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A Survey of Agricultural Household Models: Recent Findings and Policy Implications

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Semicommercial farms that produce multiple crops make up a large part of the agricultural sector in developing economies. These farms or agricultural households combine two fundamental units of microeconomic analysis: the household and the firm. Traditional economic theory has dealt with these units separately. But in developing economies in which peasant farms dominate, their interdependence is of crucial importance. Researchers at the Food Research Institute, Stanford University, and at the World Bank have developed models of agricultural households that combine producer and consumer behavior in a theoretically consistent fashion. Recent empirical applications of these models have extended them and expanded the range of policy issues which can be investigated using this general framework.

This article reports the results of empirical applications of this model in India, Indonesia, Japan, the Republic of Korea, Malaysia, Nigeria, Senegal, Sierra Leone, Taiwan, and Thailand. It provides a comparative analysis of the policy implications of the approach for such matters as the welfare of farm households, the size of marketed surplus, the demand for nonagricultural goods and services, and for hired labor, and the availability of budget revenues and foreign exchange.

In most developing countries, agriculture remains a major source of income for the majority of the population, an important earner of foreign exchange, and a focal point for government policy. Efforts to predict the consequences of agricultural policies, however, are often confounded by the complex behavioral interactions characteristic of semicommercialized, rural economies. Most households in agricultural areas produce partly for sale and partly for own-consumption. They also purchase some of their inputs—such as fertilizer and labor—and provide some inputs—such as family labor—from their own resources. Any change in the policies governing agricultural activities will therefore affect not only production but also consumption and labor supply.

Agricultural household models are designed to capture these interactions in a theoretically consistent fashion and in a manner that allows empirical applica-

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tions so that the consequences of policy interventions can be illuminated. The existence of such models would enable the analyst to examine the consequences of policy in three dimensions.

First, one could examine the effects of alternative policies on the well-being of representative agricultural households. Well-being may be interpreted here to mean household income or some other measure such as nutritional status. For example, in examining the effect of a policy designed to provide cheap food for urban consumers, an agricultural household model would allow the analyst to assess the costs to farmers of depressed producer prices. The nutritional benefits for the urban population may be more than offset by the reduced nutritional status of the rural population that results from lower farm incomes.

Second, an understanding of the behavior of agricultural households would shed light on the spillover effects of government policies on other segments of the rural population. For example, since most investment strategies are designed to increase production, their primary impact is on the incomes of agricultural households. As a result, rural investment strategies may not reach landless households or households engaged in nonagricultural activities. A model that incorporates total labor demand and family labor supply, however, would allow the analyst to explore the effects of investment policy on the demand for hired labor and hence on the rural labor market and the incomes of landless households. Similarly, a model that incorporates consumer behavior would allow the analyst to explore the consequences of increased profits for agricultural households on the demand for products and services provided by nonagricultural, rural households. Since the demand for nonagricultural commodities is often thought to be much more responsive to an increase in income than the demand for agricultural staples, this spillover effect may well be important.

Third, governments are interested in the performance of the agricultural sector from a more macroeconomic perspective. For example, agriculture is often an important source of revenue for the public budget and a major earner of foreign exchange. In assessing the effects of pricing policy on the budget or the balance of payments, the government is obliged to consider how agricultural households will alter their production and consumption in response to changes in prices. A reduction in export taxes, for example, may increase earnings of foreign exchange and budget revenues if households market enough additional production. Since agricultural household models capture both consumption and production behavior, they are an appropriate vehicle for examining the effect of pricing policy on marketed surplus and hence on foreign exchange earnings and budget revenues.

The importance of agricultural households in the total population and the significance of sector policies combine to make the behavior of agricultural households an area warranting thorough theoretical and empirical investigation. Many different approaches to the analysis of agricultural households have been followed, each with its own relevance and its own advantages and disadvantages. This article reports the results of a large body of work that has followed a similar basic approach to the analysis of agricultural household behavior.[1] This approach offers important policy insights that differ significantly from the results of more traditional approaches in which production and consumption decisions are examined separately.

Section I outlines the theoretical properties of a general model of producer, consumer, and labor supply decisionmaking. In truly subsistence households, these decisions are made simultaneously. Without access to trade, a household can consume only what it produces and must rely exclusively on its own labor. A large part of agriculture, however, comprises semicommercial farms in which some inputs are purchased and some outputs are sold. In these circumstances, producer, consumer, and labor supply decisions are no longer made simultaneously although they are obviously connected because (ignoring credit) the market value of consumption cannot exceed the market value of production less the market value of inputs. In fact, in these circumstances decisionmaking is recursive—production decisions are made with reference to market prices but are independent of other decisions, whereas consumption and labor supply decisions depend crucially on the income derived from the household's production. Section I clarifies the circumstances in which these decisions must be treated simultaneously and those in which they can be treated recursively.

Section II summarizes the major conclusions from this body of applied studies. First, it reconfirms the empirical importance of the approach for the analysis of agricultural policy. The results of comparable studies are used to demonstrate the quantitative significance of treating the main household decisions in a consistent manner for such policy-relevant magnitudes as the welfare of farm households, marketed surplus, the demand for nonagricultural goods and services, the rural labor market, budget revenues, and foreign exchange earnings. Comparative results on selected price elasticities are presented for a range of economies—Japan, Korea, Malaysia, Nigeria, Sierra Leone, Taiwan, and Thailand. The section also demonstrates the empirical significance of the approach by comparing the results of models that treat production and consumption decisions separately and those emerging from models in which the decisionmaking process is recursive.

Section III summarizes the implications for agricultural pricing policy of the results of section II. This section also draws out the policy conclusions of extensions of the basic model. It is shown that the model allows an exploration of the effects of government policy on nutritional status, health, savings, investment, and budget deficits. Studies of India, Indonesia, Korea, Senegal, and Sierra Leone are drawn upon to illustrate these extensions.

1. An in-depth analysis of this work is contained in the book *Agricultural Household Models: Extensions, Applications, and Policy* (Singh, Squire, and Strauss 1986), from which this article is derived.

I. Theoretical Framework

Modeling the Agricultural Household

In general, any analysis of the consumption or labor supply of agricultural households has to account for the interdependence of household production and consumption. Agricultural households combine the household and the firm, two fundamental units of microeconomic analysis. When the household is a price taker in all markets, for all commodities which it both consumes and produces, optimal household production can be determined independent of leisure and consumption choices. Then, given the maximum income level derived from profit-maximizing production, family labor supply and commodity consumption decisions can be made.

Given this sequential decisionmaking, the appropriate analytical framework is a recursive model with profit- and utility-maximizing components. Empirical analysis of both household consumption and production becomes considerably more tractable in a recursive model, which as a result has been used by most (but not all) empirical analyses.

In this section, a prototype static model is developed. (A more detailed treatment with derivations is found in Strauss 1986b.) For any production cycle, the household is assumed to maximize a utility function:

$$U = U(X_a, X_m, X_l) \tag{1}$$

where the commodities are an agricultural staple (X_a), a market-purchased good (X_m), and leisure (X_l). Utility is maximized subject to a cash income constraint:

$$p_m X_m = p_a(Q_a - X_a) - p_l(L - F) - p_v V + E$$

where p_m and p_a are the prices of the market-purchased commodity and the staple, respectively; Q_a is the household's production of the staple (so that $Q_a - X_a$ is its marketed surplus); p_l is the market wage; L is total labor input; F is family labor input (so that $L - F$, if positive, is hired labor and, if negative, is off-farm labor); V is a variable input (for example, fertilizer); p_v is the variable input's market price; and E is any nonlabor, nonfarm income.

The household also faces a time constraint; it cannot allocate more time to leisure, on-farm production, or off-farm employment than the total time available to the household:

$$X_l + F = T$$

where T is the total stock of household time. It also faces a production constraint or production technology that depicts the relationship between inputs and farm output:

$$Q_a = Q(L, V, A, K)$$

where A is the household's fixed quantity of land and K is its fixed stock of capital.

