Journal of Philippine Development
Number Twenty-Three, Volume XIII, 1986

METHODS FOR AGRICULTURAL POLICY ANALYSIS: AN OVERVIEW

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The economic outcomes attending public sector investments in rural areas and policy interventions in agricultural product and/factor markets are important. They affect the welfare of both rural and urban households. These outcomes are subject to analysis at two levels. The first is at the household or farm level. At this level, the analysis is "partial equilibrium" in character since prices and other factors beyond the control of the household or the farm are taken as exogenous to the analysis. The second level is the economy level where "general equilibrium" analysis is possible. At this level, prices of products and factors are treated as endogenously determined by market clearing forces.

We are currently experiencing a renewed interest in the second level of analysis because of advances in computational technology. The advent of "computable general equilibrium" models promises more consistency than possible in previous models because it ensures market clearing. It is important to note, however, that the relevance and consistency of general equilibrium models, rests on an econometric base. If we do not have a solid, econometrically estimated model of farm and household behavior, the computational power of modern, computable general equilibrium models is of little value.

In this paper, we summarize several papers presented at a "Workshop on Methods for Agricultural Policy Analysis" held at UPLB on August 13-14, 1985. The focus of the workshop was on methods, both in theory and estimation, for analysis both at the partial and general equilibrium levels. The summary is organized in four parts. The first three

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are directed toward partial equilibrium analyses, the fourth toward general equilibrium analyses.

In Part I, the focus is on farm production and on productivity change. The unit of analysis is the farm and the economic motivation is that of cost minimization or profit maximization subject to constraints. In Part II, the focus is on consumption, particularly food consumption. The unit of analysis is the consumer or the consuming household (both rural and urban). The economic motivation is that of utility maximization subject to budget constraints. In Part III, the focus is on the rural and agricultural household functioning in market settings that are imperfect. Both producing and consuming activities are considered, and production in the household is given special attention. The economic motivation is that of utility maximization subject to budget, time, market and production technology constraints (cost minimization is implied).

The focus of the final section is on the methodologies for combining the partial equilibrium components into a consistent general equilibrium framework.

Figure 1 provides a schematic view of the relationships between the four areas of concern. it shows the general structure of a model encompassing two sets of markets directly relevant to the agricultural sector. These are the markets for agricultural *factors* (labor, power, and chemicals) and for agricultural *products* (rice, animal products, and other goods). Two behavioral "cores" are depicted as fundamental to these markets. The first is the producer core, the subject of Part I of this summary (and of the papers by Bantilan, Sardido and Evenson, and Evenson). Producer behavior generates the demand size of the agricultural factor markets and the supply side of the agricultural product markets. The second core is the consumer core, the subject of Part II (and of the paper by Quisumbing). Consumer behavior generates the demand side of the agricultural product markets.

Agricultural households also supply labor to the agricultural labor market. Agricultural labor markets (and other markets) are not perfect because of transaction costs and related supervison and maintenance costs. Part III and the papers by Fabella, Roumasset and Evenson, and Sah address these issues.

A full model requires the specifications of the supply side of all agricultural markets and an specification of other sectors of the economy. Part IV of this paper and the papers by Evenson and Habito discuss two approaches to specifying a full model in which prices are

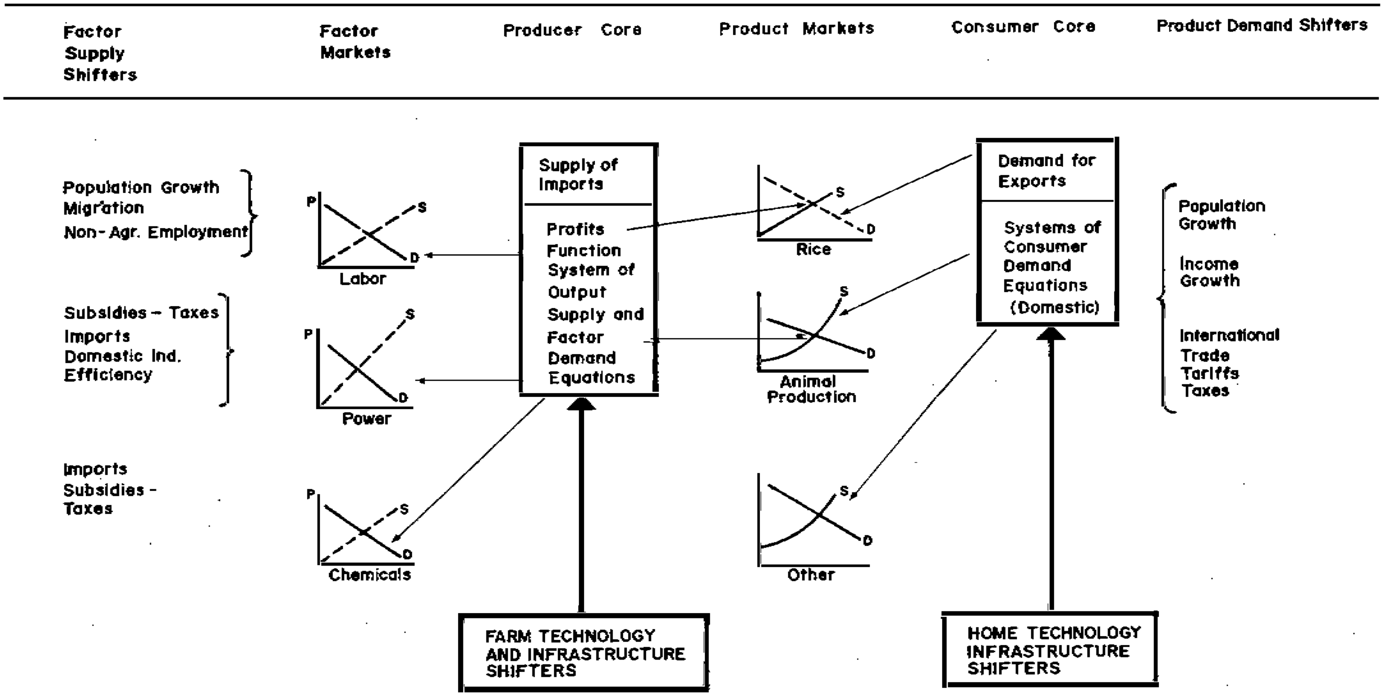
Factor Supply Shifters
Factor Markets
Producer Core
Product Markets
Consumer Core
Product Demand Shifters
Population Growth
Migration
Non-Agr. Employment
Subsidies – Taxes
Imports
Domestic Ind. Efficiency
Imports
Subsidies - Taxes
Labor
Power
Chemicals
Supply of Imports
Profits Function System of Output Supply and Factor Demand Equations
Rice
Animal Production
Other
Demand for Exports
Systems of Consumer Demand Equations (Domestic)
Population Growth
Income Growth
International Trade Tariffs Taxes
FARM TECHNOLOGY AND INFRASTRUCTURE SHIFTERS
HOME TECHNOLOGY INFRASTRUCTURE SHIFTERS

FIGURE 1

endogenous. One approach, the "impact multiplier" approach, is based on differential calculus methods and is suited to comparative static analysis. The second is based on recently developed "computable general equilibrium" methods.

In Figure 1, policy variables are termed "shifters" and are of four classes. Farm technology and infrastructure shifters operate through the producer core. Their impact on factor demand and product supply (holding prices constant) is complex and shifts all of the equations in th producer core. These impacts must be estimated with actual data because there is no *a priori* theory that can specify their impact. Home technology and infrastructure shifters are of the same type. These two classes of shifters can also fruitfully be analyzed in partial equilibrium analyses in which prices are held fixed.

These two classes of shifters can, of course, also be fruitfully analyzed in the more general case where equilibrium prices are allowed to change. The other two classes of shifters, those affecting factor supply and those affecting product demand, directly affect prices and can most effectively be analyzed in the general equilibrium framework. In contrast to the first two classes of shifters, each of which shifted several functions, the factor supply and product demand shifters can be treated as affecting only a single function.

I. PRODUCTION AND PRODUCTIVITY

While the main focus of the studies under review in Part I is the producer core system of product supply and factor demand equations, the concept of productivity is also important. Many programs are designed to have an impact on productivity. Sardido and Evenson (this issue) report a regional productivity analysis. In view of the importance and wide usage of productivity measures, we find it useful to begin this section with a discussion of these measures.

The term "productivity" as generally used in reports and studies does not always have a consistent meaning. Some studies of a macroeconomic nature use the term to mean output per unit of labor. Some agricultural reports and studies use the term to mean output per unit of land. Other studies use the term to mean output per unit of input or more strictly an index of output divided by an index of inputs. Some studies attempt to interpret a "change in productivity" as equivalent to a "change in technology." Other studies attempt to adjust and correct the measurement of outputs, inputs and prices in such a fashion as to eliminate the productivity residual.[1]

A clear distinction should be made between "partial" and "total factor" or "multifactor" indexes of productivity. Partial indexes are ratios of output to a single input. The labor productivity index and the yield or land productivity index mentioned above are cases in point. Partial productivity indexes where there is only one output and one input have a simple and sometimes useful and intuitive meaning. Yield indexes of rice, for example, mean the same thing in different regions and countries.

