Estimating Food Demand in Rural China

Under the Perspectives of Agricultural Household Models

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Abstract

We present in this study an agricultural household model that describes the joint production-consumption decision making of Chinese rural households under imperfect market. We conclude that the marginal value of a food product consumed is the sale price if there is a net sale for this food item; it is the purchase price if there is a net purchase; and it is the shadow price if there is no purchase or sale. A preliminary empirical food estimation analysis confirms that it provides superior demand estimates to use these "effective prices" rather than traditionally used purchase prices or weighted average of sale and purchase prices in rural food demand analysis in less developed countries (LDCs).

Introduction

This study aimed at gaining a credible knowledge of food consumption behavior in rural China, by estimating a complete demand system, in a way consistent with the microeconomic behavior of a Chinese agricultural household not only as a food consumer, but also as a food producer, under imperfect market situations.

Our study focuses on food products since they have been the center of all economic activities in most of the rural China. Rural households allocate a large portion of their resources for food production, so as to guarantee income sources for consumption, be it on food or on other commodities and services. This is especially true for farmers with limited off-farm work opportunities. The rural households in Heilongjiang Province, for example, allocate about 39.0% of their total cash expenditures in agricultural production purposes and gain about 70.3% of their cash incomes from the sales of farm and livestock products in 2001. For these farmers, when we deal with their joint food consumption-production behavior in an agricultural household model, we cover most of their economic activities. Much more effective welfare and policy analysis can result from this study.

In this study, we model rural food demand under the perspective of agricultural household models, in order to take into account how consumption decision is affected by production decision and market situations. The influence of production decision on consumption is captured through the "profit effect" (Singh and Strauss 1986). As a food producer, an agricultural household may supply part of the food consumed from its own production (self-sufficiency). When the price of a food item increases, a rural household

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will produce more of the food product to obtain more income. As far as consumption is concerned, the increased price may increase the consumption of the exact same food item due to increased income from profit. Thus a positive own price response of consumption may result, which should never happen in the traditional demand theory. In the empirical estimation of demand characteristics (usually represented by a set of parameters in a complete demand system) of rural households, a biased and inconsistent estimation will result when this joint production-consumption decision is ignored. And the typical indication of a biased estimation is often reflected in a positive own price elasticity (For example, Halbrendt, Tuan, Gempesaw and Dolketz 1994).

Market situations also affect the consumption decision of an agricultural household. High transaction costs, due to low infrastructure and relatively little market development in most less-developed countries (LDCs), usually increase the costs of acquiring and selling food products and make self-sufficiency of food consumption more attractive.

Previous rural food demand studies in China mostly ignored the joint consumption-production decision-making under various market situations and directly estimated a food demand system (Fan, Wiles and Cramer 1994, 1995; Gao, Wailes and Cramer 1996; Halbrendt, Tuan, Gempesaw and Dolketz 1994; Huang and David 1993, 1998; Lewis and Andrews 1989; Ton and Wahl 1998; Wang, Fuller, Hayes and Halbrendt 1998). The legitimacy and accuracy of this relatively simple approach are under question since it is based on the microeconomic model of utility maximization given fixed prices and income. This assumption is no longer appropriate here since

rational rural households constantly adjust their food production and thus incomes according to market prices, and in some occasions, even prices might not be exogenous.

We present in this study an agricultural household model that describes the joint production-consumption decision making of Chinese rural households under imperfect markets with transaction costs. We conclude that the marginal value of a food item consumed is the sale price if there is a net sale for this food item; it is the purchase price if there is a net purchase; and it is the shadow price if there is no purchase or sale. A Quadratic Almost Ideal Demand System (QAIDS) is used to compare demand estimations under traditional approaches and a simplified approach derived from the agricultural household model. The demand estimation under the perspective of an agricultural household model shows significant improvement. Future agenda for further improvement in estimation is also addressed in this paper.

An Agricultural Household Model for Chinese Rural Households

Agricultural household models have been used to address a variety of issues in the LDCs, such as agricultural price policy (Yotopoulos and Lau 1974), labor supply (Goodwin and Holt 2002), food demand and nutrition (Strauss 1984), environmental issues (Vandusen 2000), migration (deBrauw, Taylor and Rozelle 2002) and many more. Also, the applications of the agricultural household models are not restricted to less developed countries (LDCs) only. Offutt (2002), Administrator of the Economic Research Service, U.S. Department of Agriculture, points out the importance of applying agricultural household models in the future farm policy analysis, since off-farm income

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has become a major source of income for farmers in the United States and they can no longer be treated only as a producer.

Conceptualization of Alternative Scenarios

Without loss of generality, we assume that an agricultural household produces and consumes two food items only, grain (good 1) and vegetables (good 2), with given endowment such as land. The objective of this agricultural household is to maximize its utility. There are three scenarios that can be constructed for this model. The first two are adopted from Taylor and Adelman (2003).

Scenario 1: Missing market

Figure 1 illustrates the extreme case of no markets for either grain or vegetables. The household produces a certain bundle of vegetables and grain. Constraint in the technology is illustrated by the production possibility frontier (PPF). Under this scenario, the agricultural household consumes all of its own-produced products. Thus, its optimal choice of production and consumption should be at the point E , where the marginal rate of substitution is equal to the marginal rage of transformation ($MRS = MRT = -p_1 / p_2$). Although unobservable, the absolute value of the slope for the tangent line is just the relative shadow prices for grain and vegetables.

