Estimation of Elasticities of Factor Substitution

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1.Introduction

This paper reports the econometric estimation of the factor demand parameters which enter the elasticities file for PARA. The values of these supply side parameters are crucial for the performance of general equilibrium systems like PARA and it is therefore appropriate that we report their estimation in detail. Most general equilibrium models constructed to date are weak as regards the empirical basis for the supply side parameters that are actually used. Parameters are typically based upon what the authors describe as 'literature review', which all too frequently proves to mean that they have very little 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.

The paper is divided into three major parts. The first concerns the interpretation of the parameters required and some technical issues involved in their estimation. The next two parts are concerned with the empirical estimation of the required parameters relating to agricultural and non-agricultural production in Thailand, respectively. The reason for the dichotomy between agricultural and non-agricultural production is that the data are available for estimation are distinct for these two sets of industries. In the econometric literature, different methodologies have been used for the estimation of the parmeters of interest in this paper and the results of estimation can be sensitive to the methods employed. Choice of the appropriate estimation methodology is therefore a necessary theme of the paper. Our principal purpose in this paper is to document the set of estimates that was eventually selected for use in the PARA data base, but it is also important to explain why alternative possible methodologies were *not* used.

Section 2 reviews the economic issues involved in this estimation work and Section 3 discusses the econometric estimation issues involved. Sections 4 and 5 then discuss the estimation of the required parameters for agriculture and non-agriculture, respectively. Each of these sections is divided into discussion of the data used, results and conclusions on the parameter values to be used in PARA. Section 6 summarises the overall conclusions.

2. Interpretation

Consider the conditional factor demand equation

$$F_{vj} = \varphi^{vj}(X_j, W_j), \tag{1}$$

where F_{vj} denotes the level of demand for factor v in industry j, X_j denotes the output of industry j and W_j denotes the vector of factor prices (returns) faced by industry 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,

$$dF_{vj} = \varphi_X^{vj} dX_j + \sum_k \varphi_k^{vj} dW_{kj} . \tag{2}$$

Now, dividing by F_{vj} and rearranging terms

$$f_{vj} = \beta_{vxj} x_{vj} + \sum_k \beta_{vkj} w_{kj} , \tag{3}$$

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 industry j with respect to the output of that industry and the price of factor k, respectively. Property (i) above requires that $\beta_{vxj}=1$ and property (ii) requires that

$$\sum_k \beta_{vkj} = 0. \tag{4}$$

The basic structural equations of PARA for which parameter estimates are required are given by equations (1.1.2) and (1.2.2) of the equation set, which in simplified notation is:

$$f_{vj} = x_j + \sum_k \beta_{vkj} w_j \tag{5}$$

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 industry j, and we require that these estimates are consistent with properties (i) to (iv), above.

3. Methodology

The most popular methodology currently used for estimation of factor demand equations such as (5) 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 output 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 PARA will then be made on the basis of these econometric results.

3.1 Selection of Functional Forms

The functional forms used are:

(i) *Primal Approach*

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

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

$$+\sum_{i=1}^{K}\alpha_i \ln X_i + \frac{1}{2}\sum_{i=1}^{K}\sum_{j=1}^{K}\beta_{ij}\ln X_i \ln X_j, \tag{6}$$

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

$$S_i = \alpha_i + \sum_{j=1}^{K}\beta_{ij}\ln X_j + \alpha_{it}\ln t, \qquad i = 1,2,\ldots,K \tag{7}$$

where

$$S_i = \frac{\partial \ln V}{\partial \ln X_i} = \frac{\partial V}{\partial X_i}\cdot\frac{X_i}{V} = \frac{P_{Xi}}{P_v}\cdot\frac{X_i}{V}. \tag{8}$$

The equations used for estimation are these share equations (7), jointly with the full production function given by (6).

(ii) *Dual Approach*

We esimate the parameters of the Normalized Quadratic profit function (NQPF), given by

$$\pi_t = \alpha_0 + \sum_{i=1}^{K}\alpha_i\frac{w_{it}}{p_t} + \frac{1}{2}\sum_{i=1}^{K}\sum_{j=1}^{K}\alpha_{ij}\frac{w_{it}}{p_t}\frac{w_{jt}}{p_t}, \tag{9}$$

using output as numeraire. Differentiating (9) with respect to the output price p_t and input price w_{it} we obtain the output supply and input demand functions implied by this functional form:

$$y_t = \alpha_0 - \frac{1}{2}\sum_{i=1}^{K}\sum_{j=1}^{K}\alpha_{ij}\frac{w_{it}}{p_t}\frac{w_{jt}}{p_t}$$

(10)

and

$$-x_{it} = \alpha_i + \sum_{j=1}^{K} \alpha_{ij} \frac{w_{jt}}{p_t}, \qquad i = 1,2,\dots,K.$$

(11)

The equations used for estimation are the input demand equations (11), jointly with the output supply equation given by (10).

