Factor Demand and Technical Change in Philippine Agriculture

Peter G. Warr

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Peter G. Warr
Australian National University

Abstract

The econometric estimation of elasticities of factor demand in Philippine agriculture is studied in this paper. The central purpose of this work is to provide the parameters required for incorporation into a large, applied general equilibrium model of the Philippine economy, known as APEX. The values of these supply side parameters are crucial for the performance of general equilibrium systems like APEX, but the econometric literature offers several alternative possible methodologies for their estimation. These include both primal and dual methods. The first objective of this paper, therefore, is to attempt to discriminate among these alternative methodologies according to the predictive performance of the estimates that they produce. A second objective is to examine the sensitivity of the resulting general equilibrium model to factor demand elasticity estimates derived from these alternative methodologies by means of experiments on the economic effects of technical change in Philippine agriculture.

FACTOR DEMAND AND TECHNICAL CHANGE IN PHILIPPINE AGRICULTURE*

Peter G. Warr

Australian National University

1. Introduction

The econometric estimation of the elasticities of factor demand in Philippine agriculture is studied in this paper. The central purpose of this work is to provide the parameters required for incorporation into a large, applied general equilibrium model of the Philippine economy, known as APEX. The values of these supply side parameters are potentially important for the performance of general equilibrium systems like APEX, but the econometric literature offers several alternative possible methodologies for their estimation. These include both primal and dual methods.

The first objective of this paper, therefore, is to attempt to discriminate among these alternative methodologies according to the predictive performance of the estimates that they produce. A second objective is to examine the sensitivity of the resulting general equilibrium model to factor demand elasticity estimates derived from both primal and dual methodologies by means of experiments on the economic effects of technical change in Philippine agriculture.

Most general equilibrium models constructed to date have been weak as regards the empirical basis for the supply side parameters that enter them. Parameters are typically based upon what the authors describe as 'literature review', which all too frequently proves to mean that they have very little

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empirical foundation at all. The intended users of the results of such models are entitled to wonder what basis exists for supposing that their quantitative results, and perhaps even their qualitative results, bear much relationship to the properties of the actual economies they supposedly represent. Closer attention to econometric estimation is therefore a necessary condition for applied general equilibrium modelling to earn greater credibility among policy makers.

Section 2 reviews the economic issues involved in this estimation work and Section 3 discusses the econometric estimation issues involved. Section 4 then discusses the estimation of the required parameters for Philippine agriculture and Section 5 focuses upon the importance of these results for the performance of the APEX applied general equilibrium model. It does so by analysing the sensitivity of the simulated effects of technical change in Philippine agriculture with respect to the values of the factor demand elasticities which enter the model. Finally, Section 6 summarises the overall conclusions.

2. Interpretation

2.1 Input-Output Separability

Figures A.1 and A.2 summarise the structure of the agricultural component of the APEX model. Agriculture in the Philippines has a strong regional dimension and output (but not factor employment) data are available over many years on a regional basis. These facts are reflected in the structure of the APEX model. Agricultural production is assumed to be a joint production process in each region. The structure of agricultural production in each region conforms to the strong assumption of input- output separability. Factors of production are employed in each region to produce composite regional agricultural output. The proportions in which the factors of production are employed depend on relative prices. This composite output then generates the outputs of the various commodities. The key implication is that for a given level of composite regional output, so determined, the proportions in which the factors of production are used does not affect the proportions in which the various commodity outputs can be produced.

Consider the most general implicit production function for a joint production process. In region r,

$$f^r(F_{1r},\ldots,F_{Vr},X_{1r},\ldots X_{Jr})=0 \tag{1}$$

where $F_{1r},\ldots,F_{Vr}$ are the levels of the V inputs and $X_{1r},\ldots,X_{Jr}$ are the levels of the J commodities produced. The assumption of input-output separability states that the function f^r can be written as

$$g^r(F_{1r},\ldots,F_{Vr})-h^r(X_{1r},\ldots X_{Jr})=0. \tag{2}$$

The input-output separability assumption may or may not be a good characterisation of the joint production processes occurring in Philippine agriculture. The available data made this assumption necessary, however, for the reasons discussed below.

Empirical estimates were required for the parameters corresponding to the category labelled 'FFF factor demand' in Figure A.2, where FFF denotes 'flexible functional form' relationships. These parameters are the focus of this paper. The production of composite fertiliser from its imported and domestic components is governed by an Armington substitution process. Econometric estimation of these Armington parameters was conducted separately, and is not discussed here. Regional issues will not be important for most of the discussion which follows. We shall concentrate upon the estimation of factor demand elasticities at the national level.

2.2 Factor Demands

Consider the conditional factor demand equation. In region j

$$F_{vj} = \varphi^{vj}(X_j, W_j) \tag{3}$$

where F_{vj} denotes the level of demand for factor v in region j, X_j denotes the output of region j and W_j denotes the vector of factor prices (returns) faced by region j. We require that the properties of the function φ^{vj} include:

(i) homogeneity of degree one in X_j (constant returns to scale);

(ii) homogeneity of degree zero in W_j;

(iii) symmetric second derivatives (Young's theorem); and

(iv) consistency with concavity of the production function.

Property (i) implies that when output doubles, for given factor prices, demand for each factor also doubles. Property (ii) implies that for a given value of output, factor demands depend upon relative prices and not absolute factor prices; so when all factor prices double, holding output constant, factor demands do not change. Property (iii) implies that the effect of a change in the price of factor k on the demand for factor v is the same as the effect of a change in the price of factor v on the demand for factor k. Property (iv) implies that the own-price derivatives of (1) are non-positive ($\varphi_v^{vj} \leq 0$).

Differentiating equation (1) totally,

$$dF_{vj} = \varphi_X^{vj} dX_j + \sum_k \varphi_k^{vj} dW_{kj} . \tag{4}$$

Now, dividing by F_{vj} and rearranging terms

$$f_{vj} = \beta_{vxj} x_{vj} + \sum_k \beta_{vkj} w_{kj} , \tag{5}$$

where lower case Roman letters describe proportional changes in variables defined in levels (for example, $x_j = dX_j / X_j$, $f_{vj} = dF_{vj} / F_{vj}$, and so forth) and the Greek letters β_{vxj} and β_{vkj} denote the elasticities of demand for factor v in region *j* with respect to the output of that regional industry and the price of factor *k*, respectively.

Property (i) above requires that β_{vvj}=1. This can be seen by supposing that all factor prices are held constant ($w_{kj} = 0$ for all *k* and *j*); outputs and factor demands must then move in the same proportions. Property (ii) requires that

$$\sum_k \beta_{vkj} = 0. \tag{6}$$

Doubling all factor prices, for example, does not alter the ratio of individual factor demands to output, given by $f_{vj} - x_j$, or the ratios in which any two factors are used at a given level of output, given by $f_{vj} - f_{kj}$. Symmetry (property (iii)) requires that $\partial F_{ij} / \partial W_{kj} = \partial F_{kj} / \partial W_{ij}$, or that

$$\beta_{ikj} S_{ij} = \beta_{kij} S_{kj}, \tag{7}$$

where S_{ij} is the share of factor *i* in the value of output in region *j*, etc. Finally, a necessary condition for property (iv) is that all own price elasticities of demand are non-positive ($\beta_{vvj} \leq 0$).

The basic structural equations of APEX for which parameter estimates are required are thus given by:

$$f_{vj} = x_j + \sum_k \beta_{vkj} w_{kj} \tag{8}$$

We require estimates of the parameters β_{vkj}, where each represents the output-compensated elasticity of demand for factor *v* with respect to the price of factor *k* in region *j*, and we require that these estimates are consistent with properties (i) to (iv), above. Our estimation will be conducted at an aggregate level. That is, we shall be interested in the aggregate factor demand elasticities for the Philippine agriculture as a whole.

