to be negative for all production for a utility maximizer under constant risk aversion. Same results can be derived for a profit maximizer under certainty.

All the parameters for time trend are positive for output supplies and negative for (negative) input demands indicating progressive technical change in Chinese agriculture. However, as discussed previously, one is not able to determine if it is globle indirect Hicks neutral technical progress or technical changes of some other forms by the approximations of t-ratios.

Monotonicity of expected indirect utility function ($\partial E(U^*)/\partial P_i \geq 0$) implies that estimated output supplies and (negative) input demands must be nonnegative. Model simulation with estimated parameters proved that monotonicity was not violated at the sample points.

While homogeneity in prices is ensured in normalized quadratic profit functional form, the symmetry property is not tested in the present study due to following considerations. The first one is to save degrees of freedom so that the empirical estimation can be carried out in this study given the small sample of data. Estimation of the model without symmetry restriction needs nine more parameters. However, because the model incorporates the current Chinese economic system, only observations for the years 1978 through 1988 are relevant. Furthermore, eigenvalue decomposition method has already made the model highly parameterized. The second one is that maintaining symmetry is necessary to test convexity when eigenvalue decomposition methodology is employed.

To test for the convexity, unrestricted model maintaining homogeneity and symmetry without imposing convex restriction needs to be estimated. The coefficients of own prices and the associated t-ratios from restriced and unrestricted models are presented in Table 6.7. Again, becuase of small sample size, these t-ratios can only give approximations of significance of these estimates. The estimates show that one out of seven own price parameters estimated without imposing convex restriction is negative. This indicates a negatively sloped output supply function for protein feed from crop which violates the convex property of the expected indirect utility function under the assumption of constant risk aversion.

The convexity restriction can be imposed by the eigenvalue decomposition method. This methodology relies on the ground that a real symmetric matrix is positive semidefinite if and only if all its eigenvalues are nonnegative. Based on this property, the convexity is imposed by restricting the smallest eigenvalue to be nonnegative when matrix $[b_{ij}]$ is reparameterized and implied eigenvalues are calculated.

Estimated ridge model maintaining all theoretical restrictions fits the data reasonably well. R-square coefficients ranged from 0.82 for nonfood agriculture output supply equation to 0.99 for fertilizer input demand (see Table 6.6). two of five R-square coefficients are at or higher than

Table 6.7. Comparision of own price coefficients of restricted and unrestricted ridge models[a]

	Unrestricted Model[b]		Restricted Model[c]	
	Estimates	t-ratios	Estimates	t-ratios
GRANP	129.67521	0.531	114.70518	11.677
PFFCP	-5.69442	0.200	7.39059	0.612
NFAGP	2.06847	0.789	3.01131	0.642
FERTP	279.17617	1.168	15.95033	1.715
BOMTP	0.00016	1.480	0.00017	2.267
DAIRP	0.00038	0.076	0.00072	0.390
OTHMP	0.000003	0.010	0.000004	0.230

[a]Crop sector from ridge model and livestock sector from original model.

[b]Convexity not imposed.

[c]Convexity imposed.

0.95, accounting for 40 percent of the total. three out of five R-square coefficients are higher than 0.90, about 60 percent of the total R-square coefficients. The generalized R-square measuring overall explanatory power of the ridge model of crop sector is 0.98 which indicates that the overall goodness of fit is high.

A log-likelihood ratio test statistics is used to validate the ridge model. This test statistics is defined as:

$$(6.7) \qquad -2 \log \lambda = -2[\log L(\gamma_o) - \log L(\gamma^*)],$$

where γ_o denotes the value of restricted maximum likelihood function and γ^* represents the value of unrestricted maximum likelihood function. Asymptotically, $-2 \log \lambda$ is distributed as chi-square with I degree of freedom (I equaling the number of independent restrictions being tested) under the null hypothesis that γ_o is true. As a result of restricting the coefficient of equivalent income variation equal to -0.4002 the value of log-likelihood function reduced from -1.8393 in the original model to -1.9823 in the ridge model. The calculated chi-square 0.286 is lower than the critical value 3.84 for 5% level of significance and 1 degree of freedom indicating that the ridge model is to be accepted. The reason that fails to reject the ridge model is obviously because of the problem of multicollinearity in the original crop model.

6.2 Price Elasticities of Supplies and Input Demands

Price elasticities of output supplies and input demands are reported in Table 6.8. Elasticity of ith product (Y_i) with respect to jth expected price (EP_j) is calculated by following formulas at sample means:

$$(6.8) \quad \epsilon_{ij} = b_{ij} * EP_j/Y_i \qquad \forall\ i,j \text{ except numeriare}$$

$$(6.9) \quad \epsilon_{ih} = - \sum_{k=1}^{K} b_{ik} * EP_k/Y_i \qquad \forall\ i,k \text{ except numeriare}$$

$$(6.10) \quad \epsilon_{hj} = - \sum_{k=1}^{K} b_{jk} * EP_k * EP_j/Y_h \qquad j,k \text{ except numeriare}$$

$$(6.11) \quad \epsilon_{hh} = \sum_{i=1}^{I} \sum_{j=1}^{J} b_{ij} * EP_j * EP_i/Y_h \qquad \forall\ i,j \text{ except numeriare}$$

where h represents the numeriare products. The elasticities reported in Table 6.8 are calculated using the parameter estimates from ridge model for crop sector reported in Table 6.6 and from original model for livestock sector presented in Table 6.2. These elasticities are calculated while all theoretical restrictions of homogeneity, symmetry, and convexity are maintained.

Because elasticities are from the model maintaining convex restriction, positive own price elasticities of output supplies

Table 6.8. Price elasticities of output supplies and input demands for the full model with restriction of convexity

Price/ Netput	Elasticities with Respect to								
	GRANP	PFFCP	OFFCP	NFAGP	FERTP	BOMTP	DAIRP	OTHMP	FEEDP
GRAIN	0.133(0.171)	0.001	-0.019	-0.145	-0.008				
PFDFC	0.372(0.014)	0.933	-0.462	-0.180	-0.306				
OFDFC	0.315(-0.08)	-0.041	0.070	0.038	0.013				
NFDAG	-0.778(-1.12)	-0.047	0.114	1.000	0.056				
FERUS	0.105(0.267)	0.360	-0.168	-0.251	-0.208				
BOMET						0.169	0.029	-0.042	-0.152
DAIRY						0.119	0.025	-0.090	-0.054
OTHEM						-0.002	-0.001	0.026	-0.023
FEDUS						0.032	0.003	0.100	-0.135

are preserved. But, convex restriction does not impose any constraint on the signs of the cross price elasticities. The own price elasticities for outputs distributed from 0.025 for dairy products to 0.100 for nonfood agricultural products. Nonfood agricultural product is the most elastic output. Of all sectors, nonfood agriculture sector has the least government intervention and the elastic supply function is consistent with this situation. Nonfood agriculture and other food have positive elasticities with respect to fertilizer price.

Note that the own and cross elasticities with respect to grain price reported in Table 6.8 are the sum of direct price elasticity and indirect price elasticity. Figures in the parentheses are direct price elasticities.

It is worth pointing out that the elasticities of protein feed from crop, nonfood agriculture, and other food from crop with respect to price of grain are 0.372, 0.315, and -0.778, respectively, while the elasticities of grain with respect to prices of protein feed, nonfood agriculture, and other food from crop are 0.001, -0.145, and -0.019, respectively. These phenomenon again, reflect the current situation in Chinese agricultural production where farmers have less flexibility to adjust grain production than all other nongrain production since grain production is under much more restrict control of the government, direct or indirect, than any other crop productions.

Negative elasticities of own prices for input demands are ensured as a results of imposing restriction of convexcity on the model. Own price elasticity is -0.208 for fertilizer and -0.135 for feed. As expected for the Chinese agriculture, fertilizer is not very elastic input because the distribution of fertilizer among farmers is more or less subject to the government intervention. Cross price elasticities vary from sector to sector both in sign and magnitude. Overall, the elasticities are plausible.

6.3 Directly Substituting Approach

In this study, $(P - P_S)Y_S$ was defined as equivalent income variation and was treated as an explanatory variable in each equation in the model. But, P also appeared as an independent variable in each equation, resulting in multicollinearity problem. Another method to solve the multicollinearity problem is called directly substituting approach by collecting same term and rewriting the equation arithmetically.

To simplify the description of the approach, let start with a model with only price, state prices, and state quota of grain,

$$(6.12) \quad Y = aP + b(EIV) = aP + b(P - P_S)Y_S$$

where Y is netput, P is price of grain, P_S is the state price of grain, Y_S is the state quota of grain, and a and b are parameters to be estimated. This model can be rewritten as followings:

(6.13) $Y = (a + bY_s)P - bP_sY_s$, or

(6.14) $Y = cP - bP_sY_s$,

where $c = a + bY_s$, or

(6.15) $Y = ap + bPY_s - bP_sY_s$, and

(6.16) $Y = ap + b_1PY_s - b_2P_sY_s$.

Equation (6.13) seems to be a reasonable one. However, the convexity restriction can be imposed only at the mean of Y_s. That is, convex property is not ensured at each sample point. This will cause problems in policy scenario analysis by dynamic historical simulation. In Equation (6.14), $a + bY_s$ is set to be a constant. Since b is a parameter to be estimated and Y_s is changing over time, some information must be lost if output supply and input demand equations are estimated using this Equation.