3.2 Selection of Primal vs. Dual Functional Form

We wish to determine whether a primal or dual approach to deriving the required elasticities is more consistent with the available data for Thailand. Our procedure is to estimate both primal and dual functional forms, as above. We then ask which of these functional forms is more consistent with the data. For this purpose it is necessary to compare variables generated by both 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.

4. Estimation for the Agricultural Sectors

4.1 Data

The data used for estimation purposes for the agricultural sector were derived from two sources. The first is the annual (crop year) production and farm gate prices of the principal crops produced in Thailand. The data cover the 13 years 1977 to 1989 and include information on the following nine crops, with their PARA industry codes shown in parentheses:

paddy (1),

cassava (3),

maize (2),

sugarcane (7),

cotton (10),

kenaf (9),

groundnut (5),

mungbean (6),

sorghum (8), and

soybeans (4).

Information is available separately for each of the four principal agricultural regions of Thailand:

North-east,

North,

Central, and

South.

The source of these data is the Center for Agricultural Statistics, Office of Agricultural Economics of Thailand's Ministry of Agriculture and Cooperatives.

The second data source is the use of primary factors in crop production and their farm gate prices. The factors of production defined in the data are:

unskilled labour,

animal power,

tractors,

fertilizers, and

land.

Factor use is available for each of the above factors by crop, as defined above and for each of the above four regions. The years covered are again 1977to 1989. The units of primary factors used in compiling these data in consistent form followed the following conventions:

1 year = 300 man days

1 man day = 8 hours

1 tractor = 1,500 hours use per year.

Prices were available for each of the above factors except land. The source of these data was the Annual Cost Survey conducted by the Office of Agricultural Economics of Thailand's Ministry of Agriculture and Cooperatives. The cost survey data gave the use of each factor per rai (unit of area) on each crop. These were combined with data on the total area of each crop in each year, from Agricultural Statistics of Thailand, Office lof Agricultural Economics, to obtain the total use of each factor on each crop in each region in each year.

To create sufficient degrees of freedom to make estimation possible, these data were normalised by output and then pooled. Regional dummy variables were used to capture variation between the above four regions. To match the categories of primary factors used in PARA the data were on animal power and tractors were aggregated into a single category. This might best be called draft power, but for simplicity we shall subsequently refer to it as 'tractors'. Data were available on the quantities of all factors and on the prices of all but land. The price of land was treated as a residual in our analysis.

4.2 Estimation

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 of equation (6), obtained from estimation of the Translog functional form $B = [\beta_{ij}]$ can be replaced by the negative of the product of a lower triangular matrix, say C, and its transpose, C^T. That is,

$$B = -CC^T, \tag{11}$$

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 PARA, 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.

4.3 Results

Tables 1 and 2 summarise the comparison between the predictive performance of the primal and dual estimation methods. Estimation was possible for nine agricultural commodities. The primal method out-performed the dual for all commodities but one - mungbeans. In the case of mungbeans, a single, possibly erroneous observation proved to be responsible for the difference in results. Table 2 also compares the weighted average root mean squared prediction error (RMSE) across all nine commodities, using sectoral shares of the value of output, evaluated at the midpoint of the data set as weights. The weighted RMSE using the primal approach was roughly 0.16, while the same statistic using the dual approach was around one third higher, at 0.22.

Figures 1 to 4 summarise these results for four commodities, chosen for their significance in the value of total agricultural output. These are the first four commodities listed in Tables 1 and 2: paddy, cassava, maize and sugar. Figure 1 shows the actual output of paddy in each region, over the time period covered by the data set, compared with the simulated output obtained from the estimated results obtained with the primal approach (Translog production function), in panel (a), and the dual approach, (Normalised Quadratic profit function), in panel (b). In these figures, 'Y' denotes actual output levels, while 'YHAT-PRIMAL' and 'YHAT-NQ' denote simulated output derived from the primal (Translog) and dual (NQ) sets of estimates, respectively. It is apparent from comparison of the two panels that the primal results are more compatible with the data. Figures 2 to 4 present the results of analagous simulation exercises for cassava, maize and sugar, respectively. Similar conclusions can be drawn. The primal approach produces better predictions of output.