Scenario 1 is of little interest in terms of policy implications. Since the markets are missing, the agricultural household will always stick to the autarky and thus few policies can help improve its welfare, except a direct subsidy of grain or vegetables or construction of infrastructures to help develop markets.
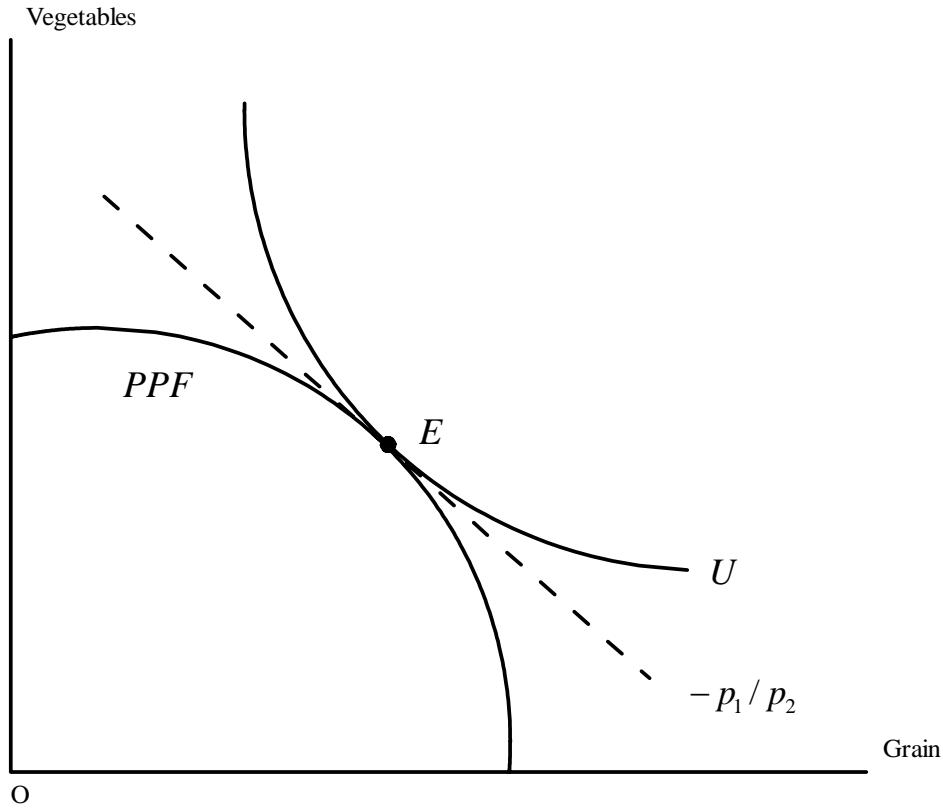
Vegetables

Figure 1: Agricultural Household Behavior with Missing Market

Scenario 2: Perfect Market

Suppose market exists for both vegetables and grain and the market is perfect in the sense that there are no transaction costs. Suppose the exogenously determined relative price for grain and vegetables is p_1/p_2. With the perfect market, the agricultural household can make decisions on production and consumption separately. It first maximizes its profit (its only income source in this case). The profit maximization point is *A* in Figure 2, where the marginal rate of transformation is equal to the relative price ($MRT = -p_1/p_2$). With attainable income associated with maximizing output choice of A, the agricultural household then trades the products to attain a bundle of consumption

of E_1, which yields maximum utility. Compared to the autarky, the existence of the market benefits the agricultural household.

Vegetables

$-p'_1 / p'_2$

$-p_1 / p_2$

PPF

B

A

U_1

$U_2 > U_2$

E_2

E_1

Grain

O
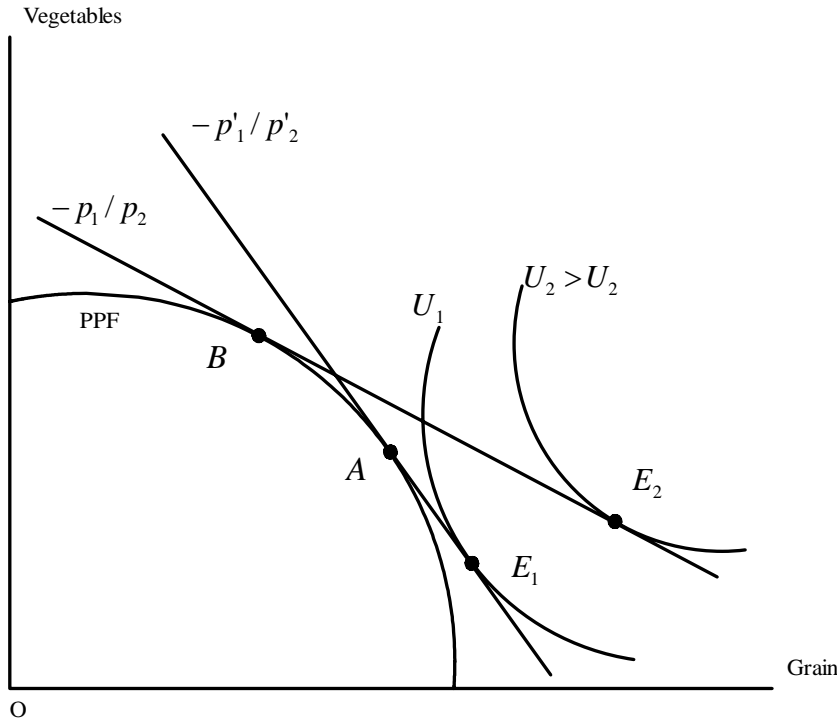
Figure 2: Impact of an Increase in Vegetable Price with a Perfect Market

Now we are interested in what may happen if the relative price of vegetables increases (i.e. $p_1'/p_2' < p_1/p_2$). First the agricultural household would change its production plan to B, producing more of vegetables since vegetable price increases. With the new budget constraint associated with the profit attainable at point B, the household can trade vegetables for grain to attain the consumption bundle at point E_2. Notice that at E_2, the consumption of vegetables increases from the level at E_1 even though vegetable price has increased. Thus we have a positive correlation between price and consumption for vegetables. This will never happen in the traditional demand model, where

households are treated as consumers only and thus there is always a negative relationship between the consumption of a commodity and its price.

Empirically, we can use this separability of production and consumption decision under perfect markets for the ease of demand. The procedure is simple. We first treat the sum of exogenous incomes and the maximized level of profit from food production as the "fixed" income, and then use this income and prices of all commodities consumed to estimate a single demand function or a complete demand system.