If Equation (6.15) is used to reflect producer behavior, Equation (6.16) should also be estimated, so that the hypothesis of $b_1 = -b_2$ can be tested. Let define PY_s and P_sY_s as EVPYS and VPSYS, respectively, and all other definition are the same as those in previous models. Estimated crop supply and input demand equations by model (6.15) are reported in Table 6.9. As a result of restricting $b_1 = -b_2$, the value of log-likelihood

Table 6.9. Substituting model of output supply and input demand equations of crop sector

$$
\begin{aligned}
GRAIN_t = {} & \underset{(2255.917)^{a}}{-16039.99907} + \underset{(3.399)}{133.21335} * GRANP_t + \underset{(0.811)}{27.54120} * PFFCP_t \\
& - \underset{(1.408)}{21.13374} * NFAGP_t - \underset{(1.924)}{143.67235} * FERTP_t \\
& - \underset{(2.443)}{7.21659} * LNDUS_t + \underset{(40.358)}{8.75780} * YEAR_t \\
& - \underset{(6.0D-7)}{8.1D-13} * EVPYS_t + \underset{(6.0D-7)}{8.1D-13} * VPSYS_T
\end{aligned}
$$

R-square = 0.91

$$
\begin{aligned}
PFDFC_t = {} & \underset{(599.721)}{-1730.24107} + \underset{(0.811)}{27.54120} * GRANP_t + \underset{(0.274)}{7.32504} * PFFCP_t \\
& + \underset{(0.062)}{0.26841} * NFAGP_t - \underset{(1.764)}{56.40407} * FERTP_t \\
& - \underset{(0.008)}{0.01176} * LNDUS_t + \underset{(8.508)}{0.87485} * YEAR_t \\
& - \underset{(0.634)}{0.32410} * EVPYS_t + \underset{(0.634)}{0.32410} * VPSYS_t
\end{aligned}
$$

R-square = 0.93

[a]Figures in parentheses are approximate and absolute values of t-ratios.

Table 6.9. (continued)

$$NFDAG_t = \underset{(36.343)}{-838.84717} - \underset{(1.408)}{21.13374} * GRANP_t + \underset{(0.062)}{0.26841} * PFFCP_t$$

$$+ \underset{(0.709)}{1.62913} * NFAGP_t + \underset{(0.574)}{5.43316} * FERTP_t$$

$$+ \underset{(0.607)}{0.38320} * LNDUS_t + \underset{(7.830)}{0.39871} * YEAR_t$$

$$+ \underset{(1.419)}{0.33260} * EVPYS_t - \underset{(1.419)}{0.33260} * VPSYS_t$$

R-square = 0.88

$$FERUS_t = \underset{(4140.866)}{7708.32364} - \underset{(1.924)}{143.67235} * GRANP_t - \underset{(1.764)}{56.40407} * PFFCP_t$$

$$+ \underset{(0.574)}{5.43316} * NFAGP_t + \underset{(7.385)}{308.87861} * FERTP_t$$

$$- \underset{(0.028)}{0.07933} * LNDUS_t - \underset{(19.050)}{3.88308} * YEAR_t$$

$$+ \underset{(1.021)}{1.20449} * EVPYS_t - \underset{(1.021)}{1.20449} * VPSYS_t$$

R-square = 0.82

Table 6.9. (continued)

$$OFDFC_{tb} = \underset{(2.731)}{-2247.20977} + \underset{(0.606)}{0.28297} * LNDUS_t + \underset{(2.825)}{1.13094} * YEAR_t$$

$$+ \underset{(0.844)}{0.24955} * EVPYS_t - \underset{(0.844)}{0.24955} * VPSYS_t$$

$$- 0.5 \sum_{i=1}^{N-1} \sum_{j=1}^{N-1} b_{ij} EP_{it} EP_{jt}$$

R-square = 0.70

System statistics:

Log-likelihood value: - 2.340 $R^{2*} = 0.99$[c]

[b]This equation was estimated conditional on the rest of the crop system. Thus, N-1 includes all other netputs in crop sector.

[c]Baxter-Craigg R-square, see text for details.

function changed from -4.852 in the model without restriction to -2.340 in the restricted model. The calculated chi-square 5.024 is lower than the critical value 9.488 for 5% level of significance and 4 degree of freedom. This log-likelihood ratio test statistics suggests that the model with restriction of $b_1 = -b_2$ be accepted.

Estimated model with restriction on alternative signs and equal magnitudes of b_1 and b_2 maintaining all theoretical restrictions fits the data reasonably well, as implied by R-square coefficients (see Table 6.9).

Price elasticities of output supplies and input demands are presented in Table 6.10. Most of the estimates of elasticities are plausible. However, elasticity of fertilizer demand with respect to fertilizer price is -4.027. This very high elasticity does not reflect the behavior of demand for fertilizer in China. Fertilizer is not such elastic input in Chinese agriculture. Elasticities of protein feed with respect to price of grain is also very high (3.567). Furthermore, as the coefficients of EVPYS and VPSYS are very small (8.1D-13), elasticities of grain with respect to state price and state quota of grain are approximately zero, implying that the state price the state quota of grain have no impacts on grain supply. This does not reflect the Chinese economic system. Thus, ridge model is more appropriate for policy scenario analysis.

Table 6.10. Price elasticities of output supplies and input demands for the substituting model with restriction of convexity

Price/ Netput	Elasticities with Respect to GRANP	PFFCP	OFFCP	NFAGP	FERTP
GRAIN	0.199(0.199)[a]	0.070	0.008	-0.169	-0.108
PFDFC	3.567(2.052)	0.925	-0.976	0.107	-2.108
OFDFC	0.139(-0.009)	-0.085	0.208	0.194	0.108
NFDAG	2.601(-1.31)	0.028	0.571	0.541	0.168
FERUS	1.711(3.734)	2.484	-1.434	-0.756	-4.027

[a]Figures in parentheses are estimates of direct elasticities with respect to price of grain.

6.4 Nested Model

In the present study nonjointness between crop and livestock sectors is assumed. This assumption does not allow the interaction between the two models. However, as genaral multioutput models the interaction among all outputs and input is permitted within each individual model. This means that production of one output is allowed to respond to changes in prices of all other outputs within its sector. While this is a logical implication of a multioutput technology in general, it is not necessary that every output will respond to changes in prices of all other outputs. This is especially striking in the Chinese agriculture because in China some crops are grown on and some livestocks are raised in geographically different regions and the infrastructure facilities are poor. It is possible that non-jointness among outputs exists within own sector. Because the t-ratios reported in Table 6.2 and Table 6.6 give us only approximations of significance of these estimates due to small sample size, we need to test non-jointness of the models. This can be done by the means of the "nested model", that is, the models are reestimated by setting b_{ij}s, the coefficients of cross output prices be zero. Elasticity estimates from crop and livestock nested models maintaining symmetry and convexity are presented in Table 6.9. As it is shown in Table 6.9 that three b_{ij} coefficients in crop model and three b_{ij} coefficients in livestock model are restricted to zero in the nested models. It is hypothesized that cross price elasticities estimated using nested model would be bigger in magnitude compared to the corresponging full model. The elasticity estimates reported in Table 6.11 indicate, however, that in crop nested model out of sixteen cross price elasticities only five are bigger than those in full model. similar phenomenon can also be observerd in livestock nested model. Among six cross price elasticities one is smaller than the corresponding one in the livestock full model.

A log-likelihood ratio test statistics is used to validate the nested models (see Equation 6.7). As three b_{ij} coefficiens are restricted to zero, the value of log-likelihood function decreased from -1.9823 in full ridge model to -2.7824 in nested ridge model. The calaulated chi-square is lower than the critical value 7.81 for 5 percent level of significance and three degree of freedom suggesting that the nested model is accepted. The statistical acceptance of the nested crop model is, however, possibaly because estimation of the nested model requires less information compared to full model. Since the sample size in this study is small, it is, thus, risky to statistically accept the nested model. Futhermore, the coefficient of equivalent income variation was arrived when all cross effects were accounted (see Equation 6.4) in the ridge regression. This coefficient was then used as predetermined

Table 6.11. Price elasticities of output supplies and input demands for the nested model with restriction of convexity

Price/	Elasticities with Respect to								
Netput	GRANP	PFFCP	OFFCP	NFAGP	FERTP	BOMTP	DAIRP	OTHMP	FEEDP
GRAIN	0.010(0.048)	0.000	0.026	0.000	-0.022				
PFDFC	-0.012(0.000)	0.061	0.021	0.000	-0.082				
OFDFC	0.037(-0.08)	0.002	0.136	-0.061	-0.00002				
NFDAG	0.349(0.000)	0.000	-0.178	0.186	-0.008				
FERUS	1.364(0.752)	0.097	0.001	0.037	-0.886				
BOMET						0.169	0.000	0.000	-0.169
DAIRY						0.000	0.033	0.000	-0.033
OTHEM						0.000	0.000	0.106	-0.106
FEDUS						0.035	0.002	0.456	-0.493

value in both full model and nested model. As the nested model was estimated under the hypothesis that some cross effects do not exist, it may lead inconsistent conclusion using an estimated coefficient reflecting full effects as a predetermined value when estimating the nested model.

Three b_{ij} coefficients are restricted to zero in livestock nested model. The value of log-likelihood function decreased from -0.2225 in full model to -2.2633 in nested model. The calculated chi-square is lower than the critical value 7.81 for 5 percent level of significance and three degree of freedom. This statistical indication implies that the nested model is true. However, for the same reason of small sample size it is not safe to accept nested model.

6.5 Validation of the Model

Since the restricted model is to be used for policy scenario analysis of the effects of the government intervention, the validation of the model must be first examined. Validation of the model is to evaluate its overall ability to reproduce the actual historical data of the endogenous variables. A criterion employed to validate a model is the fit of the individual variables in a simulation context. One way to measure the model is to conduct a historical simulation and examine how closely each endogenous variable tracks the historical data series over the same sample period. Good historical simulation provides added reliability to the policy scenario analysis based on the model.

The estimated equations of seven output supplies and two input demands in full models (ridge full model for crop sector) are used for the historical simulation. The sample period that the historical simulation series ranges from 1978 to 1988. The statistics to measure the model's simulation performance include mean absolute percent error (MAPE) and Theil's forecast statistics.

MAPE measures the average of the absolute difference between the actual historical series (A_t) and simulated series (S_t) relative to the actual historical series. MAPE is calculated by the formula:

$$(6.17) \quad MAPE = (1/N) \sum_{t=1}^{T} |(A_t - S_t)|/A_t,$$

where T is the number of periods of simulation. The MAPE implies a linear loss function. Small MAPE indicates good simulation performance while large MAPE poor simulation performance.