We conclude that results obtained with the primal method. Considering that the bias, if any, in our test favoured selection of the dual 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. The reason for the difference 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 poorer 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 adequtely in the data, allowing the production function method to identify this relationship.

It should be noted, however, that the output prediction obtained from the primal and dual methods are highly correlated. This is shown in Table 3. For each commodity, the correlation coefficient between the output predictions obtained from the two methodologies, pooled across regions, exceeds the critical value of that correlation coefficient at the 5 per cent level of significance.

4.3 Estimation of Factor Demand Elasitcities

The input demand elasticities were calculated using the relation

$$\eta_{ij} = \sigma_{ij} \cdot S_i, \tag{12}$$

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

$$\sigma_{ij} = \frac{|G_{ij}|}{|G|}$$

(13)

where $|G|$ is the determinant of

$$G = \begin{bmatrix} 0 & S_1 & S_2 & S_3 & S_4 & S_5 \\ S_1 & \beta_{11} + S_1^2 - S_1 & \beta_{12} + S_1 S_2 & \beta_{13} + S_1 S_3 & \beta_{14} + S_1 S_4 & \beta_{15} + S_1 S_5 \\ S_2 & \beta_{21} + S_2 S_1 & \beta_{22} + S_2^2 - S_2 & \beta_{23} + S_2 S_3 & \beta_{24} + S_2 S_4 & \beta_{25} + S_2 S_5 \\ S_3 & \beta_{31} + S_3 S_1 & \beta_{32} + S_3 S_2 & \beta_{33} + S_3^2 - S_3 & \beta_{34} + S_3 S_4 & \beta_{35} + S_3 S_5 \\ S_4 & \beta_{41} + S_4 S_1 & \beta_{42} + S_4 S_2 & \beta_{43} + S_4 S_3 & \beta_{44} + S_4^2 - S_4 & \beta_{45} + S_4 S_5 \\ S_5 & \beta_{51} + S_5 S_1 & \beta_{52} + S_5 S_2 & \beta_{53} + S_5 S_3 & \beta_{54} + S_5 S_4 & \beta_{55} + S_5^2 - S_5 \end{bmatrix}$$

(14)

and $|G_{ij}|$ is the cofactor G_{ij} in G.

The resulting elasticity values computed from the Translog estimation results are presented in Table 4. These are the agricultural factor demand elasticities which enter PARA. Of the 20 agricultural industries defined within PARA, usable estimates were obtained for the nine industries shown in Table 4. Within the PARA industry code, these are industries (1) through (10) except for (9), kenaf and jute. Elasticities for the other 11 commodities were set equal to estimated elasticities for industries which seemed most likely to be similar.[1]

5. Estimation for the Non-agricultural Sectors

5.1 Data

(a) The raw data

The main source of data used was the annual Industrial Survey for Thailand. The data set contains the following variables:

1. tsic - industry code (TSIC)

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[1] These 11 industries, and the industries whose estimated values were used in their place (the latter shown in parentheses) were: 9 (3); 11 (3); 12 (7); 13 (7); 14 (4); 15 (4); 16 (10); 17 (3); 18 (10); 19 (10); 20 (10).

2. year
3. region - Bangkok and the rest of Thailand
4. size - 20 or more persons engaged and 10-19 persons
5. npersons - total number of persons engaged
6. wages - total wages and salaries paid
7. vadded - value added
8. male - number of male employees
9. female - number of female employees
10. vassets - book value of fixed assets
11. vland - book value of land
12. vbldg - book value of buildings
13. vmach - book value of machinery and equipments
14. vvhcl - book value of vehicles
15. vothers - book value of other fixed assets
16. tdeprc - total depreciation for fixed assets
17. dbldg - depreciation for buildings and other constructions
18. dmach - depreciation for machinery and equipments
19. dvhcl - depreciation for vehicles
20. dothers - depreciation for other fixed assets

(b) Construction of data for estimation

For output

Prices - The prices used were the implicit price indices for gross domestic product originating from manufacturing as reported in National lEconomic and Social Development Board, *National Income of Thailand,* various issues.

Quantity - obtained by dividing the value added which is available from the Industrial Survey by the implicit price indices.

For factors

LABOUR

Quantity - no. of persons engaged.