In this presentation, various complexities are omitted. For example, the possibility of more than one crop is ignored. In addition, it is assumed that family labor and hired labor are perfect substitutes and can be added directly. Production is also assumed to be riskless.[2] Finally, and perhaps most importantly, it is assumed that the four prices in the model—p_a, p_m, p_v, *and* p_l—are not affected by actions of the household. That is, the household is assumed to be a price taker in the four markets; as seen below, this will result in a recursive model.

The three constraints on household behavior can be collapsed into a single constraint. Substituting the production constraint into the cash income constraint for Q_a and substituting the time constraint into the cash income constraint for F yields a single constraint:

$$p_m X_m + p_a X_a + p_l X_l = p_l T + \pi + E \tag{2}$$

where $\pi = p_a Q_a(L, V, A, K) - p_l L - p_v V$ and is a measure of farm profits. In this equation, the left-hand side shows total household "expenditure" on three items: the market-purchased commodity, the household's "purchase" of its own output, and the household's "purchase" of its own time in the form of leisure. The right-hand side is a development of Becker's concept of full income, in which the value of the stock of time ($p_l T$) owned by the household is explicitly recorded, as is any labor income (Becker 1965). The extension for agricultural households is the inclusion of a measure of farm profits, $p_a Q_a - p_l L - p_v V$, with all labor valued at the market wage, this being a consequence of the assumption of price-taking behavior in the labor market. Equations 1 and 2 are the core of all the studies of agricultural households reported in this article.

Equations 1 and 2 reveal that the household can choose the levels of consumption for the three commodities, the total labor input, and the fertilizer input into agricultural production. Maximization of household utility subject to the single constraint yields the following first-order conditions:

$$\text{(3a)} \quad p_a \frac{\partial Q_a}{\partial L} = p_l \qquad \text{(3b)} \quad p_a \frac{\partial Q_a}{\partial V} = p_v$$

$$\text{(4a)} \quad \frac{\partial U}{\partial X_a} \Big/ \frac{\partial U}{\partial X_m} = \frac{p_a}{p_m} \qquad \text{(4b)} \quad \frac{\partial U}{\partial X_l} \Big/ \frac{\partial U}{\partial X_m} = \frac{p_l}{p_m}$$

plus the constraint. Equations 3a and 3b show that the household will equate the marginal revenue products for labor and fertilizer to their respective market prices. An important attribute of these two equations is that they contain only two endogenous variables, L and V. The other endogenous variables, X_m, X_a, and X_l, do not appear and do not, therefore, influence the household's choice of L or V (provided second-order conditions are met). Accordingly, farm labor and fertilizer demand can be determined as a function of prices (p_a, p_l and p_v), the

2. These assumptions can be relaxed and have been in the literature. For a more general treatment of the static model, see Strauss (1986b). Roe and Graham-Tomasi (1986) treat the case of production risk.

technological parameters of the production function, and the fixed area of land and quantity of capital. Since equations 3a and 3b depict the standard conditions for profit maximization, it can be concluded that the household's production decisions are consistent with profit maximization and independent of the household's utility function.

The maximized value of profits can be substituted into equation 2 to yield:

$$p_m X_m + p_a X_a + p_l X_l = Y^* \tag{5}$$

where Y^* is the value of full income associated with profit-maximizing behavior. Equations 4a, 4b, and 5 can be thought of as the first-order conditions of a second maximization. That is, having first maximized profits (see equations 3a and 3b), the household then maximizes utility subject to its (maximized) value of full income. Equations 4a, 4b, and 5 can then be solved to obtain the demand equations for X_m, X_a, and X_l as functions of prices (p_m, p_a, p_l) and full income (Y^*). This demonstrates, given the assumptions made about markets, that even though the household's production and consumption decisions may be simultaneous in time, they can be modeled recursively (Nakajima 1969; Jorgenson and Lau 1969).

The presence of farm profits in equation 5 demonstrates the principal message of the farm household literature—that farm technology, quantities of fixed inputs, and prices of variable inputs and outputs affect consumption decisions. The reverse, however, is not true provided the model is recursive. Preferences, prices of consumption commodities, and income do not affect production decisions; therefore, output supply responds positively to own price at all times because of the quasi-convexity assumption on the production function. However, for consumption commodities (X_a) which are also produced by the household (Q_a), own-price effects are

$$\frac{dX_a}{dp_a} = \left.\frac{\partial X_a}{\partial p_a}\right|_{Y^*} + \frac{\partial X_a}{\partial Y^*} \quad \frac{\partial Y^*}{\partial p_a} \tag{6}$$

The first term on the right-hand side of this expression is the standard result of consumer demand theory and, for a normal good, is negative. The second term captures the "profit effect," which occurs when a rise in the price of the staple increases farm profits and hence full income. Applying the envelope theorem to equation 6,

$$\frac{\partial Y^*}{\partial p_a} dp_a = \frac{\partial \pi}{\partial p_a} dp_a = Q_a dp_a \tag{7}$$

that is, the profit effect equals output times the price increase and therefore is unambiguously positive. The positive effect of an increase in profits (and hence farm income), an effect totally ignored in traditional models of demand, will definitely dampen and may outweigh the negative effect of both income and substitution in standard consumer demand theory. The presence of the profit effect is a direct consequence of the joint treatment of production and consumption decisions.

The assumption that farm households are price takers may not always be appropriate. To explore the consequences of making prices endogenous to the household, it will be convenient to use duality results to express the equilibrium of the household. We can define the full income function as the maximization of full income with respect to outputs and variable inputs subject to the farm production function. As indicated in equation 2, the full income function can be written as the sum of the value of endowed time, a restricted (or short-run) profits function, and exogenous income. For the expenditure side of full income, we can define an expenditure function as the minimum expenditure (equation 5) required to meet a specified level of utility, $e(p_l, p_m, p_a, \bar{U})$.

Now we are in a position to relax our assumption that prices are fixed. The household's equilibrium is characterized by equality between the household's full income function and its expenditure function, e (•), where the expenditure function is evaluated at the utility level achieved at the household's optimum. This condition will hold whether or not households face given market prices. Now suppose that a household is constrained (or chooses) to equate consumption with production for some commodity(ies), for example, labor. One possible reason for this would be the nonexistence of a market. Another reason might be heterogeneous commodities—for example, family and hired labor may be imperfect substitutes, with the household choosing to sell no family labor off the farm. Alternatively, sales and purchase prices might differ for an identical commodity so that the price paid to farmers for their output is much lower than that which the farm household would have to pay to buy the goods later in the year when the household supply was depleted. Thus the family may decide to produce all of that good which it would need.

Consequently, the household's equilibrium will be characterized by a set of additional conditions—equality of household demand and household supply for each such commodity. The "virtual price" is that which would induce the household to equalize its demand and supply if a market existed (Deaton and Muellbauer 1980; Neary and Roberts 1980).

Virtual prices are not fixed for the household, as market prices are assumed to be. Rather they are determined by the household's choices. From the household's equilibrium, it can be seen that they will be a function of market prices, time endowment, fixed inputs, and utility. Consequently, these prices depend on both the household's preferences and its production technology. Changes in market prices will now affect behavior both directly, as before, and indirectly through changes in virtual prices.

The consequences of this additional effect can be shown provided one is willing to assume that commodities are substitutes or complements in consumption or production. If, for instance, the price of the farm good rises, the demand schedule for labor should shift upward. If leisure and food consumption are substitutes, substitution and income effects will cause supply to shift upward. Given that other market prices and fixed inputs are constant, the virtual wage has to rise to re-equate labor supply with demand. The rise in the virtual wage will influence household choices; for example, when the virtual wage rises, farm output will rise less than otherwise in response to a rise in its price. Indeed, it is possible for the virtual wage to rise so sharply as a response to increased food prices that farm output could actually fall as a consequence of a rise in farm output prices.[3]

If prices are endogenous for commodities which are both consumed and produced by the household, this affects the type of interdependence which exists between the household's consumption and production choices. For such commodities, the virtual prices are functions of both household preferences and production technology. Because these prices help to determine both consumption and production choices, production technology will influence household commodity demands both through the virtual price and through full income. Output supplies and input demands also will depend on preferences because preferences are partial determinants of the virtual price. If, however, the household faces only market prices, or if it faces a virtual price for a commodity which is consumed but not produced (or vice versa), then production choices will not depend on household preferences, but consumption choices will depend on production technology through full income. The model is then recursive.