Three Theil's forecast statistics decomposed from mean square error: U_m, U_s, and U_c are used in the evaluation. These decomposition measures are given by:

$$(6.18) \quad U_m = T*(\mu_s - \mu_a) \;/\; \sum_{t=1}^{T} (A_t - S_t)^2,$$

$$(6.19) \quad U_s = T*(\sigma_s - \sigma_a) \;/\; \sum_{t=1}^{T} (A_t - S_t)^2, \text{ and}$$

$$(6.20) \quad U_c = 2T*(1 - \rho)*(\sigma_s - \sigma_a) \;/\; \sum_{t=1}^{T} (A_t - S_t)^2,$$

where μ_s, μ_a, σ_s, and σ_a are the means and standard deviations of the series A_t and S_t, respectively, and ρ is their correlation coefficient. U_m, U_s, and U_c are called the bias, the variance, and the covariance proportions, respectively. The bias proportion U_m is an indication of systematic error, since it measures the extent to which the average values of the simulated and actual series deviate from each other. The variance proportion U_s indicates the ability of the model to replicate the degree of variability in the variable of interest. The covariance proportion U_c shows unsystematic error. The perfect correlation of the simulated values with actual values would imply the ideal distribution over these three sources as $U_m = U_s = 0$ and $U_c = 1$ (Pindyck and Rubinfeld, 1981).

Mean absolute percent errors and Theil's forecast error decomposition proportions are presented in Table 6.12. Out of nine equations, MAPE for seven equations are well below 5 percent. MAPE for the remaining two equations are at about 8

Table 6.12. Simulation statistics of the estimated full model with the restriction of convexity

		Theil's Forecast Error Statistics		
Equation	MAPE	Bias(U_m)	Variance(U_s)	Covariance(U_c)
GRAIN	2.79	0.000	0.032	0.968
PFDFC	4.50	0.000	0.000	1.000
OFDFC	1.52	0.000	0.019	0.981
NFDAG	10.32	0.000	0.005	0.995
FERUS	2.18	0.000	0.000	1.000
BOMET	1.49	0.001	0.001	0.998
DAIRY	2.18	0.000	0.003	0.997
OTHEM	3.94	0.000	0.006	0.994
FEDUS	8.19	0.000	0.018	0.982

and 10 percent, respectively. The bias proportions for all equations are zero except for bovine and ovine meat product supply which is at 0.001, indicating that there is no systematic bias in the model. The actual and the simulated series fitted very well. The variance proportions for all the nine equations are small in magnitude with the highset one at 0.032. Finally, all the covariance proportions are either one or close to one. In general, the model performs very well in tracking the actual values. Figures 6.8 to 6.16 plot the predicted versus actual values of seven output supplies and two input demands.

To be careful to reject nested model in favor of full model, the validation statistics for nested model are presented in Table 6.11. The results indicate that bias proportion statistics for other food from crop is 0.993, which is too high such that the covariance proportion is only about 0.065. Such high bias proportion and low covariance proportion coefficients indicate that the nested model can not simulate the Chinese agricultural output supplies and input demands well. This findings support the conclusion that the full model is a better model in reflecting current Chinese agriculture than the nested model.

Overall, the validation statistics reported in Table 6.10 indicate that the restricted full model simulates the Chinese agricultural output supplies and input demands satisfactorily. This satisfactory simulated model provides us further confidence