Price - ratio of total wages and salaries paid to the no. of persons employed

CAPITAL (Land, Vehicle, Building and Constructions, Machinery and Equipment)

Prices were computed for each item of capital as follows:

$$P_i = (r^* + d_i)A_i \qquad (15)$$

where

r^* denotes the real discount rate (real Treasury Bill Rates),

d_i: denotes the depreciation rate = depreciation cost / book value of fixed assets, and

A_i denotes the asset price (implicit price indices for GFCF in construction, machinery and vehicles).

Quantities were computed from

$$Q_i = V_i / A_i \qquad (16)$$

where V_i is the book value of capital item i (after deducting the accumulated depreciation).

Hence, the cost of capital item i is :

$$R_i = Q_i * P_i = V_i(r^* + d_i).$$

(17)

All price indices used 1976 as the base year. In the estimation, the factors were grouped into:

1. labour
2. land and buildings,
3. machinery and vehicles

Land and buildings, and also machinery and vehicles were aggregated using the following method:

For land and buildings:

$$P = (R_{land} / (R_{land} + R_{bldg})) * P_{land} + (R_{bldg} / (R_{land} + R_{bldg})) * P_{bldg}$$

(18)

$$Q = (R_{land} + R_{bldg}) / P$$

(19)

For machinery and vehicles:

$$P = (R_{mach} / (R_{mach} + R_{vhcl})) * P_{mach} + (R_{vhcl} / (R_{mach} + R_{vhcl})) * P_{vhcl}$$

(20)

$$Q = (R_{mach} + R_{vhcl}) / P$$

(21)

5.2 Estimation

Primal method

The following translog share equations were estimated using IZEF:

$$S_i = \alpha_i + \sum_{j=1}^{3} \gamma_{ij} \ln X_j + \alpha_{it} \ln t + \sum_{j=1}^{NI-1} \delta_{ij} DI_j + \lambda_{i1} DR_i + \lambda_{i2} DS_i$$

(22)

where:

$i = 1$ (Labour), 2 (Buildings and Land), 3 (Machinery and vehicles)

NI = no. of industries in the sector of interest

S_i = cost share of capital item i

DI - dummies for the industries

DR - dummy for the regions

DS - dummy for the size of firms

Note that only 2 of the 3 share equations were actually estimated. Symmetry restrictions and constant returns to scale (CRTS) were imposed in the estimation. The Translog parameters in the residual share equation which was not estimated were computed using the estimated parameters of the two estimated equations and using the following restrictions imposed by CRTS:

$$\sum_i \alpha_i = 1; \qquad \sum_i \gamma_{ij} = \sum_j \gamma_{ij} = 0$$

(23)

The Allen partial elasticities of substitution and output compensated input demand elasticities were computed as in equations (12) to (14) above.

Dual nethod

The Normalised Quadratic functional form was estimated as described for the agricultural estimation above.

5.3 Results

(a) Comparison of Primal and Dual Performance

The Normalized Quadratic dual method performed very poorly with Thai manufacturing data, compared with the primal (Translog) method. Tables 5 and 6 summarises these results. Poor data on factor prices are probably the reason for this outcome. In view of these results, we proceed directly to estimate the required elasticities based on the primal method.

(b) Elasticity Values

Table 7 reports the elasticity values estimated from the above Translog production function estimates and which are incorporated into PARA. Of the 40 non-agricultural industries defined within PARA usable elasticity estimates were obtained for 25 industries. The other 15 fell into two groups: industry codes (21) through (27) and (53) through (60). Estimated elasticities for industry (28) - meat processing - were used for the first group of industries and the estimated elasticities for industry (52) - other manufacturing - were used for the second group.

6. Conclusions

In this paper we have estimated the parameters required for incorporation into the PARA model using the available Thai data. It was not possible to estimate the required parameters for every sector of the economy represented in PARA, but it was possible to estimate a high proportion of them. Parameters for non-estimated sectors were set equal to values for estimated sectors,.as seemed appropriate. Due to the different data available for agricultural and non-agricultural sectors for Thailand, the analysis was conducted separately for these two sets of sectors. These data were used to explore the respective merits of two methodological approaches. These were the primal approach and the dual approach. The dual approach estimates the requi9red 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 (Translog) 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 dual results in the case of both agricultural and non-agricultural data for and these (primal) results were therefore used as the basis for the parameters incorporated into PARA.