3. Estimation of Factor Demand Elasticities

3.1. Methodology

The most popular methodology currently used for estimation of factor demand equations such as (8) above, is the *dual method*, the essence of which is that the right hand side variables used in estimation are the prices of factors of production. Several different functional forms have been used for this purpose. A potential problem with reliance on this methodology, regardless of the particular functional form that is chosen, is that, especially in developing countries, factor price data available for estimation may be of poor quality relative to the data available on quantities, both of outputs and factor use. But because factor price data appear on the right hand side of the relevant estimation equations, serious errors in variables problems are likely to result.

An alternative approach, seemingly less sensitive to errors in factor price data, is what we shall call the *primal method*. This method estimates the parameters of production functions for the industries concerned and *derives* the required parameters of factor demand equations analytically by imposing the assumption of profit maximisation. Econometric practice has tended to favour the dual approach on the grounds that the factor quantities appearing on the right hand side in the estimation of a production function will be endogenous to the system. This is a genuine issue, but not necessarily decisive. Methods exist for testing for the existence of endogeneity and for dealing with it where it is present. But problems of errors in variables are potentially more serious. Consequently, it would seem that whether the primal or dual approach is more appropriate can be established only in the context of a particular data set.

We shall attempt to derive factor demand parameters using each of the above methodologies and to compare their respective performance systematically. The selection of estimates for inclusion into APEX will then be made on the basis of these econometric results.

3.2 Selection of Primal vs. Dual Functional Form

The functional forms used are:

(i) *Primal Approach*

We estimate the parameters of the *Translog production function* (TLPF). Because of the Leontief assumption regarding intermediate inputs, we are interested in the relationship between industry value-added and primary factor inputs, given by

$$\ln V = \ln \alpha_0 + \alpha_t \ln t + \frac{1}{2}\alpha_{tt}(\ln t)^2 + \sum_{i=1}^{K} \alpha_{it} \ln X_i \ln t$$

$$+\sum_{i=1}^{K} \alpha_i \ln X_i + \frac{1}{2}\sum_{i=1}^{K}\sum_{j=1}^{K} \beta_{ij} \ln X_i \ln X_j, \qquad (9)$$

where V denotes industry value-added, deflated by the price of the industry's output and $\ln V$ is its natural logarithm, t is time, X_i is the input of factor i and lower case Greek letters represent parameters. We suppose that there are K factors of production. The first-order conditions for cost minimisation imply factor share equations of the form

$$S_i = \alpha_i + \sum_{j=1}^{K} \beta_{ij} \ln X_j + \alpha_{it} \ln t, \qquad i = 1,2,\ldots,K \qquad (10)$$

where

$$S_i = \frac{\partial \ln V}{\partial \ln X_i} = \frac{\partial V}{\partial X_i} \cdot \frac{X_i}{V} = \frac{P_{Xi}}{P_v} \cdot \frac{X_i}{V}. \qquad (11)$$

The equations used for estimation are these share equations (9), jointly with the full production function given by (8).

(ii) *Dual Approach*

We wish to estimate the parameters of the *Normalized Quadratic profit function* (NQPF), given by

$$\pi_t = \alpha_0 + \sum_{i=1}^{K} \alpha_i \frac{w_{it}}{p_t} + \frac{1}{2}\sum_{i=1}^{K}\sum_{j=1}^{K} \alpha_{ij} \frac{w_{it}}{p_t}\frac{w_{jt}}{p_t} + \sum_{i=1}^{K} \alpha_{it} \frac{w_{it}}{p_t} t + \alpha_t t + \frac{1}{2}\alpha_{tt} t^2, \qquad (12)$$

using output as numeraire. From Hotelling's lemma,

$$\partial\pi / \partial(w_i / p) = -x_i,$$

$$= \alpha_i + \sum_{j=1}^{K} \alpha_{ij} \frac{w_{jt}}{p_t} + \alpha_{it} t \qquad (13)$$

Substituting back into the profit function,

$$y_t = \pi_t - \sum_{j=1}^{K} x_{jt} \frac{w_{jt}}{p_t}$$

$$= \alpha_0 - \frac{1}{2}\sum_{i=1}^{K}\sum_{j=1}^{K} \alpha_{ij} \frac{w_{it}}{p_t}\frac{w_{jt}}{p_t} + \alpha_t t + \frac{1}{2}\alpha_{tt} t^2 \qquad (14)$$

The equations used for estimation are the input demand equations (12), jointly with the output supply equation given by (14).

An alternative dual approach is to estimate the parameters of a cost function. We shall consider the *Translog cost function* (TLCF) given by

$$\ln C_t = \alpha_0 + \alpha_t \ln t + \frac{1}{2}\alpha_{tt}(\ln t)^2 + \sum_{i=1}^{K} \alpha_{it} \ln W_{it} \ln t$$

$$+\alpha_{tt} \ln t$$

$$+\sum_{i=1}^{K} \alpha_i \ln W_{it} + \alpha_Y \ln Y_t + \sum_{i=1}^{K} \alpha_{iY} \ln W_{it} \ln Y_t + \frac{1}{2}\sum_{i=1}^{K}\sum_{j=1}^{K} \beta_{ij} \ln W_{it} \ln W_{jt} \qquad (15)$$

Differentiating with respect to W_{it} gives the factor share equations

$$S_{it} = \alpha_i + \sum_{j=1}^{K} \beta_{ij} \ln W_{jt} + \alpha_{iY} \ln Y + \alpha_{it} \ln t. \tag{16}$$

These share equations are estimated jointly with the cost function itself, imposing constant returns to scale, concavity of the production function and homogeneity. These assumptions imply

$$\alpha_Y = 1$$

$$\sum_{i=1}^{K} \alpha_i = 1$$

and

$$\sum_{i=1}^{K} \beta_{ij} = \sum_{j=1}^{K} \beta_{ij} = 0.$$

We wish to determine which of the above approaches to deriving the required elasticities is most consistent with the available data for the Philippines. Our procedure is to estimate all three of the primal and dual functional forms described above. We then ask which of the three is most consistent with the data.

3.3 Data

(a) Labour

Labour is measured in equivalent man days spent in agricultural production. The main source of data for this input series are the October rounds of the *Philippine Statistical Survey of Households* (now renamed the *Integrated Survey of Households*) published by the Bureau of Census and Statistics. This survey reports total employment in agriculture, fishing, and forestry as a group.

(b) Agricultural machinery

Available data proved to be inadequate and a new data series was constructed as follows. Annual stocks of farm equipment were computed using the following formula:

$$K_t = (1-d)K_{t-1} + I_t \qquad (17)$$

where

K_t = value of capital stock in year t,

I_t = investment in year t, and

d = annual depreciation rate (0.062).

The value of the capital stock of farm equipment reported in the 1948 Census of Agriculture was used as a benchmark. Investment data was taken from the gross domestic capital formation in agricultural machinery and tractors as reported in the *National Income Accounts* published by the National Economic Development Authority.

The data on gross domestic capital formation report separate estimates of investment in agricultural machinery and tractors for the years 1948-1966, combined estimates in 1967-1980, and then revert to separate estimates from 1981 onwards. The value of investment in agricultural tractors was estimated by assuming that 95 per cent of the total investment in tractors during 1948 to 1957 was made by the agricultural sector, and 90 per cent during 1958-90. During the years where data on agricultural machineries and tractors were combined (ie. 1967-80), 10 per cent was deducted from the total value to make the necessary adjustment.

The value of capital services (in current prices) was then computed using the formula:

$$K_t^S = (r+d)K_t \qquad (18)$$

where:

K_t^S = value of capital service in year t,

K_t = deflated value of capital stock in year t,

r = rate of interest (0.10), and

d = depreciation rate (0.062).