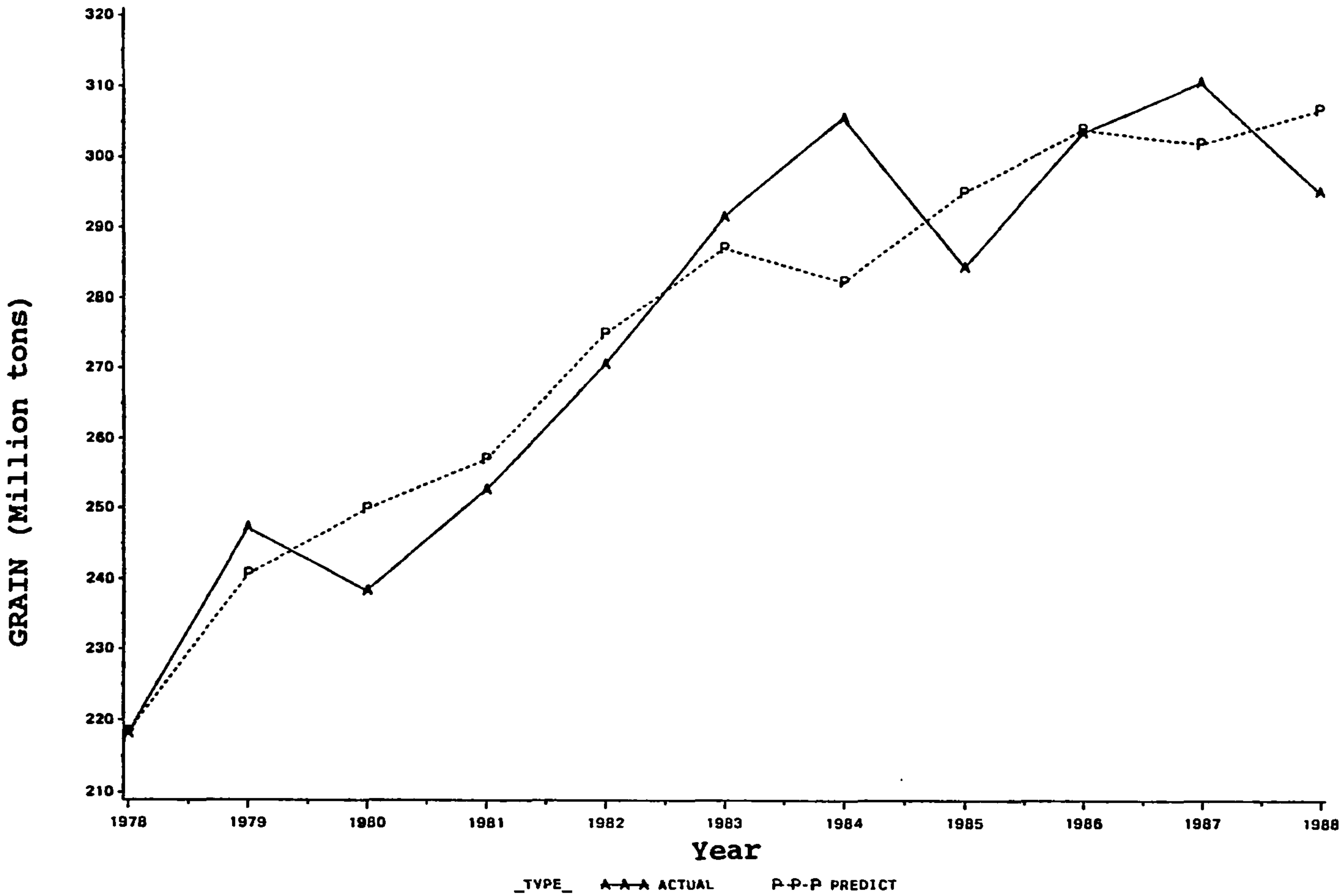

Figure 6.8. Predicted versus actual quantity of China grain production

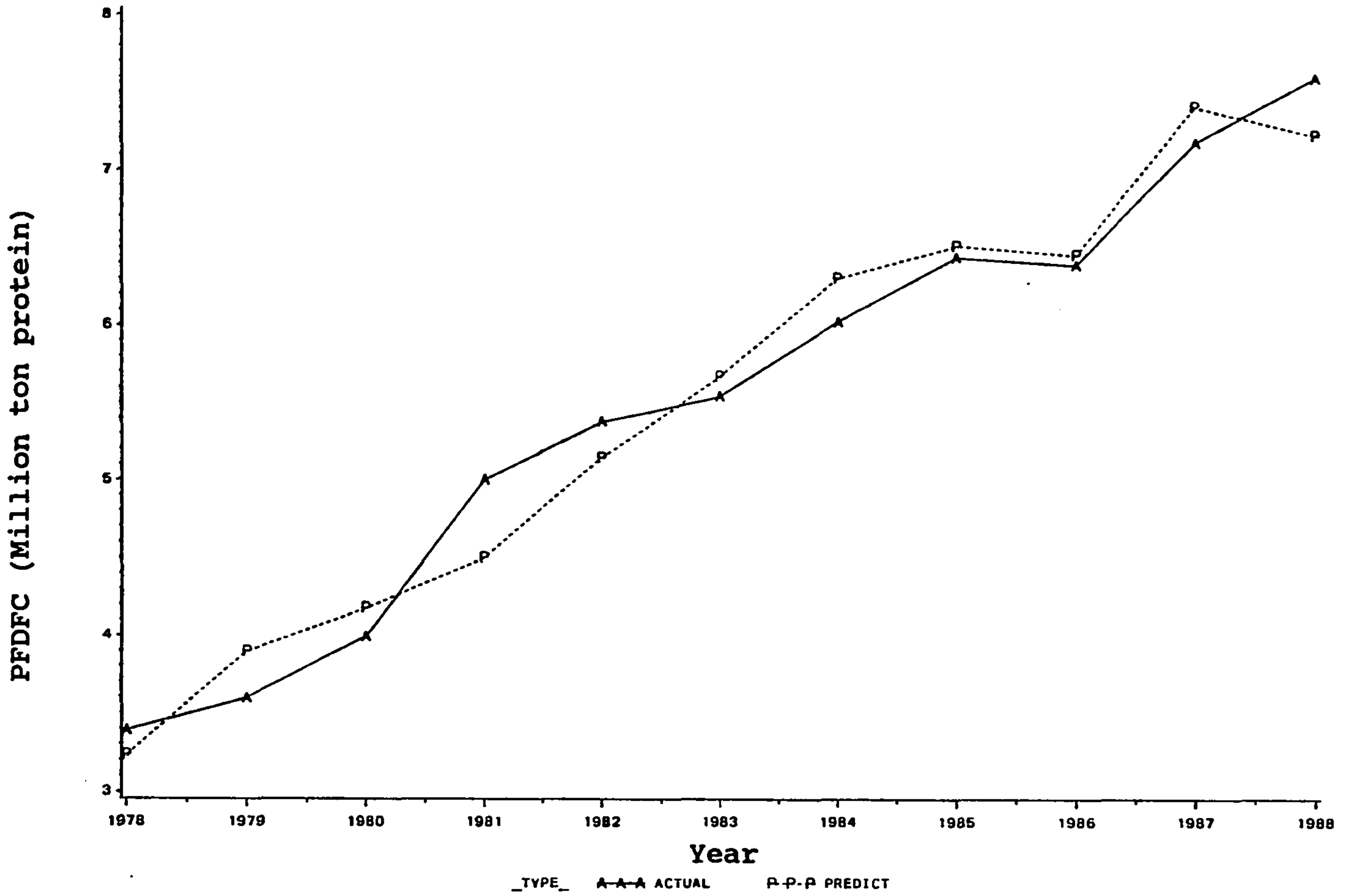

Figure 6.9. Predicted versus actual quantity of China protein feed production

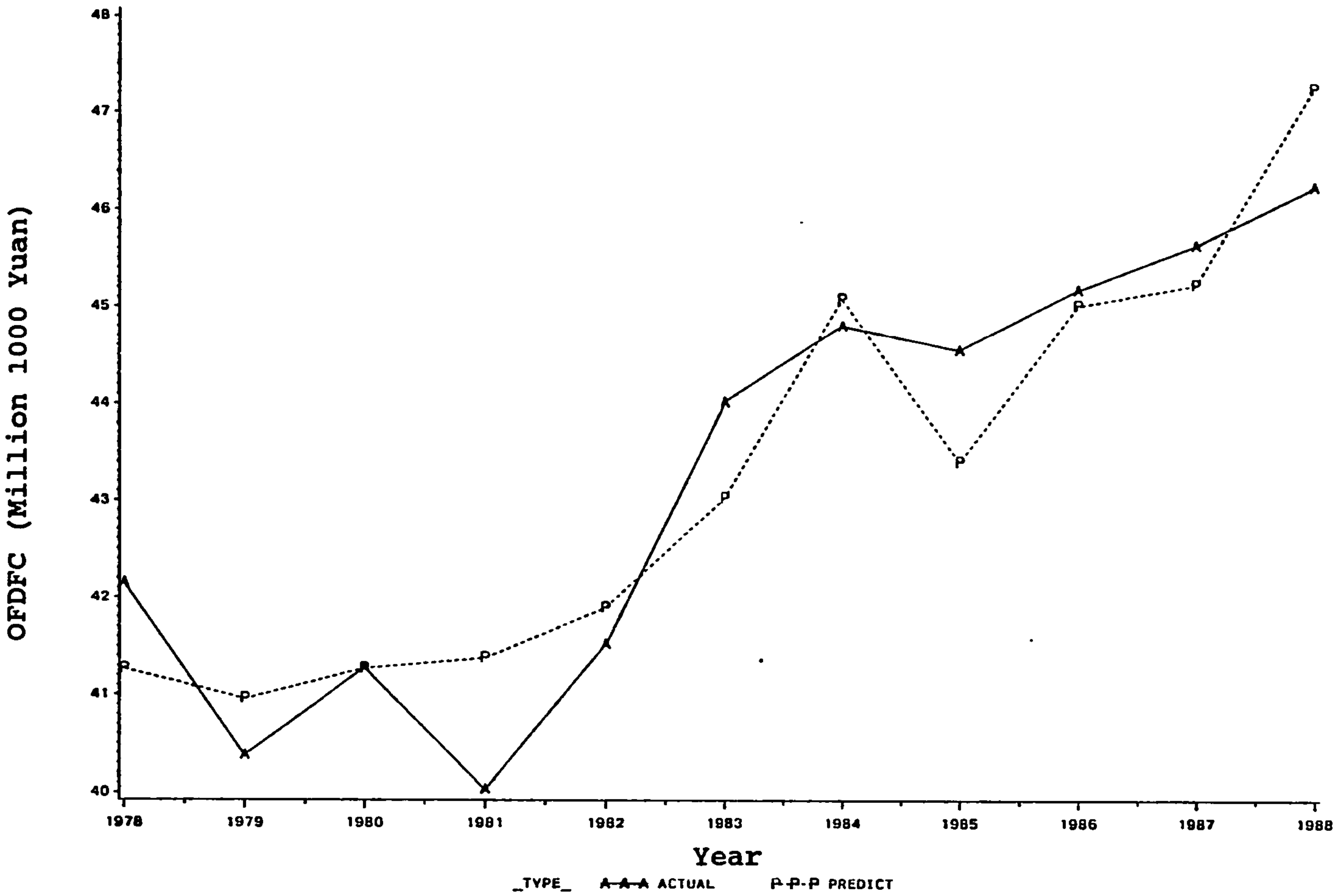

Figure 6.10. Predicted versus actual quantity of China other food from crop production

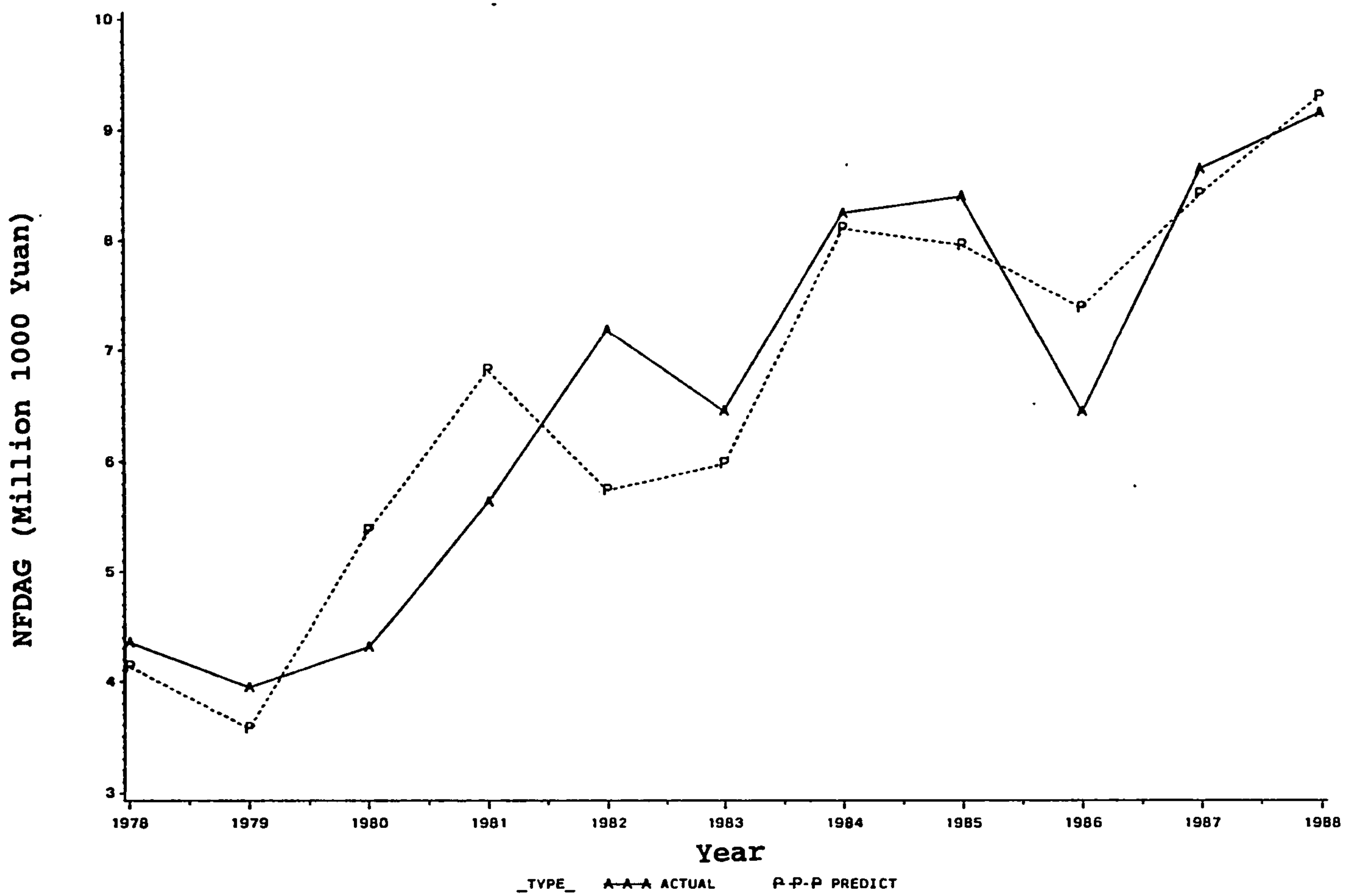

Figure 6.11. Predicted versus actual quantity of China nonfood agricultural production