Table 1 Thailand Agriculture: Comparison of Primal and Dual Estimation Performance

Sector / statistic	Actual	Predicted	
		Translog production function	Normalised quadratic profit function
1. Paddy			
Mean	1	1.0004	0.99952
Variance	0.24353	0.22363	0.22082
Minimum	0.21414	0.2271	0.025091
Maximum	1.8145	1.5985	1.5769
Correlation with Actual		0.95834	0.93265
RMSE		0.13960	0.17658
2. Cassava			
Mean	1	1.0051	1
Variance	0.47498	0.47503	0.45942
Minimum	0.04337	0.050512	-0.051364
Maximum	2.3779	2.0753	1.9637
Correlation. with Actual		0.97703	0.97025
RMSE		0.14589	0.16496
3. Maize			
Mean	1	1.0053	1.0022
Variance	0.18614	0.16398	0.14695
Minimum	0.24232	0.26322	0.42895
Maximum	1.9402	1.7484	1.7694
Correlation with Actual		0.90057	0.86891
RMSE		0.18592	0.21097
4. Sugar			
Mean	1	0.99557	0.9964
Variance	0.73131	0.67853	0.6837
Minimum	0.14402	0.16536	-0.013139
Maximum	2.854	2.6517	2.4136
Correlation with Actual		0.98102	0.95202
RMSE		0.16442	0.25866

5. Cotton

Mean	1	1.0213	1.0017
Variance	0.25602	0.2044	0.45272
Maximum	2.1423	2.7155	1.7522
Correlation with Actual		0.92256	0.47825
RMSE		0.21847	0.44655

6. Groundnut

Mean	1	1.0048	1.0007
Variance	0.73057	0.74164	0.70488
Minimum	0.027083	0.053139	-0.050582
Maximum	2.9792	2.8525	2.5873
Correlation with Actual		0.98678	0.97139
RMSE		0.13838	0.20123

7. Mungbean

Mean	1	1.104	0.99979
Variance	1.7279	1.9696	1.6915
Minimum	0.013826	0.00595	-0.10803
Maximum	3.9266	5.6372	3.3928
Correlation with Actual		0.92412	0.98151
RMSE		0.53292	0.24939

8. Sorghum

Mean	1	1.0184	1.007
Variance	0.4553	0.42906	0.38524
Minimum	0.035009	0.11009	-0.00217
Maximum	2.2522	1.9144	1.7435
Correlation with Actual		0.95439	0.83126
RMSE		0.20001	0.37498

9. Soybean

Mean	1	1.0091	0.98822
Variance	1.6975	1.617	1.31
Minimum	0.02331	0.034445	-0.86822
Maximum	5.6297	5.4502	3.0175
Corr. with Actual		0.98277	0.83821
RMSE		0.23802	0.70336

Table 2. Thailand Agriculture: Summary of Prediction Error From Primal and Dual Estimation Results

Sector	Sector Share	Root Mean Squared Error of Prediction	
		Translog production function	Normalised quadratic profit function
Paddy	0.02307	0.13960	0.17658
Cassava	0.66225	0.14589	0.16496
Maize	0.02154	0.18592	0.21097
Sugar	0.01112	0.16442	0.25866
Cotton	0.09061	0.21847	0.44655
Groundnut	0.10817	0.13838	0.20123
Mungbean	0.01443	0.53292	0.24939
Sorghum	0.06080	0.20001	0.37498
Soybean	0.00802	0.23802	0.70336
Weighted Mean[a]		0.16219	0.21500

Notes: [a] Sector shares of the value of total output are used as weights.

Table 3 Thailand Agriculture: Root mean Squared Difference and Correlation Coefficient Between Output Predictions From Primal and Dual Methods

Sector	Root mean sq. difference	Correlation coefficient	n	Critical value for Correlation
Paddy	0.11651	0.96888	52	0.26711
Cassava	0.17721	0.96567	39	0.30669
Maize	0.18411	0.88948	39	0.30669
Sugar	0.15540	0.98181	39	0.30669
Cotton	0.49528	0.48196	39	0.30669
Groundnut	0.17717	0.97820	52	0.26711
Mungbean	0.45698	0.94504	52	0.26711
Sorghum	0.32530	0.86805	39	0.30669
Soybean	0.67486	0.84512	39	0.30669

Table 4 Thailand Agriculture:

Elasticities Derived Fron Primal (Translog) Estimation

	With respect to price of:			
	Labour	Tractor	Fertilizer	Land
1. Paddy				
Labour	-0.213	0.188	0.018	0.007
Tractor	0.304	-0.639	0.051	0.284
Fertilizer	0.225	0.389	-0.934	0.320
Land	0.018	0.463	0.069	-0.550
2. Cassava				
Labour	-0.014	0.010	0.000	0.004
Tractor	0.646	-0.827	0.013	0.168
Fertilizer	0.371	0.305	-0.971	0.296
Land	0.421	0.281	0.021	-0.723
3.Maize				
Labour	-0.410	0.260	0.008	0.142
Tractor	0.590	-0.740	0.008	0.142
Fertilizer	0.590	0.260	-0.991	0.140
Land	0.590	0.260	0.008	-0.858
4. Sugarcane				
Labour	-0.021	0.010	0.003	0.007
Tractor	0.765	-0.943	0.110	0.068
Fertilizer	0.298	0.158	-0.657	0.201
Land	0.645	0.083	0.169	-0.897