After estimation of the demand, we may be interested in price policy analysis. In this case we cannot leave the production decision out of the picture. First we need to predict how production plan and profits may react to price changes. Then with the updated changes in profit (and thus those in income) and the updated prices, we can then use the estimated demand function to predict the future food demand under new prices. Prediction of food product supply can be conducted by calculating the difference between predicted production and predicted consumption.

Scenario 3: Imperfect Market with Transaction Cost

Scenario 3 deals with an imperfect market common in the LDCs, including China. One common cause of market imperfection is the existence of transaction costs. For the same food product, a household typically sells it for a lower price than the price at which he can purchase in the market.

Suppose the purchase price for grain is p_1 and the sale price for grain is $s_1 < p_1$; suppose the purchase price for vegetables is p_2 and the sale price for vegetables is $s_2 < p_2$. The bundles of grain and vegetables available for consumption (after self production and trade) are in the curve $DBAC$ as illustrated in Figure 3.

Vegetables
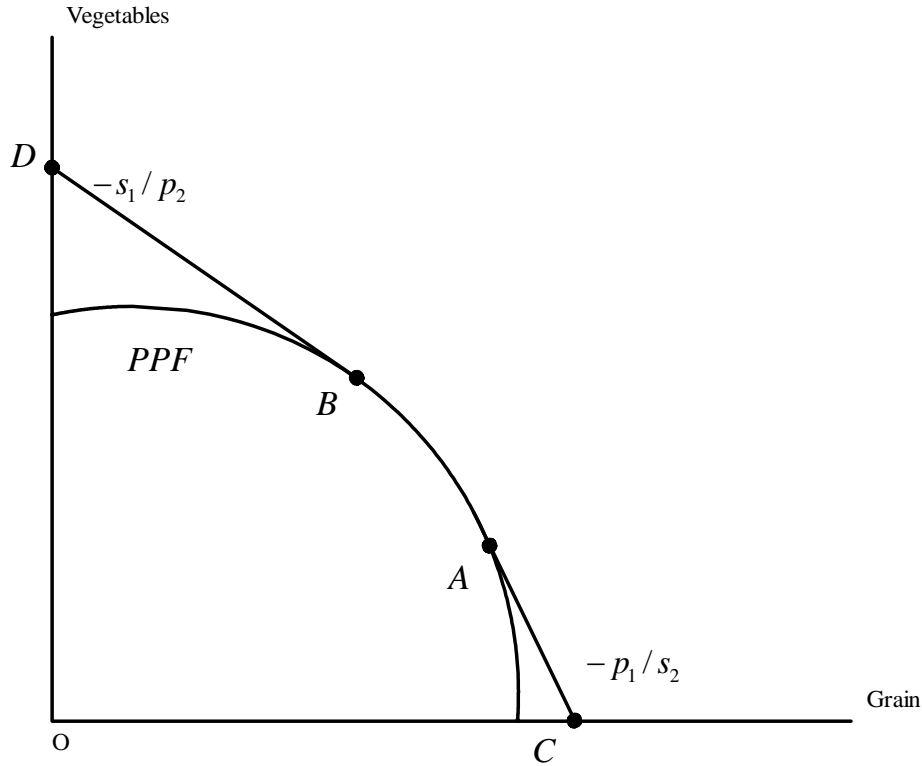
Figure 3: Budget Constraint in a Market with Transaction Costs

Let A and B be the tangent points of two price lines on the PPF as shown in Figure 3. The agricultural household chooses to produce at points A or B or any points on curve AB along the PPF. When the household produces at point A, it can acquire additional grain from the market by trading vegetables for grain (it can acquire more grain from production too, but that is more costly since the shadow price of production will be no less than the market price). The effective purchase price for grain in relative term is p_1 / s_2. Thus any point on line AC is attainable for the agricultural household. When the agricultural household produces at point B, on the other hand, it can acquire more vegetables from the market by selling grain. The effective sale price for grain in

relative term is s_1 / p_2. The effective purchase price is always higher than effective sale price $p_1 / s_2 > s_1 / p_2$. When the agricultural household chooses to produce at a point on the curve AB along the PPF, there is no incentive to trade, since the shadow price in relative term for grain (the absolute value of the slope for the tangent line) is between the effective sale price and purchase price. A loss will always occur with trade under this production plan. In summary, the curve $DBAC$ represents the set of best attainable bundle of grain and vegetables under the technology and the market with transaction cost. Thus, it is the budget constraint for the agricultural household.

With this budget constraint in mind, we have a clear picture of utility maximization for the agriculture household (Figure 4).
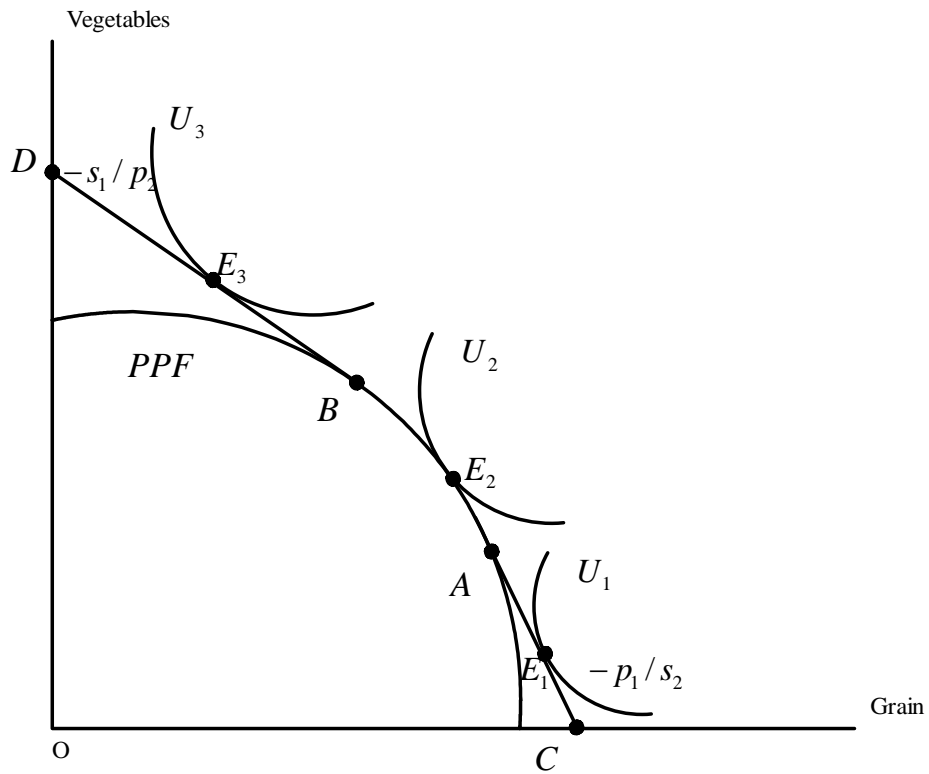