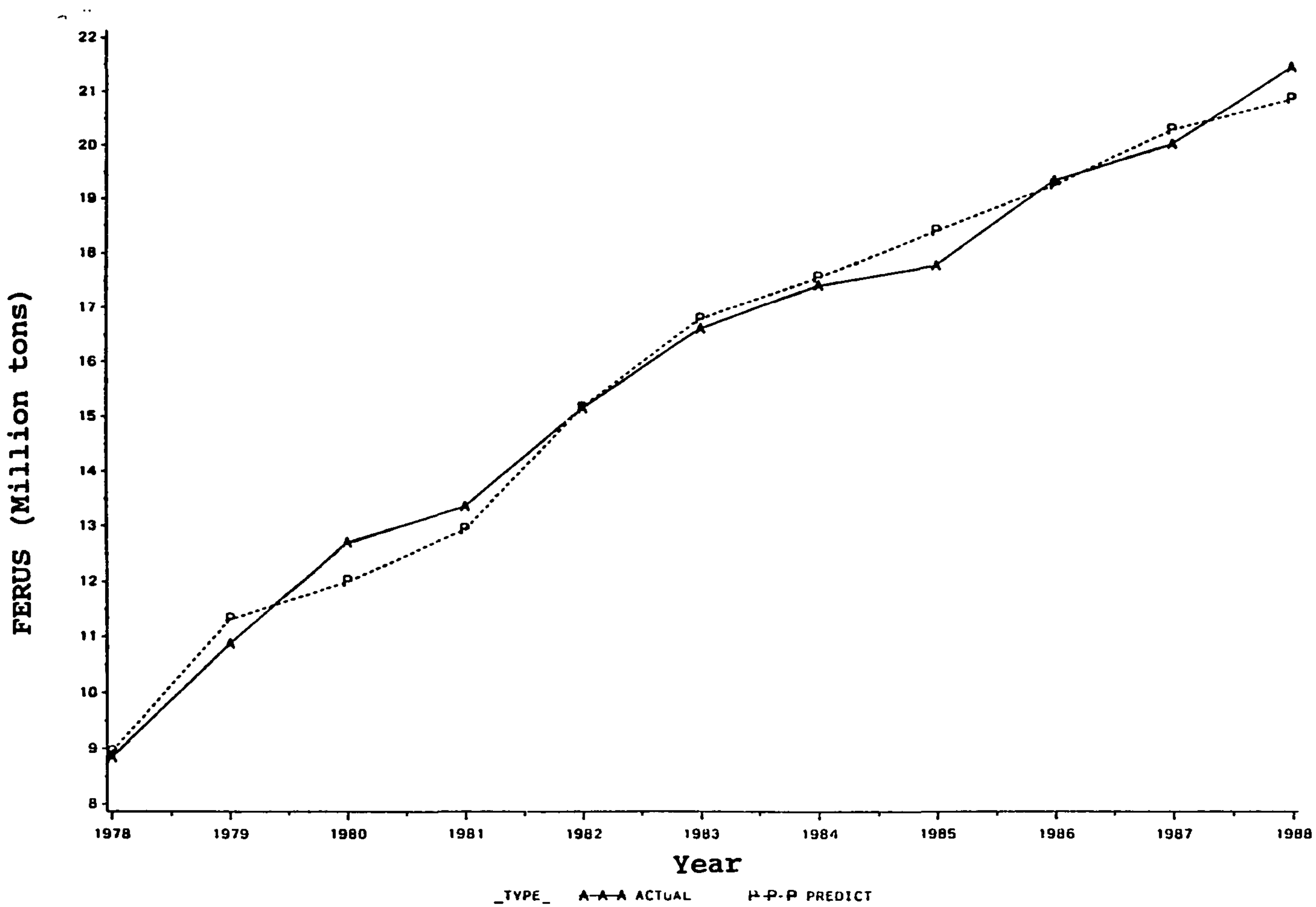

Figure 6.12. Predicted versus actual quantity of China fertilizer demand

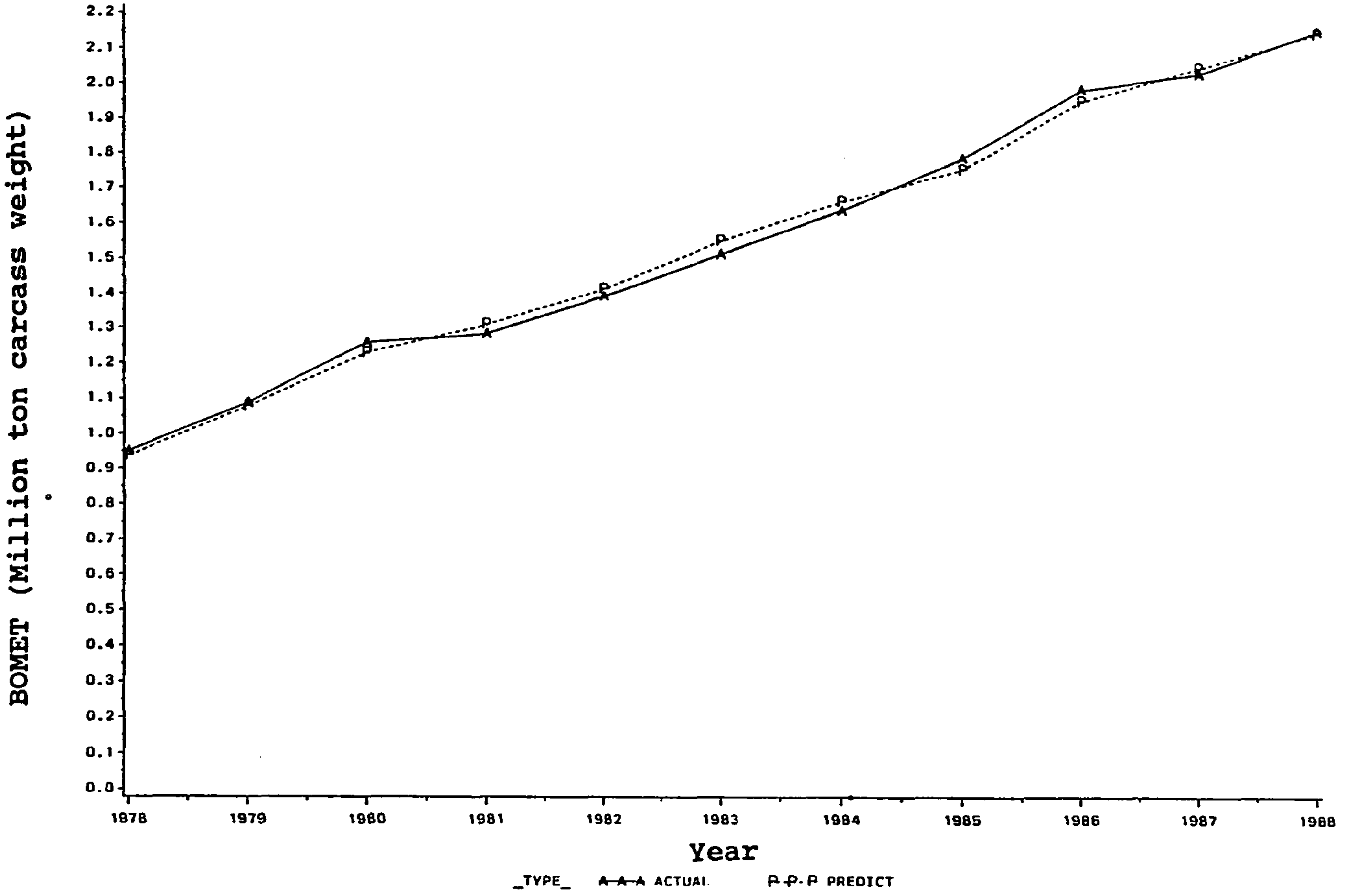

Figure 6.13. Predicted versus actual quantity of China bovine meat production

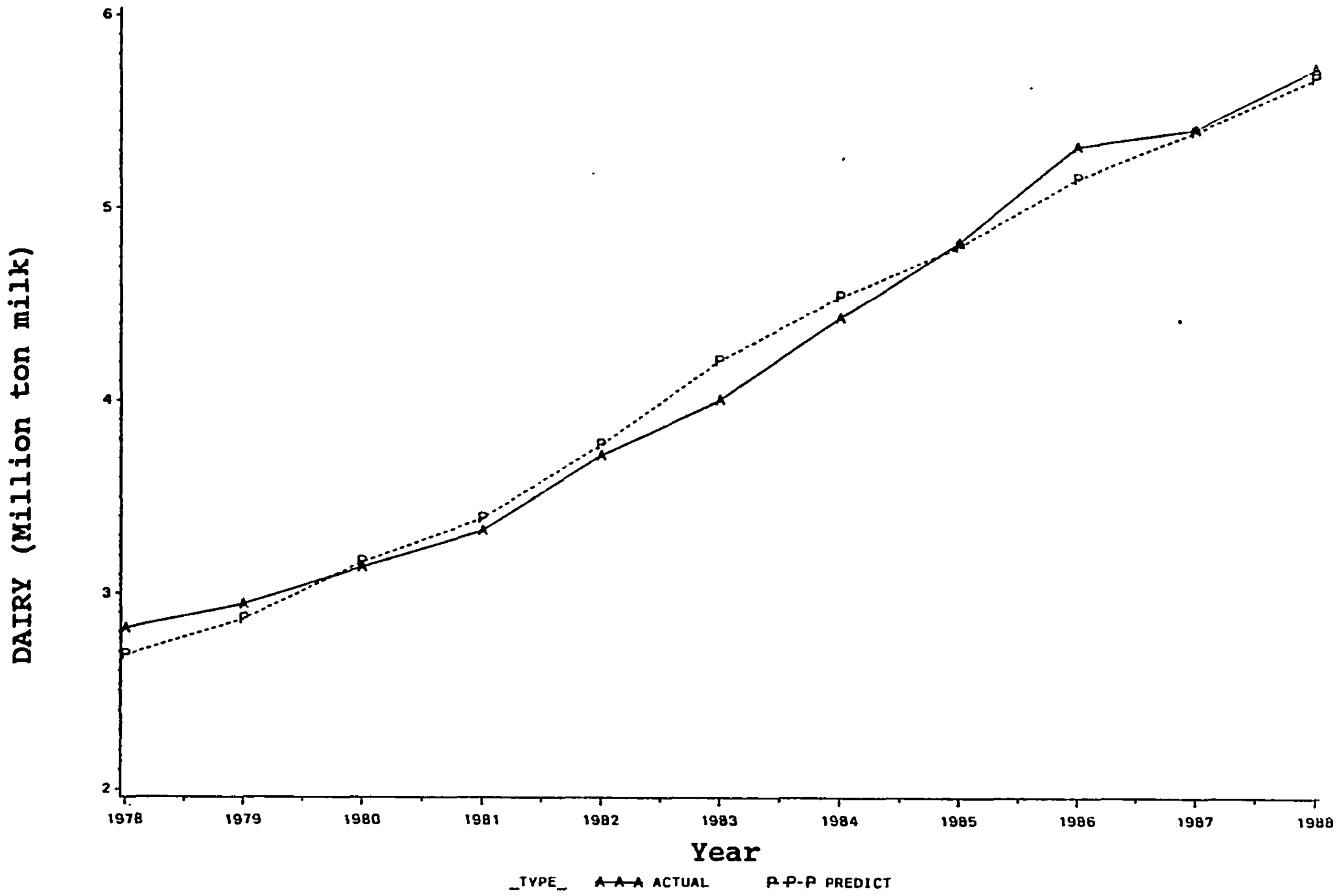

Figure 6.14. Predicted versus actual quantity of China dairy product production

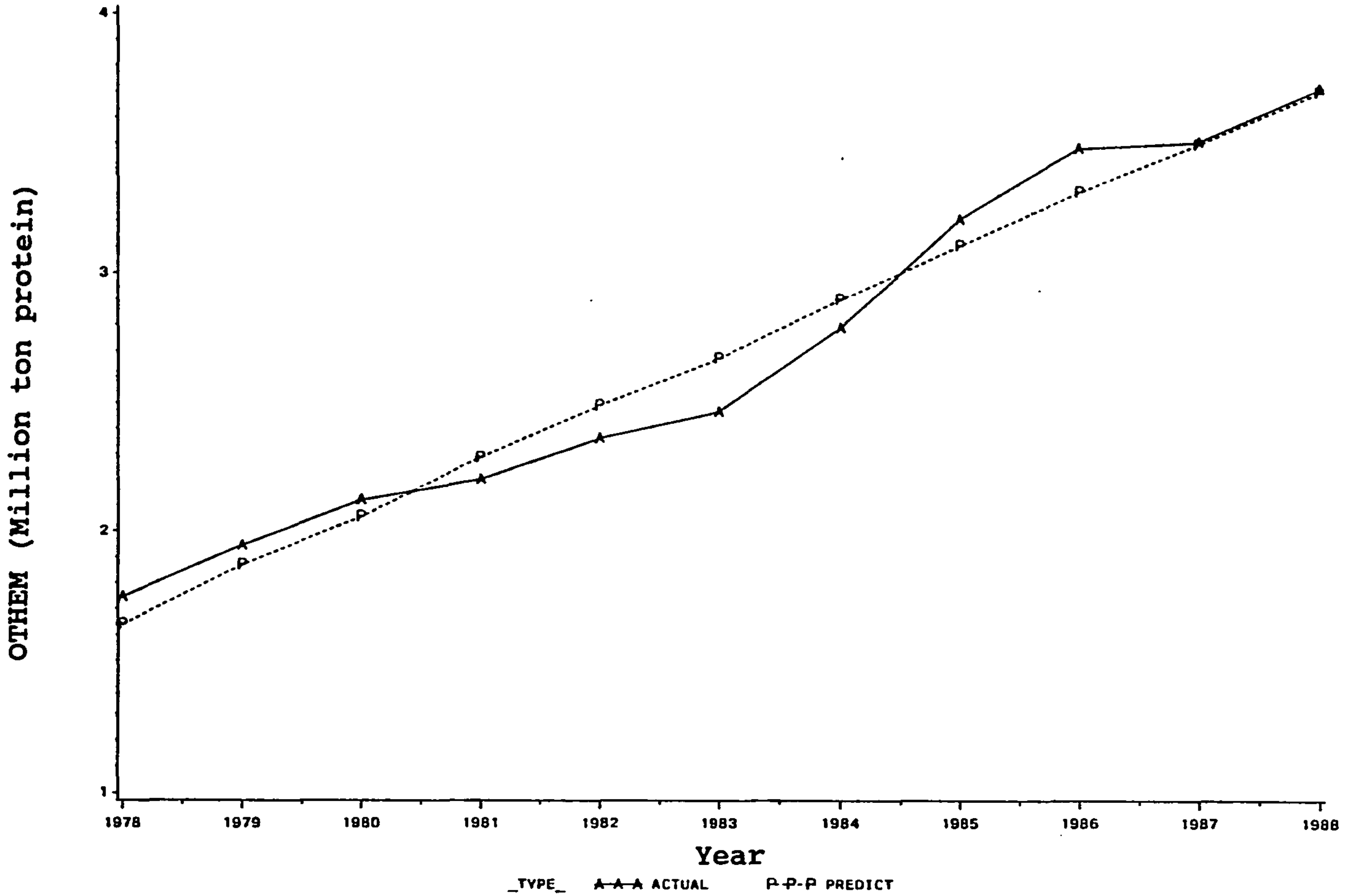

Figure 6.15. Predicted versus actual quantity of China other meat production

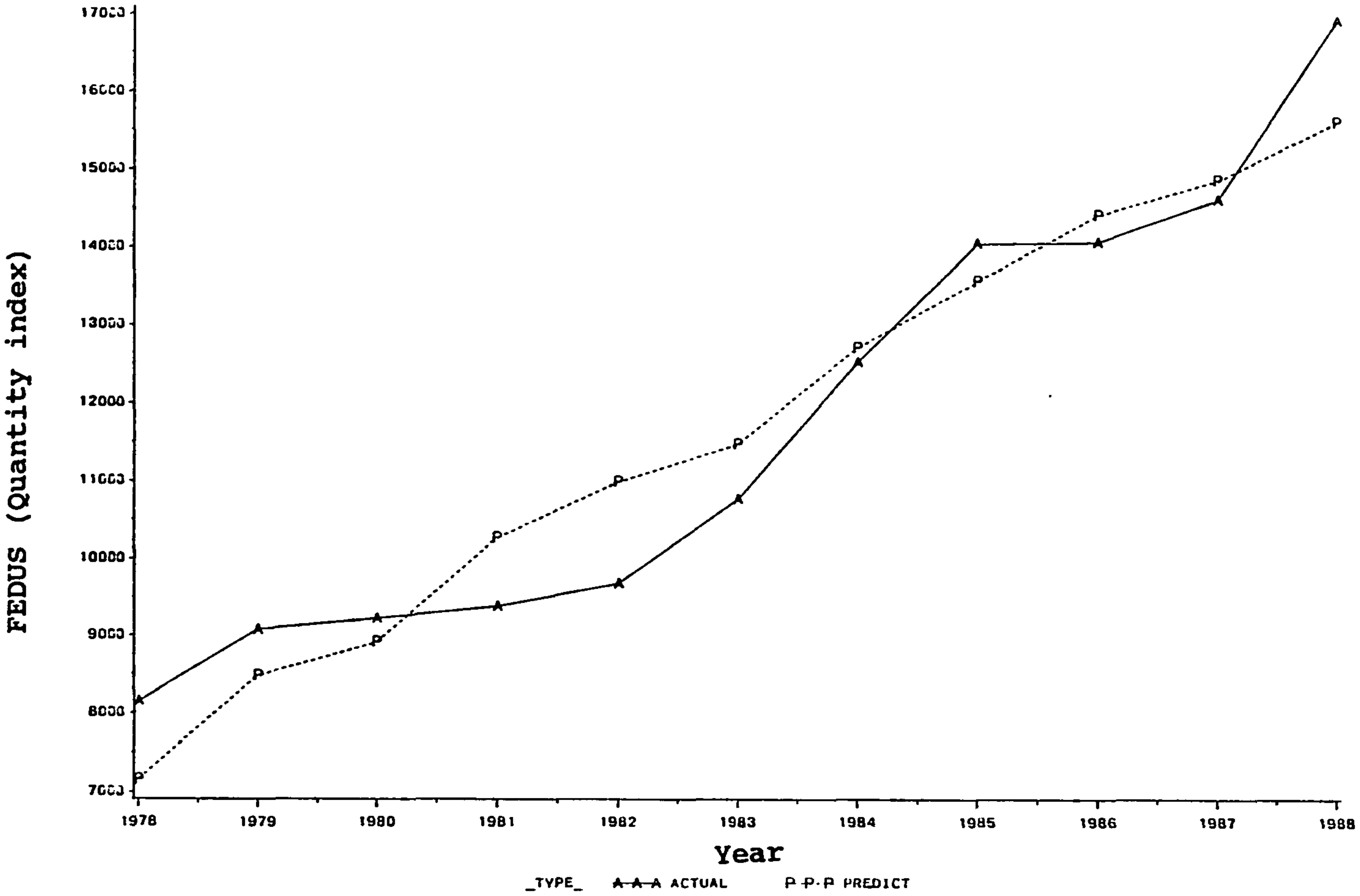

Figure 6.16. Predicted versus actual quantity of China feed demand

Table 6.13. Simulation statistics of the estimated nested model with the restriction of convexity

		Theil's Forecast Error Statistics		
Equation	MAPE	Bias(U_m)	Variance(U_s)	Covariance(U_c)
GRAIN	3.60	0.000	0.033	0.967
PFDFC	2.91	0.000	0.006	0.994
OFDFC	4.91	0.993	0.002	0.065
NFDAG	10.20	0.000	0.054	0.946
FERUS	3.09	0.000	0.001	0.999
BOMET	1.78	0.001	0.002	0.997
DAIRY	2.64	0.000	0.004	0.996
OTHEM	4.42	0.000	0.005	0.995
FEDUS	8.90	0.000	0.002	0.998

that the estimated model maintaining all theoretical restrictions adequately incorporates the production technology under current mixed system of planning and markets. Hence, the model can be used for policy scenario analysis.

7 POLICY SCENARIO ANALYSIS

For the main objective of this study, to analyze the impacts of the policy instruments on the Chinese agriculture, the estimated output supply and input demand equations with policy variables developed in the preceding chapter are used to evaluate the comparative static results using dynamic policy simulation exercises. The exogenous policy variables are parametrically changed, the dynamic results with and without the shock are compared, and inferences are made aout the impacts of these policy instruments on Chinese gricultural production and input usage.