Once one moves to a more general index such as a total factor productivity (TFP, sometimes called a "multifactor" productivity index), the physical interpretation is lost. Such indexes can be given a cost function or a production function interpretation if only one output is involved. They require an aggregate index of two or more inputs or factors. (They also usually aggregate outputs.) If this aggregation is based on cost accounting, the TFP index can be given a cost of production interpretation. A TFP index of 110 for a region or time period indicates that the cost of production has fallen by 10 percent relative to the base period or region.[2]

There is no basis for interpreting productivity indexes as technology change indexes unless additional information is brought to bear on the issue.[3] In fact, many sources of measured productivity change other than the development of new technology may exist. Errors of measurement, left out factors of production and weather-related changes in product will all be reflected in productivity measures. Ultimately, the purpose of productivity measurement is to account for growth and efficiency. Productivity measures themselves attempt to separate the growth contribution of standard changes in factors as conventionally measured from other sources. This improves the prospects for identifying other contributions, as from research and extension, for example, through further statistical analyses.[4]

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1. See Griliches and Jorgenson (1967) for an example of this. Also, see Denison (1965) for a critique of these adjustments.

2. The development of the productivity index from a minimized cost function is explained below.

3. A number of critics of productivity measurement (Nelson 1985) are critical of the strong interpretations placed on these measures.

4. See Sardido and Evenson, this issue.

The least restrictive basis for productivity measurement is based on simple accounting. Suppose that all inputs and outputs are measured correctly and that we also measure prices correctly including rents and quasi-rents to fixed factors. Then the following accounting identity will hold:

$$(1) \qquad \sum_i P_i Y_i = \sum_j R_j X_j = V$$

where P_i is the price of the ith output, Y_i
and R_j is the price of the jth factor of production, X_j

The value of the vector of outputs, Y, will be equal to the value of the vector of inputs, X, as long as competition prevails (i.e., no abnormal profits accrue to firms instead of to factors). Now differentiate (1) totally with respect to time

$$(2) \quad \sum_i P_i \frac{\partial Y_i}{\partial t} dt + \sum_i Y_i \frac{\partial P_i}{\partial t} dt = \sum_j R_j \frac{\partial X_j}{\partial t} dt + \sum X_j \frac{\partial R_j}{\partial t} dt$$

Note that this equation is exact for small changes.
Now divide (2) by V and multiply the four terms by

$$Y_i / Y_i, \quad P_i / P_i, \quad X_j / X_j, \text{ and } R_j / R_j$$

$$(3) \quad \sum_i \frac{P_i Y_i}{V Y_i} \frac{\partial Y_i}{\partial t} dt + \sum \frac{Y_i P_i}{V P_i} \frac{\partial P_i}{\partial t} dt = \sum_j \frac{R_j X_j}{V X_j} \frac{\partial X_j}{\partial t} dt + \sum_j \frac{X_j R_j}{V R_j} \frac{\partial R_j}{\partial t} dt$$

Define $\frac{P_i Y_i}{V} = S_i$ the output share of the ith output and

$\frac{R_j X_j}{V} = C_j$ the cost share of the jth factor and $\frac{1}{Y_I} \frac{\partial Y_I}{\partial t} dt = \hat{Y}_I$ the rate of change in the ith output and similarly for factors.

Then, (3) can be rewritten as

(4) $\Sigma S_i \hat{P}_I + \Sigma S_I \hat{Y}_I = \Sigma C_J \hat{R}_J + \Sigma C_J \hat{X}_J$

or

(5) $\hat{P} + \hat{Y} = \hat{R} + \hat{X}$ or $\hat{Y} - \hat{X} = \hat{R} - \hat{P} = \hat{T}$

where $\hat{P} = \Sigma_I S_I \hat{P}_I$ etc.

This equation provides the standard definition of total factor productivity change $\hat{T}$ and shows the equivalence of a definition based on the difference in growth rates between outputs and inputs ($\hat{Y} - \hat{X}$) and input prices and output prices ($\hat{R} - \hat{P}$). Productivity is thus measured as a residual.[5]

This development did not impose any restrictions on the production function. Indeed, it did not even claim that one existed. The relationship holds only for "small changes," and the practical implication of this is that one should compute it from the smallest changes possible, for example, between two short time periods. A longer period index can be formed by adding up the period-to-period indexes. This produces a "chained" index where the weights, S_i and C_j are not constant but are specific to each period. (This procedure is generally known as the Tornquist approximation to a Divisia index.)[6]

The TFP index $\hat{T}$ has several interpretations:

(a) Suppose all inputs are constant (i.e., $\hat{X} = 0$) then $\hat{T} = \hat{Y}$ measures the increase in output achievable at constant input levels.

(b) Suppose outputs are constant (i.e., $\hat{Y} = 0$) then $\hat{T} = -\hat{X}$ measures the reduction in inputs required to produce a given set of outputs.

(c) Suppose output prices are constant($\hat{P} = 0$) as when the goods are traded in a large market, then $\hat{T} = \hat{R}$ shows the rate of increase in factor prices made possible by efficiency gains.

(d) Suppose input prices are constant($\hat{R} = 0$), then $\hat{T} = -\hat{P}$ shows the output price reduction made possible by technical change.

5. The price definition, it should be noted, presumes that a long-run adjustment in the full market takes place. When commodities are traded internationally this becomes quite complex in practice because prices may not reflect costs very well. That is, (1) may not hold.

6. See Griliches and Jorgensen (1967) for a discussion on the Divisia index.

(e) If both input and output prices change, $\hat{T} = \hat{R} - \hat{P}$ measures the increase in real factor incomes made possible by productivity change.

The index $\hat{T} = \hat{Y} - \hat{X}$ can be derived from a production function. This derivation requires much stronger assumptions than the accounting index but it also yields more insight into the interpretation of the index. Suppose one output and several inputs:

$$(6)\quad Y_1 = F(X_1, X_2 \ldots X_n)$$

By writing down this function we are implicitly assuming that underlying the function there is a given known *set* of technologies and a given infrastructure (roads, markets, etc.) in which producers operate.[7]

Differentiate (6) totally with respect to time to obtain

$$(7)\quad \frac{\partial Y_1 \; dt}{\partial t} = \sum_j F_j \frac{\partial X_j \; dt}{\partial t} + F_i \; dt$$

In this expression $F_i dt$ is a natural definition of productivity change. If $F_j(\;)$ is homogeneous of degree one we have:

$$(8)\quad F_j = \partial Y / \partial X_j = R_j / P_1$$

and

$$(9)\quad Y_1 = \Sigma F_j X_j$$

Dividing by Y, and substituting (8) and (9) into (7)

$$(10)\quad \frac{\partial Y_1}{\partial t} \quad \frac{dt}{Y_1} = \sum_j \frac{R_j X_j}{P_1 Y_1} \quad \frac{\partial X_j}{\partial t X_j} \; dt + \frac{F_i}{Y_1} dt$$

or

$$(11)\quad \hat{Y}_1 = \Sigma C_j \hat{X}_j + \hat{T} = \hat{X} + \hat{T}$$ [8]

Now we can point out that $\hat{T}$ can be the result of changes in physical or biological environments, the available technology, public sector infrastructure, errors in measurement or departures from the profit maxi-

7. We could also consider other imperfections such as different skills in (6). See (2) below.

8. Note that the derivation of this index has not imposed a particular functional form on the production function (6).

mization and scale economy assumptions used in constructing (11).[9]

Such measures are also useful for identifying some of the effects or impacts of policy-determined shifter variables. The production function (6) can be written more generally as:

(12) $Y_1 = Y_1(X, F, E) \quad Y_1 \quad X$

In (12), Y_1 is the maximum output technically possible given known technologies of production, the vector of variable factors, X (such as fertilizer and labor), the vector of fixed factors, F (i.e., factors, such as total land cultivated or proportion irrigated, which are variable in the long run), and environmental characteristics, E. (The vector of environmental characteristics includes soil, climate and factors, market and related infrastructure such as roads and communication facilities and characteristics of technology availability and use such as farmer schooling, availability of extension services, and research stock variables.)[10]

(13) dY_1/dF_j gives the marginal products of fixed factors

dY_1/dE_k gives the marginal products of environmental factors

These marginal product computations can have an important policy relevance. The value of the marginal products of the variable factors, for example, can be compared to prices of variable factors to assess allocative efficiency. The underlying econometric assumption for much production function analysis is that the observed X vector is in fact the "cost-minimizing" vector of X's. Since the cost-minimizing vector is a function of prices and of the F and E vectors, it is not actually endogenous (see below).

The marginal products of the F and E vectors are of more direct policy relevance since they can be directly influenced by governments.

9. Measures of T are useful to policymakers if the measurement is undertaken in a consistent fashion. The paper by Sardido and Evenson in this volume, for example, provides measures of T on a regional basis for Philippine agriculture. These indexes provide a perspective on changes in efficiency and are useful even if the productivity function foundations are not imposed.

10. A TFP index derived from (12) will be a function of the E variables (and possibly the F variables if they have not been properly measured. Sometimes (12) is estimated directly, but in some situations it is useful to first derive a measure of T from production data and then statistically analyze its determinants. This is a useful technique when several regions are involved. T can be measured in different regions using different cost shares. Then these measures can be "pooled" in a statistical analysis taking advantage of more cross-section variance in E variables than possible in an aggregate production function analysis.

A substantial body of literature estimating returns to agricultural research and returns to schooling of farmers is based on production function estimates. Similarly, returns to irrigation investment and other types of government investments have been analyzed in this particular "partial equilibrium" framework.

