A Model of an Agricultural Household in a Multi-crop Economy: The Case of Korea
A MODEL OF AN AGRICULTURAL HOUSEHOLD IN A MULTI-CROP ECONOMY: THE CASE OF KOREA

Choong Yong Ahn, Inderjit Singh, and Lyn Squire

I. Introduction

A large part of world agriculture comprises semi-commercial family farms operating in a multi-crop environment. These family farms or agricultural households combine two fundamental units of microeconomic analysis—the household and the farm. Although traditional economic theory has dealt with each separately, in developing agriculture, it is their interdependence that is of crucial importance. Models of such households, therefore, should allow for the integration of production and consumption decisions within the context of a single theory of behavior. That is, labor supply, household consumption (of leisure as well as goods) and the composition of farm output and resource use (including family labor) should all be determined simultaneously.

Existing models have tended to focus on selected aspects of this simultaneous problem. Thus, econometric models have been developed which allow for the integration of consumption and production decisions but which do not consider the crop composition decision. On the other hand, linear programming (LP) models have had as their main purpose an analysis of the allocation of resources to competing crops, but have not allowed for the simultaneous determination of consumption and production decisions. It is the purpose of this paper to describe one method of extending the empirical applicability of the theory of the farm-household to multi-crop economies by integrating the econometric and linear programming models already available in the literature.

The paper is organized as follows. In section II, the theoretical model is presented. In section III, Korean data are used to assess the quantitative significance of the approach by calculating and comparing household response to changes in input and output prices for two different specifications of the models. First, the household is analyzed from the consumption side on the assumption that farm profits are exogenous; this corresponds to the standard approach in consumer demand theory. And second, results are presented for a model in which consumption and production responses are integrated in a theoretically consistent fashion, and farm profits are allowed to reflect production responses to price changes.

II. A Theoretical Model

The model of household behavior describes a semi-commercial family farm with a competitive labor market. A major part of agriculture in LDCs may be characterized by this type of model which lies intermediately on a continuum between a wholly commercialized farm employing only hired labor and marketing all output and a pure subsistence farm using family labor and producing solely for home consumption.

The planning horizon is assumed to be one agricultural cycle. As a result, decisions relating to the total supply of household factors of production—family labor force and area operated—are treated as given. Similarly, it is assumed that the household has already made some decision concerning its desired level of saving. The model, therefore, focuses on the short-run determination of the allocation of expenditure to different commodities (including own-consumption and leisure), and the allocation of inputs to different production activities.

Further, it is assumed that there is a market for agricultural and other types of labor and that all
households participate in the labor market either as buyers or sellers of labor. Thus, the use of labor time and the disposal of output are determined with reference to market wages and prices. In output and input markets, the household is assumed to be a price taker. Finally, it is assumed that land, if rented, is rented by means of fixed charges and that there are no sharecropping or other contractual arrangements which might lead to nonstandard profit maximizing conditions.

With these points in mind, the model is formulated in matrix notation as follows:

Max \( U = U(C) \) \hspace{1cm} (1)

subject to

\[ [1]' X_i \leq Z_i \quad i = 1, \ldots, k \] \hspace{1cm} (2)

and

\[ P'C = \Pi' X + Y = E \] \hspace{1cm} (3)

where

\( C \) is a \((h \times 1)\) vector of items consumed (own-consumption and purchased) including leisure;

\( [1]' \) is a \((1 \times n)\) unit vector;

\( X_i \) is an \((n \times 1)\) vector of land use by crop and technologies on the \( i^{th} \) type of land (or other quasi-fixed resource), and \( X \) is an \((m \times 1)\) vector of \( X_i \);

\( Z_i \) is the maximum available quantity of the \( i^{th} \) type of land (or quasi-fixed resource);

\( P' \) is a \((1 \times h)\) vector of prices of consumed goods including leisure;

\( \Pi' \) is a \((1 \times m)\) vector of net returns to fixed factors (after labor costs have been excluded) by crop and by technology and by land type;

\( Y \) is Becker’s concept of ‘full income’ and equals the market value of total time available to the household plus any (net) nonlabor income.

Thus, the household is assumed to maximize its utility function subject to a land constraint by quality or type (e.g., lowland, upland, irrigated and unirrigated) and a combined income and time constraint. The consumption of family leisure is included on the left-hand side of equation (3) and is valued at the market wage. The total (family and hired) labor input into crop production, again valued at the market wage, is included on the right-hand side of equation (3) in the determination of \( \Pi \).