Estimation Issues

Recursive models are much easier to estimate empirically because they allow all prices to be taken as exogenous to the household. From the household's equilibrium, one can then derive a set of commodity demand equations (including leisure or labor supply) and a set of output supply and variable input demand functions (or equivalently, a production function). The commodity demands are functions of commodity prices and full income.[4] Holding full income constant, these demand functions satisfy the usual constraints of demand theory; they satisfy the budget constraint, are homogeneous of degree zero with respect to prices and exogenous income, and display symmetry and negative semidefiniteness in the Slutsky-substitution matrix. The output supplies and input demands are functions of input and output prices and of farm characteristics (including land and fixed capital stock). They are derived from a profit function which obeys the usual constraints from the theory of the firm: they are homogeneous of degree one and convex with respect to prices. These results can be used as a guide when specifying the model for estimation since they imply restrictions on functional forms and on parameters, both within and between equations.[5]

In a recursive model, the output side can be modeled either by programming techniques (see Ahn, Singh, and Squire 1981; Singh and Janakiram 1986) or by

3. This point was emphasized by Sen (1966) and Nakajima (1969). Other differences in comparative statics between recursive and simultaneous models are detailed in Strauss (1986b).

4. Household characteristics, such as size and age/sex composition, might also be entered into the model as quasi-fixed factors which affect household utility. This would ignore the choice nature of these variables.

5. Issues of estimating demand equations are outside the scope of this article. The interested reader should consult a source such as Deaton and Muellbauer (1980).

econometric estimation of a multiple output profit or cost function. If estimation is to be by econometric means, errors have to be added to the model. The issues involved in sensibly specifying an error structure are outside the scope of this paper. For simplicity, suppose the errors are added to the demand and output supply equations. If, for a given household, the errors in the input demand and output supply equations are uncorrelated with the errors in the commodity demand equations, the entire system of equations is statistically block recursive. In this case, profits will be uncorrelated with the commodity demand disturbances so that the latter equations may be consistently estimated as a system independent from the output supply and input demand equations.[6] The practical advantage which results from separate estimation of the demand and production sides of the model is that far fewer parameters need to be estimated for each side separately. This is potentially important if the equations are nonlinear in parameters and have to be estimated using numerical algorithms, since expense is greatly reduced and tractability increased. Thus models with greater detail can be estimated.

Estimation does not have to be of a system of equations, since single equations can be consistently estimated as well. This may be especially advantageous when the underlying model is not recursive. In that case, virtual prices and hence farm profits are endogenous so that the commodity demand, output supply, and input demand equations are not in reduced form. To estimate the full set of "structural" equations is expensive (see Lopez 1986 for such a study). At the other extreme, one can specify the reduced-form equations. The disadvantage of that approach is that it is usually not possible to solve for the reduced form analytically. Consequently one cannot take full advantage of economic theory in imposing (or testing) parameter restrictions, though some of the restrictions may be readily apparent. Nevertheless, one can specify what variables belong in the reduced form and thus can estimate a least-squares approximation to it. Several of the studies included in this survey are of this type. As a compromise, a subset of the structural equations might be estimated, and the endogeneity of any choice variables taken into account. In this way, some economic structure can be imposed (tested) on the data.

Recursive versus Simultaneous Models

Since most of the empirical work to date has assumed that production and consumption decisions are recursive, it is of interest to investigate the significance of this assumption. This assumption has to be examined on a case-by-case basis. The relevant questions are whether markets exist and, if they do, whether an individual household is able to influence the market price. In most countries, it may be reasonable to expect that households are price takers both in their

6. However, if production and consumption side errors are correlated, then profit is correlated with the demand side errors, and its endogeneity must be accounted for to estimate the demand equations consistently, whether or not the deterministic model is recursive.

output markets and in the markets for their main nonlabor inputs such as fertilizer. Price determination may be more problematic in factor markets. Iqbal (1986), for example, argues that the interest rate paid by households in his study is a function of the amount borrowed and is thus influenced by the household. He therefore employs a reduced-form equation to capture the resulting simultaneity. Iqbal's model has two periods and is expressly concerned with borrowing and investing decisions. For single-period models, labor is the most important factor. While the labor market warrants careful attention in each case, several recent surveys have provided some support for the price-taking assumption (Binswanger and Rosenzweig 1984; Squire 1981).

Given the relative convenience of estimation in the case of recursive models, one may also wish to investigate the magnitude of any error introduced when a recursive model is used in a situation where it is not fully justified. Recall that the comparative statics of a simultaneous model contain additional terms because virtual prices respond to changes in exogenous variables. Even if the utility and production function parameters were correctly estimated, elasticities calculated on the assumption of a recursive model would be in error because the virtual prices would be incorrectly treated as constant. How important this omission is depends on the responsiveness of the virtual price to the changing exogenous variable and on the responsiveness of the dependent variable (of policy interest) to the virtual price. It seems intuitively clear that if the changing exogenous variable and the variable of policy interest are not closely linked to the market that is cleared by a virtual price, the issue of simultaneity is less important.

The above argument presumes that the underlying utility and production functions are known, which empirically, of course, they are not. In this case, a second bias enters into the elasticity calculations—the statistical bias of the estimates of these underlying parameters. The magnitude of this statistical bias is not known, and even its direction may not be known. Furthermore, the combined effects of parameter inconsistency and missing terms in the comparative statics may reinforce or offset each other.

The only evidence on this question comes from Lopez's (1986) study of country-level Canadian data, in which all the structural equations of a simultaneous model are estimated. In this model, self-employment and off-farm employment have different impacts on household well-being. That is, they are imperfect substitutes in the utility function, an assumption which is not easily testable. In addition, family and hired labor are assumed to be imperfect substitutes in the farm production function, a more easily testable assumption. These two assumptions imply a simultaneous model. Households supply on-farm and off-farm labor and demand family and hired farm labor. At the given market farm wage, it would be a coincidence for on-farm labor supply and demand, which are both nontraded, to be equated; therefore, in general a virtual farm wage will exist which does equate the two.

Lopez estimates a more standard, recursive model in addition to the simultaneous one described above. In this example, the exogenous variables are wage rates of off-farm employment and hired farm labor, the variable of interest is labor supply, and the virtual price is also a wage rate (of family farm labor). He finds that the total (on-farm plus off-farm) labor-supply elasticity with respect to wage (both hired-in on-farm and hired-out off-farm) is much lower if the simultaneous model estimates (0.04) rather than the recursive model estimates (0.19) are used. In this circumstance, the difference between a recursive and a simultaneous specification is likely to be at its greatest. We conjecture that the sensitivity of other elasticities—such as the marketed surplus elasticity with respect to output price—is less.[7]

Unfortunately, it is not easy to assess the overall importance of this issue. It may be possible to assess the bias in comparative statics caused by ignoring simultaneity, but even then the potential bias depends on the hypothetical sources of the simultaneity, and these will differ from study to study. Some questions will lead naturally to a simultaneous model (for example, Iqbal's study) but, before abandoning the recursive assumption, the analyst should carefully consider both the potential sources of simultaneity and the interaction among changes in exogenous variables, changes in the virtual price, and changes in the variables of policy interest. The bulk of the existing empirical work on agricultural household models notwithstanding, the essential lesson of the approach is the importance of combining production and consumption decisions. Whether the method of combination should involve a recursive model or a simultaneous model is a secondary issue which must be decided on a case-by-case basis.

II. Summary of Recent Empirical Findings

What can be learned about the economic response of rural, mainly farming households from these empirical studies which use an integrated approach to modeling the behavior of agricultural households? Does the new agricultural household modeling approach matter empirically both in terms of predicting economic behavior as well as in terms of the policy implications that follow from it? Although the studies summarized in this paper differ in the details of the applied methods, the characteristics of the sampled households, and the focus of their policy interest, nonetheless they share the view that integrating production and consumption decisions is not only the proper approach to modelling economic behavior of agricultural households but that the empirical results and their policy implications are sufficiently different to justify the effort.