Some of these analyses have been flawed by the failure to recognize (1) that some of the elements in E may have responded to farm output and the X's; and (2) that the assumption that the X vector is itself a function of prices and F and E means that additional effects are involved. The first issue constitutes an econometric estimation problem. This problem requires the estimation of an "auxiliary" regression to account for simultaneity bias. The second also requires the estimation of related "factor demand" equations.

Consider the second problem. The full model includes (14) in addition to (12):

$$(14)\quad X_i = X_i\ (P,\ F,\ E)$$

where (14) is the set of variable factor demand equations derived from a cost minimizing problem (to be analyzed below).

Since an element in E, say, extension services, enters in both (12) and (14) we cannot conclude that the marginal impact of extension services is fully captured by:

$$(15)\quad \partial Y_1 \ / \ \partial E_{ext}$$

The full effect is:

$$(16)\quad \partial Y_1 \ / \ \partial E_{ext} \ \sum_i \frac{dY}{dX} \cdot \frac{dX}{dE}$$

where the second term measures the impact of extension services on variable factor allocation. The first term might then be considered a "technical efficiency" effect while the second is an "allocative efficiency" effect. Many public investments such as schooling and extension are explicitly directed toward achieving an allocative efficiency effect.[11]

The minimized cost or "cost function" extension of the basic production theory, along with the closely related maximized "profits function" approach, has enabled a significant advance in the analysis of production. This advance is based on the theory of "duality" between a minimized cost function or a maximized profits function and the un-

11. See Huffman (1984).

derlying production function. This duality enables the specification of a functional form for the "dual" function (the costs or profits function) such that if certain properties hold for the dual function they will also hold for the "primal function" (the production function).

Consider the case of the cost function. In this case the farmer minimizes the costs per unit of production subject to the production function (12). The accounting definition of variable costs is:[12]

(17) $C = \Sigma R_i X_i = RX$

minimizing (6) subject to (12) yields first order conditions:

(18) $R_i = \lambda F_i$

These can solve for X_i^*, the variable cost-minimizing set of variable inputs X_i, as functions of prices, R, fixed factors, F, and environmental factors, E. Substituting the X_i^* for the X in (6) gives us the minimized unit cost function:

(19) $C^* = C^* (R, F, E)$ where C^*, F' and E' are expressed in per unit output terms.

We can now apply the Shephard-Hotelling Lemma to (19), the minimized cost function, to obtain the factor demand equations per unit of output. This Lemma states that the first partial derivatives of C^* with respect to each factor price yield the demand equation for that factor.

(20) $\dfrac{dC^*}{dR_i} = X_i (R, F, E)$ (see (14))

The expression for $\hat{T}$, total productivity change, can also be derived from this cost function.

Differentiating (19) we obtain:

(21) $\dfrac{\partial C^*}{\partial t} dt = \Sigma C_j \dfrac{\partial R_i}{\partial t} dt + C_t^* dt$

Using the transformation noted earlier, this implies

(22) $\hat{C} = \hat{R} + \hat{T}$

and since in competition $\hat{C} = \hat{P}$ we again have $\hat{T} = \hat{R} - \hat{P}$.

We can also define productivity in terms of factor demand equations.

12. Both costs and profits function analysis are inherently "short-run" in nature. A distinction between variable and fixed factors is required. Recent developments (e.g. Lopez 1984) are improving these models by adding a dynamic element in the form of fixed factor investment equations.

Differentiate (20) totally,

$$(23)\quad \frac{\partial X_j}{\partial t}\,dt = \sum_j \frac{\partial R_j}{\partial t}\,dt + \frac{\partial X_j}{\partial t}\,dt$$

Define Factoral Productivity Rates as [13]

$$(24)\quad \hat{A}_j = \frac{\partial X_j}{\partial t}\,\frac{1}{X_j}\,dt$$

The reduction in per unit costs is $C^* = \Sigma_j\, R_j\, X_j^*$

$$(25)\quad \frac{\partial C^*}{\partial t}\,\frac{1}{C^*}\,dt = \hat{T}\sum_j R_j \frac{\partial X_j}{\partial t}\,dt\,\frac{1}{C^*} = \sum_j R_j \frac{R_j}{\partial t}\,dt\,\frac{1}{C^*}$$

$$+ \Sigma R_j \frac{\partial X_j}{\partial t}\,dt\,\frac{1}{C^*} \quad \text{thus,}\quad \hat{T} = \Sigma\, C_j\, \hat{A}^*_j$$

In this development we have not assumed profit maximization, only that farmers minimize variable costs for each unit of output.[14] A more general and stronger economic motivation is profit maximization, where farmers not only minimize the costs of producing any level of output Y, but also produce that level of output that maximizes profits. The definition of variable profits is:

$$(26)\quad \pi = P_1\; Y_1 \;-\; R_j\; X_j$$

The first order conditions for profit maximization are

$$(27)\quad P_1\; F_j = R_j$$

These can be solved for optimal output, Y_1^*, and optimal inputs X_j^* as functions of P, R, F, and E. Substitution back into (26) yields the maximized profits function:

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13. Factoral productivity rates can be measured residually. They can be aggregated into TFP indexes as in (25). They also measure productivity biases consistently. (See Binswanger and Ruttan, 1978, for a fuller development.)

14. This assumes that output is exogenously determined.

$$(28)\quad \pi^* = \pi^* (P, X, F, E)$$

The Shephard-Hotelling Lemma can be applied to (28) yielding the output supply equation and the factor demand equations.

$$(29)\quad \frac{d\pi^*}{dP_1} = Y_1 = Y_1 \ (P_1, R, F, E,)$$

$$\frac{d\pi^*}{dR_i} = X_i = X_i \ (P_1, R, F, E)$$

A yet more general formulation allows for a multiple output production process. Multiple output production processes (including "joint" production) are common in agriculture. They are characterized by a transformation function instead of a production function.

(30) $g\ (Y, X, F, E) = 0$ where Y is a vector of outputs.

Variable profits are defined as:

$$(31)\quad \pi = PY - RX$$

and the maximized "profits" function can be written as;

$$(32)\quad \pi^* = \pi^* \ (P, R, F, E)$$

Again the Shephard-Hotelling Lemma gives a system of output supply and factor demand equations.

$$(33)\quad d\pi^* / dP_i = Y_i = Y_i \ (P, R, F, E)$$

$$d\pi^* / dR_j = X_j = X_j \ (P, R, F, E)$$

The duality theory developments show that the profits (or cost) dual functions must have the following properties if a "well behaved" transformation or production function underlying it is to be assured:[15]

15. See Diewert (1971) and Fuss and McFadden (1978) for a fuller development.

a) The profit function must be monotonically increasing in P and decreasing in R.

b) The profits function must be symmetric in second cross partial derivatives:

c) The profits function must be convex, i.e., the matrix of second partial derivatives must be positive semidefinite over the range of relevant data points, and its characteristic roots must be zero or positive.

d) The profits function must be homogenous of degree one in P and R and the output supply and factor demands must be homogenous of degree 0 in P and R.

e) $\eta_{ij} = \dfrac{dY_i}{dP_j} \dfrac{P_j}{Y_i}$ defines elasticities and $\sum_{i=1}^{n} \eta_{ij} = 0$

The reader may now note that the dual functions (19), (28) and (32) ostensibly contain all of the technical information in the primal production and transformation functions (12) and (30). Thus, one can proceed to estimate (19), (28), or (32), or more practically their derivative systems (20), (29) or (33). This allows a much richer specification for the policy variable of interest. For example, if system (33) is estimated with an extension variable we can compute:

$$(34)\ dY_1/dE_{ext}\ \ dY_2/dE_{ext} \cdot ---, dX_1\ /\ dE_{ext} ---, dX_n\ /\ dE_{ext}$$

This allows the calculation of the full impact of extension or of other E-type variables.

Productivity measures can also be applied to profits function systems. Define output productivity rates as:

$$(35)\ \hat{E}_i = \frac{\partial Y_i}{\partial t}\ \ Y_1\ dt$$

Using substitutions and definitions given above we can derive:

$$(36)\ \hat{T} = \sum_i S_i \hat{E}_i + \sum_j C_j \hat{A}_j$$

The paper by Bantilan in this issue addresses econometric issues in estimating systems such as (29) and (33). Three issues are discussed,[16]

16. Fabella (this issue) addresses questions related to risk form behavior and the "separation" of producer and consumer decisions.

namely: (a) the problem of mode 1 selection, (b) the use of panel data, and (c) the bias in nonrandom sampling. The choice of the above issues was motivated by problems encountered in the use of the farm level surveys conducted by the International Rice Research Institute from 1966 to 1984.

The paper shows that the estimation of the dual functions or their associated systems (or the joint estimation of both) has econometric advantages over the estimation of primal functions provided that one has price data variations. First, right hand side variables are explicitly exogenous. The quality principle has allowed us to move from a transformation function that is a function of endogenous variables (quantities) to a dual cost or profit function that is a function of exogenous variables (prices, fixed factors). As a consequence, simultaneity problems are avoided. Furthermore, multicollinearity problems are reduced since there is less covariance in prices than in quantities. Second, the functional forms for the systems can be linear and economical in parameters and can still have the property of flexibility.

On the first issue discussed, that is, the problem of model selection, the problem posed is determination of a mathematical formulation for the dual cost or profit function. To this end, functional forms that are flexible, meaning that the parameters can take arbitrary values so that they do not necessarily impose restrictions on the curvature of the production technology, are chosen.