It is assumed that technology is linear. Thus for the \( r^{th} \) crop on the \( i^{th} \) type of land we have

\[ \Pi_{ir} = p_r a_{ir} - \sum_j q_j b_{irj} \] \hspace{1cm} (4)

where \( p_r \) is the price of the \( r^{th} \) crop (and hence the \( r^{th} \) consumption good), \( a_{ir} \) is the yield of the \( r^{th} \) crop on the \( i^{th} \) type of land, \( q_j \) is the price of the \( j^{th} \) input, and \( b_{irj} \) is the \( j^{th} \) input requirement per unit of the \( i^{th} \) type of land for the \( r^{th} \) crop. As noted above, the total (family and hired) labor requirement is included as one of the inputs.

Forming the Lagrangian expression, we have

Max \( L = U(C) - \lambda (P'C - \Pi'X - Y) + \Sigma V_i (Z_i - [1]' X_i) \) \hspace{1cm} (5)

The first-order Kuhn-Tucker conditions are

\[ (P'C - \Pi'X - Y = 0) \quad (6) \]

\[ \lambda \Pi' - V \leq 0 \quad (7) \]

\[ IX [\lambda \Pi' - V] = 0 \quad (8) \]

\[ Z_i [1]' X_i \geq 0 \quad i = 1 \ldots k \quad (9) \]

\[ V_i [Z_i - [1]' X_i] = 0 \quad i = 1 \ldots k \quad (10) \]

where \( V \) is an \((m \times 1)\) vector of \( V_i \) and \( I \) is a unit matrix.

Equations (6) and (7) correspond to the standard first-order conditions of consumer demand theory. Equations (8)-(11) represent the production side of the model. If equation (10) is binding for the \( i^{th} \) type of land then \( V_i \geq 0 \) represents the

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1 In reality labor markets in LDCs are very complex. The recent literature on labor markets in LDCs, however, suggests that they have many competitive features and there is ample evidence to show that most farm-households, at least in the Asian context, hire in and hire out labor at the market wage. See Squire (1979) for a general review of the issues and Rozenweig (1978) for an empirical test of alternative theories using Indian data.

2 The model thus has \( k \) consumption goods (of which one is leisure), \( k \) types of land, \( n \) crops, and \( m = k \times n \) different possible crop combinations or activities by land type and technology.

3 Noting that all \( C_i \)s and \( \lambda \) (the marginal utility of income) are positive.
shadow price of that type of land. If for the \( r \)th crop \( \lambda_1 \Pi_r \leq \Pi_i \), the \( r \)th crop will not be grown on the \( i \)th type of land. For the \( s \)th crop, however, assume that \( \lambda_1 \Pi_s = \Pi_s \) — in this event the \( s \)th type of land will be allocated completely to the \( s \)th crop. The model thus produces the standard result of complete specialization by land type. The results also indicate that the production side of the model can be solved independently of the value of \( \lambda \) (the marginal utility of income). Since \( \Pi_i = \lambda_1 \Pi_s \) where \( s \) is the most profitable crop, a comparison between \( \Pi_i \) and \( \lambda_1 \Pi_s \) for any \( r \neq s \) is not affected by the value of \( \lambda \); \( \lambda \) is a scalar which can be cancelled out, the allocation of land to competing crops being determined exclusively by a comparison of profitability at market prices.

The model may be treated, therefore, as a block recursive one, in which production decisions are first determined by profit maximization and then the consumption decisions are determined by utility maximization given the level of maximized profits. For any given farm technology and set of input and output prices, the linear programming model of farm production (using data for a representative farm) allows the determination of the level of farm profits, which is then introduced into the consumption side of the model to arrive at the household’s expenditure pattern.

The consumption side of the model is specified econometrically to conform to the linear expenditure system. To differentiate between the use of time by dependents and working family members the system is developed in per capita terms. For an individual member of the family the utility function is written as

\[
U = \Sigma u = n_1 \beta_1 \ln (c_1 - \gamma_1) + n_2 \beta_2 \ln (c_2 - \gamma_2)
\]

subject to

\[
n_1 \sigma_{Yi} + \Sigma p_i c_i = \Pi' X + Y = E
\]

where \( i = 2 \ldots h \), \( c_i = (t - s) = \) consumption of leisure, \( t = \) total time available per individual, \( w \) is the market wage, and \( s \) is the quantity of time supplied to work activities. (Note for dependents since \( s = 0 \), \( c_i = t \).) Household characteristics are introduced by making the \( \gamma \)'s linear functions of household composition; that is,

\[
\gamma_i = \alpha_{i0} + \alpha_{i1} n_1 + \alpha_{i2} n_2 \quad i = 1 \ldots h.
\]