The Surveyed Studies

Table 1 lists some essential characteristics of the different partial equilibrium studies which are summarized in this paper. The first empirical studies giving estimates of agricultural household models were conducted at Stanford Univer-

7. See Singh, Squire, and Strauss (1986, chap. 2) for a more detailed treatment.

Table 1. *Selected Characteristics of Surveyed Partial Equilibrium Studies*

Study	*Economy*	*Type of data*	*Number of observations*	*Variation in prices*	*Type of analysis*[a]	*Policy problems addressed*
Lau, Lin, and Yotopoulos (1978)	Taiwan	Average by farm size and region for each of two years	80	By region and all prices.	LLES and Cobb-Douglas profit function estimated for three commodities.	Consumption of agricultural commodity, marketed surplus, and labor supply.
Barnum and Squire (1979b)	Malaysia	Cross-section household level	207	By region for wages only.	LES and LLES estimates for three commodities along with Cobb-Douglas production function.	Rice consumption, labor supply, and marketed surplus.
Kuroda and Yotopoulos (1980)	Japan	Cross-section average by farm size and region	72	By region for all prices.	LLES and Cobb-Douglas profit function for four commodities. Leisure disaggregated by farm workers and off-farm workers.	Consumption of agricultural commodity, marketed surplus, and labor supply.
Rosenzweig (1980)	India	Cross-section household level for all India	862	By region for male and female wages.	Reduced-form estimates of male and female off-farm labor supply equations.	Off-farm labor supply by sex.
Ahn, Singh, and Squire (1981)	Korea	Cross-section household level	443	By region for wages and subset of prices.	Multiple (six) commodities analyzed. Linear programming used for production side and LES estimated for demand side.	Effects of technological change on consumption of agricultural commodity.

Adulavidhaya, Kuroda, Lau, and Yotopoulos, (1984)	Thailand	Separate household cross-section data sets used for demand system and input demand system	440[b]; 480	By region for prices.	LLES and Cobb-Douglas profit function for three commodities.	Consumption of agricultural commodity, marketed surplus, and labor supply.
Strauss (1986a)	Sierra Leone	Cross-section household level	138	By region for all prices.	Multiple (seven) commodities analyzed. QES estimated on demand side with constant elasticity of transformation Cobb-Douglas output supply equations.	Price and income responsiveness of caloric availability.
Singh and Janakiram (1986)	Northern Nigeria	Cross-section household level	312	By region.	Multiple commodities analyzed (intercropping). Linear programming used for production side and LES for demand equations.	Production choice among alternative crops. Substitutability of certain crops in consumption.
Iqbal (1986)	India	Panel data, household level for all India	1,602	By region for interest rate and wages.	Reduced form estimates of borrowing and interest rate equations; nonseparable.	Determinants of borrowing and interest paid for large and smallholding farmers.
Pitt and Rosenzweig (1986)	Indonesia	Cross-section household level	2,347	By region for all prices.	Farm profits, male labor supply, reduced form illness, and health input demand equations; separability tested.	Effects of health on profits and labor supply and determinants of individual health status. Intrafamily distribution considered.

a. Demand systems abbreviated are LLES, Linear Logarithmic Expenditure System; LES, Linear Expenditure System; QES, Quadratic Expenditure System. All models are separable, except as noted.

b. Observation numbers for demand side and production side analyses respectively.

Table 2. *Selected Elasticities in Response to Changes in Agricultural Commodity Prices*

Economy	*Agricultural commodity*	*Consumption of agricultural commodity*	*Consumption of market-purchased goods*	*Marketed surplus*	*Labor supply*
Japan	Farm output	−0.35	0.61	2.97	−1.01
Korea	Rice	0.01	0.81	1.40	−0.13
Malaysia	Rice	0.38	1.94	0.66	−0.57
Nigeria[a]	Sorghum	0.19	0.57	0.20	−0.06
Sierra Leone	Rice	−0.66	0.14	0.71	−0.09
Taiwan	Farm output	0.22	1.18	1.03	−1.54
Thailand	Farm output	−0.37	0.51	8.10	−0.62

Sources: Listed for each economy in the first column of table 1.

Note: Each value shown is the ratio of the percentage change in the endogenous variable (the column heading) to the percentage change in the price of the listed agricultural commodities.

a. Northern portion only.

sity by Lau, Yotopoulos, and their collaborators (Lau, Lin, and Yotopoulos 1978; Kuroda and Yotopoulos 1980; Adulavidhaya, Kuroda, Lau, and Yotopoulos 1984), and at the World Bank by Barnum and Squire (1979, 1980). These econometric studies specify recursive models and estimate commodity demands and either output supply and input demand or a production function.

Subsequent studies have extended the basic methodology in various ways. One study has disaggregated commodities on the consumption side of the model with the objective of providing a more careful accounting of caloric intake (Strauss 1986a). Another paper looks at determinants of health within a farm household framework (Pitt and Rosenzweig 1986). A third extends the model to endogenize saving and investment decisions (Iqbal 1986). Both the latter two studies estimate reduced-form equations, the first for health and the second for borrowing, rather than estimate the full system of demand and supply equations. In addition, this article reviews several recent attempts to embed agricultural household models in a multimarket framework. This framework allows a more comprehensive analysis of agricultural policies since it accounts for important interactions that are neglected in partial equilibrium models (Braverman and Hammer 1986).

Main Results

Table 2 presents a subset of elasticities calculated from the seven studies which estimate the full system of commodity demand equations. The table reports the effect of changes in the price of the agricultural commodity on consumption of the agricultural commodity, consumption of market-purchased goods, marketed surplus, and labor supply.

For consumption of the agricultural commodity, the studies show an almost even split between those which report a positive own-price elasticity and those which report a negative one. Both positive and negative elasticities are small. The positive response indicates that the profit effect has more than offset the traditional negative effect of both income and substitution predicted by standard consumer demand theory. For consumption of market-purchased goods, the most important result is the strongly positive cross-price elasticities. This result also attests to the strength of the profit effect in increasing total expenditure. The reported elasticities suggest that the level of farm incomes and the availability of nonfarm goods are important determinants of responsiveness. For example, Sierra Leone, which has a low per capita income and relatively thin market and infrastructural development, has much lower elasticities than those of the East Asian countries.

Elasticities of marketed surplus are strongly positive, whereas those for total family labor supply are negative. The positive elasticities of marketed surplus indicate that, even where the profit effect is strong enough to make consumption response positive, the total output response is always large enough to offset increased household consumption. The negative responses for labor supply suggest a strong profit effect and reflect the fact that leisure is a normal good.

Do Agricultural Household Models Matter?

Agricultural household models integrate production and consumption decisions in rural farm households. This requires a complex theoretical structure as well as much data for empirical estimation. Is the additional effort justified? Can practitioners make do with far simpler techniques that have been traditionally used to model farm behavior—that is, with the demand and supply sides separated? The answer lies at two levels. First, at the empirical level, we must ask whether these models, which account for the interdependence of production and consumption decisions, provide estimates of elasticities that could not have been obtained otherwise. Second, at the policy level, we must ascertain whether the resulting differences in these elasticity estimates lead to policy implications that differ from those emerging from traditional methods. The remainder of this section addresses the first issue—that of the empirical significance of agricultural houshold models. The policy implications are discussed in section III.