Figure 4: Agricultural Household Behavior in a Market with Transaction Costs

Depending on the preference of the agricultural household, there are three different cases of production and consumption joint decision:

(1) With utility specified as U_1, the agricultural household chooses the production plan at point A. It then trades vegetables for grain to attain the utility maximization bundle of consumption at E_1. The vegetables consumption is completely self-sufficient. In this case, the grain consumption is partially self-sufficient. The effective relative market price under this scenario is p_1 / s_2 because there is a net sale of vegetables and a net purchase of grain. In the empirical demand estimation, we can use the budget given as line AC. Only the sale price of vegetables and the purchase price of grain are relevant for demand estimation.

(2) With utility specified as U_2, the agricultural household chooses the production plan at point E_2. This also happens to be the utility maximization choice of consumption. There is no incentive to trade since the shadow price is between effective sale and effective purchase price. Both grain and vegetable consumptions are completely self-sufficient. For the empirical estimation of demand, we need to solve for preference characteristics and production characteristics together under the frameworks of general equilibrium, using the first order condition that the negative of shadow prices (in relative term) are equal to both MRS and MRT.

(3) With utility specified as U_3, the agricultural household chooses the production plan at point B. It then trades grain for vegetables to attain the utility

maximization bundle of consumption E_3 . The grain consumption is completely self-sufficient, and the vegetable consumption is partially self-sufficient. The effective relative market price under this scenario is s_1 / p_2 because there is a net purchase of vegetables and a net sale of grain. In the empirical demand estimation, we can use the budget given by BD. Only the sale price of grain and the purchase price of vegetables are relevant for demand estimation.

This model can be easily generalized to the case of multiple food products. The bottom line is: in empirical estimation, we should use sale price for a food product with net sale; we should use purchase price for a food product with net purchase; and for the food products without any trade (completely self-sufficient), we need to estimate its shadows price and apply the shadow price in estimation. The formal proof will be provided in mathematical model that follows.

A Model for Chinese Rural Households

Without considering the leisure-labor choice, an agricultural household model is developed below to capture the joint production-consumption decisions of a Chinese rural household. This model is specified to capture the essential join production-consumption decisions for the estimation of food demand. A general agricultural household model can be found in Sadoulet and de Janvry (1995).

Let X_i ($i = 1,2,\cdots,N$) be the ith commodity consumed, with its correspondent purchase price p_i . Especially let X_i be food products when $i = 1,2,\cdots,F$, where $F < N$. The agricultural household can choose only food products to produce and sell. And let the sale price be not larger than the purchase price ($s_i \leq p_i$) due to imperfect market. For

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convenience, we may write the complete consumption bundle as $\mathbf{X}$. Let $G(\mathbf{Q}, \mathbf{v}, K) = 0$ describes the production technology for the agricultural household, where $\mathbf{Q} = (Q_1, Q_2, \cdots, Q_F)$ is a set of outputs of food products, $\mathbf{v} = (v_1, v_2, \cdots, v_I)$ is a set of required inputs with $\mathbf{q} = (q_1, q_2, \cdots, q_I)$ as its set of market prices, and K represents land and capital stock. With given exogenous income E, utility function specified as $U(X_1, X_2, \cdots, X_N)$, technology specified as $G(\mathbf{Q}, \mathbf{v}, K) = 0$, and the market prices, the agricultural household chooses a joint production-consumption scheme, including the amount of food products to sell ($\mathbf{S} = (S_1, S_2, \cdots, S_F)$) or to purchase ($\mathbf{P} = (P_1, P_2, \cdots, P_F)$), to maximize its utility:

$$\underset{\mathbf{Q}, \mathbf{v}, \mathbf{S}, \mathbf{P}, \mathbf{X}}{MAX} \quad U(X_1, X_2, \cdots, X_N), \tag{1}$$

subject to the following constraints:

$$N \geq F, \tag{2}$$

$$\sum_{i=1}^{F} p_i P_i + \sum_{j=F+1}^{N} p_j X_j = (\sum_{k=1}^{F} s_k S_k - \sum_{l=1}^{I} q_l v_l) + E \tag{3}$$

$$p_i \geq s_i > 0 \text{ for all } i = 1, 2, \cdots, F, \tag{4}$$

$$X_i = Q_i + P_i - S_i \geq 0 \text{ for all } i = 1, 2, \cdots, F, \tag{5}$$

$$X_j \geq 0 \text{ for all } i = F+1, F+2, \cdots, N, \tag{6}$$

$$P_i \geq 0, \text{for all } i = 1, 2, \cdots, F, \tag{7}$$

$$S_i \geq 0, \text{for all } i = 1, 2, \cdots, F, \tag{8}$$

$$\text{and} \quad G(\mathbf{Q}, \mathbf{v}, K) = 0, \tag{9}$$

Equation (2) says that the total number of commodities (including food products) is larger than the total number of food products, which is obvious.