The solution to this problem is described in Barnum and Squire (1979) and their estimation procedure is followed here. In our case the final set of estimating equations yields estimates of \( \beta_i \) for \( i = 2 \ldots h \). The value of \( \beta_i \) is then obtained by the adding-up restriction, i.e., that marginal expenditures must exhaust the budget. The transformation of the demand curve for leisure into a supply curve of labor allows us to replace \( \lambda_i / \lambda_i \) by \( \lambda_i / \lambda_i \) in all the estimating equations where \( \lambda_i = t / \lambda_i \). Accordingly, the estimating equations yield estimates of \( \alpha_{i0}, \alpha_{i1}, \) and \( \alpha_{i2} \) for \( i = 2 \ldots h \) and \( \alpha_{i0}, \alpha_{i1}, \) and \( \alpha_{i2} \) where \( \alpha_{i0} + \alpha_{i1} n_1 + \alpha_{i2} n_2 = \gamma_i \). The \( \gamma \)'s can then be computed for different household types using equation (15).

III. Results for Korean Agricultural Households (1970)

The linear expenditure system is estimated for six "commodities": labor supply (\( s = t - c_1 \)), paddy (\( c_2 \)), barley (\( c_3 \)), other farm produce (\( c_4 \)), market purchased food items (\( c_5 \)), and market purchased nonfood items (\( c_6 \)). The final parameter estimates are shown in table 1. By substituting \( \lambda_i \) for \( \lambda_i \) in the estimating equations the need to measure total time available to the household in order to compute \( V \), Becker's concept of "full income," can be avoided. In the particular case of the demand curve for leisure, the same substitution allows the elimination of \( c_i \) on the left-hand side and replacement by \( s = t - c_i \), where \( s \) equals total hours worked. The estimating equations thus require data on hours worked, and not on total time available or leisure. See Abbott and Ashenfelter (1976).

Data are from the Korean Farm Household Survey for 1970.
FAMILY FARMS IN A MULTI-CROP ECONOMY: KOREA

TABLE 1.—ESTIMATED PARAMETERS OF THE LINEAR EXPENDITURE SYSTEM FOR AN AGRICULTURAL HOUSEHOLD IN KOREA

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>Estimate</th>
<th>Coefficient</th>
<th>Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta_1$</td>
<td>0.23</td>
<td>$\alpha_{s1}$</td>
<td>-18.40 (-2.90)</td>
</tr>
<tr>
<td>$\beta_2$</td>
<td>0.05 (4.01)</td>
<td>$\alpha_{s0}$</td>
<td>4,373.30 (1.84)</td>
</tr>
<tr>
<td>$\beta_3$</td>
<td>0.03 (2.68)</td>
<td>$\alpha_{s1}$</td>
<td>-649.10 (-3.04)</td>
</tr>
<tr>
<td>$\beta_4$</td>
<td>0.81 (68.32)</td>
<td>$\alpha_{s2}$</td>
<td>-330.30 (-2.02)</td>
</tr>
<tr>
<td>$\alpha_{s0}$</td>
<td>580.30 (8.28)</td>
<td>$\sigma_{s0}$</td>
<td>60,969.60 (4.46)</td>
</tr>
<tr>
<td>$\alpha_{s1}$</td>
<td>73.70 (3.07)</td>
<td>$\sigma_{s1}$</td>
<td>-14,056.30 (-4.84)</td>
</tr>
<tr>
<td>$\alpha_{s2}$</td>
<td>233.90 (6.71)</td>
<td>$\sigma_{s2}$</td>
<td>-4,775.50 (-1.83)</td>
</tr>
<tr>
<td>$\sigma_{s1}$</td>
<td>-27.50 (-3.63)</td>
<td>$\sigma_{s2}$</td>
<td>-27.50 (-3.63)</td>
</tr>
</tbody>
</table>

Note: $N = 445$ households. Five equations were estimated jointly using an iterative least squares procedure described in Barnum and Squire (1979). Statistically insignificant estimates were eliminated after a preliminary set of results had been obtained and the system was re-estimated. The table reports the final parameter estimates. $t$-statistics are shown in parentheses. The only parameter in the sixth equation (the labor supply curve) not estimated by this procedure is $\beta_1$. This was calculated from the adding-up restriction. That is, $\alpha_1 + \beta_1 + \ldots + \beta_4 = 1$ where $\alpha_1 = \alpha_0$ and was set at its mean value of 0.5082.