Table 4 (Continued)

5. Cotton				
Labour	-0.148	0.091	0.006	0.051
Tractor	0.741	-0.836	0.009	0.086
Fertilizer	0.790	0.132	-0.992	0.070
Land	0.756	0.155	0.008	-0.919
6. Groundnut				
Labour	-0.162	0.094	0.011	0.056
Tractor	0.629	-0.824	0.027	0.168
Fertilizer	0.565	0.201	-0.957	0.190
Land	0.504	0.225	0.034	-0.763
7. Mungbean				
Labour	-0.335	0.159	0.008	0.168
Tractor	0.658	-0.839	0.009	0.173
Fertilizer	0.651	0.163	-0.967	0.153
Land	0.653	0.162	0.008	-0.823
8. Sorghum				
Labour	-0.957	0.254	0.003	0.700
Tractor	0.051	-0.663	-0.003	0.615
Fertilizer	0.013	-0.062	-0.460	0.509
Land	0.032	0.142	0.005	-0.179
9. Soybean				
Labour	-0.179	0.141	0.011	0.028
Tractor	0.652	-0.829	0.022	0.156
Fertilizer	0.476	0.202	-0.967	0.289
Land	0.205	0.250	0.050	-0.506

Table 5. Thailand Non-Agriculture: Summary of Prediction Error From Primal and Dual Estimation Results

Sector / statistic quadratic function	Actual	Predicted	
		Translog production function	Normalised profit
1. SECTOR 29			
Mean	1	1.0713	-55.862
Variance	3.5712	1.318	7.4662
Minimum	0.0007	0.3577	-63.455
Maximum	15.038	6.9427	-50.977
Corr. with Actual		0.82862	-0.0023
RMSE		1.1366	56.9506
2. SECTOR 30 &32			
Mean	1	1.1649	110.26
Variance	5.4355	0.3691	5.5758
Minimum	0.0003	0.6952	104.46
Maximum	12.573	3.9445	114.74
Corr. with Actual		0.5613	0.00198
RMSE		2.0372	109.312
3. SECTOR 33 &34			
Mean	1	1.3951	-33.789
Variance	2.4472	0.5795	32.986
Minimum	0.0004	0.7969	-46.022
Maximum	7.1228	3.6328	-26.795
Corr. with Actual		0.3823	0.1759
RMSE		1.4902	35.2386
4. SECTOR 35			
Mean	1	1.1165	-85.615
Variance	4.3099	2.8099	4.2697
Minimum	0.00039	0.3441	-91.256
Maximum	8.6353	7.5096	-82.614
Corr. with Actual		0.9085	-0.00313
RMSE		0.892	86.6652

Table 5 (Continued)

Sector / statistic	Actual	Predicted	
		Translog production function	Normalised quadratic profit function
5. SECTOR 36			
Mean	1	1.1417	-11.943
Variance	4.2016	3.6449	1.4899
Minimum	0.0004	0.18383	-14.608
Maximum	17.618	14.186	-9.4694
Corr. with Actual		0.94636	0.00609
RMSE		0.6749	13.4177
6. SECTOR 38			
Mean	1	0.96134	-81.649
Variance	2.9197	0.98421	13.01
Minimum	0.00122	0.24356	-96.659
Maximum	12.687	4.2837	-76.036
Corr. with Actual		0.7159	-0.26405
RMSE		1.2103	82.7635
7. SECTOR 42 &45			
Mean	1	0.8793	18.253
Variance	5.422	1.2115	16.79
Minimum	0.0005	0.377	9.5829
Maximum	12.246	5.0672	24.87
Corr. with Actual		0.7687	0.13647
RMSE		1.63	17.802

Table 6. Thailand Non-Agriculture: Summary of Prediction Error From Primal and Dual Estimation Results

Sector	Sector Share	Root Mean Squared Error of Prediction		Root Mean Squared Difference
		Translog production function	Normalised quadratic profit function	Between Predictions
Sector 29	0.10101	1.1366	56.9506	56.9949
Sector 30 & 32	0.08501	2.0372	109.3120	109.1242
Sector 33 & 34	0.22867	1.4902	35.2386	35.5783
Sector 35	0.11448	0.8920	86.6652	86.7724
Sector 36	0.25499	0.6749	13.4177	13.2557
Sector 38	0.08308	1.2103	82.7635	82.6903
Sector 42 & 45	0.13276	1.6300	17.8020	17.8131
Weighted Mean[a]		1.21991	45.68525	45.71781

Notes: [a] Sector shares of the value of total output are used as weights.