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Equation (3) is the cash budget constraint. We assume that the agricultural household produces food products only. The food items consumed come from either purchase or self-production while the non-food commodities consumed come from purchase only. The purchases for all these commodities are supported by the cash income, the sum of profit from sales of food products, $(\sum_{k=1}^{F} s_k S_k - \sum_{l=1}^{I} q_l v_l)$, and exogenous income E, such as property income or transfer income.

Equation (4) says that purchase price is usually higher than, if not equal to, the sale price for the same food product, due to transaction costs. The sale price could not be higher than the purchase price for the same food products. Otherwise, arbitrage will occur.

Equation (5) is the balance equation for the food products. The agricultural household acquires food products from production $\mathbf{Q}$ or purchase $\mathbf{P}$, and it uses them on consumption $\mathbf{X}$ or sale $\mathbf{S}$. In the real world, however, rural households in China stock food products, especially grain, either for future consumption, or for seeding for next season. Storage and seeding usage are ignored in our model to avoid the need of constructing a complicated inter-temporal utility maximization problem. Also, some food products may be acquired in ways other than production or purchase; and they may be used for other purposes than sale. For example, fruit is commonly used as a gift in China and a part of grain is used as feed. All these are ignored for simplicity.

Another set of constraints is non-negativity for the amounts of commodities consumed, purchased or sold for any food product. This is captured in equations (5), (6), (7), (8).

Equation (9) is the technology constraint for production, with K representing land and other capital goods, under the assumption of no labor constraint.

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The Lagrangean function for this optimization problem is as the following:

$$L = U(X_1, X_2, \cdots, X_N) + \mu(\sum_{k=1}^{F} s_k S_k - \sum_{l=1}^{I} q_l v_l + E - \sum_{i=1}^{F} p_i P_i - \sum_{j=F+1}^{N} p_j X_j)$$
$$+ \sum_{i=1}^{F} \gamma_i (Q_i + P_i - S_i - X_i) + \theta G(Q, v, K) \quad (10)$$

First, notice that since $p_i > s_i$ for all $i = 1, 2, \cdots, F$, we will have either $P_i = 0$ or $S_i = 0$ for all $i = 1, 2, \cdots, F$. Since purchase price is greater than sale price, there is no reason for purchase and sale of the same item at the same time since this means a loss of money. In the real world situation, however, a rural household may sell and also purchase the same product within the same period. For example, we see many households who sell and also purchase vegetables within the same year. One possible explanation is that the vegetables sold and those purchased are not of the same kinds. In this case, there is an issue of heterogeneity in products which is not handled in this study. Another possible explanation is seasonal consumption smoothing. During the production seasons, rural households may produce more vegetables than they can consume and thus would sell the extra. In other seasons during the same year, they may be short of self-produced vegetables and need to purchase them for consumption. In our model, we will ignore all these factors, and concentrate on the net sale amount (or the net purchase amount).

First order conditions for utility maximization yield:

$$\partial L / \partial X_i = \partial U / \partial X_i - \gamma_i = 0 \quad (11)$$

$$\text{with } \gamma_i = \begin{cases} \mu s_i \text{ if } S_i > 0 \text{ and } P_i = 0 \\ \mu p_i \text{ if } P_i > 0 \text{ and } S_i = 0 \\ \theta \partial G / \partial Q_i = \mu p_i^* \text{ if } S_i = P_i = 0 \end{cases}, \text{ for } m = 1, 2, \cdots, F \quad (12)$$

where p_i^* is a convenient notation for the shadow price of ith food product.

$$\partial L / \partial X_j = \partial U / \partial X_j - \mu p_j = 0, \text{for all } j = F + 1, F + 2, \cdots, N \qquad (13)$$

For non-food commodities, the first order conditions are familiar—the marginal rate of substitution (MRS) is equal to the price ratio:

$$\frac{\partial U / \partial X_j}{\partial U / \partial X_k} = \frac{p_j}{p_k} \text{ for } j, k \in \{F + 1, F + 2, \cdots, N\}, \qquad (14)$$

since $\partial U / \partial X_j = \mu p_j, \partial U / \partial X_k = \mu p_k$ for $i, j \in \{F + 1, F + 2, \cdots, N\}$.

For a food product $i \in \{1, 2, \cdots, F\}$, there are three possible situations:

(1) If there is net sale for this product, $\partial U / \partial X_i = \mu s_i$, and thus the MRS is

$$\frac{\partial U / \partial X_i}{\partial U / \partial X_j} = \frac{s_i}{p_j} \text{ for } j \in \{F + 1, F + 2, \cdots, N\}. \qquad (15)$$

Let p_i^e be the effective price for the consumption of food item i. With a net sale for a food product, the sale price serves as the effective price ($p_i^e = s_i$). From the marginal point of view, the agricultural household chooses either to sell one extra unit or keep this extra unit of food product for consumption. Therefore the effective price for the consumption of this food item is the sale price.

(2) If there is net purchase for this product, $\partial U / \partial X_i = \mu p_i$, and thus the MRS is

$$\frac{\partial U / \partial X_i}{\partial U / \partial X_j} = \frac{p_i}{p_j} \text{ for } j \in \{F + 1, F + 2, \cdots, N\}. \qquad (16)$$

In this case, the purchase price serves as the effective price ($p_i^e = p_i$). From the marginal point of view, the consumption of one extra unit of this food product comes only from purchase. Therefore the effective price for the consumption of this food item is the purchase price.