The estimated model is used to calculate two sets of elasticities: first, when household and farm behavior are treated separately, and the responses of endogenous variables in the utility maximization problem to exogenous variables are estimated assuming farm profits to be exogenous; and second, when household and farm behavior are treated jointly and the responses of the exogenous variables incorporate the change in farm profits that may result from any changes in the exogenous variables. The first set of elasticities corresponds to those obtained by the standard approach to consumer theory, while the second corresponds to the integrated approach we have developed in section II. A comparison

| TABLE 2.—A COMPARISON OF SELECTED HOUSEHOLD RESPONSE ELASTICITIES FROM KOREA AND MALAYSIA |
|-------------------------------------|-------------------------------------|
| **Expenditure Elasticities**        | **Own-Price Elasticities**          |
| **Korea**                           | **Malaysia**                        |
| Paddy                              | 0.57                                |
| Market-purchased goods              | 2.76                                |
| Labor supply                        | -0.45                               |
| **Own-Price Elasticities**          | **Market-purchased goods**          |
| **Korea**                           | **Malaysia**                        |
| Paddy                              | -0.18                               |
| Market-purchased goods              | -0.87                               |
| Labor supply                        | 0.51                                |

9 Further details underlying the estimation of the demand system and the construction of the LP model are available from the authors.

10. Excludes labor spent on orchards, mulberry, and tobacco production which is a very small proportion of total labor use and nonagricultural activities for which no data are available.

11. The interest rate on borrowing charged for rice is 24%/ annum and is close to the commercial bank rate. The lending rate on agricultural cooperatives is perhaps lower about 18%/ accounting for the overestimation of interest charges in the model.

12. The household survey data do not give information on area sown to various crops except for rice. The observed values are from a national survey of cropped land reported in the Yearbook of Agriculture and Fisheries, 1971. Ministry of Agriculture and Fisheries, Korea, and a total correspondence between this and the household survey figures is not to be expected. The area planned to orchards, mulberry, and tobacco is deleted in computing this cropping pattern because of the very small proportion of total area devoted to these crops.
of these elasticities allows an assessment of the quantitative significance of the integrated model (see table 4).

The results are easily summarized. Of the 12 elasticities (in the upper part of the table) for which a comparison is possible, 4 change sign and 2 others change by more than ±0.5. All of the remaining elasticities are absolutely small and so large (absolute) changes are not to be expected. In addition, the integrated model allows the estimation of elasticities with respect to nonlabor input prices which are not defined for models that focus exclusively on consumption behavior (see lower part of table 4). These results demonstrate the quantitative significance of the model and indicate the importance of integrating consumption and production decisions when analyzing the behavior of agricultural households. Several interesting and important policy implications follow.

IV. Policy Implications

To begin with consider the own- and cross-price elasticities for rice, the most important food item (and hence nutrition source) in the household's consumption bundle and the most important crop on the farm. Traditional consumer theory suggests that own-consumption of rice will decrease if its price is raised (the estimated elasticity is −0.18), but the integrated model predicts that it will increase (the estimated elasticity now being 0.01), because increased prices also mean increased profits (and income) for agricultural households, thus swamping the price and income effects predicted by consumer theory. Similarly, positive elasticities are predicted for paddy-consumption and nonfood purchases with respect to not only the price of rice but also the prices of all other crops grown on the farm. Thus, while raising farm output prices may have a negative impact on the nutritional status of nonfarming rural households, it has a positive impact on agricultural households.

By the same token, for a given output response, marketed surplus response is lower because own-consumption of farm-produced goods increases rather than decreases in response to increased prices. Nonfarm households, however, may benefit from increased wages and employment opportunities because increased output prices also decrease the supply of farm family labor as profits and income increase and increase the demand for total labor input (not shown). The integrated model predicts that households are willing to take part of their increased incomes in increased leisure, so that any increased demand for labor in agricultural production (say, through land intensification programs) will have some spillover effects on the demand for hired labor (hence the incomes of the landless) even where the farm size is very small.

Finally, there is the set of elasticities that can be estimated only for the integrated model—those with respect to input costs. Thus our model correctly predicts reduced expenditures on all commodities and increased work effort as input

10 Traditional consumer theory includes both price and "income" effects of price changes by allowing the slope of the budget line to change. Our model traces, in addition, the shifts in the budget line itself through farm production and its impact on farm profits and hence total income.