Flexible linear functional forms can be specified directly for the dual function. As long as this form meets the properties specified above over the relevant range of data, the duality principle assures that the primal form is well-behaved. The "flexible forms" commonly used for the dual relationships are themselves nonlinear but have linear derivatives. Forms with linear derivatives are not generally "globally convex," i.e., convex at all possible data points, but are convex over certain ranges. These forms are said to be flexible in that they are "second order" (or Taylor Series) approximations to any underlying actual dual functions. Thus, they do not impose restrictions on elasticities of substitution between one pair of commodities.[17] Bantilan discusses the limitations of the most widely used flexible forms and suggests alternative forms.

17. See Lau (1974, p. 87). This does not mean that it is impossible or always undesirable to use higher-order expansions. Two studies of the power generating industry use third-order Taylor-series in their analyses: Fuss and McFadden (1978b) and Stevenson (1980).

With respect to the second issue, that is, on the use of panel data, discussion is primarily directed on errors in variables in panel data. Sources of bias are presented and a methodology in identifying the "true" parameters is discussed in a panel data context. Cited is a clever approach proposed by Griliches and Hausman (1984).

The third issue discussed by Bantilan addresses the sampling bias problem that results when randomization in the implementation of survey work is not realized. The key idea put forward in correcting for the bias is the incorporation of known or assumed probabilities of selection or the inclusion of sampling units. Econometrically, this is implemented in two ways, namely: (a) reparameterization of the model to integrate the available information; and (b) incorporation of the information into the error structure of the model. An example of such implementation is given in the paper.

The paper on infrastructure, output supply and input demand by Evenson in this issue reports the provisional estimates of a profit function-based system for Philippine agriculture. A number of E variables are included in the analysis.

II. CONSUMPTION STUDIES

Conventional analyses of consumption behavior are effectively equivalent in structure to the analysis of production and costs.[18] Demand functions are obtained through (1) maximization of a direct utility function subject to a budget constraint, or (2) applying the duality theory to obtain demand functions from the first derivative of an expenditure function.[19] In the first case, we obtain Marshallian demand functions in nominal prices and income; in the second, Hicksian (compensated) demand functions in nominal prices and real income.

Let us first take up the utility maximization approach. We specify a direct utility function

$$(37) \quad U = U\,(G_1, G_2, \ldots, G_n)$$

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18. We are indebted to E. Torres, L. Lauffer, D. Canlas, R. Alonzo, and H. Bouis for constructive comments on the papers in this section.

19. For a review of both methods, see Deaton and Muellbauer (1980, pp. 637-50).

The goods, G, are treated as "market goods" with prices M. Some of these may, in fact, be home-produced but M can then be interpreted as the alternative cost of the good to the household. Cases where this interpretation does not hold are discussed in Part III.

Utility is maximized subject to a budget constraint.

$$(38) \quad Y = \sum_{i=1}^{n} M_i G_i \qquad i = 1,\ldots,n$$

where Y, or income, is usually treated as "predetermined" or exogenous.

This maximization yields first order conditions from which demand functions can be derived. Solving the first order conditions (39) and (40) for G in terms of M yields a system of demand equations (41).

$$(39) \quad \frac{\partial U}{\partial G_i} = \lambda M_i$$

$$(40) \quad \Sigma M_i G_j = Y$$

$$(41) \quad G^{o} = G\ (Y, M)$$

The demand systems derived from utility maximization should also satisfy the following restrictions: (1) homogeneity of degree zero in income and prices; (2) negative definiteness and symmetry of the Slutsky substitution matrix; and (3) share-weighted sum of income elasticities equal to 1.0.

In the second case, based on the duality theory, the same procedure utilized to derive a "minimum" cost function may now be employed to derive a "minimum" expenditure function which shows the minimum expenditure required to achieve a given level of utility.

$$(42) \quad e^{x} = e\ (M_i,\ Y, \bar{U})$$

Note that we "substituted out" the G in the expenditure function in the same way that we did in the minimized cost function (19).

We can also derive an "indirect" utility function which is the equivalent of the maximized profits function. The indirect utility function M^* shows maximized utility as a function of prices and income.

$$(43)\quad M^X = I\ (M_i,\ Y).$$

Roy's identify applied to (43) yields a system of Marshallian demand functions in nominal income and prices, while direct differentiation of the expenditure function (42) generates Hicksian (compensated) demand functions with prices and real income as explanatory variables.

$$(44)\quad G_i = G_i\ (M_i,\ \bar{Y}_r)$$

where Y_r indicates that real income is used in the expression.

Young's theorem and the Slutsky adding-up constraint impose cross equation symmetry ($I_{ij} = I_{ji}$), a homogeneity of degree zero in prices, and a weighted sum of income elasticities equal to one. Cross equation (Slutsky) symmetry holds for the compensated or real income constant price terms.

In empirical work, these restrictions are more easily imposed on Hicksian demand functions due to the difficulty of imposing cross-equation symmetry on Marshallian demand functions, which have uncompensated coefficients. It is therefore important that income be expressed in "real" terms utilizing a proper deflation procedure to enable this symmetry to be imposed.

Swamy and Binswanger (1983) point out that this depends upon the definition of a suitable deflator for nominal income, or suitable approximations to the true deflators if the consumer's utility function is unknown. Fortunately, recent advances in index number theory permit the estimation of such approximators. According to Diewert (1976), if the cost (or indirect utility) function is unknown but is approximated by a flexible functional form, then certain index numbers can be estimated which, when used to deflate nominal income, provide estimated changes in real income that correspond exactly to changes in utility levels. Diewert has shown that any quadratic mean of order r quantity index can approximate an arbitrary nonhomogeneous utility function to the second second degree and that any quadratic mean of order r price index can similarly approximate an arbitrary cost or indirect utility function.

Despite the existence of a large body of theoretical work on demand systems, early empirical work in the field largely ignored the problem of consistency between the characteristics of the utility function and the characteristics of demand functions. The Linear Expenditure System (LES) was developed to achieve such consistency. This was an important development at the time and placed empirical work on a consistently analytic footing. Unfortunately, the LES is a highly restrictive form. Theoretically, the LES assumes additive preferences; empirically, the system imposes restrictions on the structure of estimated parameters, particularly the absence of complementarity and the inelasticity of the price coefficients, as well as the exclusion of inferior goods. In their survey of models of consumer demand, Brown and Deaton (1972, p. 1197) point out that the imposed structure may be largely independent of actual price effects if variations in real income are larger than variations in relative income. Timmer (1981) also argues that additivity may not be warranted for demand systems with a high degree of disaggregation, since substitutability within groups would become significant.

In spite of its restrictiveness, the LES still remains in use today because it requires relatively little data. (In effect income (supernumerary expenditure) is used to identify what are interpreted as price parameters.) In cases where data are scarce, and where the analysis is limited to broad commodity groups, some versions of the LES provide a quick way of estimating price coefficients. An example is Canlas' (1981) application of an augmented Stone-Geary utility function with leisure as an additional good to a cross-section data set without price data. Using wage rates as a proxy for the price of leisure, together with data on total and property income, Canlas first estimated a demand-for-leisure equation, the parameters of which were used to estimate some parameters of the LES for goods. In this case, variation in the price of leisure was sufficient to generate a plausible set of price and income elasticities.

Further developments in the field have produced more flexible systems from particular utility function specifications. More recent work is being based on duality theory and flexible functional forms. This work lags behind the parallel work on the production side, probably because of the data aspect of the simplier inflexible systems. Quisumbing discusses these developments and related econometric issues in her paper.

Another trend in consumption analysis has been the estimation of income-group specific demand parameters. This is a departure from earlier studies which applied consumer theory, though formulated from the decision perspective of a utility maximizing consumer or household, to aggregate market data expressed in per capita or per household terms (Timmer and Alderman 1979). Income-group-specific parameter estimation has been proposed on the grounds that substantial differences in consumption behavior exist at different income levels. This is easily verifiable from income elasticities estimated from cross-section budget studies, but recent estimates of price elasticities do provide evidence that price responsiveness varies with income, usually inversely, for food and other necessities.

Income-variation of uncompensated price elasticities follows from Slutsky's equation (45):

$$(45)\quad e_{ij} = S_{ij} - W_i\ E_i \qquad i, j = 1, \ldots, n$$

where e_{ij} is the uncompensated price elasticity, S_{ij} is the Slutsky (pure substitution) elasticity, W_i the budget share, E_i the income elasticity. Empirical work has shown that, following Engel's law, budget shares and income elasticities for basic commodities such as food (and starchy staples) tend to decline as income increases. Even if we assume that the substitution elasticities S_{ij} do not vary, falling budget shares and income elasticities would lead to declining e_{ij} as income increases. However, Timmer (1981) carries the agreement further to suggest that Slutsky elasticities also vary inversely with income, i.e., even when compensated for the income effects of price changes, the poor are more responsive to price changes than the rich. Timmer has called this an income-related "curvature" in the Slutsky matrix.

Some of the reasons behind the "curvature" have been discussed by Bouis (1982), who says that different constraints on nutrition-related consumer behavior may be considered binding at various income levels. However, Bouis disagreed that the relationship between elasticities and income was a monotonic inverse relationship, citing evidence for a "parabolic" pattern particularly for cereals. That is, elasticity may be low and then rise with an increase in income, and then follow a monotonic decline. His discussion focuses on the interaction between the "bulk" constraint which must be satisfied first, and the consumer's desire to obtain the other characteristics in food, e.g., taste, diversification. This "parabolic" (or inverted U-shaped) pattern is corroborated by some of the studies reviewed by Quisumbing in this volume.