The above estimate of the value of capital services in farm equipment includes services from all durable agricultural equipment such as tractors, ploughs, harrows, threshers, etc. However, in this data set, the whole value was assumed to be the value of tractor services. This seems reasonable since tractors apparently account for an average around 90 per cent of total investment in farm equipment.[1]

The next step was to decompose the value of capital services into hand tractor and four-wheel tractor services. This was done by using the same proportions of hand tractor and four-wheel tractor services as that which was used in an earlier study by Evenson and Sardido (1986). These proportions were based on the ratio of annual series of sales for each type available from 1960 to 1974 for hand tractors and from 1955 to 1974 for four-wheel tractors. Since the Evenson-Sardido data set covers only the period up to 1984, the same proportion was used for the remaining years as that of 1984. The price series for both hand tractors and four-wheel tractors were based on common prevailing custom hire rates. The 1948-84 data series was taken from the Evenson-Sardido data set.

4 Estimation and results

4.1 Estimation

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[1] This estimate is based on data for the years 1960-63. Data on the share of tractors for other years was not available

All estimation was performed using non-linear estimation methods. The estimates from a Translog function do not necessarily satisfy the concavity requirement given by condition (iv), above. In this case, the matrix of coefficients of the input variable cross-product terms obtained from estimation of the Translog functional form $B=\left[\beta_{ij}\right]$ can be replaced by the negative of the product of a lower triangular matrix, say C, and its transpose, C^T. That is,

$$B=-CC^T. \tag{19}$$

In the estimation, we express the β_{ij} in terms of its corresponding γ_{mn} terms. The technical index t was defined as exp(t'), where t' is time.

Constant returns to scale cannot be imposed with the Normalised Quadratic (NQ) functional form, and this condition therefore is not necessarily met by our estimates. This fact reduces the value of the resulting set of NQ estimates for the purpose of their potential use within APEX, but the fact that the constraint of constant returns was not imposed means that our comparison between the primal and dual methods is biased *in favour* of the latter. Since we have not forced the dual estimates to satisfy a restriction that the data may not accept (constant returns) it is possible that the dual method could explain the data better than the primal estimates which were required to satisfy this restriction.

4.2. Results

We now ask how the above three sets of estimates compare in terms of predictive performance. For this purpose it is necessary to compare the same variables variables generated by these methodologies. The TLPF and NQPF results can be compared by looking at their predictions of output. For comparisons of these two methodologies our approach is to use the estimated parameters in each case together with the right hand side variables provided by the data to predict the value of industry output (value added). We then compare these predictions with the actual values of industry output reported in the data. Our aim is to find the methodology which produces the smaller prediction error. Both the agricultural and non-agricultural estimation analysis reported below will follow this strategy. We shall use the measure of root mean squared error (RMSE) to make this comparison.

Comparisons of output predictions cannot be used to assess the performance of the TLCF because it does not generate output as a dependent variable. Our approach is therefore to compare factor shares of total costs generated by the TLPF and TLCF methodologies. This cannot be done for the NQPF method because factor shares are not generated by it. By means of these two sets of pair-wise comparisons we can ensure that we are always comparing like with like.

Tables 1 and 2 summarise the comparison between the predictive performance - in terms of output - of the promal (TLPF) and dual (NQPF) estimation methods. Results are shown both with (Table 1) and without (Table 2) the imposition of concavity constraint on the estimates. In so far as the concavity constraint must be imposed on estimates to be used in a general equilibrium model, these are the results of greatest interest, but unconstrained results are shown as well, in Table 2, to verify that the method of imposing concavity has not biased the comparison between the two methods. In both cases the results indicate the clear superiority of the estimates produced by the primal method. The weighted RMSE using the primal approach was in each case roughly one half that resulting from use of the dual approach. Figure 1 summarises these results in the case of the constrained estimates.

We conclude that results obtained with the primal (TLPF) method. Considering that the bias, if any, in our test favoured selection of the dual (NQPF) method - because the dual results were not required to satisfy constant returns to scale - this is strong evidence in support of the superiority of the primal method, at least in so far as these data are concerned.

Table 3 now shows the comparison between the primal (TLPF) method and the dual (TLCF) methods. The comparison is done in terms of factor shares. The result is a victory for the primal results for each factor and hence for any wieghted sum of the factor results (Table 3a).

The reason for the superior results obtained with primal methods may be a combination of factors. First, errors in factor prices may be greater than errors in factor quantities. The consequence of this errors in variables problem is biased estimates of the required parameters and lower predictive power as a result. A second possible source of the inferior performance of the dual method is that the period covered by the data - one year - may be too short for the adjustments represented by the dual method, profit maximising adjustments to changes in factor prices, to be adequately captured; consequently, the variation in the dependent variable, as captured in the data, may not be well related to the variation in the price data which the data set contains. On the other hand, one year may be sufficient for the technical relationship between inputs and outputs to be represented adequately in the data, allowing the production function method to identify this relationship.

4.3. Derived Factor Demand Elasticities

The input demand elasticities were calculated using the relation

$$\eta_{ij} = \sigma_{ij} \cdot S_i . \qquad (20)$$

where,

η_{ij} denotes the cross price elasticity of demand of factor *j* with respect to changes in the price of factor *i;*

σ_{ij} denotes the Allen elasticity of substitution between factor *i* and *j*;

S_i denotes the share of factor *i* in total costs; and the σ_{ij} is calculated from

$$\sigma_{ij} = \frac{|G_{ij}|}{|G|} \qquad (21)$$

where $|G|$ is the determinant of

$$G = \begin{bmatrix} 0 & S_1 & S_2 & S_3 & S_4 & S_5 \\ S_1 & \beta_{11} + S_1^2 - S_1 & \beta_{12} + S_1S_2 & \beta_{13} + S_1S_3 & \beta_{14} + S_1S_4 & \beta_{15} + S_1S_5 \\ S_2 & \beta_{21} + S_2S_1 & \beta_{22} + S_2^2 - S_2 & \beta_{23} + S_2S_3 & \beta_{24} + S_2S_4 & \beta_{25} + S_2S_5 \\ S_3 & \beta_{31} + S_3S_1 & \beta_{32} + S_3S_2 & \beta_{33} + S_3^2 - S_3 & \beta_{34} + S_3S_4 & \beta_{35} + S_3S_5 \\ S_4 & \beta_{41} + S_4S_1 & \beta_{42} + S_4S_2 & \beta_{43} + S_4S_3 & \beta_{44} + S_4^2 - S_4 & \beta_{45} + S_4S_5 \\ S_5 & \beta_{51} + S_5S_1 & \beta_{52} + S_5S_2 & \beta_{53} + S_5S_3 & \beta_{54} + S_5S_4 & \beta_{55} + S_5^2 - S_5 \end{bmatrix} \tag{22}$$

and $|G_{ij}|$ is the cofactor G_{ij} in G. The resulting elasticity values computed from the Translog production function estimation results are the agricultural factor demand elasticities which enter APEX.

5. Does it Matter?

General equilibrium modellers are seldom econometricians as well and tend to be impatient with econometric estimation. They need to be convinced that it matters which estimates are used. We shall explore this matter by examining the sensitivity of experimental results with teh APEX model to changes in the agricultural factor demand elasticities used within it. We use the three sets of factor demand elasticities estimated from the above results and two other which might have been used had 'literature survey' been the source of the parameters used.

We shall repeat an experiment on the economic effects of technical change in Philippine agriculture reported in detail in Warr and Coxhead (1993). In that paper empirically estimated rates and factor biases of technical change are used to simulate their income distributional implications. The model closure and the estimated set of technical change parameters is the for these experiments is identical with that reported in that paper. Technical change shifts factor demand equations through the z terms in

$$f_{vj} = x_j + \sum_{k=1}^{K} \beta_{vkj} w_{kj} - z_j - z_{vj} - \sum_{k=1}^{K} \beta_{vkj} z_{kj} \tag{23}$$

and the effects of these shifts will presumably depend upon the β parameters - the factor demand elasticities which enter this expression. But how sensitive are the results to variations in these parameters within the range of empirically estimated values?