Table 4.—A Comparison of Selected Arc Elasticities to Test the Significance of Integrating Household Production and Consumption Decisions (Korean Agricultural Households—1970)

<table>
<thead>
<tr>
<th>Elasticity of</th>
<th>Own Consumption of Rice (q1)</th>
<th>Nonfood Purchases (q1)</th>
<th>Labor Supply ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>With Respect to</td>
<td>I</td>
<td>II</td>
<td>I</td>
</tr>
<tr>
<td>Price of rice (p1)</td>
<td>−.18</td>
<td>.01</td>
<td>−.19</td>
</tr>
<tr>
<td>Price of barley (p2)</td>
<td>.00</td>
<td>.06</td>
<td>−.02</td>
</tr>
<tr>
<td>Price of other crops (p3)</td>
<td>.00</td>
<td>.12</td>
<td>.00</td>
</tr>
<tr>
<td>Wage rate (w)</td>
<td>.16</td>
<td>.01</td>
<td>.77</td>
</tr>
<tr>
<td>Seed costs (q4)</td>
<td>n.a.</td>
<td>−.01</td>
<td>n.a.</td>
</tr>
<tr>
<td>Fertilizer and pesticide costs (q5)</td>
<td>n.a.</td>
<td>−.05</td>
<td>n.a.</td>
</tr>
</tbody>
</table>

Note: The first set of elasticities in the rows marked (I) is computed on the assumption that farm profits (II) are constant. The second set of elasticities in the rows marked (II) is computed on the assumption that farm profits (II) are variable. Changes in farm profits (II) are estimated by using the LP production model to trace the input of discrete changes in exogenous variables. The first set of elasticities corresponds to the linear expenditure system alone and the second set to the integrated model.

* n.a.—not available because responses to changes in production costs are possible only in the integrated model.
costs (seed and fertilizer-pesticide prices) are increased (see table 4).\textsuperscript{11}

The results of table 4 refer solely to the representative household.\textsuperscript{12} An important attribute of the model developed here is the explicit treatment of household characteristics such as family size and area operated. This allows us to explore the response of different household types to changes in their economic environment and thus to arrive at a more detailed appreciation of selected policy interventions. Table 5, for example, demonstrates the impact of a change in the price of rice on paddy-consumption, nonfood purchases and family labor supply as farm area operated, and hence land-labor ratios are decreased. Landless households operate no land and their behavior cannot therefore be affected by the "production" side of the model.\textsuperscript{11}

As noted above, the representative household is able to increase its consumption of rice because it is a net seller of rice and thus benefits from an increase in its price. Most of the benefit to the representative household, however, takes the form of increased consumption of nonfood, market-purchased goods and leisure (i.e., reduced family work effort). Households with smaller plots (0.01 ha instead of 1.89 ha) also benefit from the increase in price but to a lesser extent. Moreover, despite increased profits the higher rice price causes them to curtail rice consumption. Landless households are of course net buyers of rice and being without land and deriving no income from cultivation can be treated as pure "consumers." They are consequently forced to reduce their consumption of not only rice but also nonfood, market-purchased goods and leisure (i.e., increase their family work effort). The variation in household response suggests that exclusive reliance on the concept of the "representative household" may yield misleading policy conclusions.

V. Conclusion

The policy implications discussed here are not in the least exhaustive but rather indicative of the importance to be attached to the development of an integrated approach to the behavior of agricultural households. In this paper the theory of the agricultural household was extended to a multicrop economy. The results from this and other studies that use an integrated approach to production and consumption decisions highlight the need to change our perceptions concerning agricultural household response to economic incentives in developing countries and to revise the design of economic projects and policies accordingly.

\textbf{References}


\textbf{Table 5.—Response to Changes in the Price of Rice by Household Type}

<table>
<thead>
<tr>
<th>Area Operated (hectares)</th>
<th>Elasticity of Rice Consumption</th>
<th>Nonfood Purchases</th>
<th>Labor</th>
<th>Supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>A = 1.89</td>
<td>.01</td>
<td>.81</td>
<td>-.13</td>
<td></td>
</tr>
<tr>
<td>A = 1.01</td>
<td>-.02</td>
<td>.50</td>
<td>.05</td>
<td></td>
</tr>
<tr>
<td>A = 0 (landless)</td>
<td>.06</td>
<td>-.61</td>
<td>.03</td>
<td></td>
</tr>
</tbody>
</table>

\textsuperscript{11} Additional analysis involving changes in technology—both biological (say from traditional to high-yielding varieties) and mechanical (say from bullock to power tillage)—can also be costs accommodated within the model. The results are available though they are not reported in the paper.

\textsuperscript{12} The representative household operates, on the average, 1.89 ha of double-cropped land, and has 6.01 family members of which 2.96 are dependents.

\textsuperscript{13} Although landless households were not included in the estimating sample, their behavior is approximated by allowing farm profits to tend to zero in the measures of total expenditure (E). For landless households there is thus no impact on consumption decisions through changes in farm profits.
World Bank

Headquarters:
1818 H Street, N.W.
Washington, D.C. 20433, U.S.A.

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       WUI 64145 WORLDDBANK
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European Office:
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Telephone: 723.54.21
Telex: 842-620628

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