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(3) If there is no trade for this product, $\partial U / \partial X_i = \mu p_i^*$, and thus the MRS is

$$\frac{\partial U / \partial X_i}{\partial U / \partial X_j} = \frac{p_i^*}{p_j} \text{ for } j \in \{F+1, F+2, \cdots, N\}, \tag{17}$$

where p_i^* is the shadow price for this food products which satisfies

$$p_i^* = \frac{\gamma_i}{\mu} = -\frac{\theta \partial G / \partial Q_i}{\mu} = p_i^*(s, p, q, K, E) \text{ and } s_i < p_i^* < p_i. \tag{18}$$

In this case the shadow price serves as the effective price ($p_i^e = p_i^*$). Shadow prices can be solved according to the set of joint equation system as (17) and (18).

For the non-food commodities, the effective prices for their consumption are just the purchase prices. For convenience, we can define the set of effective prices for consumption as $\mathbf{p^e} = (p_1^e, p_2^e, \cdots, p_F^e, p_{F+1}, p_{F+2}, \cdots, p_N)$:

$$\text{where } p_i^e = \begin{cases} s_i \text{ if } S_i > 0 & \text{(for food product with net sale)} \\ p_i \text{ if } P_i > 0 & \text{(for food product with net Purchase)}, i = 1,2,\cdots, F \\ p_i^* \text{ if } S_i = P_i = 0 & \text{(for food product without trade)} \end{cases}$$

$$\tag{19}$$

Notice that the effective price is not exogenous. An agricultural household chooses an optimizing production, sale, purchase and consumption scheme, which in turn determines the effective price vector.

The utility maximizing choice of consumption bundle for the utility maximization problem described in equations (1)~(9) can be written as:

$$\mathbf{X}^* = \mathbf{X}^*(\mathbf{p}, \mathbf{s}, \mathbf{q}, K, E). \tag{20}$$

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It is decided by the agricultural household's utility and production characteristics and exogenous factors, including prices, capital stock and exogenous income.

For convenience, the implied "full income" can be written as:

$$Y^* = \mathbf{P^e}'\mathbf{X}^*(\mathbf{p}, \mathbf{s}, \mathbf{q}, K, E). \tag{21}$$

This is the value of consumption of all the commodities by the agricultural household.

For empirical demand estimation, notice that given the same utility function as U, given the vector of prices for the commodities as $\mathbf{P^e}$, and given the "full income" $Y^* = \mathbf{P^e}'\mathbf{X}^*(\mathbf{p}, \mathbf{s}, \mathbf{q}, K, E)$ as the budget, a consumer (and here we consider him as a consumer only, not an agricultural household who needs to deal with production and leisure-labor choice) will choose exactly $\mathbf{X}^* = \mathbf{X}^*(\mathbf{p}, \mathbf{s}, \mathbf{q}, K, E)$ as his utility maximization choice of consumption bundle since $\left.\dfrac{\partial U}{\partial X}\right|_{X=\mathbf{X}^*} = \mu\mathbf{P^e}$. Therefore, when we have data that give us the consumption bundle choice and effective price, we are able to recover the (indirect) utility function. The claim in the scenario 3 of the graphic presentation of the agricultural household model for Chinese rural households (illustrated in figure 3 and 4) is thus proved to be legitimate.

Preliminary Analysis of Rural Food Demand

We conclude in the theoretical model that it is crucially important to find the right price of consumption in food demand estimation. This paper also presents our preliminary econometric results for food demand estimation. Our demand system includes eight food groups: (1) grain, (2) oil, (3) vegetables, (4) pork, (5) poultry, (6) eggs and egg products, (7) aquatic products, and (8) fruits. Traditional approaches of

constructing prices and a new approach, still simple but more close to the spirit of agricultural household models presented in this paper, are compared in demand estimation.

Table 1: Self-sufficiency of Major Food Products (%)

	Jiangsu				Heilongjiang		Henan	
	1993	1994	1995	2001	1995	2001	1995	2001
Grain	95.2	94.6	89.7	97.9	73.5	94.6	95.6	98.1
Oil	59.2	49.7	58.2	48.9	21.3	1.1	32.0	21.6
Vegetables	81.0	70.8	82.5	77.9	69.3	67.3	34.3	61.4
Bean and Bean Products	16.4	18.0	25.4	24.3	51.4	52.0	17.0	17.6
Pork	5.8	4.0	8.9	7.3	11.9	7.8	1.7	11.2
Poultry	46.5	38.9	45.8	27.5	30.2	25.0	14.6	23.1
Eggs	70.0	65.0	67.4	46.2	60.2	39.4	42.7	38.1
Aquatic Products	21.9	19.9	17.6	7.0	7.0	5.2	18.3	4.9
Fruit	18.8	21.1	22.6	52.0	5.8	39.5	16.0	35.1

Source: Rural Household Survey, unpublished data.

The data employed in this preliminary analysis is from the rural household survey (RHS) for Henan Province in 1995, with a sample of 4200 households. Evidence of joint production-consumption decision can be found in the high self-sufficiency rates for many food items in three provinces of Jiangsu, Heilongjiang and Henan (Table 1).

The demand system used in our analysis is the Quadratic Almost Ideal Demand System (QAIDS) incorporating demographic variables by linear translating. It has the following functional form:

$$w_i = \alpha_i + \sum_j \gamma_{ij} \log p_j + (\beta_i) \log(\frac{x}{A(\mathbf{p})}) + \frac{\lambda_i}{B(\mathbf{p})} \left[\ln \frac{x}{A(\mathbf{p})} \right]^2 , \qquad (22)$$

where

$$\log A(\mathbf{p}) = \alpha_0 + \sum_i \alpha_i \ln p_i + 0.5 \sum_i \sum_j \gamma_{ij} \ln p_i \ln p_j . \qquad (23)$$

$$B(\mathbf{p}) = \prod_i p_i^{\lambda_i} . \qquad (24)$$

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With this demand system, we incorporate the following demographic variables:

$SIZE$: household size ,

$AGE11$: number of children with age below 11 in the household ,

$AGE1217$: number of persons with age 12 ~ 17 in the household ,

$EDUC$: number of persons with at least high school graduation ,

$FAFH$: total expenditure on food away from home .