Table 4 summarises the results of these experiments.[2] Effects on factor prices and hence on income distribution are highly sensitive to changes in the factor demand elasticities. It can matter greatly which parameter estimates are used.

6. Conclusions

In this paper we have estimated the parameters required for incorporation into the agricultural component of the APEX general equilibrium model of the Philippine economy, using the available Philippine data. The data were used to explore the respective merits of two methodological approaches, described as the primal approach and the dual approach. The dual approach estimates the required parameters directly, placing factor price data on the right hand side of the estimating equations. The primal approach uses the parameters of the estimated primal production function, and derives the required properties of input demand functions analytically, imposing the assumption of cost minimisation. Primal results proved to have greater predictive power than those obtained using dual methods and these (primal) results were therefore used as the basis for the parameters incorporated into APEX. Experiments simulating the economic effects of technical change in Philippine agriculture showed that model results can be significantly changed by changing the methodology used to estimate supply side parameters such as factor demand elasticities or from using hypothetical values for these parameters.

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[2] The version of APEX used in Warr and Coxhead was later found to contain data base errors which have been corrected in the version of APEX used in these experiments, known as APEX II. These data base imbalances in the earlier version of APEX explain the difference between the Translog production function results reported in this paper and those reported by Warr and Coxhead.

References

Arsenio M. Balisacan, 1993. "Agricultural Growth, Landlessness, Off-farm Employment, and Rural Poverty in the Philippines", *Economic Development and Cultural Change*, Vol. 41, pp.533-562.

Bhanoji Rao, . V.V., 1988. "Income Distribution in East Asian Developing Countries", *Asian-Pacific Economic Literature*, Vol. 2, pp.26-45.

Bantilan, Cynthia, 1989. "Production in Philippine Rice Monculture", paper presented at the Symposium on Quantitative Analysis of Agricultural Development, August 18, Philippine Institute of Development Studies, Makati, The Philippines (mimeo.).

Bautista, Romeo M., 1986. "Effects of increasing productivity in a multisectoral model for the Philippines", *Agricultural Economics*, Vol. 1, pp. 67-82.

Chowdhury S. Ahammed, and Robert W. Herdt, 1983. "Farm mechanisation in a semi-closed input-output model: the Philippines", *American Journal of Agricultural Economics*, Vol.65, pp. 516-525.

Codsi, George, K.R. Pearson and Peter J. Wilcoxen, 1991."General Purpose Software for Intertemporal Modelling", *Impact Working Paper* , No.IP-51 University of Melbourne, Melbourne, Victoria, Australia (May).

Coxhead, Ian A., 1992. " Environment-specific Rates and Biases of Technical Change in Philippine Agriculture", *American Journal of Agricultural Economics*, Vol. 74, pp.592-562.

____________ and Peter G. Warr, 1991. "Technical Change, Land Quality and Income Distribution: A General Equilibrium Analysis", *American Journal of Agricultural Economics*,, Vol. 73 , pp. 345-360.

___________ and Peter G. Warr, 1992. "Does Technical Change in Agriculture Reduce Poverty?", *Australian Journal of Agricultural Economics*, forthcoming.

David, Cristina C. and Keijiro Otsuka (eds.) 1994. *Modern rice Technology and Income Distributin in Asia*, Lynne reiner Publishers, Boulder, Colorado.

Diewert, W. and T. Wales 1987, "Flexible Functional Forms and Global Curvature Conditions", Econometrica 55, 43-68.

Dixon, Peter B., B. R. Parmenter, John Sutton and D.P. Vincent, 1982. *ORANI; A Multisectoral Model of the Australian Economy*, North-Holland Publishing Company, Amsterdam.

Evenson, Robert E., and Moises L. Sardido, 1986. "Regional Total Factor Productivity Change in Philippine Agriculture" *J. Phil. Development* , Vol. 13, pp. 40-61.

Falcon, Walter P., 1970. "The Green Revolution: Generations of Problems", *American Journal of Agricultural Economics*, Vol. 52, pp.698-710.

Fuss, M., 1977, "The Demand for Energy in Canadian Manufacturing: An Example of the Estimation of Production Structures with Many Inputs", *Journal of Econometrics*, 5, 89-116.

Gotsch, Carl H., 1972. "Technical Change and the Distribution of Income in Rural Areas", *American Journal of Agricultural Economics*, Vol. 54, pp.326-341.

Hayami, Yujiro and Robert W. Herdt, 1977. "Market price effects of technological change on income distribution in subsistence agriculture", *American Journal of Agricultural Economics*, Vol. 59, pp. 245-256.

Hayami, Yujiro and Vernon W. Ruttan, 1985. *Agricultural Development: An International Perspective,* Johns Hopkins University Press, Baltimore.

Lawrence, D and J. Zeitsch 1989 "Production Flexibility Revisited",Contributed paper to the Thirty-third Conference of the Australian Agricultural Economics Society, Christchurch, New Zealand, 7-9 February 1989.

Quizon, Jaime B. and Hans P. Binswanger, 1983. "Income distribution in agriculture: a unified approach", *American Journal of Agricultural Economics,* Vol. 65, pp. 526-538.

Timmer. C. Peter, 1988. "The Agricultural Transformation" in Hollis Chenery and T. N.. Srinivasan, eds. *Handbook of Development Economics*, Vol. 1, North Holland, Amsterdam.

Warr Peter G. and Ian A. Coxhead, 1993 'The Distributional Impact of Technical Change in Philippine Agriculture: A General Equilibrium Analysis' *Food Research Institute Studies*, vol.22, 253-274.

Wiley, D., W. Schmidt and W. Bramble 1973, "Studies of a Class of Covariance Structure Models", *Journal of the American Statistical Association* 68, 317-23.

Table 1: Output Forecasts from Constrained Functions:
PRIMAL (TLPF) vs. DUAL (NQPF):

Year	Actual	Translog	N-Quadratic
1957	1.1269	1.1558	1.2774
1958	1.1560	1.1321	1.2603
1959	1.2031	1.2029	1.2578
1960	1.2092	1.2061	1.2989
1961	1.1956	1.2773	1.3480
1962	1.3127	1.3472	1.3566
1963	1.3594	1.3535	1.3783
1964	1.3773	1.3794	1.4209
1965	1.3894	1.4241	1.4326
1966	1.4073	1.4965	1.4786
1967	1.4720	1.5372	1.5308
1968	1.5500	1.5170	1.5574
1969	1.5445	1.5954	1.5980
1970	1.7130	1.6396	1.6328
1971	1.8103	1.7403	1.6812
1972	1.7789	1.7799	1.7915
1973	1.7844	1.7571	1.7838
1974	2.0253	1.9623	1.8125
1975	2.2460	2.0781	1.8177
1976	2.5529	2.6220	2.5484
1977	2.5712	2.6547	2.6596
1978	2.7842	2.7616	2.6147
1979	2.8910	2.8169	2.7082
1980	3.1525	2.8229	2.7669
1981	3.1627	3.0183	2.8175
1982	3.2606	3.0527	2.8110
1983	3.0965	3.0532	2.9458
1984	2.9896	3.0607	3.0802
1985	3.0716	3.1458	3.2046
1986	3.1391	3.2796	3.2937
1987	3.0359	3.2534	3.4070
1988	3.1165	3.2748	3.5803
1989	3.2327	3.2638	3.6404

Table 1a: Statistical Properties of the Forecasts

Statistics	Actual	Translog	N-Quadratic
Mean	2.1430	2.1413	2.1452
Variance	0.6388	0.6311	0.6383
Minimum	1.1269	1.1321	1.2578
Maximum	3.2606	3.2796	3.6404
Corr. with Actual	1.0000	0.9910	0.9641
RMSE (Forecast)	0.0000	0.1053	0.2110
RMPE(Forecast)	0.0000	0.0410	0.0832

Table 2: Output Forecasts from Unconstrained Functions
PRIMAL (TLPF) vs. DUAL (NQPF)