Table 7. Estimated Elasticities for the Manufacturing Sectors Using Translog Share Equations

Sector 29 Food Processing

	Labor	Buildings	Machineries & Vehicles
Labor	-0.856	0.339	0.517
Buildings	0.62	-2.563	1.943
Machineries&Vehicles	0.395	0.812	-1.206

Sector 35 Spinning

	Labor	Buildings	Machineries & Vehicles
Labor	-1.541	0.297	1.244
Buildings	0.593	-1.049	0.456
Machineries&Vehicles	1.081	0.199	-1.279

Sector 38 Wood and Paper

	Labor	Buildings	Machineries & Vehicles
Labor	-1.234	0.269	0.965
Buildings	0.575	-2.2	1.626
Machineries&Vehicles	0.84	0.662	-1.502

Sector 39 Printing and Publishing

	Labor	Buildings	Machineries & Vehicles
Labor	-0.574	0.072	0.502
Buildings	0.446	-1.637	1.192
Machineries&Vehicles	0.538	0.207	-0.745

Sector 40 Chemicals

	Labor	Buildings	Machineries & Vehicles
Labor	-0.898	0.343	0.555
Buildings	0.415	-1.49	1.075
Machineries&Vehicles	0.281	0.449	-0.73

Sector 44 Cement and Non-metallic

	Labor	Buildings	Machineries & Vehicles
Labor	-0.887	0.39	0.498
Buildings	0.935	-1.545	0.61
Machineries&Vehicles	0.489	0.25	-0.738

Table 7. Estimated Elasticities for the Manufacturing Sectors Using Translog Share Equations (Cont'd)

Sector 45 Basic Metal

	Labor	Buildings	Machineries & Vehicles
Labor	-0.579	0.199	0.38
Buildings	0.504	-1.815	1.311
Machineries&Vehicles	0.425	0.581	-1.006

Sector 46 Metal Products

	Labor	Buildings	Machineries & Vehicles
Labor	-0.757	0.058	0.699
Buildings	0.148	-2.676	2.527
Machineries&Vehicles	0.533	0.758	-1.291

Sector 49 Electrical Equipments

	Labor	Buildings	Machineries & Vehicles
Labor	-0.791	-0.018	0.808
Buildings	-0.028	-1.44	1.468
Machineries&Vehicles	0.444	0.51	-0.954

Sectors: Meat Processing(28), Rice Milling(30), Sugar Refinery(31), Animal Feeds(32)

	Labor	Buildings	Machineries & Vehicles
Labor	-1.447	0.374	1.072
Buildings	0.348	-1.264	0.917
Machineries&Vehicles	0.441	0.406	-0.848

Sectors: Beverages(33), Cigarettes(34)

	Labor	Buildings	Machineries & Vehicles
Labor	-0.931	0.988	-0.057
Buildings	0.99	-4.42	3.429
Machineries&Vehicles	-0.025	1.484	-1.46

Sectors: Textiles and Garment(36), Leather and Footwear(37)

	Labor	Buildings	Machineries & Vehicles
Labor	-0.626	0.019	0.607
Buildings	0.054	-2.507	2.453
Machineries&Vehicles	0.686	1.007	-1.693

Table 7. Estimated Elasticities for the Manufacturing Sectors Using Translog Share Equations (cont'd)

Sectors: Fertilizers and Pesticides(41), Petroleum Refinery(42), Rubber and Plastic(43)

	Labor	Buildings	Machineries & Vehicles
Labor	-0.824	0.37	0.454
Buildings	0.7	-2.127	1.427
Machineries&Vehicles	0.342	0.569	-0.912

Sectors: Agricultural Machineries(47), Other Machineries(48)

	Labor	Buildings	Machineries & Vehicles
Labor	-0.43	0.122	0.307
Buildings	0.327	-3.066	2.739
Machineries&Vehicles	0.305	1.017	-1.321

Sectors: Motor Vehicles(50), Motor Vehicles Repair(51)