Demographic variables are incorporated by linear translating, i.e. simply replacing α_i with $\alpha_i + \alpha_{i1} SIZE + \alpha_{i2} AGE11 + \alpha_{i3} AGE1217 + \alpha_{i4} EDUC + \alpha_{i5} FAFH$ in the demand equation (22).

Slutsky symmetry, linear homogeneity and adding-up condition requires:

$$\sum_{i=1}^{8} \alpha_i = 1 , \tag{25}$$

$$\sum_{i=1}^{8} \alpha_{ik} = 0 , \text{for } k = 1,2,\cdots,5 \tag{26}$$

$$\sum_{i=1}^{8} \beta_i = 0 \tag{27}$$

$$\sum_{i=1}^{8} \lambda_i = 0 \tag{28}$$

The homogeneity condition can be expressed as:

$$\sum_{j=1}^{8} \gamma_{ij} = 0 , \text{for } i = 1,2,\cdots,8 \tag{29}$$

The symmetry condition requires:

$$\gamma_{ij} = \gamma_{ji} , \text{for any } i, j = 1,2,\cdots,8 \tag{30}$$

The method of seemingly unrelated regression (SUR) is used in the estimation of parameters in the system with homogeneity and symmetric conditions imposed. The adding-up restrictions are automatically satisfied in this system of budget share equations.

Three approaches of demand estimation are compared in the analysis. They differ only in ways of constructing food prices for consumption. The first approach uses the purchase price, derived from the ratio of total expenditure to the total purchase quantity for a food item. Examples for this approach are the studies by Halbrendt, Tuan, Gempesaw and Dolketz (1994), and Tong, Han and Tomas I. Wahl. (1998).

The second approach uses the weighted average of purchase price and sale price:

$$\frac{\text{Sale Price} \times \text{Self Sufficency Amount} + \text{Purchase Price} \times \text{Amount purchased}}{\text{Total Amount of Consumption}} \tag{31}$$

It takes into account that with self-sufficiency, the unit value of food consumed might not necessarily be the purchase price, and that the sale price, as part of the production side information, should be incorporated. An example for the second approach is Gao, Wailes and Cramer (1996).

The last approach is proposed in this study using the agricultural household model with some modification. For this preliminary study, we will not incorporate shadow prices into estimation due to the extreme complicacy in their computation. Rather, we use county level average purchase prices for the food items without trade; we use household-level purchase prices for food items with net purchase; and we use household-level sale prices for food items with net sale. There are outlying prices from the RHS data. For example, the sale prices of some foods for some households maybe more than ten times that of county average price. We replace these outlying prices with county level averages

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also. The descriptive statistics of the prices constructed in three different approaches are presented in Appendix Table A1.

Table 2 presents estimated expenditure and own-price elasticities from the three approaches. Let us summarize the results of comparing these three approaches. We first note that traditional approaches (1 and 2) of price construction do not produce entirely satisfactory own-price elasticities estimates. We find positive own price elasticity in the demand for poultry in approach 1 and positive own price elasticity in the demand for vegetables in approach 2. These are signs of production decision interfering. The new approach (approach 3) of constructing price results in better and more satisfactory parameter and elasticity estimates.

Table 2: Estimated Demand Elasticities

Food Item	Approach 1		Approach 2		Approach 3	
	Expenditure Elasticities	Own-price Elasticities	Expenditure Elasticities	Own-price Elasticities	Expenditure Elasticities	Own-price Elasticities
Grain	0.95826	-0.71453	1.03503	-0.85758	0.96865	-0.73987
Oil	1.17207	-0.54821	0.84889	-0.99516	1.17176	-0.66243
Vegetables	1.09472	-0.55758	0.91294	-0.80980	1.08391	-0.43480
Pork	1.07289	-0.62457	0.76928	-0.68851	1.06722	-0.65602
Poultry	0.81314	-0.66107	2.11608	-1.65477	1.08392	-0.34644
Eggs	0.96958	-0.25091	0.84193	**0.72291**	0.92602	-0.37753
Aquatic Products	1.07839	**0.04042**	0.38656	**0.93496**	1.13592	-0.23964
Fruits	1.38329	-0.66671	1.34656	-0.45174	1.19786	-0.50829

The estimators from the new approach are much more robust. It is highly insensitive to outlying prices. The estimators from traditional approaches, however, are highly sensitive to outliers. The estimated own-price elasticities can change by a large magnitude. And with outliers, the problem of positive own-price elasticities is more profound.

We note that the relative magnitudes of the estimated expenditure elasticities for several food items are not expected. In particular, we are troubled by the very high expenditure elasticities for grain and vegetables, close to unity. This could also be an indication that we do not get rid of production interaction completely, since increase in income may induce rural households to sell less of grain or vegetables for cash.

As a second version, we also incorporate the self-sufficient rates for each food item consumed into the model, by means of linear translating. This is just to replace

$$\alpha_i \quad \text{with} \quad \alpha_i + \alpha_{i1}SIZE + \alpha_{i2}AGE11 + \alpha_{i3}AGE1217 + \alpha_{i4}EDUC + \alpha_{i5}FAFH + \sum_{k=1}^{8} \delta_{ik}SS_k \quad ,$$

where SS_j is the self-sufficiency rate of the jth food products.

The estimated expenditure and price elasticities are presented in Table 3. Interestingly, we do not find positive own-price elasticities by purchase price approach any more, but this persists when weighted average prices are used. The results of the approach 3, version 2 incorporating self-sufficiency rates are not much different form those of the new approach without incorporating self-sufficiency. This is an indication that the new approach has taken care of much production side information (through sale prices), while the traditional approaches have not.