Two agricultural policy scenarios are assessed for the simulation period from 1978 through 1988. The first policy scenario is a 10 percent increase in the state price of grain commodity. The second one is a 10 percent rise of the state quota of grain sold to the state at the low state prices. Because nonjointness between crop and livestock sectors is assumed, the reported potential impacts of policy scenarios exclude the livestock sector.

7.1 Impacts of the State Price

The dynamic simulation results of a 10 percent increase in the state price of grain supply over the periods 1978 to 1988 are presented in Table 7.1. To better evaluate the impacts, the results are reported in base-run, scenario-run, and percent changes of scenario figures over the baserun.

The theoretical immediate impacts of an increase in the state of grain commodity, as discussed in the preceding chapters, are comprehensive. However, there are two, among others, significant effects. One is that the producer equivalent income variation is reduced, which will increase the total grain production. But, recall that the impacts on other production may not be necessarily negative for a utility maximizer. The other immediate effect is that changes in the state price of grain will alter the distribution of the market price of grain. This in return will affect the grain production as well as other output supplies and input demands. Because no adequate data allow to assess the dynamic relations between the state prices and market prices, what reported in this study is only the immediate impacts through equivalent income variation. In other words, it is assumed that increase in the state price of grain commodity has no effects on the distribution of the market price of grain commodity.