In assessing the empirical significance of agricultural household models, it is useful to recall that their distinguishing characteristic is the inclusion of the profit effect, which results from the increase in income when crop prices are raised. Table 3, which compares two sets of elasticities—those with and those without the profit effect—clearly establishes the empirical significance of agricultural household models. The estimates of the elasticity of demand with respect to own-price not only differ significantly in the cases of Japan, Sierra Leone, and Thailand, but change sign in the cases of Korea, Malaysia, Nigeria, and Taiwan. Thus, whereas traditional models of demand, as we would expect, predict a decline in own-consumption in response to an increase in agricultural commodity prices, the agricultural household models predict an increase for three cases. This is because the profit effect offsets the negative substitution and

Table 3. *Analysis of the Profit Effect: Agricultural Price and Wage Elasticities of Commodity Demand and Labor Supply*

	Elasticity					
	Of agricultural commodity demand		Of nonagricultural commodity demand		Of labor supply	
Economy	A[a]	B[b]	A[a]	B[b]	A[a]	B[b]
Elasticity with respect to agricultural prices						
Japan	−0.87	−0.35	0.08	0.61	0.16	−1.01
Korea	−0.18	0.01	−0.19	0.81	0.03	−0.13
Malaysia	−0.04	0.38	−0.27	1.94	0.08	−0.57
Nigeria[c]	−0.05	0.19	−0.14	0.57	0.03	−0.06
Sierra Leone	−0.74	−0.66	−0.03	0.14	0.01	−0.09
Taiwan	−0.72	0.22	0.13	1.18	0.21	−1.54
Thailand	−0.82	−0.37	0.06	0.51	0.18	−0.62
Elasticity with respect to wage rates						
Japan	0.29	0.15	0.39	0.25	0.15	0.45
Korea	0.16	0.01	0.77	0.05	0.00	0.11
Malaysia	0.06	−0.08	0.29	−0.35	−0.07	0.11
Nigeria[c]	0.06	0.02	0.04	0.01	0.01	0.10
Sierra Leone	0.47	0.37	0.78	0.57	0.14	0.26
Taiwan	0.14	−0.03	0.05	−0.12	−0.12	0.17
Thailand	0.57	0.47	0.62	0.52	0.08	0.26

Sources: Listed for each economy in the first column of table 1.

Note: Each value shown is the ratio of the percentage change in the endogenous variable (the column heading) to the percentage change in agricultural price or wage.

a. Holding profits constant.

b. Allowing profits to vary.

c. Northern portion only.

income effects. In these cases, farm households increase their own-consumption as prices are raised. Whether or not this would reduce the amounts they offer on the market will depend on the elasticity of output. We know that this marketed surplus elasticity remains positive in these cases (table 2). The response, however, is dampened by the profit effect.

The differences in the elasticity of demand for nonagricultural goods with respect to the price of agricultural goods are also striking. The elasticities change sign in four cases, and in the other three cases the magnitudes are much larger when the profit effect is included. Whereas cross-price elasticities estimated using traditional demand models tend to be low or negative because of negative income effects, the agricultural household model estimates are positive and large because of the positive profit effect. The elasticities of household labor supply with respect to the price of the agricultural good also differ dramatically. In the traditional demand models, an increase in the price of the agricultural good reduces not only the consumption of that good but also that of leisure, which implies an increase in the family work effort (table 3). In contrast, agricultural household models predict a negative response of household labor supply to increased output prices because households are willing to take part of their increased incomes in increased leisure and thereby reduce their work effort.

While fewer signs change when responses to agricultural wage rates are examined, the magnitudes do. In traditional demand models, an increase in the wage rate implies an increase in real household incomes, which results in a positive demand response for agricultural and nonagricultural goods and a negative or inelastic response of household labor supply. These effects are partially offset in agricultural household models because an increase in wages also affects the production side and reduces total farm incomes. As a result, demand responses for both the agricultural and nonagricultural goods are either dampened or totally offset (Malaysia, Taiwan), while labor supply response becomes positive or more elastic.

Rosenzweig (1980) looks at the market (or off-farm) labor supply responses of landed and landless households in rural India and provides a different type of evidence that agricultural household models matter. After separately estimating market supply equations for landless and agricultural households, Rosenzweig compares coefficients between the two groups and finds that twenty-one out of twenty-two comparisons conform to the predictions of the agricultural household framework. For instance, the male off-farm labor response of landless households to increases in the market male wage is less than for agricultural households, as would be predicted because of the negative profit effect of raising male wages.

In addition to differences between elasticities estimated from traditional models and those estimated from agricultural household models, there are other elasticities provided by the latter which are not even defined for models that focus exclusively on consumption behavior. These are the elasticities of demand with respect to nonlabor input prices, stocks of fixed factors of production (including land), and farm technology. A selection of these elasticities is shown in table 4. While the absolute magnitudes are small in most cases, the point to recall is that they have no counterpart in models that do not integrate production and consumption. Thus, while traditional demand models can predict demand responses to output prices, they tell us nothing about such responses to input prices or changes in the fixed factors of production or technology. Similarly, traditional supply models can predict supply responses to changes in output and input prices and in fixed factors of production and technology but fail to tell us anything about the demand responses to these exogenous factors. Agricultural household models therefore provide a vital link between demand and supply responses to exogenous policy changes. While these links can be established informally between traditional supply and demand models, in agricultural household models they are handled directly within a consistent theory and framework of estimation.

The results of tables 3 and 4 allow us to identify when the use of a full agricultural household model is likely to be important. Since the profit effect is the distinguishing feature of these models, this amounts to identifying when the

Table 4. *Selected Elasticities with Respect to Fertilizer Prices and Land Availability*

Economy	Agricultural commodity demand	Nonagricultural commodity demand	Marketed surplus	Labor supply
Elasticity with respect to fertilizer prices[a]				
Japan	−0.03	−0.03	−0.09	0.07
Korea	−0.05	−0.23	0.34	0.04
Malaysia	−0.03	−0.18	−0.15	0.05
Taiwan	−0.11	−0.11	−0.24	0.18
Thailand	−0.03	−0.03	−0.41	0.05
Elasticity with respect to land availability				
Japan	0.19	0.19	0.96	−0.43
Korea	0.10	0.49	0.81	−0.08
Malaysia	0.26	1.37	1.15	−0.41
Nigeria[b]	0.10	0.16	0.06	−0.08
Sierra Leone	0.01	0.02	0.02	−0.01
Taiwan	0.46	0.46	1.00	−0.77
Thailand	0.11	0.11	1.48	−0.19

Sources: Listed for each economy in the first column of table 1.

Note: Each value shown is the ratio of the percentage change in the endogenous variable (the column heading) to the percentage change in fertilizer price or the area of land available.

a. Fertilizer is barely used in the Sierra Leone and Nigeria samples and therefore was not modeled.

b. Northern portion only.

profit effect is likely to be important. Three points regarding this effect are worthy of note. First, changes in some exogenous prices have a small effect on farm profits. For example, the profit effect is much more important in Malaysia than in Sierra Leone (table 3) partly because the effect of a price change on profits is much larger in Malaysia, where a 10 percent increase in output price results in a 16 percent increase in profits. In Sierra Leone, the same percentage increase in output price increases profits by only 2 percent.

Second, even if profits are affected by an exogenous price increase, profits may be only a small part of full income (equation 2) and it is full income that appears in the demand equations. For our sample economies, the share of profits in full income ranges from 0.5 in Malaysia to 0.2 in Thailand. It follows that a given percentage increase in profits will have a much bigger impact on total income in Malaysia than in Thailand.

Third, the effect of full income on demand varies among commodities. It is much more important, for example, in the case of nonagricultural commodities than agricultural ones since demand in the latter tends to be inelastic with respect to income. In Malaysia, the elasticity of demand for rice with respect to full income is only 0.5, compared with 2.7 for market-purchased goods. As a result, the profit effect is much more significant in the case of nonagricultural goods than in that of agricultural goods (table 3).

These remarks suggest that if profits are relatively insensitive to producer prices and constitute a relatively small part of full income, and if consumption of a particular item is relatively insensitive to full income, then couching the analysis in the context of an agricultural household model will not yield much of an increase in accuracy. This proves to be the case, for example, with the elasticity of demand for agricultural goods with respect to changes in producer prices in Sierra Leone (although it is not true for low-income households in that study [Strauss 1986a]). If these three conditions are reversed, however, as the example of the elasticity of demand for nonagricultural goods with respect to producer prices in Malaysia reveals, a full agricultural household model is of critical importance.