One major constraint to estimating income-varying price elasticities without the imposition of additivity assumptions is the need for a fairly large cross-sectional data set with adequate price variation. Fortunately, such data series do exist for the Philippines and are now beginning to be used extensively for this purpose. Most of the efforts to estimate these parameters have followed conventional demand specification with prices and income as explanatory variables; while most applications have been in the area of food and nutrition policy analysis.

Although recent consumption analysis has moved toward the analysis of distributional effects, the conventional methodology for consumption studies ignores the fact that most goods in final "ready to consume" form have been partially produced in the household. In addition, the simple model discussed above has only price and income measures as explanatory variables, neglecting the effect of household composition, schooling, and other demographic variables. Furthermore, the model does not really address the matter of the appropriate unit of observation. In practice, most consumption data are observed by household, not by individual, and are converted to per capita terms to conform to the individual utility-maximizing model of conventional consumption analysis.

Fortunately, a second and quite independent line of analysis has emerged over the past 20 years or so – one that does recognize the importance of production in the household and which recognizes that households have to be regarded as the core of analysis. There is considerable convergence between this household economic approach and the older consumption literature and the duality literature but it is not complete. As a result, we find that conventional empirical consumption analysis, even when taking into account some demographic variables, still retains a fair amount of anomalies. For example, some authors have included demographic variables, schooling, and other variables in their model specifications. It is sometimes argued that these variables affect tastes or the "pre-committed" quantities that are part of the LES system. Beyond that, however, the analysis is sadly lacking. Demographic scaling procedures are also used to deal with the household "problem" in a number of studies. One of the more popular methods is the use of an "adult equivalent scale" instead of simply converting household level data to per capita terms. Most adult equivalent scales use relative recommended daily allowances (RDAs) to express nutritional requirements for family members of different age and sex groups in terms of a reference adult male. However, this method does not completely correct for the unequal distribution of food and nutrients within households *beyond* the biological requirements of the RDA, a reflection that the actual household decision-making process may involve interdependent utility functions.

In many ways, therefore, the household economics perspective is a much more consistent framework for analysis. It requires that the household unit be regarded as the decision making unit because production is undertaken by the household unit, not by individuals. This requires the specification of a "joint" household utility function, and this has been somewhat problematic. Conventional utility analysis specifies an individual utility function, and empirical work is based on "supposed" individual demand functions. In practice, however, very little data on individual consumption are collected. Virtually all such data are collected at the household level. Furthermore, it is quite obvious that production does take place in households; most food items are consumed in very different form than are the marketable ingredients. It is also quite obvious that there are individuals who are members of households and families who do not have independent incomes (e.g., children and wives), and that they are part of an interdependent economic unit.

The modern household economic models at least deal with this issue. A household can be treated as having a "joint" or aggregate utility function under fairly weak conditions (these are the same as are required for a social utility function). Essentially, as long as there is a consistent income-sharing rule among members, individual utility functions can be aggregated to the household level. The household economics approach has a great advantage in that it allows for an analysis of nonmarket goods that do not have market prices. It enables the specification of demand functions for these goods (such as child services, prepared meals, etc.), as well as the specification of demand equations for marketed goods and for the allocation of time to leisure, home production and work.

Household economics is an integration of both production and consumption analysis. The following relatively simple model illustrates this:

Define the household utility function to be:

$$(46) \quad U^*, = U\ (N, H, L_c, L_m, L_f, S)$$

where

N = the number of children
H = health or human capital per child
L_c, L_m, L_f = leisure hours for children, mother and father.
S = a bundle of other goods

Notice that none of these goods need to marketed and have a price. The essential ingredients of the household model are the production – like constraints:

$$(47)\quad \begin{aligned} N &= N\ (X_n,\ T_{nm}\ ,\ K) \\ M &= H\ (X_n\ ,\ T_{nm}\ ,\ H^x\ ,\ K) \\ S &= S\ (X_s\ ,\ T_{sm}\ ,\ K) \end{aligned}$$

(Note that we could add an agricultural transformation function for an agricultural household; see Part III.)

The first constraint simply indicates that the maintenance of children requires goods purchased in the market, X_n, and time input by the mother (T_{nm}). Managerial and other technical skills (K) are also factors affecting the efficiency of this production.

The second constraint shows that health (H) is derived from purchased foods, X_f mothers' time, T_{nm}, and capital H^X which may be owned by the family or provided by the community.

The third constraint simply shows that other goods may be processed and prepared in the home.

In addition to these technical constraints, time constraints hold:

$$(48)\quad \begin{aligned} L_c &= T_c = T_{wc} \\ L_m &= T_m - T_{nm} - t_{nm} - t_{sm} - t_{wm} \\ L_f &= T_f - t_{wf} \end{aligned}$$

Leisure is constrained to be total time less home production time less work time (t_{we}, t_{wm}, t_{wf}).

The financial budget constraint for this household is:

$$(49)\ V + N W_c\ T_{wc} + W_g\ t_{wg} + W_m\ t_{wm} = P_n X_n + P_f X_f + P_s X_s$$

Maximization of (46) subject to (47), (48) and (49) yields three sets of related jointly determined demands.

(50) a) Demands for nonmarketed goods

$$\begin{aligned} N &= N\ (P_n, P_f, P_s, W_c, W_f, W_m, V, K, H^X) \\ H &= H\ (P_n, P_f, P_s, W_c, W_f, W_m, V, K, H^X) \\ T &= T\ (P_n, P_f, P_s, W_c, W_f, W_m, V, K, H^X) \\ S &= S\ (P_n, P_f, P_s, W_c, W_f, W_m, V, K, H^X) \end{aligned}$$

b) Demands for marketed goods

$$X_n = X_n\,(P_n, P_f, P_s, W_c, W_f, W_m, V, K, H^x)$$
$$X_f = X_f\,(P_n, P_f, P_s, W_c, W_f, W_m, V, K, H^x)$$
$$X_s = X_s\,(P_n, P_f, P_s, W_c, W_f, W_m, V, K, H^x)$$

c) Time allocation

$$T_{fl} = T_{fl}\,(P_n, P_f, P_s, W_c, W_f, W_m, V, K, H^x)$$
$$T_{fw} = T_{fw}\,(P_n, P_f, P_s, W_c, W_f, W_m, V, K, H^x)$$

etc.

The maximization inherent in this household system can be simplified by viewing the household as both a "firm" and a consumer. As a firm the household cost-minimizes just as a firm does. For any particular combination of household goods, N, H, etc., the firm component will seek to produce these goods at minimum costs. This cost-minimizing behavior produces "marginal" costs for each nonpriced household good. These costs of producing an added unit are usually termed "shadow prices." The household as a consuming unit then chooses the set of household goods that maximizes utility by viewing these shadow prices as the relevant prices.

Thus, the demand functions for "inputs," i.e., the purchased market goods, are derived from the implicit "profits function" of the household firm, as well as from its indirect utility function. The shadow prices are internal prices to each household and are weighted averages of external or exogenous prices. The weights reflect the utility parameters and production technology of the household. To see this more clearly, we can substitute the time constraints (45) into the financial constraints (46). This yields the "full income" expression. In addition, we can define time and goods intensities as weights:

$$(51) \quad X'_n = X_n / N; \quad X'_h = X_n / H; \quad X'_s = X_s / S$$
$$t'_{nm} = t_{nm} / N; \; t'_{nc} = t'_{nc} / N; \; t'_{nm} = t_{nm} / H; \; t'_{sm} = t_{sm} / S$$

Using these definitions, the full income constraint can be written in shadow price form:

$$(52)\quad V + W_m T_m + W_f T_f + NW_cT_c = L_m (W_m) + L_f (W_f) + NL_c (W_c) + N (P_n X'_n + W_m T'_{nm}) + NH (P_n X'_n + W_m t'_{nm}) + S (P_s X'_s + W_m t'_{sm})$$

In this expression, the shadow prices of the goods in the utility function are shown in parentheses. Note that the shadow price of children N has three parts. The first is the direct cost in the term following N. The second is H times the shadow price of H. The third is the negative term for child earnings $WcTwc$ implicit in the term $WcTc$. This analysis is pursued further in the paper by Roumasset and Evenson elsewhere in this issue.

The relevant part of the household model for consumption analysis is that systems of demand equations such as (50) derived from the household model require several variables in relation to members because of different specializations in home production. They require variables characterizing fixed factors of home production and skills. They also require nonlabor income variables which can be used to identify the pure income effect. Conventional income (and expenditure) measures have time prices imbedded in them and do not properly identify income effects.[20]

III. RURAL MARKETS AND THE AGRICULTURAL HOUSEHOLD

In the household model discussed in the previous section certain home-produced goods did not have markets. They were not traded or exchanged. This meant that the "internal demand" for these goods equalled this "internal supply." The "shadow price" or "marginal cost" of these goods was in fact the internal equilibrium price. It is partially based on market prices and also based on the household's own utility function for goods. Thus, it varied from household to household.[21]

20. See the household economics studies in the *Philippine Economic Journal*, Number 36, Vol. XVII, Nos. 1 and 2, 1978, for a discussion of these issues. The studies in that volume present some of the initial attempts to apply the household economics framework to the analysis of Philippine data. These studies can be classified into two groups: those investigating the demand for household goods, chiefly related to child services and nutritional status, and those investigating the allocation of time within rural households. Several of the studies utilize data obtained from a Laguna survey of time allocation and nutrient intake, while others use national data to analyze consequences of public education and health and wife's employment or fertility as well as migration decisions.