As theoretically expected, a ten percent increase in the state price in all years during the period 1978 through 1988 resulted in positive impacts on grain production, however, negative effects on others. Thus, the overall effect on crop production is ambiguous. During the same period, grain

Table 7.1. Dynamic impacts of a sustained increase in the state price of grain by ten percent on crop sector

Variable	Base/ Scenario	1978	1979	1980	1981	1982
GRAIN	Base	218.277	240.641	249.881	257.021	274.854
	Scenario	218.709	241.247	250.364	257.527	275.368
	% change	0.198	0.252	0.193	0.197	0.187
PFDFC	Base	3.221	3.891	4.173	4.495	5.140
	Scenario	3.139	3.775	4.081	4.399	5.042
	% change	-2.558	-2.984	-2.215	-2.140	-1.902
OFDFC	Base	41.265	40.960	41.270	41.379	41.900
	Scenario	40.821	40.336	40.774	40.858	41.371
	% change	-1.076	-1.523	-1.202	-1.258	-1.262
NFDAG	Base	4.136	3.573	5.368	6.824	5.741
	Scenario	4.040	3.439	5.261	6.712	5.627
	% change	-2.319	-3.758	-1.984	-1.646	-1.977
FERUS	Base	8.939	11.309	11.994	12.931	15.149
	Scenario	8.832	11.159	11.875	12.806	15.002
	% change	-1.197	-1.326	-0.992	-0.967	-0.838

Table 7.1. (continued)

1983	1984	1985	1986	1987	1988	Average
287.050	282.211	294.886	303.789	301.792	306.656	274.278
287.700	282.915	295.603	305.517	302.656	307.409	275.001
0.226	0.249	0.243	0.569	0.286	0.246	0.259
5.666	6.297	6.505	6.447	7.404	7.217	5.496
5.542	6.163	6.368	6.117	7.239	7.073	5.358
-2.192	-2.132	-2.103	-5.117	-2.235	-1.993	-2.506
43.027	45.077	43.399	45.008	45.224	47.236	43.249
42.359	44.352	42.662	43.230	44.334	46.461	42.505
-1.552	-1.608	-1.699	-3.950	-1.968	-1.636	-1.703
5.979	8.103	7.954	7.385	8.407	9.296	6.615
5.835	7.947	7.795	7.002	8.215	9.129	6.455
-2.408	-1.928	-1.998	-5.191	-2.286	-1.798	-2.481
16.777	17.542	18.386	19.225	20.267	20.832	15.759
16.616	17.367	18.209	18.797	20.053	20.646	15.580
-0.960	-0.998	-0.963	-2.226	-1.056	-0.893	-1.129

production increased from 0.187 percent in 1978 to 0.569 percent in 1986, aout 0.259 percent on average. A ten percent percent increase in the state price of grain brought about negative impacts on the productions of protein feed, other food from crop, and nonfood agricultural products. Decreasing rate in protein feed production ranged from -1.902 in 1982 to -5.117 in 1986. The average change rate over the sample period was about -2.506. Other food production decreased from -1.076 percent 1n 1978 to -3.950 in 1986, about -1.703 percent decrease per year. Production of nonfood agriculture decreased by an average -2.481 percent as a result of ten percent increase in the state price of grain products. The results show that farmers intend to produce more grain products and less protein feed from crop, other food from crop, and nonfood agriculture if the state price of grain increases.

Since as a result of a ten percent increase in the state price of grain, grain production goes up while all other nongrain productions go down, the net effects of increase in the state price on fertilizer use is negative, ranging from -0.838 to -2.226, about -1.129 on average. That is, the decrease in demand for fertilizer by nongrain crop is greater than the increase in demand for fertilizer by grain crop. Consequentely, demand for fertilizer by crop sector is going down. Thus, the overall effects of a ten percent increase in the state price of grain on crop sector is mixed. These results confirm the theoretical argument made in the previous chapters that, for a utility maximizer, increase in the state price is not necessarily leading to increase in all individual crop production.

7.2 Impacts of the State Quota

In this scenario, the state quota of grain output that farmers have an obligation to sell to the state at the state price increased by ten percent while all other things being equal. The dynamic simulation results of a ten percent increase in the state quota of grain are reported in Table 7.2. Unlike the changes in the state price, increase in the state quota will only have direct impacts on farmers anticipated income level: farmers' equivalent income variation which then affects farmers production decision making. Increase in the state quota has nothing to do with the distribution of market price directly.

A ten percent increase in the state quota of grain sold to the state at the state price also has mixed effects. In other words, effects of an increase in the state quota of grain on production and input use varied from crop to crop and from year to year. As increase in the state quota of grain will reduce farmers' equivalent income variation, grain production decreased by an average of -0.134 percent during the same period, ranging from -0.035 percent in 1987 to -0.267 percent in 1978. An

Table 7.2. Dynamic impacts of a sustained increase in the state quota of grain by ten percent on crop sector

Variable	Base/ Scenario	1978	1979	1980	1981	1982
GRAIN	Base	218.277	240.641	249.881	257.021	274.854
	Scenario	217.694	240.031	249.491	256.680	274.529
	% change	-0.267	-0.253	-0.156	-0.133	-0.118
PFDFC	Base	3.221	3.891	4.173	4.495	5.140
	Scenario	3.333	4.007	4.247	4.561	5.203
	% change	3.468	2.992	1.782	1.460	1.217
OFDFC	Base	41.265	40.960	41.270	41.379	41.900
	Scenario	41.866	41.588	41.672	41.729	42.235
	% change	1.456	1.532	0.974	0.847	0.798
NFDAG	Base	4.136	3.573	5.368	6.824	5.741
	Scenario	4.265	3.709	5.455	6.899	5.814
	% change	3.127	3.793	1.622	1.106	1.264
FERUS	Base	8.939	11.309	11.994	12.931	15.149
	Scenario	9.083	11.460	12.091	13.016	15.230
	% change	1.612	1.335	0.809	0.657	0.535

Table 7.2. (continued)

1983	1984	1985	1986	1987	1988	Average
287.050	282.211	294.886	303.789	301.792	306.656	274.278
286.675	281.754	294.673	303.582	301.686	306.468	273.930
-0.131	-0.162	-0.084	-0.068	-0.035	-0.061	-0.134
5.666	6.297	6.505	6.447	7.404	7.217	5.496
5.738	6.385	6.553	6.487	7.424	7.253	5.562
1.265	1.393	0.734	0.619	0.272	0.499	1.427
43.027	45.077	43.399	45.008	45.224	47.236	43.249
43.413	45.547	43.655	45.221	45.333	47.429	43.608
0.898	1.043	0.590	0.473	0.241	0.413	0.842
5.979	8.103	7.954	7.385	8.407	9.296	6.615
6.062	8.204	8.009	7.431	8.430	9.338	6.923
1.393	1.251	0.694	0.620	0.275	0.447	1.418
16.777	17.542	18.386	19.225	20.267	20.832	15.759
16.870	17.655	18.448	19.276	20.294	20.879	15.846
0.554	0.644	0.337	0.265	0.133	0.256	0.646

increase in the state quota of grain has, however, positive impacts on all other nongrain production. Production of protein feed from crop increased from 0.272 percent in 1987 to 3.469 percent in 1978, resulting an average of 1.427 percent increase per year. The positive effects of a ten percent increase in the state quota can also be found on the productions of other food from crop and nonfood agriculture. During the same historical period, production of other food from crop increased by an average of 0.842 percent and production of nonfood agriculture increased by an average of 1.427 percent. This mixed effects on crop production result in an increase in fertilizer use at an average of 0.646 percent per year. This is because the increase in demand for fertilizer by nongrain crop, as a result of increase in nongrain production, is higher than the decrease in demand for fertilizer by grain crop as grain production is reduced. The results reported in Table 7.2 confirm the argument the increase in the state quota of grain sold to the state at the low state price does not necessarily have negative effects on individual crop production for a utility maximizer, given other things being equal.

By comparision of absolute percentage of changes in crop sector due to a ten percent increase in the state price of grain and a ten percent increase in the state quota of grain, one can find that changes in the state price of grain has more significant impacts on output supplies and input demand than changes in the state quota of grain. This finding reflects the real policy structure in China. This result suggests that the government should increase the state price of grain rather than decrease the state quota of grain if grain production is a higher priority.

8 SUMMARY AND CONCLUSIONS

8.1 Summary

The two major objectives of the present study are: (1) to construct a theoretical model of the farm producer decisions on the output supplies and input demands incorporating current Chinese mixed system of planning and markets; and (2) to estimate the supply and input demand system maintaining all theoretical restrictions.

Policy variables were directly modeled into producer objective function. Producer decision rules on output supplies and input demands were explored in the theoretical framework of microeconomics. When there is no uncertainty involved, the necessary and sufficient conditions for profit maximizers much like those for producers in the market economy are directly applicable. As the state prices are lower than market prices and the state quotas are lower than the production, the state prices and the state quotas have no impacts on producer marginal decision making. Only market prices affect the marginal decision making for output supplies and input demands. However, the state prices and quotas do matter in determining maximum attainable profits. When producers are subject to price uncertainty, the producer marginal decision rules involve not only market prices but also the state prices and the state quota.

A multioutput-multiinput technology in a dual framework was employed for the present study. Output supply and input demand equations for risk averse producers were derived from a specific utility function and a normalized quadratic profit function. The derived supply and input demand system prossesses all theoretical properties of monotonicity, homogeneity, symmetry, and convexity.

The complete model consists of seven outputs (grain, protein feed, other food from crop, nonfood agricultural products, bovine meat, dairy products, and other meat), two variable inputs (fertilizer and feed), two fixed inputs (land and livestock inventory), two policy variables (the state price of grain and the state quota of grain sold to the state at the state price), and a time variable.

Two submodels, crop and livestock, were separately estimated using annual data for the period from 1978 to 1988. Maximum likelihood methods by Fortran-GQ-OPT were used in the estimation maintaining all the theoretical restrictions. Empirical results are consistent with the theoretical microfoundations. The elasticity estimates are plausible and meaningful. The statistics of model validation in a historical simulation indicated that this model performed satisfactorily.

The estimated model was then used to analyze two policy scenarios. One is a ten percent increase in the state price of grain sold to the state. The other one is a ten percent increase in the state quota of grain that farmers have obligation to sell to the state at the state prices. The results showed that both scenarios have mixed effects. Effects of an increase in the state prices of grain is positive on grain production and negative on all nongrain crop production. Production of grain increased by an average of 0.259 percent. Productions for protein feed, other food from crop, and nonfood agriculture decreased by an average of -2.506, -1.703, -2.481 percent, respectively. The overall effects on crop production resulted in a decrease in use of fertilizer by -1.129 percent on average.