Year	Actual	Translog	N-Quadratic
1957	1.1269	1.0643	0.9519
1958	1.1560	1.1323	1.0779
1959	1.2031	1.2023	1.2570
1960	1.2092	1.2082	1.2774
1961	1.1956	1.2810	1.1810
1962	1.3127	1.3501	1.1724
1963	1.3594	1.3559	1.4166
1964	1.3773	1.3813	1.3869
1965	1.3894	1.4261	1.4405
1966	1.4073	1.5004	1.5864
1967	1.4720	1.5399	1.5667
1968	1.5500	1.5218	1.6160
1969	1.5445	1.6020	1.6653
1970	1.7130	1.6431	1.6871
1971	1.8103	1.7425	1.7466
1972	1.7789	1.7805	1.8282
1973	1.7844	1.7588	2.1699
1974	2.0253	1.9632	1.8866
1975	2.2460	2.0823	1.9567
1976	2.5529	2.6129	2.6904
1977	2.5712	2.6454	2.6095
1978	2.7842	2.7557	2.8586
1979	2.8910	2.8124	2.8404
1980	3.1525	2.8208	2.8851
1981	3.1627	3.0215	2.8689
1982	3.2606	3.0563	2.9599
1983	3.0965	3.0436	3.0846
1984	2.9896	3.0673	3.1797
1985	3.0716	3.1498	3.1582
1986	3.1391	3.2902	3.1377
1987	3.0359	3.2642	3.1308
1988	3.1165	3.2870	3.2377
1989	3.2327	3.2796	3.2681

Table 2a. Statistical Properties of the Forecasts

Statistics	Actual	Translog	N-Quadratic
Mean	2.1430	2.1407	2.1449
Variance	0.6388	0.6388	0.6232
Minimum	1.1269	1.0643	0.9519
Maximum	3.2606	3.2902	3.2681
Corr. with Actual	1.0000	0.9907	0.9819
RMSE (Forecast)	0.0000	0.1076	0.1492
RMPE(Forecast)	0.0000	0.0426	0.0745

Table 3: Factor Share Forecasts from Constrained Functions: PRIMAL (TLPF) vs DUAL (TLCF)

A. PRIMAL (Translog Production Function)

Statistic	Predicted Values (Shares)			
	Labour	Machinery	Fertilizer	Land
Mean	0.4634	0.024	0.0335	0.4792
Variance	0.0323	0.0000025	0.000068	0.0293
Minimum	0.2911	0.0199	0.00599	-0.1412
Maximum	1.1141	0.0272	0.0419	0.643
RMSE	0.0887	0.005	0.0072	0.0861
RMPE	0.1914	0.2087	0.2145	0.1798
R-square between observed and predicted :				
	0.8375	0.1249	0.6101	-
Correlation with Actual .				
	0.8794	0.0588	0.7243	0.8746

B. DUAL (Translog Cost Function)

Statistic	Predicted Values (Shares)			
	Labour	Machinery	Fertilizer	Land
Mean	0.4727	0.0237	0.0339	0.4698
Variance	0.0262	0.0000056	0.000087	0.024
Minimum	0.3145	0.0158	0.0156	-0.1521
Maximum	1.1106	0.0278	0.0457	0.6198
RMSE	0.1021	0.0051	0.0086	0.1024
RMPE	0.2159	0.2142	0.2535	0.218
R-square between observed and predicted				
	0.7905	0.1164	0.5427	-
Correlation with Actual :				
	0.8345	0.1501	0.6217	0.8154

C. Actual Values

Statistic	Actual Values (Shares)			
	Labour	Machinery	Fertilizer	Land
Mean	0.4581	0.024	0.0335	0.4844
Variance	0.0034	0.000024	0.00011	0.0312
Minimum	0.269	0.0124	0.0086	0.1053
Maximum	0.8538	0.0322	0.0547	0.6653

Table 3a: RMSE AND RMPE from the four share equations combined

A WEIGHTED BY FACTOR SHARES

	PRIMAL	DUAL
RMSE	0.08270	0.09678
RMPE	0.18697	0.21814

B NON-WEIGHTED

	PRIMAL	DUAL
RMSE	0.06197	0.07246
RMPE	0.24788	0.28983

Table 4: Sensitivity analysis with non-neutral technical change

	Underlying functional forms for the elasticity estimates*				
				CES	
	TLPF	TLCF	NQPF	σ=0.5	σ=1.0
Real GDP					
at market price	0.520	0.671	0.110	0.212	0.199
at factor cost	0.087	0.063	0.152	0.122	0.127
Real aggregate consumption	0.644	0.828	0.148	0.268	0.252
Consumer price index (CPI)	-0.524	-0.590	-0.368	-0.479	-0.454
Real wages					
unskilled labour	-2.376	-2.643	-0.091	-0.819	-0.960
skilled labour	2.069	2.594	-0.159	0.605	0.615
Relative wages (skilled/unskilled)	4.445	5.237	-0.068	1.424	1.575
Real consumption expenditure by households					
HH1 (poor)	0.204	0.322	0.348	0.289	0.239
HH2	0.269	0.402	0.280	0.258	0.216
HH3	0.314	0.460	0.226	0.233	0.193
HH4	0.343	0.508	0.174	0.207	0.163
HH5 (rich)	1.044	1.271	0.052	0.307	0.324
Output supply					
Irrigated Palay	3.216	3.562	2.376	2.716	2.646
Non-irrigated palay	-4.219	-3.927	-4.935	-4.654	-4.710
Corn	1.323	1.640	0.539	0.853	0.790
Aggregate agricultural commodity	1.147	1.614	0.002	0.483	0.384
Aggregate agricultural processing commo	0.721	0 985	0.044	0.306	0.258
Producer price					
Palay	-13.684	-14.851	-10.978	-12.274	-11.975

* The underlying functional forms for the estimation of factor demand elasticities in agricul

TLPF: Translog production function

TLCF: Translog cost function

NQPF: Normalized quadratic profit function

CES: Constant elasticity of substitution

Figure 1: Out-of-Sample Output Forecasts:
Translog Production Function vs. Normalised Quadratic
Profit Function