21. This section has benefited from comments and the presentations of Raaj Sah and Wilfrido Cruz.

These 'household goods" are not the only cases of goods without markets. Several lines of recent research on rural development problems have explored cases where markets do not exist (or where there are substantial transactions costs) for labor and other agricultural goods. Models of interlinked markets, incomplete markets and asymmetric information have now been utilized to explore some of the implications for the analyses of market exchange in rural economies.

Interestingly, the household model discussed in the previous section did not lead very directly to the analysis of incomplete markets for "conventional" goods and factors even though it was designed to handle nonmarketed household goods. The "agricultural household" model has emerged as a somewhat differentiated line of analysis for these problems.[22] The agricultural household model in its simpler versions includes an agricultural production (or transformation) function as a constraint (see 47) but typically ignores household production constraints.

When household production is ignored and when efficient markets exist for all goods and factors, the agricultural household model shows that production decisions are independent of consumption decisions. Consumption decisions, on the other hand, depend on the income or profit from agricultural production. Thus, a change in a nonagricultural price will affect consumption but not production (it will affect family leisure and labor supply but it will not affect total farm labor utilized). A change in an agricultural price, on the other hand, will affect the consumption of agricultural goods directly, the production of agricultural goods and the consumption of all goods through the income or profit effect.[23] The independence of production decisions from con-

22. See Strauss, J., Singh, I.J. and Squire, L., World Bank, 1986, for a development of the agricultural household model.

23. For the agricultural household the effect of a change in .he price of a good produced by the household will include a profit effect.

The full effect is:

$$\frac{\partial X_c}{\partial P_c} = \left.\frac{\partial X_c}{\partial P_c}\right/_{u} + (Q_c - X_c)\frac{\partial X_c}{\partial \pi}$$

marketed surplus of the good — the first term in the expression — is the substitution effect. The term $-X_c\,(\partial X_c/\partial \pi)$ is an income effect. For agricultural households, the term $\partial X_c/\partial \pi$ is the added profit effect. A similar effect of wages on labor supply includes a profit term.

sumption considerations (but not vice versa) implies that the production system can be solved as a block, and then recursively fed into the system of consumption equations. This is termed "block recursiveness" in the literature.

The motivation behind most agricultural household models is to analyze the full effects of changes in agricultural prices on both consumption and production of agricultural households. However, the model has also been expanded to explore the implications of imperfect markets for labor and agricultural goods. A number of studies have provided evidence that transactions and other costs can be quite substantial in rural markets. These costs from the point of view of a farmer hiring laborers, for example, include the costs of searching for workers, negotiating contracts and monitoring and supervising the work. These additional costs raise the real costs of hired labor significantly in some markets. From the perspective of the seller of labor there are also costs, and these can be quite high. In an extreme case (as envisioned by Chayonov 1956) these costs could effectively mean that labor markets would not exist and that family organization of production would dominate because the family as an institution can lower these costs through ties and "bonds" between members. In such a case, labor becomes in effect a household good where internal demand equals internal supply and where market wages do not exist but a shadow or "virtual" wage exists at which wage labor supplied equals labor demanded. Under conditions, the separability between consumption and production (or block-recursiveness) no longer holds.[24] A rise in a non-agricultural price will now change consumption prices and have an effect on the leisure-labor supply choice. The virtual price of labor or leisure may thus change and the total work effect will change, thus affecting production.[25]

It should be noted that separability between agricultural production and household production and consumption is maintained if perfect markets exist for all agricultural goods. The existence of household pro-

24. Fabella, elsewhere in this issue, derives conditions for separability when farmers are risk averse and shows that under certain error assumptions separability holds. He also derived separability with scale economies.

25. Strauss (1984) derives expressions for the virtual-price of labor in the case where a labor market is absent. He shows that a rise in the agricultural output price has two effects on the leisure work-mix in the household. An income effect through profits increases the demand for leisure. The virtual wage effect may have a negative or positive sign.

duction (e.g., in food preparation) does not mean that farm production analysis must take household production into account.

As long as well-functioning markets exist for agricultural goods and factors, standard production analysis can be undertaken.

The introduction of risk into the analysis makes the existence of well-functioning markets a necessary but not a sufficient condition for block-recursiveness. Under conditions of production risk and perfect competition in the labor market or an institutionally fixed wage, Fabella (this issue) shows that (1) if production risk is additive, the household production model is block-recursive; (2) if the production risk is multiplicative of finite variance, then the household production model is non-block-recursive; and (3) if the farm household exhibits decreasing absolute risk aversion, then the household production model becomes more approximately block-recursive as risk increases. For the farmer, additive risk comes in the form of fluctuations he cannot control, such as natural calamities and man-made disasters such as social unrest and wars. Multiplicative risk is tied up with the production process, such as new technology which alters factor utilization, e.g., new cultivation methods which utilize new seeds, fertilizer and different labor intensities. Farmers may resist innovations, even if these increase productivity, since they are perceived to increase farming risks. Under conditions of price risk due to changes in demand, block-recursiveness holds if either: (1) production is for subsistence consumption (and thus would not be affected by market price fluctuations); or (2) the household exhibits diminishing absolute risk aversion and the production variance approaches infinity. The important conclusion of this paper is that if the conditions for profit-maximization hold under uncertainty, so will block-recursiveness.

Production and consumption decisions may also be interdependent if there exist endogenous shadow prices which would become a basic linkage between the production and consumption sector of the model (Lopez 1984). In particular, if time allocations between on- and off-farm work have different utility connotations, then the shadow price of on-farm work is endogenously determined within the farm-household unit even if its members work off the farm. This is evident when commuting time is explicitly introduced, even when there are identical preferences for on- versus off-farm work: commuting time represents an additional sacrifice or cost of off-farm work.

Roumasset and Evenson (this issue) analyze the implications of a partially incomplete labor market in the rural Philippines. By partially incomplete, the authors mean that labor markets do exist, that some rural households hire out family labor, some hire in labor in addition to utilizing family labor, and some are roughly self-sufficient. This type of equilibrium can exist when there are transactions and related costs that are significant but not prohibitive. Under these conditions, the value of family labor (and the earnings of children) will differ markedly according to the land resources of the family. Families with relatively large holdings will receive higher returns to labor. Thus, the distribution of land in such economies will have two components. The first is simply that land produces rents that accrue to owners. The second is that land confers rents to family labor as well. These, in turn, affect family decisions regarding contraception, child work and child health as shown in the Roumasset-Evenson study.

The "rents to family labor" can be partially collected by tenants. Thus, one of the reasons for widespread tenancy – as opposed to hired labor systems – when land ownership is unequally distributed is the existence of high transactions costs in labor markets. Landowners can collect part of the family labor "premium" by renting out land rather than by farming it themselves.[26]

Transaction costs not only influence the organization of farms (and of other firms as well); they also influence contracts between farmers, laborers, credit suppliers and others. The absence of high cost of two or more markets can lead to interlinked contracts where sellers and buyers operate in more than one market. Braverman and Srinivasan (1985) and Srinivasan (1985) and others have analyzed these problems.

In many developing countries an apparently bewildering variety of resource allocation mechanisms spanning the spectrum from bilateral contracts between agents who know each other and extending over a number of crop seasons or years to arms length transactions involving anonymous agents (for instance, in the market for casual labor) for a short duration seems to coexist even within a limited domain in space and time. Some of these institutions, such as sharecropping and other forms of land tenure, have been analyzed, theoretically and empirically, for a long time. On the other hand, the widely observed phenomenon of "interlinked transactions," i.e., transactions between the *same two parties* in more than one commodity or service (for instance, land

26. This does not explain why share tenancy instead of fixed-rent tenancy exists.

tenancy, labor service, credit and marketing of output, has only recently begun to receive scholarly attention.[27]

Economic theorists, particularly neoclassical economists, have viewed this phenomenon as a response to the absence of a complete set of contingent markets and to pervasive problems of asymmetric information and moral hazard, as well as of significant transaction costs. The recent literature on principal-agent problems, credit-rationing balancing incentives and risk-sharing aspects of contractual arrangements in an uncertain world are beginning to be applied in analyzing agricultural institutions.

Different stages of development also appear to be associated with different systems of organizing resources. Rural economies with low physiological densities, low rates of technological change, and high marketing costs have a greater incidence of collective and nonmarket institutions, e.g., collective, extensive systems of fallow-rotation agriculture; exchange labor; indentured labor, tenancy partnership, and other factor-linking arrangements; low market surplus and low value added from off-farm agricultural industries.

Raaj Sah (this issue) addresses several of the issues associated with labor markets and contracts in agricultural households. He shows that high supervision costs and the supervision premium to family workers affect farm organization.

IV. MULTISECTOR MODELS FOR AGRICULTURAL POLICY ANALYSIS

Past analysis of agricultural policy issues has been constrained to some extent by available methodologies.[28] Most work undertaken was of a partial equilibrium nature, and was thus unable to capture the intersectoral effects of changes introduced in the economy, particularly those pertaining to the agricultural sector. This in turn significantly limited the kind of policy prescriptions that could be derived from such analyses.