III. Policy Results

Results from the Basic Model

Agricultural household models provide policy insights in three broad areas: the welfare or real incomes of agricultural households; the spillover effects of agricultural policies on the rural, nonagricultural economy; and, at a more aggregate level, the interaction between agricultural policy and international trade or fiscal policy. To illustrate the potential role of agricultural household models, this section draws policy conclusions in each of these three dimensions for a typical agricultural policy. The policy chosen is that of taxing output (either through export taxes or marketing boards) in order to generate revenue for the national treasury and simultaneously subsidizing a major input (usually fertilizer) to restore, at least partially, producer incentives. Other policies can be examined with the use of agricultural household models, but this particular combination is a common characteristic of agriculture in developing countries and illustrates well the type of issue that can be analyzed in this framework. Care must be taken when interpreting these policy implications because the analyses are partial equilibrium in nature. A major exception are the multimarket analyses discussed below.

Consider first the effect of pricing policy on the welfare or real full income of a representative agricultural household. For some price changes—for example, a change in the price of fertilizer—the resulting change in nominal full income is an accurate measure of the change in real income since the prices of all consumer goods have remained unchanged. In other cases, however, the commodity in question may be both a consumption good and a farm output or input. For example, if the price of an agricultural staple is reduced, the household will lose as a producer but gain as a consumer. As long as the household is a net producer of the commodity, the net effect will be negative (see Strauss 1986b). Nevertheless, if one wishes to quantify the net impact on the household, allowance must be made for both the negative effect coming through farm profits and the positive effect coming through a decline in the price of a major consumption item.

Table 5 presents estimates of the elasticities of real full income with respect to changes in output price and fertilizer price for the seven studies examined earlier. For marginal changes, the decrease in real income following a reduction in the price of the agricultural output equals marketed surplus times the price decline,

Table 5. *Real Income Elasticity with Respect to Prices of Output and Fertilizer*

	Response of Income	
Economy	*To output prices*	*To fertilizer prices*
Japan	0.34	−0.03
Korea	0.40	−0.10
Malaysia	0.67	−0.07
Nigeria[a]	0.12	—
Sierra Leone	0.09	—
Taiwan	0.90	−0.11
Thailand	0.10	−0.03

Sources: Listed for each economy in the first column of table 1.

Note: Each value shown is the ratio of the percentage change in real income to the percentage change in prices of output or fertilizer.

a. Northern portion only.

— Not applicable. Fertilizer is barely used in the Sierra Leone and Nigeria samples and therefore was not modeled.

while the increase following a reduction in the price of an input equals the quantity of the input times the price reduction. Thus, knowing prices, marketed surplus, and full income, these short-run elasticities can be calculated without reference to price and income elasticities. However, for nonmarginal changes, it would be necessary to use information on the underlying structure of preferences to calculate equivalent or compensating variation.

The table reveals that the percentage change in real income is less than the percentage change in either the output price or the fertilizer price. In addition, the table suggests that the loss in real income arising from a given percentage reduction in the output price can be offset only if the price of fertilizer is reduced by a much larger percentage. In Malaysia, for example, a 10 percent reduction in output price would reduce real income by almost 7 percent, whereas a 10 percent reduction in the price of fertilizer would increase real income by less than 1 percent. This result arises from the relative magnitudes of marketed surplus and fertilizer use and indicates that, if policymakers are interested primarily in the welfare of agricultural households, intervention in output markets is likely to be much more important than intervention in the markets for variable, nonlabor inputs.

Policymakers are also concerned with the welfare of rural households that do not own or rent land for cultivation. Landless households either sell their labor to land-operating households or engage in nonfarm activities (see, for example, Anderson and Leiserson 1980). Governments, however, have very few policy instruments that affect the welfare of these households directly. Policies such as price interventions and investment programs that are directed at land-operating households nevertheless have spillover effects which may or may not be beneficial for these households. What can agricultural household models tell us about these effects?

An increase in the price of a major agricultural staple will obviously hurt households that are net consumers of that item (if other prices are held constant). The direct effect of a price increase, therefore, will be unambiguously negative for landless households and nonfarm households. If general equilibrium considerations are ignored, policymakers thus face a dilemma: if they want to improve incentives and increase the incomes of agricultural households, they do so at the expense of other rural households. There are, however, offsetting indirect effects. For example, table 6 below reveals that if the price of the agricultural commodity is increased, agricultural households increase their demand for total—hired and family—farm labor and reduce the supply of family labor (that is, increase their leisure time). As a result, the demand for hired labor can be expected to increase substantially to the benefit of landless households. In Malaysia, the reported elasticities of labor demand (1.61) and labor supply (−0.57) imply an elasticity of demand for hired labor of 10.9. While this result in part reflects the initial small percentage of hired labor in total labor (19 percent), it nevertheless implies a substantial change in labor market conditions and would undoubtedly exert upward pressure on rural wage rates. At least to some extent, it thereby offsets the negative consequences for landless households of higher prices of agricultural commodities.

The policy implications of these findings are very significant because they also shed light on the extent to which the positive gains from technological improvements trickle down via the labor market to the rural landless. It is now widely accepted that technological innovations associated with the Green Revolution (improved seeds, increased use of fertilizers and pesticides, increased irrigation and cropping intensity) have had a dramatic impact on the demand for total

Table 6. *Indirect Effects of Changes in Prices of Output and Fertilizer*

	Response		
Economy	*Of labor demand*	*Of labor supply*	*Of consumption of nonagricultural goods*
Response to changes in output prices			
Japan	1.98	−1.01	0.61
Korea	0.57	−0.13	0.81
Malaysia	1.61	−0.57	1.94
Nigeria[a]	0.12	−0.06	0.57
Sierra Leone	0.14	−0.09	0.14
Taiwan	2.25	−1.54	1.18
Thailand	1.90	−0.62	0.51
Response to changes in fertilizer prices[b]			
Japan	−0.13	0.07	−0.03
Korea	−0.12	0.04	−0.23
Malaysia	−0.12	0.05	−0.18
Taiwan	−0.23	0.18	−0.22
Thailand	−0.11	0.05	−0.03

Sources: Listed for each economy in the first column of table 1.

Note: Each value shown is the ratio of the percentage change in the endogenous variable (the column heading) to the percentage change in agricultural commodity or fertilizer price.

a. Northern portion only.

b. Fertilizer is barely used in the Sierra Leone and Nigeria samples and therefore was not modeled.

labor. But the concern has been whether this increased demand could be translated into an equal impact on hired labor, most of which comes from the smallest farms and the landless (see Quizón and Binswanger 1986). The empirical findings show that it can be. When an increase, either in the fixed factors of production or technologies, boosts incomes on the farm, they tend to reduce the amount of the family's labor effort (table 4 illustrates this using land as an example). Any increase in the demand for total labor therefore results in an even larger increase in the demand for hired labor. The labor supply and demand elasticities emerging from empirical applications of agricultural household models provide strong support for the view that trickle-down effects are both positive and significant.

Table 6 identifies a second indirect effect of increased output prices: a significant increase in the demand for nonagricultural goods. The elasticity is positive and greater than 1 in two economies—Taiwan and Malaysia—and positive and greater than 0.5 in all economies except Sierra Leone (though for low-income households in Sierra Leone it is also high: 0.9). Some of this demand will be for imports and urban-produced commodities, but a large part will be for rurally produced goods and services and therefore will increase demand for the output of nonfarm, rural households. Any increase in farm profits, whether caused by a price change or a technological improvement, can be expected to lead to a substantial increase in the demand for goods and services produced by nonagricultural households. Thus, spillover effects on output markets will at least partially offset the negative effects on nonfarm households of an increase in agricultural prices and will ensure that the benefits of technological improvements are dispensed throughout the rural community.

Table 6 also traces the effects of a change in the price of fertilizer. As noted in the discussion of the effects on the welfare of agricultural households, changes in the price of fertilizer have only a minor impact. The results suggest that small or moderate changes in fertilizer prices can be made without generating large negative or positive spillover effects.

As mentioned earlier, governments often tax agricultural output to generate revenue and simultaneously subsidize key inputs such as fertilizer to restore production incentives in the hope of achieving self-sufficiency or earning foreign exchange. Can agricultural household models shed light on these revenue and balance of trade issues? Because the models provide information on the effect of pricing policy on marketed surplus and fertilizer demand, they can be used as inputs into calculations of self-sufficiency, balance of payment effects, and budgetary effects.