If the state quota of grain increased ten percent in the sample period, effects on crop production and input use were also varied. Production of grain decreased by -0.134 percent on average. Increase in grain quota have positive impacts on the productions of all nongrain products. Protein feed from crop was found to go up on an average of 1.427 percent per year. Other food from crop increased by 0.842 percent per year on average. Nonfood agriculture were observed to increase at an average rate of 1.418 percent a year. Fertilizer use was found to increase as the state quota of grain increased.

8.2 Conclusions

The policy conclusion drawn from the dynamic simulation of the effects of the government policy scenarios for the Chinese agriculture can be summarized as follows.

First, the state prices and the state quotas work jointly like producer tax dispensing with producer equivalent income variation. The impacts of the equivalent income variation on farmers' maximum attainable profits are negative. However, for a constant risk aversion producer, the effects of changes in the state prices or the state quotas on individual crops are not alike. The government should raise the state prices of grain or/and reduce the state quotas of grain if grain production is a higher priority in the Chinese economic development. This policy scenario can, however, reduce productions of protein feed, other food from crop, and nonfood agriculture. If the state prices are reduced or/and the state quotas are increased, the opposite results would be observed. Changes in the state price of grain has more significant impacts on crop sector than changes in the state quota of grain.

Second, changes in expected market prices of grain have two effects, direct and indirect. The indirect effect through the equivalent income variation indicates how farmers respond to the changes as a result of anticipated income effects. The indirect effect will vanish if the state price changes by the same amount as the expected free market price given the state quota unchanged. The policy to be drawn involve the importance of not ignoring the free market in such mixed systems. It is the free market price that primarily determines decisions of producers. But, if the free market is treated as a residual in the state planning process, unintended price variations may have significant impacts on producer resource allocation decisions and incomes. Both the planning and market sectors must be taken into account in formulating state planning targets so the mixed system of planning and markets can be working well.

More generally, the results indicate that modern microeconomic theory can be used to analyze mixed systems of planning and markets. The combination of a microeconomic theory and structural policy specification in dual system provides the basis for operational policy analysis system that can be effectively used in developing countries.

8.3 Suggestions for Further Research

Because the model is developed for the current Chinese economy, only very short historical period exists for observing the economy even if all statistical data after 1978 are available. A strong assumption of nonjointness between crop and livestock sectors has been made in estimation due to the limitation of the availability of adequate data and the small number of observations. This assumption should be relaxed as more statistical data become available.

Also because of the limitation of adequate data, the current study used highly aggregated commodity classification. If more detailed commodity grouping is used as the more observations become possible, the empirical findings of policy analysis would be more interesting. And, hence, more valuable policy inference from empirical results will be made.

The present model for the Chinese agriculture does not contain consumer demand for agricultural commodities and input supply equations as well as nonagricultural sector. Thus, results of the empirical policy analysis are only partial in nature because no simultaneous price determination mechanism was incorporated. The policy impacts can be fully captured if policy implementation is constructed in a general equilibrium model.

Furthermore, this study does not involve financial and monetary markets. Government policy alternatives in these areas are not incorporated in determining agricultural supplies and input demands in this model. Incorporating these policy variables in the model may generate different empirical results of policy analysis.

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APPENDIX

Table A.1. Production of tuber and soybeans and their share in total grain production[a]

Year	Grain Production	Tuber Production	Soybean Production	Tuber + Soybean/ Total Grain
1978	304.77	31.74	7.57	12.90%
1979	332.12	28.46	7.46	10.82%
1980	320.56	28.73	7.94	11.44%
1981	325.02	25.97	9.33	10.86%
1982	354.50	27.05	9.03	10.18%
1983	387.28	29.25	9.76	10.07%
1984	407.31	28.48	9.70	9.37%
1985	379.11	26.04	10.50	9.64%
1986	391.51	25.34	11.61	9.44%
1987	402.98	28.20	12.47	10.01%
1988	394.08	26.97	11.65	9.80%

[a]Collected from Statistical Yearbook of China, 1989 (State Statistical Bureau, 1989). Quantities in million tons.

Table A.2. Grain data used for estimation[a]

YEAR	GRAIN	GRANP	GRNQS[b]	GRNPS[c]	EIVGN
1978	218.10	602.00[d]	41.978	256.00	14524.388
1979	247.26	602.00	47.555	300.00	11888.750
1980	238.35	550.00	44.094	304.00	9921.150
1981	252.62	529.00	49.094	316.00	10800.680
1982	270.57	536.00	53.142	328.00	10150.122
1983	291.51	519.00	73.405	329.00	14460.785
1984	305.45	526.00	83.982	319.00	16460.472
1985	284.33	515.00	71.627	382.00	9239.883
1986	303.36	511.00	75.049	445.00	5628.675
1987	310.48	520.00	76.701	463.00	12042.057
1988	295.03	620.00	73.227	496.33	15426.732

[a]See Table 5.1 for variable explanation and data sources.

[b]Grain output sold to the state at the state price. Data were calculated by the formula expressed in Chapter 5.

[c]The state price of grain. Data from 1978 to 1983 were collected from China Trade and Price Statistics: 1952-1983 and 1988 (State Statistical Bureau, 1984, 1989) and from 1984 to 1988 were calculated according to the formula described in Chapter 5.

[d]Since market price of grain in 1977 is not available, it is set equal to the market price of grain in 1978.

Table A.3. Other data used in the estimation[a]

YEAR	PFDFC	OFDFC	NFDAG	BOMET	DAIRY	OTHEM
1978	3.381721	42.152048	4.355302	0.950	2.819	1.746
1979	3.589446	40.375008	3.950347	1.086	2.945	1.944
1980	3.986926	41.276128	4.314205	1.256	3.137	2.119
1981	4.995923	40.030176	5.630856	1.282	3.328	2.199
1982	5.372530	41.523744	7.186606	1.390	3.714	2.360
1983	5.538893	44.018464	6.456290	1.497	4.002	2.463
1984	6.014861	44.802469	8.242928	1.633	4.434	2.785
1985	6.430641	44.550128	8.395777	1.782	4.823	3.202
1986	6.382493	45.170432	6.445998	1.979	5.320	3.478
1987	7.171000	46.625000	8.641000	2.026	5.411	3.502
1988	7.590000	46.219000	9.147000	2.146	3.707	3.707

[a]See Table 5.1. for variable explanations and data sources.

Table A.3. (continued)

YEAR	PFFCP	OFFCP	NFAGP	BOMTP	DAIRP	OTHMP
1978	617	996	2152	1742	164	19856
1979	644	942	2165	1836	181	28147
1980	785	1112	2685	1983	181	28792
1981	863	1228	3245	2079	195	34589
1982	928	1359	2781	2349	177	31786
1983	993	1488	2724	2447	217	22677
1984	1054	1522	3561	2625	241	23322
1985	1166	1529	3623	2664	247	24417
1986	1199	1869	3077	3407	304	30734
1987	1304	1644	3491	3195	315	48976
1988	1320	1931	4438	3766	371	57730

Table A.3. (continued)

YEAR	FERUS	FEDUS	LNDUS	NANIN	FERTP	FEEDP
1978	8.840	8138.552	150.104	523.538	223	1.291
1979	10.863	9070.176	148.477	541.954	231	1.192
1980	12.694	9218.375	146.379	574.196	236	1.279
1981	13.349	9378.546	145.157	564.416	237	1.355
1982	15.134	9675.689	144.755	554.731	243	1.512
1983	16.598	10761.633	143.993	558.643	260	1.611
1984	17.398	12513.572	144.221	543.564	259	1.588
1985	17.758	14039.402	143.626	547.318	322	1.726
1986	19.306	14062.901	144.204	547.100	370	1.799
1987	19.993	14614.036	144.957	595.087	381	1.978
1988	21.420	16902.087	144.869	602.721	428	2.248

Table A.4. Data used to derive Divisia Index for feed input use[a]

	Feed from Grain		Feed from Bovine Meat	
Year	Quantity[b]	Price[c]	Quantity	Price
1977	2808	150	0.0550	582
1978	2998	180	0.0550	449
1979	3188	180	0.0550	554
1980	3118	190	0.0550	573
1981	3250	220	0.0605	582
1982	3711	230	0.0660	585
1983	4454	220	0.0649	587
1984	5091	270	0.0682	611
1985	5135	260	0.0715	758
1986	5432	330	0.0748	781
1987	6635	320	0.0767	921

[a]Quantities in 10 thousand tons and prices in Yuan/10 thousand tons. Collected from FAO aggregates except otherwise indicated. It is assumed that previous products are used as this year's feed input uses.

[b]Provided by China Statistical Information and Consultancy Service Center, State Statistical Bureau of the People's Republic of China.

[c]Prices in 1978, 1980 and 1983-1987 are collected from China Rural Statistics, 1985, 1986, 1987, and 1988 (State Statistical Bureau, 1985, 1986, 1987, and 1988). The rest are the estimates derived by time trend method based on available data.

Table A.4. (continued)

	Feed from Dairy Product		Feed from Protein Feed	
Year	Quantity	Price	Quantity	Price
1978	24.9031	37	101.6921	607
1979	25.9872	46	117.0532	626
1980	26.9430	49	127.9711	771
1981	29.2845	53	150.1614	846
1982	31.1089	59	166.2732	927
1983	34.7955	67	193.8927	989
1984	35.8867	63	185.8934	1042
1985	41.1272	62	214.3645	1144
1986	42.6320	75	212.7652	1169
1987	46.2358	89	201.1075	1235
1988	49.9327	94	235.9391	1283

Table A.4. (continued)

	Feed from Other Food		Divisia Index[d]	
Year	Quantity	Price	Quantity	Price
1978	533.7701	1062	813855.17	1.291
1979	616.4440	757	907017.57	1.192
1980	587.3036	860	921837.46	1.279
1981	605.3948	908	937854.56	1.355
1982	606.6197	975	967568.85	1.512
1983	645.0074	1063	1076163.30	1.612
1984	758.6565	1070	1251357.20	1.588
1985	822.2160	974	1403940.20	1.726
1986	816.8496	1154	1406290.10	1.799
1987	844.4182	1001	1461403.60	1.978
1988	882.5078	1552	1690208.70	2.248

[d]See Chapter 5 for the discription of Divisia Index.