It has increasingly been recognized that, in assessing the likely impacts of agricultural policy changes, it is important to examine the

27. Baverman and Srinivasan show that a policy to control the price income market (e.g., maximum rental rates or interest rates) may be ineffective because the contract will compensate for these controls in other linked markets.

28. This section has benefited greatly from the comments and contributions of T.N. Srinivasan, M. Montes, J. Lim, R. Mariano, and L. Gonzales.

linkages between the agricultural and nonagricultural sectors in general, as well as those among individual sectors. And because of these linkages, government policies towards the nonagricultural sectors could have profound effects on the agricultural sector as well. Thus, an analysis of government policies towards the agricultural sector need not address only those policies pertaining directly to agriculture (e.g., fertilizer subsidies, grain price supports); one should also be interested in how certain nonagricultural polices (e.g., petroleum pricing, indirect taxation) bear on the agricultural sector.

Developments in quantitative economic analysis within the past decade have made possible a more comprehensive assessment of the effects of policy changes. With the development of computational techniques that permit the solution of large systems of equations, and with the computer hardware to implement them quickly, it is now possible to track the intermarket effects of specific changes introduced in certain markets of the economy. It is now also possible to generate a wealth of information on the impacts of such changes, permitting a detailed assessment of their efficiency and equity effects.

In this section, we deal with some of the available modelling approaches to policy simulation that are of potential usefulness in agricultural policy analysis. We first consider traditional macroeconometric models and their suitability to this type of analysis. We then turn to models which have come to be classed under the general heading of computable general equilibrium (CGE) models, of which two are considered here. First is the "impact multiplier" approach which uses econometric estimation to derive a system of differential equations that interrelate changes in various policy variables within the (agricultural) economy. The second is a more comprehensive simulation model which computes equilibirum prices and their consequent effects on other policy variables like income distribution and growth. Finally, some general issues related to economic modelling are discussed, including limitations of the models described herein.

Macroeconomic Models[29]

Typical macroeconomic models are normally composed of a series of econometrically estimated equations grouped into several "blocks"

29. This section draws heavily from Manuel F. Montes's paper, "Specification of a Semestral Macroeconomic Model for the Philippines," presented at this Workshop.

to specify (1) national output, (2) prices, (3) foreign transactions, (4) the monetary sector, (5) the labor market, and (6) the fiscal sector. While a highly disaggregated treatment (particularly of the national output block) is feasible, these models tend to be specified on a fairly aggregate level, often treating the whole economy as producing only one commodity, i.e., total real output. As such, they tend to explain aggregate economic outcomes independently of the underlying vector or relative prices in the economy. On the other hand, one may justify this approach on the argument that relative prices really play an important and predictable role only when the units of analysis are truly small enough in the neoclassical sense to exhibit independent behavior, and only when the economy is in the vicinity of equilibrium. Thus, macroeconomic models tend to relate real quantities directly to each other (e.g., aggregate consumption as a function of aggregate income), instead of through relative prices (e.g., aggregate consumption as the sum of individual consumption decisions based on individual incomes and relative prices).

In his workshop paper, Montes argues that an aggregative macro modelling approach may be adequate when: (1) the analysis can only be carried out at a high level of aggregation which makes it difficult to observe substitution behavior; and (2) the economy is so far removed from equilibrium that the actions of some agents could have significant quantity effects. The most important of these agents is the state, with its power to appropriate resources, set prices, and print money. And for an economy such as that of the Philippines where the state has immense price-setting power and where excess labor supply is typical, a macro model approach may be useful for policy analysis.

A highly aggregative macro model may not be very useful, however, in assessing agricultural policies which are addressed to specific sectors. In the Philippine experience, agricultural policy measures have tended to be of this type, e.g., rice input subisidies and price supports, specific trade taxes, and marketing interventions. In these cases, it is largely the policies' impacts on relative prices that determine their effects on the economy. Hence, both disaggregation and consideration of relative price effects are desirable attributes of a policy model used to analyze them. While macroeconomic models may be suitable for assessing the effects of monetary policy (e.g., interest rates) and exchange rate policy on the agricultural sector, models of the computable general equilibrium (CGE) type appear to be more appropriate for examining most other agricultural policy issues.

CGE Models: The "Impact Multiplier" Approach

One approach to modelling market interactions in the agricultural sector has been through the use of "impact multiplier" models which specify the input and output supply and demand equations as a system of linear differential equations (i.e., defined as rates of change). As such, the solution simply requires the inversion of the coefficients matrix of the equation system. This approach has been applied to the Indian agricultural sector by Quizon and Binswanger (1983) and Evenson (1984). The model is built around an econometrically estimated "producer core," which defines the output supply and input demand equations from a variable profit function via Shephard's lemma (see equations 10-17 in section 1). Output demand and input supply equations are then defined to close the model. A demand system with cross-elasticities can be derived from an indirect utility function in a manner analogous to the production system specification. Input (i.e., labor, land and capital) supply equations can include the effects of migration, labor participation rates, and capital stock growth. In both the producer and consumer systems, exogenous shifters can be included in the demand and supply equations to incorporate the effect of nonprice policy variables. Figure 1 summarizes the basic structure in the Binswanger-Quizon-Evenson model. The system of equations can be written in matrix notation as

$$GU' = K^*$$

where G is the matrix of coefficients, U^1 is the column vector of endogenous prices, and K^* is the column vector of policy variables. The solution to the model is

$$U' = G^{-1}K^*$$

Thus, knowing the inverse of G, the price and output effects of changes in policy variables can be determined.

"Full" CGE Models

A much more ambitious but potentially richer modelling approach is exemplified by full-economy CGE models which allow the endogenous interaction of all (major) sectors of the economy. The discovery of practical algorithms for solving large systems of nonlinear equations (e.g., Scarf 1977; Merill 1971; Powell 1970) ushered in the construction of moderately-sized multisectoral models which compute for a complete set of equilibrium prices in the economy. Like the "impact multiplier" models, these models are built around a set of input and output supply and demand equations, but they need not be specified as rates of change. And unlike the "impact multiplier' models described in the previous section, these models have in practice not been parameterized on the basis of prior econometric estimation. Instead, they rely on a specific benchmark year's equilibrium data set to specify the numerical relationships in the model whose producer and consumer systems are often based on Cobb-Douglas (or at most, CES) production and utility functions. This permits the model to be completely parameterized from the benchmark data set alone. However, there is nothing that precludes the use of more flexible functional forms in these models, provided that reliable parameter estimates are available.

Another severe limitation of most existing "full" CGE models is their inability to consider substitution possibilities among ouput and inputs, more particularly the latter. This arises from their being built around an input-output table which constrains the use of intermediate inputs to a fixed-coefficients technology. Input substitution is usually confined to primary inputs (labor and capital). Again, there is nothing that precludes the modelling of substitution possibilities in these models, as long as elasticity estimates are available. For example, Goulder (1982) has shown how intermediate input usage can be made price-responsive in a CGE model; the method involves updating the input-output coefficients matrix every period to reflect changes in the input mix motivated by changes in relative prices. Similarly, only the absence of reliable cross-elasticity estimates in consumption has prevented the incorporation of product demand substitutions in past models. However, it is not clear, given the lack of experience with models incorporating such behavior, whether doing so will result in serious convergence problems.

The structure of the Habito (1984) model of the Philippine economy which is to be updated and modified for agricultural policy analysis is described in the article by Habito in this journal issue. The model is composed of 18 production sectors, 11 households, and 3 primary factors of production. Changes being introduced to improve the suitability of the model to agricultural policy modelling include: (1) redefinition of the production sectors in the economy to achieve more disaggregation of agricultural sectors and more aggregation of nonagricultural sectors; (2) allowance for price-responsive input and output substitutions; (3) improvement of factor supply specification; and (4) improvement of the model's dynamic specification (i.e., savings and investment behavior).

Modelling Issues [30]

The task of economic model-building can ususally be divided into five stages: (1) specification, (2) parameter estimation, (3) validation, (4) numerical solution, and (5) interpretation.

Specification requires decisions on the scope, structure and level of disaggregation of the model. These decisions should be closely tied to the objectives of the modelling effort. In the context of agricultural policy analysis, this has to do with the types of policies one wishes to assess. For example, the model may either treat the nonagricultural sectors exogenously (e.g. as in the impact multiplier model) or endogenously (e.g. as in the full CGE model) depending on whether policies directly impacting the nonagricultural sector are to be analyzed. Similarly, a standard macroeconomic model may suffice where relative price effects are not important to the analysis. The choice of disaggregation level is likewise determined by the degree of detail required by the analysis which in turn is again influenced by the types of policies and effects to be studied. Thus a disaggregation of agricultural sectors is called for in the current modelling exercise, whereas the nonagricultural sectors can be treated more aggregatively.

Because of the utter complexity of a comprehensive multisector model, it is advisable to design it in such a way that major components may stand alone. This has at least two advantages. First, the construction of a large model involves the risk that the complete model may never work properly (e.g., due to nonconvergence problems) and a modularly designed model can remain useful even in this eventuality. Secondly, for certain analyses, it may be sufficient to use just a segment of, rather than the whole, model. Aside from saving computational costs, such a restricted analysis will at times provide more lucid insights than a full general equilibrium simulation. The present modelling effort has

30. This section incorporates points raised in the discussion over the models presented in the last session of the workshop. Comments by R. Mariano, J. Lim, M. Montes and L. Gonzales have been valuable.

a "producer core" and a "consumer core" that can stand on their own and be used for policy analyses by themselves, as has been demonstrated in the papers by Evenson and Quisumbing.