If the primary interest is in self-sufficiency, governments need to know the marketed surplus available for procurement. Table 7 reproduces elasticity estimates for agricultural production, consumption, and marketed surplus. The results illustrate two points. First, even where consumption responds positively to an increase in the price of the agricultural commodity because of the profit effect, marketed surplus still responds positively. Where the consumption re-

Table 7. *Elasticities of Output, Consumption, Marketed Surplus, and Fertilizer Demand*

	Response			
Economy	*Of agricultural output*	*Of agricultural consumption*	*Of marketed surplus*	*Of fertilizer demand*
Response to changes in output prices				
Japan	0.98	−0.35	2.97	1.98
Korea	1.56	0.01	1.40	1.29
Malaysia	0.61	0.38	0.66	1.61
Nigeria[a]	0.30	0.19	0.20	—
Sierra Leone	0.11	−0.66	0.71	—
Taiwan	1.25	0.22	1.03	2.25
Thailand	0.90	−0.37	8.10	1.90
Response to changes in fertilizer prices[a]				
Japan	−0.13	−0.03	−0.09	−1.13
Korea	0.30	−0.05	−0.34	−1.10
Malaysia	−0.13	−0.03	−0.15	−1.13
Taiwan	−0.23	−0.11	−0.23	−1.23
Thailand	−0.11	−0.03	−0.41	−1.11

— Not applicable. Fertilizer is barely used in the Sierra Leone and Nigeria samples and therefore was not modeled.

Note: Each value shown is the ratio of the percentage change in the endogenous variable (the column heading) to the percentage change in the price of the agricultural commodity or fertilizer.

a. Northern portion only.

Sources: Listed for each economy in the first column of table 1.

sponse is negative, the elasticities of marketed surplus are positive and large (see, for example, the cases of Japan and Thailand). A government therefore can use pricing policy in the output market to increase marketed surplus even when it is unable to set the prices facing consumers and producers independently. Second, efforts to offset disincentives in output markets through fertilizer subsidies will not be effective unless the percentage reduction in the fertilizer price is much larger than that in the output price.

The analyst can also derive from table 7 rough estimates of the effect of pricing policies on budget revenues and foreign exchange. For example, assume that the output is exported and that fertilizer is imported. Table 7 reveals that an increase in output price will induce an increase in marketed surplus available for export but only at the expense of an increase in the use of fertilizer. The net foreign exchange effect, therefore, is given by the difference between the additional revenues from exporting and the costs of importing additional fertilizer. Similarly, if the output is taxed and fertilizer is subsidized, one can perform a similar calculation to arrive at a rough estimate of the net impact on the budget.

The policy issues analyzed above illustrate the uses that can be made of the basic framework of the agricultural household model. The framework is very flexible and can be adapted in many ways to fit particular circumstances and issues. In the next section, we discuss the main policy conclusions of these extensions but note that at present these conclusions remain somewhat more

Table 8. *Response of Caloric Intake to Price Changes, Sierra Leone*

Commodity	*Price elasticity of caloric intake* Low-income households	Middle-income households	High-income households
Rice	0.19	−0.24	−0.20
Root crops and other cereals	0.43	0.13	0.11
Oils and fats	0.27	−0.03	−0.21
Fish and animal products	0.48	0.23	0.05
Miscellaneous foods	0.14	0.01	−0.01

Source: Strauss (1986a).

Note: Each value shown is the ratio of the percentage change in caloric intake to the percentage change in the price of the relevant food.

tentative than those emerging from the well-researched basic model because replications of the extensions have not yet been performed.

Extensions of Agricultural Household Models

The implications of price and other interventions on the nutritional and health status of target groups, especially the rural poor, are of special interest to international agencies and national governments. What do agricultural household models add to the debate? Strauss (1986a) demonstrates how the basic model can be elaborated to allow an investigation of the effect of pricing policy on caloric intake. In his model, the utility function (see equation 1) becomes

$$U = U(X)$$

where X is a vector of consumer goods including food items, nonfood items, and leisure. Calorie intake (K) can then be calculated from:

$$K = \sum_i a_i X_i \qquad i = 1 \ldots m$$

where a_i is the calorie content of a unit of the i^{th} food and X_i, $i = 1 \ldots m$, are quantities of different food items.

With this extension, Strauss is able to show that price changes exert a considerable effect on caloric intake with the profit effect playing an important role. One might expect that an increase in the price of a major food item would probably have a negative impact on caloric intake. However, table 8 reveals that, in the majority of cases, an increased price results in increased caloric intake because of an increase in profits. Thus, even if consumption of the commodity whose price is increased declines, the extra profits allow the purchase of increased quantities of other foodstuffs so that overall caloric intake responds positively. With profits held constant, however, increased food prices decrease caloric intake. This indicates that the nutritional impact of higher food prices on agricultural households is reversed (or substantially reduced) when the profit effect is incorporated.

In the case of Sierra Leone, Strauss is also able to demonstrate an important point regarding the distribution of calories among income groups. He shows that even if a price increase causes a reduction in the caloric intake of middle- and high-income households (see the case of rice in table 8), the intake of low-income households is increased. This suggests that, if policymakers are concerned primarily with the nutritional status of low-income households where few rural households are landless, price increases for major food items may prove to be beneficial. Increases in the prices of food items toward world prices may improve the nutritional status of low-income landed households and provide appropriate signals for resource allocation. The usual equity-growth trade-off may be absent in this case.[8]

Policymakers are interested in nutritional status presumably because it affects health and well-being and may also affect productivity at the individual level. Pitt and Rosenzweig (1986) take the analysis one step further, therefore, and examine the interaction between prices, health, and farm profits in the context of an agricultural household model. Their extension involves incorporation of a health variable directly into the utility function—people prefer to be healthy—and into the production function—a healthy individual is more productive. To complete their model, they introduce a production function for health:

$$H = H(X_a, X_m, X_l, Z)$$

which says that health (H) depends on consumption (X_a and X_m) and hence on nutrition, on leisure (or work effort, X_l), and on a vector (Z) of other factors which affect health, some of which (for example, boiling water) are chosen by the household and some of which (for example, well water) are community-level services.[9]

Applying their model to Indonesian data, Pitt and Rosenzweig are able to show that a 10 percent increase in the consumption of fish, fruit, and vegetables reduces the probability of illness by 9, 3, and 6 percent, respectively, whereas a 10 percent increase in the consumption of sugar increases the probability of illness by almost 12 percent. These results suggest that increases in consumption cannot automatically be interpreted as contributing to health since the composition of consumption may also change in a manner detrimental to health.

In addition to estimating the health production function, Pitt and Rosenzweig also estimate a reduced-form equation that directly links prices and health. They show that a 10 percent reduction in the prices of vegetables and vegetable oil will decrease the probability of the household head being ill by 4 and 9 percent, respectively, whereas the same percentage reduction in the prices of grains and sugar will increase the probability of illness by 15 and 20 percent, respectively, albeit from a very low base. These results, however, are calculated with profits held constant. In principle, when profits are allowed to vary, some of the results

8. Smith and Strauss (1986) provide similar evidence when they simulate the results at the national level while allowing rural wages to equilibrate the rural labor market.

9. Early work on household production activities within a household-firm framework can be found in Hymer and Resnick (1969) and Gronau (1973, 1977). See Strauss (1986b), for further discussion.

may be modified. In this application, however, the coefficient on farm profits proved statistically insignificant. The results reported above, therefore, are reasonably accurate measures of the total effect of changes in price on health.

Changes in health may also affect productivity and farm profits. Pitt and Rosenzweig demonstrate that behavior can be represented by a recursive model, in which case the effects of ill health or labor supply are not reflected in reduced farm profits since households have recourse to an active labor market. Although total labor input and hence farm profits are unaffected, family labor supply is significantly reduced by illness, and the value of full income is decreased by the value of time spent ill in bed. This result indicates that the benefits of improved health (or the costs of a deterioration in health) in agricultural households will come through family labor earnings only and will be reflected in farm profits, if at all, only through the indirect route of the labor market.