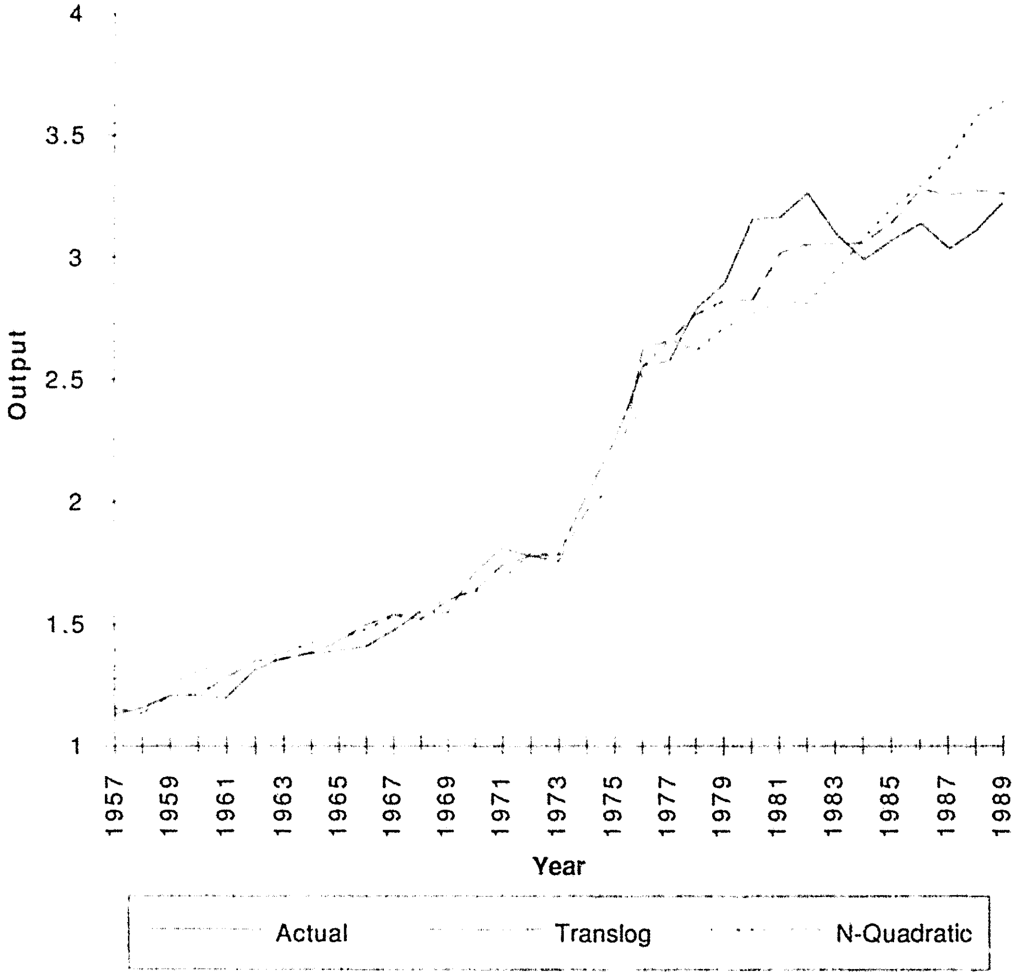


Figure 2: Philippines: Actual vs. predicted shares for labour in agriculture using Translog Cost Function

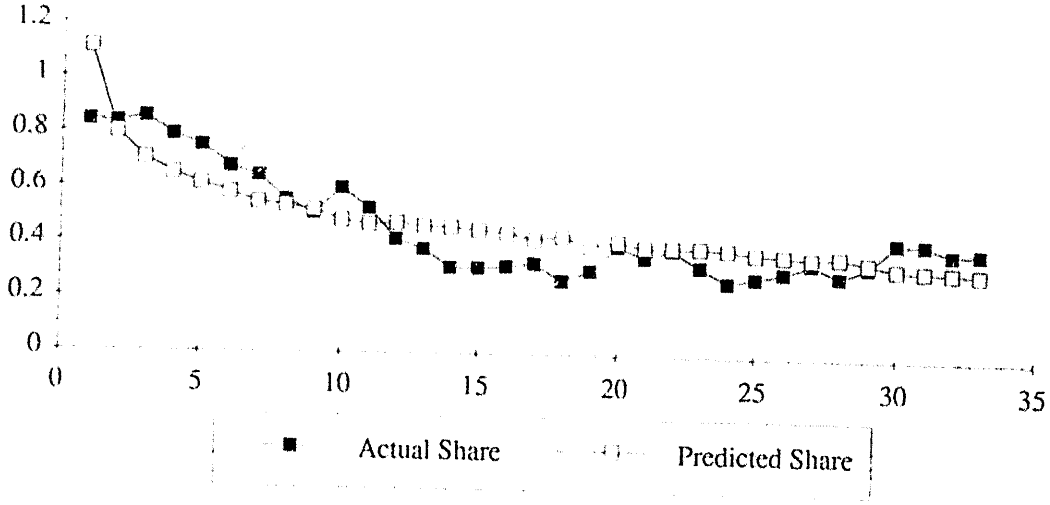


Figure 2a: Philippines: Actual vs. predicted shares for labour in agriculture using Translog Production Function

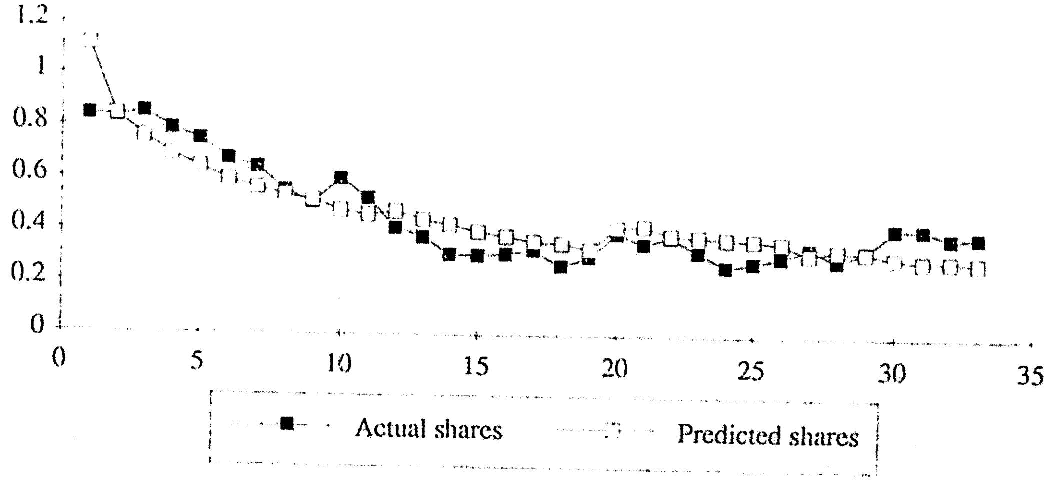


Figure 3: Philippines: Actual vs. predicted shares for machinery in agriculture using Translog Cost Function

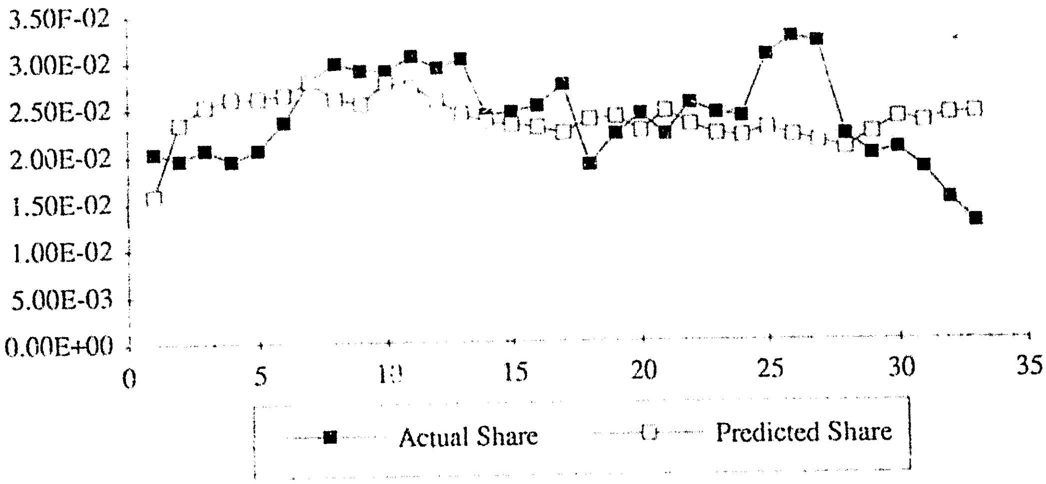


Figure 3a: Philippines: Actual vs. predicted shares for machinery in agriculture using Translog Production Function