Probably the most crucial elements of a model are the parameters, particularly the different elasticities that determine the magnitudes of responses to changes in policy variables in the model. It is therefore important to consider the properties of estimated parameters (e.g., are they appropriate only within the neighborhood of the base period?) and to validate the parameter estimates to gain confidence in their values.

Validation is another issue which has presented difficulties for CGE modellers. A completely satisfactory validation is impossible in the CGE context because numerical specification is based entirely on a single benchmark period's data. Furthermore, this benchmark data set necessarily undergoes some transformation in order to reflect a state of general equilibrium. Thus, the model is based on an "artificial" data set to start with. In the face of such difficulty, the best recourse would be to conduct sensitivity analyses on key elements of the model, in order to have a better appreciation of its weaknesses.

The numerical solution of a large economic model has ceased to become a major constraint to model-building. Many computational procedures ranging from simple iterative techniques (Gauss-Seidel) to elaborate fixed-point algorithms are now available to the modeler, and the availability of computers for their speedy implementation has reduced the costs of such an exercise One may still face the risk of nonconvergence of a general equilibrium model, although certain algorithms guarantee convergence at the cost of inflexibility in model specification and/or reduced computational speed.

Finally, an important problem with a large multisectoral model concerns the ease of interpretation of the results one gets with it. It is easy to get lost in the output of a simulation run with a large comprehensive model. One may gain a large amount of information from a complex model, but may lose insight in the process. It is therefore important to balance model size with ease of interpretation of results. The model should also be designed so as to facilitate interface with its intended users A model's usefulness is severely limited if the only person who can use it and interpret its results is the model-builder himself. Thus, every attempt must be made to make the computer software for implementing the model as "user-friendly" as possible.

V. CONCLUDING REMARKS

This workshop was structured to reflect the range of activities that are being undertaken in the current research project on agricultural policy analysis. Estimation of prouction functions for Philippine agriculture is being undertaken to update past work on production systems, particularly to make use of more recently developed econometric techniques and theoretical constructs. Similarly, work is being undertaken to reestimate consumer demand functions in the Philippines using the most up-to-date data and methodology available. Both endeavors not only will be able to lead to stand-alone policy analyses, but will also be important inputs into a more comprehensive general equilibrium modelling exercise This may be the first time that a CGE model is being formulated in coordination with actual parameter estimation for the producer and consumer segments of the model.

The emphasis of this workshop was on methods of analysis. It has become increasingly realized that a consideration of appropriate methodologies is an important first step that must be resolved prior to actual work on policy analysis. It is hoped that, at the completion of the project, we shall have undertaken some analyses on important Philippine agricultural policies backed by solid methods of analyses, thereby permitting greater confidence in their results and policy implications.

REFERENCES

Becker, Gary. "A Theory of the Allocation of Time." *Economic Journal* 75 (1975): 493-517.

Binswanger, Hans P. "A Cost Function Approach to the Measurement of Elasticities of Factor Demand and Elasticities of Substitution." *American Journal of Agricultural Economics* 56 (1974).

_________, and Mark Rosenzweig, eds. *Contractual Arrangements, Employment and Wages In Rural Labor Markets: A Critical Review.* New Haven: Yale University Press, forthcoming.

_________, and Vernon W. Ruttan. *Induced Innovation, Technology, Institutions and Development.* Baltimore: Johns Hopkins Press, 1978.

Bouis, Howart. "Demand for Cereal Staples in the Philippines." International Food Policy Research Institute, Washington, D. C. Mimeographed

Braverman, A., and T. N. Srinivasan. "Agrarian Reforms in Developing Rural Economies Characterized by Interlinked Credit and Tenancy Markets." In *Contractual Arrangements, Employment and Wages in Rural Labor Markets in Asia,* edited by H. Binswanger and M. Rosenzweig. New Haven: Yale University Press, 1984.

Brown, Alan, and Angus Deaton. "Surveys in Applied Economics: Model of Consumer Behavior." *Economic Journal* 82 (1972): 1146-246.

Canlas, Dante B. "Estimating Price and Income Elasticities of the Demand for Food: The Philippines, 1965." Paper presented at the Nutrition Seminar-Symposium Series, National Nutrition Council, University of the Philippines School of Economics, 1983.

Chayanov, A. B. *Peasant Farm Organization.* Moscow: Cooperative Publishing House, 1925. Translated in *A. V. Chayanov: The Theory of Peasant Economy.* Edited by D. Thorner, B. Kerblay and R. E. F. Smith. Homewood. Richard Irwin, 1966.

Christensen, Jorgenson, and Lawrence Lau. "Transcendental Logarithmic Production Frontiers." *Review of Economics and Statistic* 55 (1973): 28-45.

Deaton, Angus, and John Muellbauer. *Economics and Consumer Behavior.* Cambridge: Cambridge University Press, 1980.

Denison, E. F. *The Sources of Economic Growth in the United States and the Alternatives Before Us.* Washington, D. C. Committee for Economic Development, 1965.

Diewert, William E. "An Application of the Shephard Duality Theorem: A Generalized Leontief Production Function." *Journal of Political Economy* 79 (1971): 481-507.

———. "Exact and Superlative Index Numbers." *Journal of Econometrics* 4 (1976): 115-45.

Evenson, R. E. "Population Growth, Infrastructural Development, Technology and Welfare in Rural North India." Paper prepared for the IUSSP Seminar on Population and Rural Development, New Delhi, India, 1984.

Fuss, M., and D. McFadden. *Production Economics: A Dual Approach to Theory and Applications.* 2 vols. North Holland Press, 1978.

_______. "Flexibility Versus Efficiency in Ex Ante Plant Design." In *Production Economics,* Vol. I, edited by M. Fuss and D. McFadden. Vol. I:331-364.

Griliches, Zvi, and Dale Jorgenson. "The Explanation of Productivity Change." *Review of Economics and Statistics* (1967).

Hotelling, H. "Edgeworth's Taxation Paradox and the Nature of Demand and Supply Functions" *Journal of Political Economy* 40 (1932): 577-616.

Jorgenson, Dale, and Lawrence Lau. "An Economic Theory of Agricultural Household Behavior." Paper presented at the 4th Far Eastern Meeting of the Econometric Society, 1969.

Lau, L. "Comments on Applications of Duality Theory." In *Frontiers of Quantitative Economics,* edited by M. D. Intriligator and D. A. Kendrick. Amsterdam: North-Holland Publishing Co., 1974.

Lau, Lawrence, and Pan Yotopoulos. "Profit, Supply and Factor Demand Functions." *American Journal of Agricultural Economics* 54 (1972): 11-18.

Lopez, Ramon E. "Structural Models of the Farm-Household Allowing for Interdependent Utility and Profit Maximization Decisions." University of Maryland, 1985.

McFadden, D. "Cost Revenue and Profit Functions." In *Production Economics: A Dual Approach to Theory and Applications,* edited by M. Fuss and D. McFadden, 2 vols. North-Holland Press, 1978.

Merrill, O. H. "Applications and Extensions of an Algorithm that Computes Fixed Points of Certain Upper Semi-Continuous Mappings." Ph.D. dissertation, University of Michigan, 1971.

Nelson, Richard R."Industry Growth Accounts and Cost Functions When Techniques Are Proprietary." Yale University, 1986. Mimeographed.

Powell, M. J. D. "A Hybrid Method for Nonlinear Equations." In Rabinowitz, *Numerical Methods for Non-linear Algebraic Equations.* New York: Gordon and Breach, 1970.

Quizon, J. B., and H. P. Binswanger. "Income Distribution in Agriculture: A Unified Approach." *American Journal of Agricultural Economics* 65 (1983): 526-37

Rosenzweig, Mark. "The Demand for Children in Farm Households." *Journal of Political Economy* 85 (1977): 123-46.

Roumasset, J. "The New Institutional Economics and Agricultural Organization." *Philippine Economic Journal* XVII (1978): 331-48.

Scarf, H. "The Computation of Equilibrium Prices: An Exposition." Cowles Foundation Discussion Paper No. 473, Yale University, 1977.

Sen, Amartya K. "Peasants and Dualism With and Without Surplus Labor." *Journal of Political Economy* 74 (1966): 425-50.

Shephard, Ronald W. *Cost and Production Functions.* Princeton University Press, 1953.

________. *The Theory of Cost and Production Functions.* Princeton University Press, 1970.

Srinivasan, T. N. "Agricultural Backwardness Under Semi-Feudalism." *Economic Journal* (1979).

Stevenson, R. "Measuring Technological Bias." *American Economic Review* 70 (1980): 162-73.

Swamy, Gurushri, and Hans P. Binswanger. "Flexible Consumer Demand Systems and Linear Estimation: Food in India." *American Journal of Agricultural Economics* 65 (1983): 675-84.

Timmer, C. Peter. "Is there 'Curvature' in the Slutsky Matrix?" *Review of Economics and Statistics* 58 (1981): 395-402.

———, and Harold Alderman. "Estimating Consumption Parameters for Food Policy Analysis." *American Journal of Agricultural Economics* 61 (1979): 982-87.