Most of the policy issues considered so far have been static in nature and have been couched in a single-period framework. Iqbal (1986) provides a major departure from previous work by extending the single-period analysis to incorporate borrowing, savings, and investment decisions. Since governments and multinational agencies devote substantial funds to rural credit programs, this extension offers the possibility of using agricultural household models to address a new set of policy issues of considerable importance for many countries.

Iqbal uses a two-period model. In the first period, the household may borrow and invest in farm improvements. In the second period, the loan must be repaid with interest and the household enjoys higher farm profits as a result of its investment in period one. Accordingly, in Iqbal's model the single full-income constraint is replaced by two full-income constraints, one for each period:

$$\pi(K_1) + w_1T_1 + B = C_1 + I$$

and

$$\pi(K_1 + I) + w_2T_2 = C_2 + B\,[1 + r(B)]$$

where K_1 is capital in period one and I is investment, so that $K_1 + I$ is capital in period two. B is borrowing in period one, r is the interest rate, and $B\,[1 + r(B)]$ is repayment in period two. C is the value of consumption of goods and leisure. Iqbal draws a parallel between his treatment of household savings and borrowing and the treatment of own-consumption and marketed surplus or family labor supply and hired labor in the standard agricultural household model. He notes that the recursive property of the standard model carries over to this two-period extension, provided the household can borrow at a fixed rate of interest. In his application to Indian households, Iqbal argues that the interest rate is influenced by household borrowing decisions (r is a function of B in the second-period constraint), and he therefore adopts a nonrecursive specification.

Iqbal's results reveal that borrowing is significantly reduced by increases in the interest rate, the elasticity being -1.2. These results support the view that interest rate policy can have a marked effect on the level of debt held by farmers.

Iqbal also shows that farmers owning more than three hectares are highly sensitive to the interest rate whereas the coefficient on borrowing by farmers owning less than three hectares is statistically insignificant. It follows that the elimination or reduction of subsidies to programs providing agricultural credit may serve the dual purpose of increasing efficiency in the capital market and simultaneously improving equity, since the reduction in borrowing by "large" farmers will exceed that by "small" ones.

As noted earlier, governments are also interested in the effects of agricultural pricing policy on more aggregate economic variables such as budget deficits and foreign exchange earnings. For example, in 1982–83, Senegalese agricultural products generated 70 percent of total export earnings, and deficits resulting from the government's policy on agricultural pricing amounted to more than 20 percent of government expenditure and 2 percent of gross domestic product. Changes in agricultural prices can be expected, therefore, to have a major impact on these aggregates. Indeed, concern with the existing levels of foreign exchange earnings and budget deficit may be the major motivation for changes in pricing policy in many countries. In Senegal, the government has explored ways, including pricing policy, to promote the production and consumption of millet in order to reduce imports of rice and hence improve the country's balance of payments.

The effect of pricing policy on foreign exchange and budget revenues was discussed briefly earlier in this article. Braverman, Ahn, and Hammer (1983) and Braverman and Hammer (1986), however, provide an important extension to the basic model that makes the analysis of these policy issues much more complete: they add market-clearing conditions for the major outputs and inputs to the basic model of an agricultural household. The changes in consumption, production, or labor supply at the household level following any change in an exogenous variable can then be aggregated and fed into the market-clearing equations. In some cases, the market is cleared through adjustments in international trade, and prices remain fixed at levels determined by the government; that is,

$$Q(\bar{P}_a) = X_a(\bar{P}_a) + E$$

where E represents net exports and the output and consumption variables now represent national aggregates. In this event, a change in production or consumption has an immediate effect on foreign exchange earnings. Alternatively, the market may clear through adjustments in price; that is,

$$Q(P_a) = X_a(P_a)$$

Now a policy-induced change in production or consumption will result in a change in price, which will generate second-round effects on production and consumption.

In their application of the model to Senegal, Braverman and Hammer (1986) assume the first form—quantity adjustment—of marketing clearing for cotton, groundnuts, and rice and the second form—price adjustment—for maize and millet. The second-round effects flowing from induced changes in the prices of maize and millet are captured fully in their model. Table 9 provides a sample of their policy results. Compare first the effect of reducing the price of groundnuts or increasing the price of fertilizer on the government's deficit arising from its agricultural pricing policy. Both policies reduce the deficit. The reduction in the price of groundnuts, however, has a relatively small effect on net foreign exchange earnings (mainly because a reduction in rice imports offsets reduced exports), although it reduces the real incomes of farmers in the groundnut basin by almost 6 percent. An increase in the price of fertilizer, however, causes a larger fall in net export earnings (a reflection of the fertilizer intensity of export crops) but only reduces farm incomes by 1 percent. This example illustrates the policy trade-offs that can be explored within this framework. It also confirms a point made earlier: to be effective, changes in the prices of inputs such as fertilizer must be larger than changes in the prices of the main outputs.

Table 9 also illustrates a quite different point regarding the formulation of policy. Assume that a policy objective is to reduce imports of rice and hence save foreign exchange by increasing domestic production of rice and increasing consumption of domestic substitutes such as millet. How can this result be achieved? One possibility is an increase in the producer price of rice. This does indeed reduce rice imports by 7 percent, but net foreign exchange earnings fall by 4.5 percent because to increase rice production farmers switch out of export crops. The desired result—an increase in net foreign exchange earnings—fails to materialize because of substitution possibilities in production. In this case, failure to recognize substitution possibilities produces a perverse result. In other situations, however, policy may be designed to take advantage of substitution possibilities. For example, the government may increase the consumer price of rice in the hope that people will change their pattern of consumption in favor of millet. Table 9, however, reveals that this policy has little impact on net export earnings, so in this case a reliance on substitution possibilities would have been misplaced.

These examples from the Senegal study of Braverman and Hammer illustrate

Table 9. *Agricultural Price Elasticities, Senegal*

Policy	*Change in real income*	*Change in export earnings*	*Change in government deficit*
Decrease producer price of groundnuts by 15 percent	−5.7	−1.9	−18.1
Increase price of fertilizer by 100 percent	−1.1	−5.2	−10.4
Increase producer price of rice by 50 percent	0.2	−4.5	−0.1
Increase consumer price of rice by 50 percent	−4.7	−0.2	−34.8

Source: Braverman and Hammer (1986).

Note: Each value shown is the ratio of the percentage change in the endogenous variable (the column heading) to the percentage change in the price of the specified commodity.

the importance of placing agricultural household models in a multimarket framework.[10] This is likely to be especially important if attention is focused on foreign exchange earnings and government revenues. Because expansion of one crop is usually at the expense of another crop, changes in the quantities of internationally traded items and in the quantities of taxed or subsidized items will influence the overall impact of policy on foreign exchange and government revenue even if a change in a government-controlled price in one market leaves the prices in all other agricultural markets unchanged. More generally, changes in government-controlled prices will induce changes in other prices so that even measures of output response, labor supply response, consumer response, and changes in farm profits will have to allow for general equilibrium effects. These remarks suggest that the multimarket analysis of Braverman and Hammer will be likely to emerge as the most useful vehicle for generating operationally relevant policy results from agricultural household models, particularly when it is based on carefully estimated parameters from good data.

IV. Conclusion

On the basis of the empirical work to date, it seems clear that for certain purposes the agricultural household modeling approach is essential. In particular, the interaction of consumption and production decisions through farm profits is essential because it matters empirically. It is less certain whether other interactions, through virtual prices, are important. This is likely to be the subject of future research. For policy analysis, especially at the aggregate level, it will generally be imperative to account for the profit effect on consumption. Analysts cannot justifiably continue to assume that rural household consumption does not vary with economic changes. As the Senegal study shows, changes in household consumption stemming from a certain policy can have important ramifications for several different outcomes. That study also highlights the advantages of moving toward general equilibrium in policy analysis, since it allows varying production and consumption substitution possibilities to be better captured. However, more household level studies are needed to improve understanding of the decisionmaking process and to extend the basic model to cover other types of decisions.

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