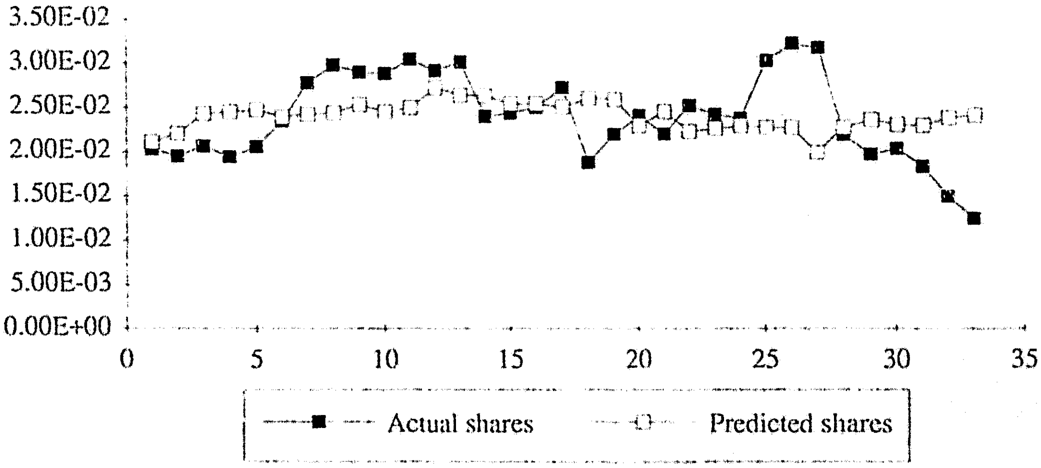


Figure 4: Philippines: Actual vs. predicted shares for fertilizer in agriculture using Translog Cost Function

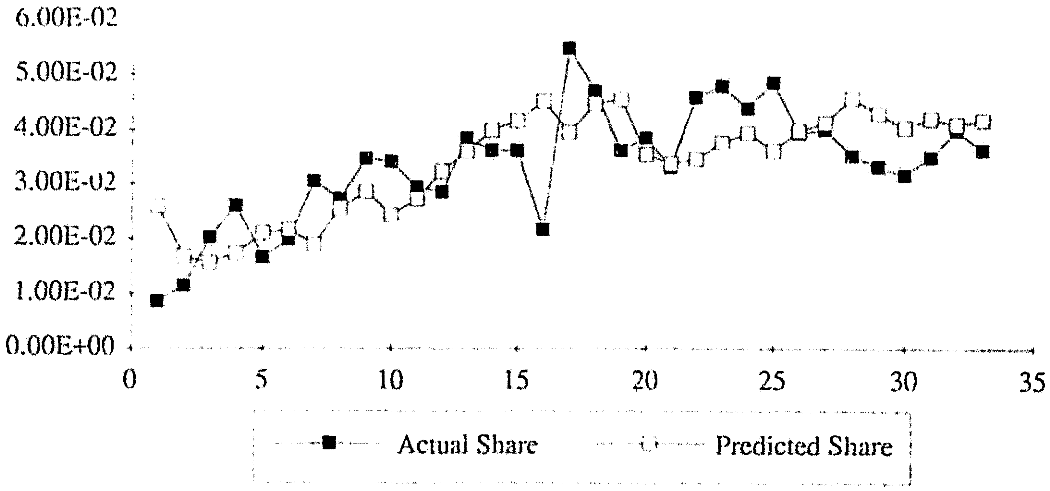


Figure 4a: Philippines: Actual vs. predicted shares for fertilizer in agriculture using Translog Production Function

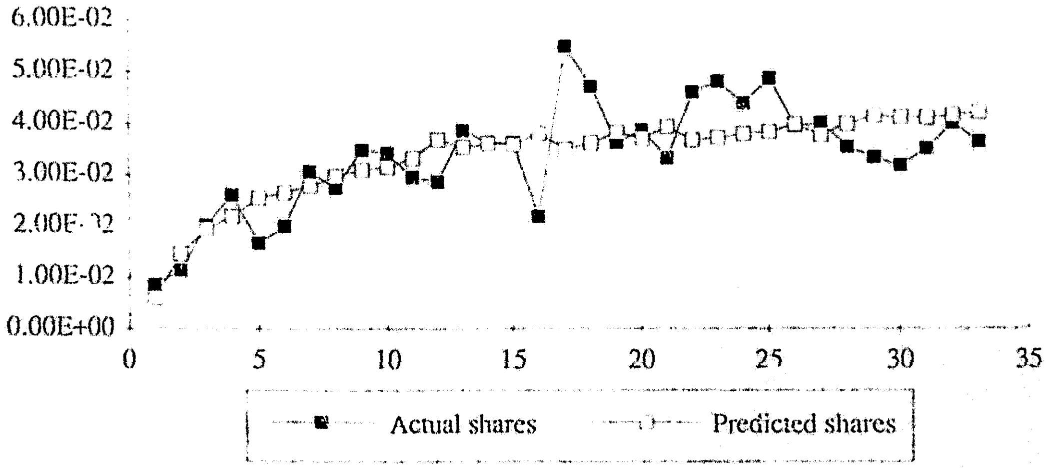


Figure 5. Philippines: Actual vs. predicted shares for land in agriculture using Translog Cost Function

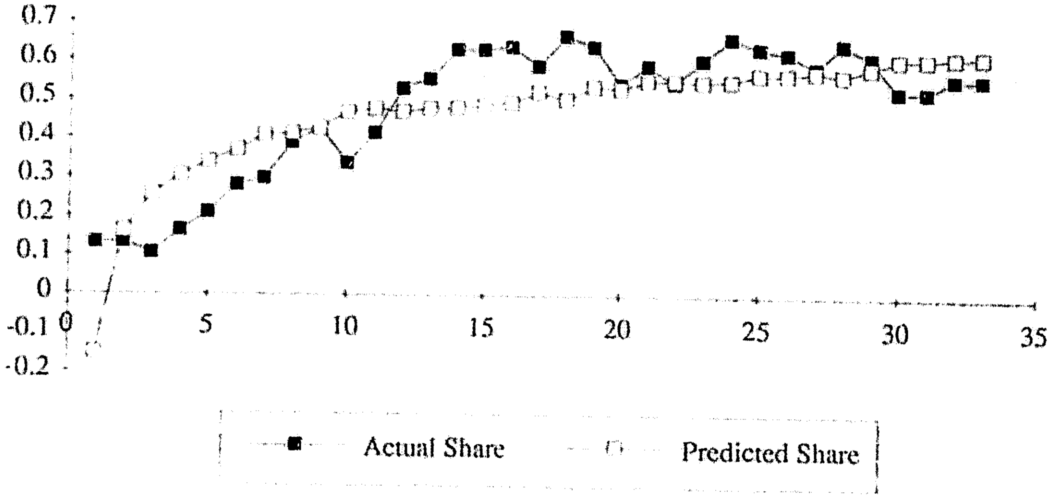


Figure 5a: Philippines: Actual vs. predicted shares for land in agriculture using Translog Production Function