Table 3: Estimated Demand Elasticities, Version 2

Food Item	Approach 1		Approach 2		Approach 3	
	Expenditure Elasticities	Own-price Elasticities	Expenditure Elasticities	Own-price Elasticities	Expenditure Elasticities	Own-price Elasticities
Grain	0.95869	-0.71141	1.03421	-0.85662	0.96859	-0.73991
Oil	1.19691	-0.62149	0.83834	-0.99890	1.17153	-0.66183
Vegetables	1.09648	-0.53077	0.92710	-0.81333	1.08435	-0.43656
Pork	1.08290	-0.66188	0.77556	-0.67183	1.06714	-0.65661
Poultry	1.12120	-0.36108	2.05775	-1.71287	1.08481	-0.34369
Eggs	0.94097	-0.21482	0.84085	**0.73581**	0.92743	-0.37833
Aquatic Products	1.24140	-0.17824	0.40603	**0.93340**	1.13593	-0.23776
Fruits	1.25094	-0.55926	1.33839	-0.43090	1.19786	1.19765

Table 4 illustrates how important it is to incorporate self-sufficiency rates into the demand system. Regardless of the approaches, all coefficients of self-sufficiency rate for the own product are shown to be significant. This indicates that its inclusion surely helps account for some of the production side complication in estimation from all three approaches. We find all coefficients for self-sufficiency positive, indicating that a higher self-sufficiency of a product will induce the rural household to consume more of the same product. These results are, of course, reasonable.

The estimated coefficients for approach 3 are also significant, probably due to the inability to compute and adopt the shadow prices for households without trade. However, the estimated elasticities show no much difference with or without incorporating self-sufficiency

Table 4:   Estimated Coefficients for Self-sufficiency Rates

	Approach 1	Approach 2	Approach 3
	Coefficient (t-ratio)	Coefficient(t-ratio)	Coefficient(t-ratio)
Grain	0.3138	0.3098	0.3099
	(22.02)	(22.13)	(22.14)
Oil	0.0770	0.0775	0.0750
	(35.44)	(35.53)	(35.32)
Vegetables	0.1037	0.0991	0.0922
	(33.90)	(32.93)	(33.97)
Pork	0.1762	0.1753	0.1721
	(20.61)	(20.66)	(20.57)
Poultry	0.0203	0.0210	0.0198
	(29.28)	(29.64)	(29.37)
Eggs and Egg Products	0.0280	0.0279	0.0284
	(19.62)	(19.34)	(20.19)
Aquatic Products	0.0075	0.0075	0.0072
	(12.29)	(12.44)	(11.90)
Fruit	N/A	N/A	N/A

Although the purchase price approach incorporating self-sufficiency produces somewhat more satisfactory results, this estimator is still very sensitive to outliers. Only

after replacing the outlying prices with the county average prices, can the estimator yield results as good as those obtained from the new approach.

In summary, the new approach is shown to be preferable to the traditional approaches. It is much more robust and it incorporates production side decision by using sale prices for products with a net sale.

Concluding Remarks

Both theoretical analysis and the preliminary empirical estimation conclude that the use of effective prices instead of traditionally used purchase prices (or the weighted averages of sale and purchase prices) is most consistent with the microeconomic behavior of Chinese agricultural households. Specifically, we should use sale prices when there are net sales and use purchase prices only when there are net purchases. When there is no trade, we should use the shadow prices. In our preliminary empirical estimation, we simply use the county-level average of purchase prices as approximation for shadow prices.

In the future, we will further introduce production information (by specifying a profit function or production function) and derive the shadow prices for more consistent food demand estimation. Another econometric problem is to deal with is the endogeneity of the self-sufficiency rates used in the estimations in version 2. A two-stage estimation can be used to correct this problem. Finally, the censorship problem should be dealt with for the food products with zero consumption, especially when some food categories such as beef and fresh milk are incorporated in the demand system.

Appendix

Table A1: Descriptive Statistics of Prices and Expenditure Shares[a]

Variables	Approach 1			Approach 2			Approach 3		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
p_1	1.5295	0.4426	4.0000	1.5432	0.5042	4.0000	1.7249	0.3333	21.7000
p_2	9.3405	1.0000	28.0000	9.3405	1.0000	28.0000	9.3405	1.0000	28.0000
p_3	0.8002	0.1933	5.2727	0.8677	0.2246	5.4140	0.8213	0.0630	27.3846
p_4	9.8054	4.1053	15.8235	9.8054	4.1053	15.8235	9.7860	4.1053	15.8235
p_5	7.9867	3.000	18.0000	8.4611	2.0833	18.0000	7.8783	1.3889	33.3333
p_6	5.6007	0.3607	12.0000	5.6859	0.4000	8.3333	5.6543	0.3607	10.0000
p_7	6.6419	0.6667	20.0000	6.6419	0.6667	20.0000	6.6473	0.6667	20.0000
p_8	1.5958	0.4000	4.0000	1.4616	0.4706	3.5000	1.5927	0.4000	4.0000
w_1	0.7064	0	0.9992	0.7051	0	0.9992	0.7193	0	0.9992
w_2	0.0587	0	0.6957	0.0584	0	0.7424	0.0560	0	0.7076
w_3	0.0804	0	0.7262	0.0870	0	0.6650	0.0761	0	0.7260
w_4	0.0787	0	0.7995	0.0783	0	0.7995	0.0755	0	0.7995
w_5	0.0053	0	0.3754	0.0053	0	0.3754	0.0050	0	0.3271
w_6	0.0309	0	0.6180	0.0315	0	0.6505	0.0301	0	0.6129
w_7	0.0058	0	0.4280	0.0057	0	0.4321	0.0055	0	0.4280
w_8	0.0338	0	0.6274	0.0286	0	0.6047	0.0324	0	0.5804

[a]The eight food groups are: (1) grain, (2) oil, (3) vegetables, (4) pork, (5) poultry, (6) eggs and egg products, (7) aquatic products, and (8) fruit. For oil, there were no sales. Thus, purchase prices are used for all approaches. Some households do not trade some food products. In this case the corresponding prices are missing. Sometimes the prices will have extreme value. The missing prices and the upper and lower 5% outlying prices are replaced by county-level average prices.

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