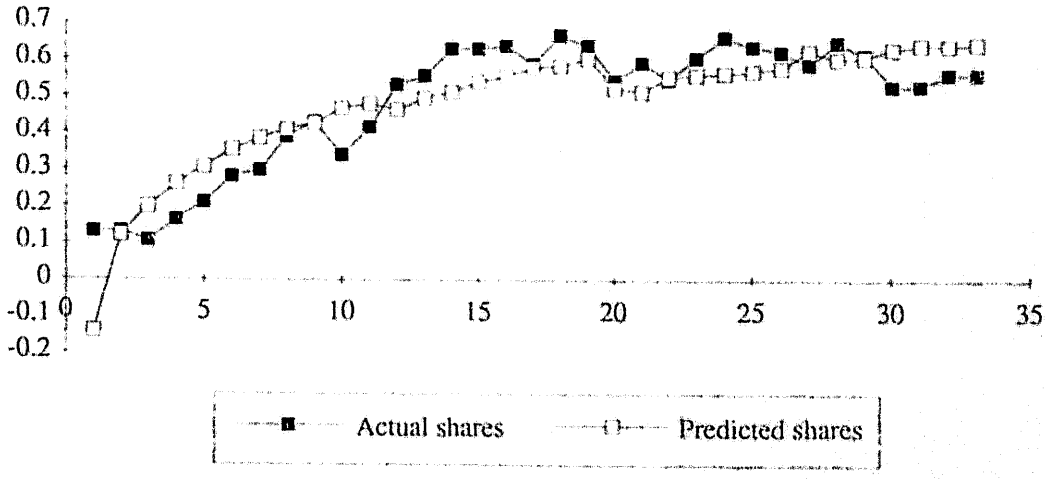
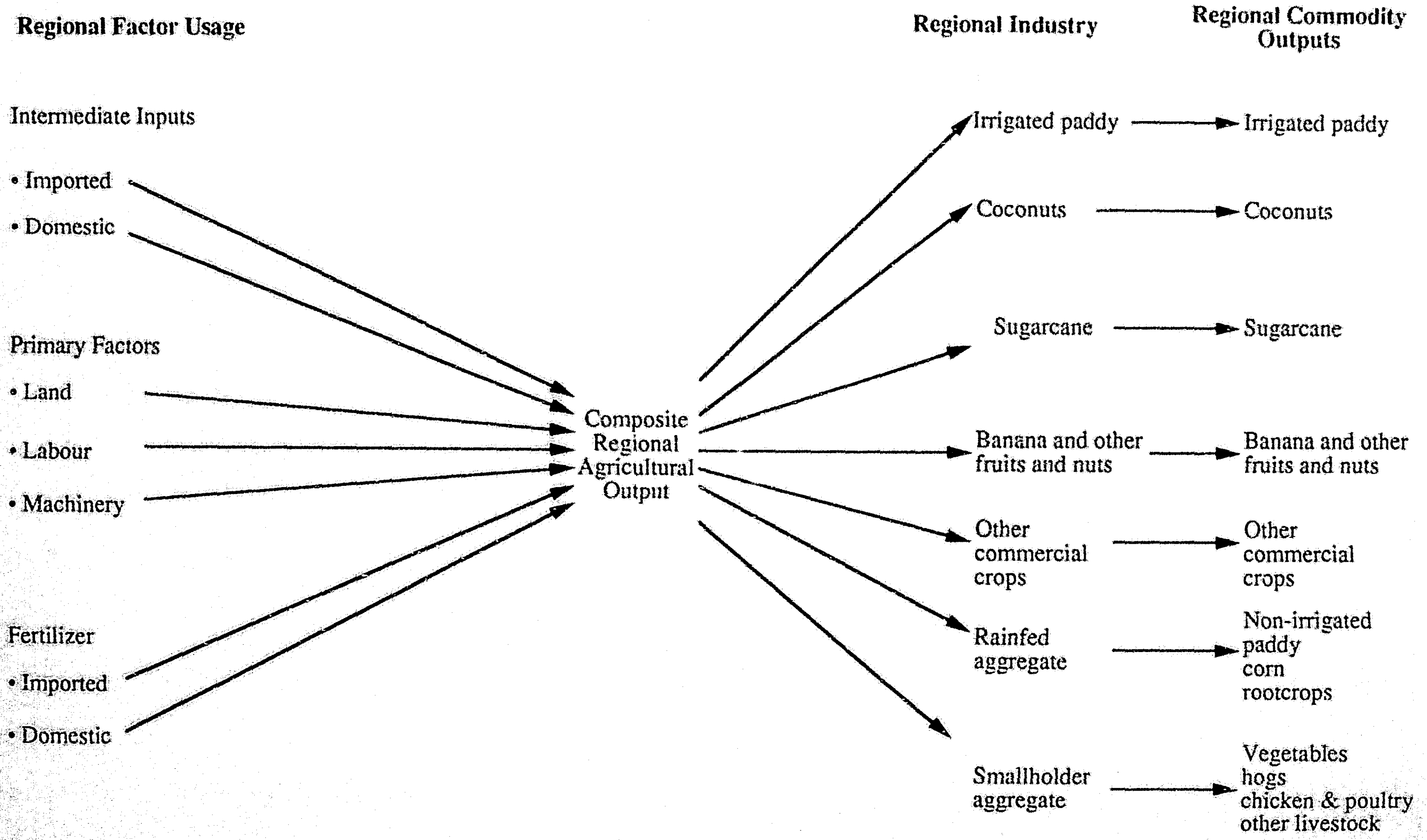


FIGURE A.1 AGRICULTURAL PRODUCTION IN EACH REGION:

- *LUZON*
- *VISAYAS*
- *MINDANAO*



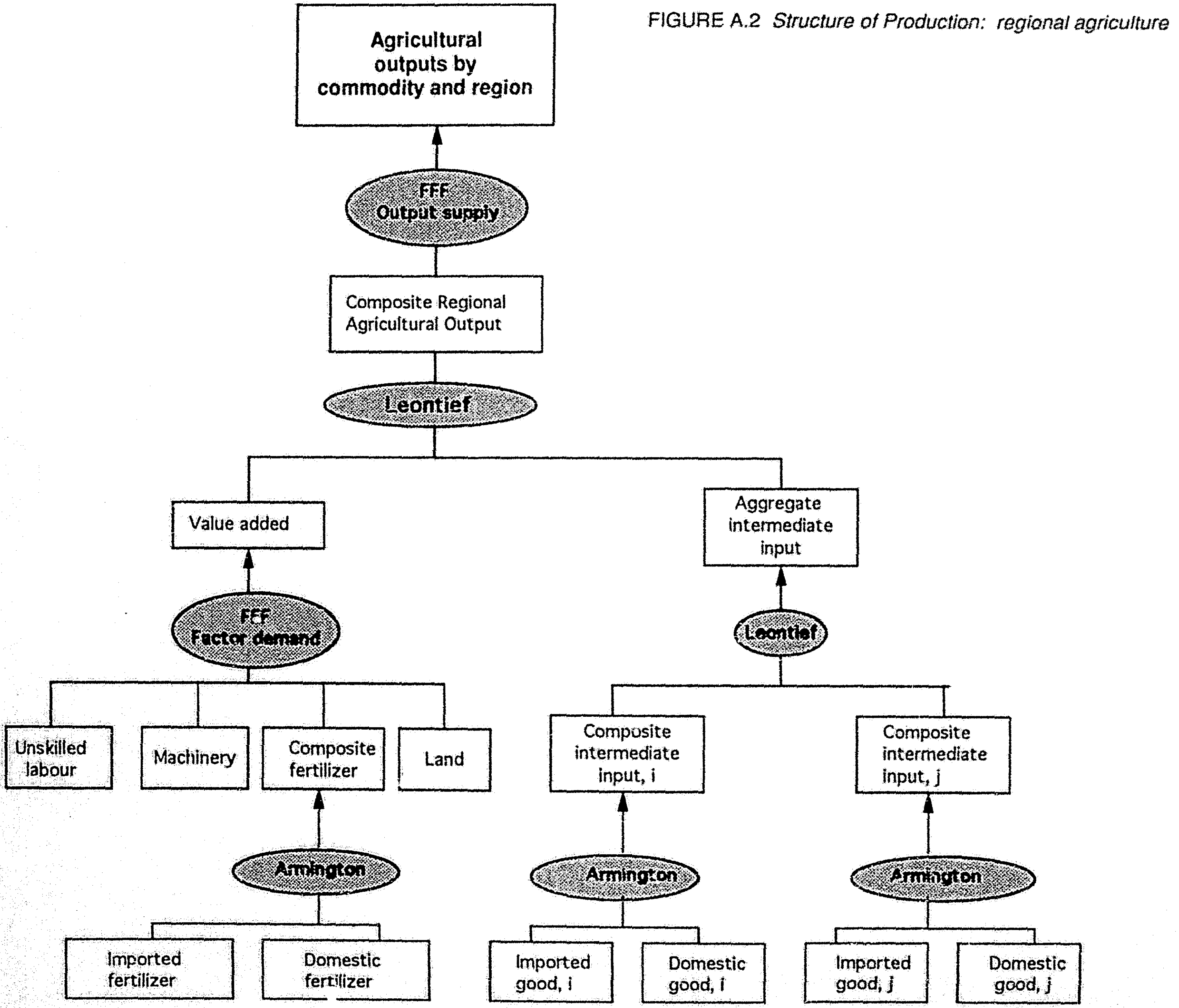


FIGURE A.2 *Structure of Production: regional agriculture*