	Labor	Buildings	Machineries & Vehicles
Labor	-0.527	0.134	0.393
Buildings	0.293	-1.446	1.153
Machineries&Vehicles	0.349	0.466	-0.815

Sector 52 Other Manufacturing

	Labor	Buildings	Machineries & Vehicles
Labor	-0.904	0.351	0.554
Buildings	0.675	-2.344	1.669
Machineries&Vehicles	0.388	0.608	-0.996

Figure 1 PADDY: Actual Output vs Simulated Output

(a) Simulation Using Primal (Translog) Estimation Results

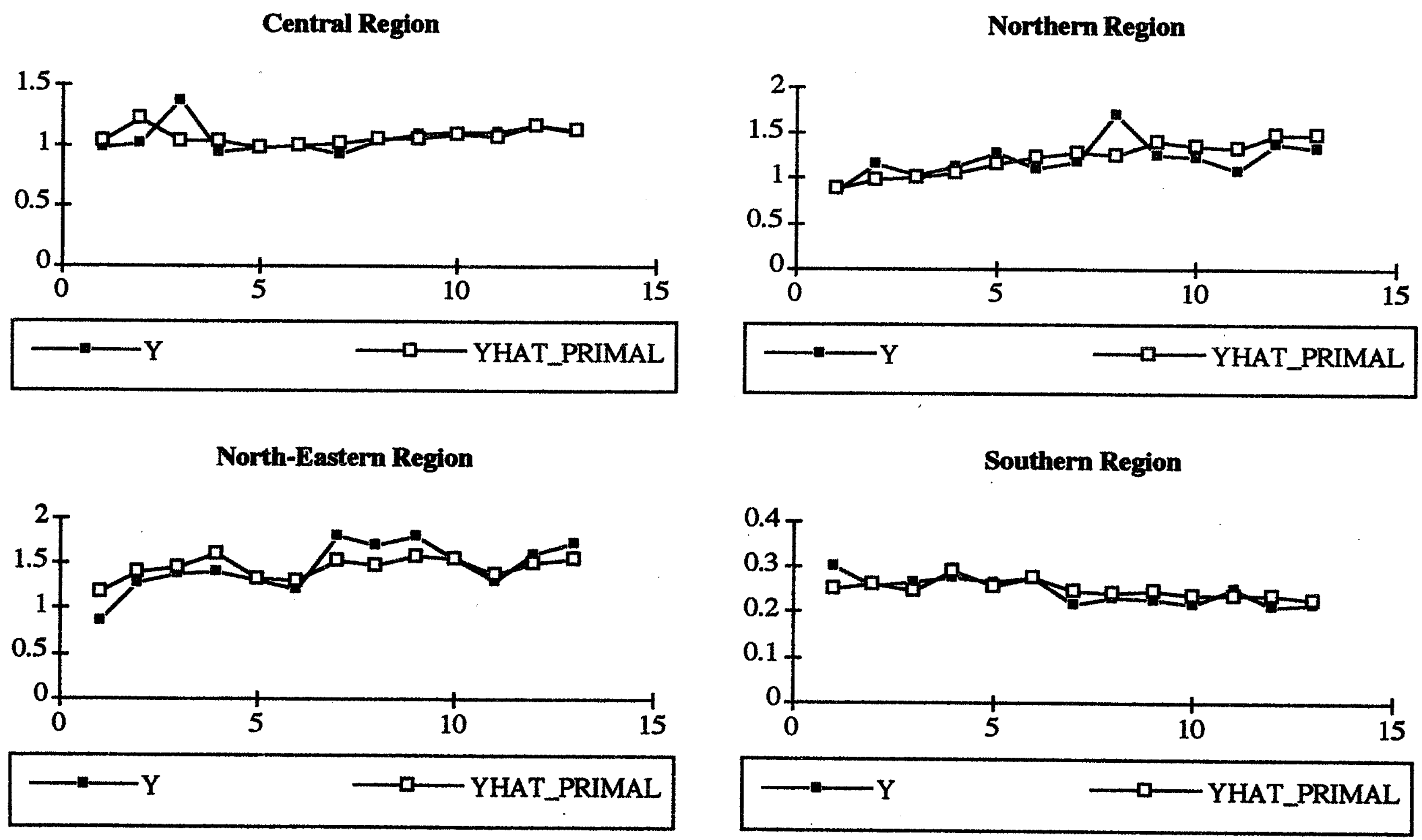


Figure 1 PADDY: Actual Output vs Simulated Output

(b) Simulation Using Dual (Normalised Quadratic) Estimation Results

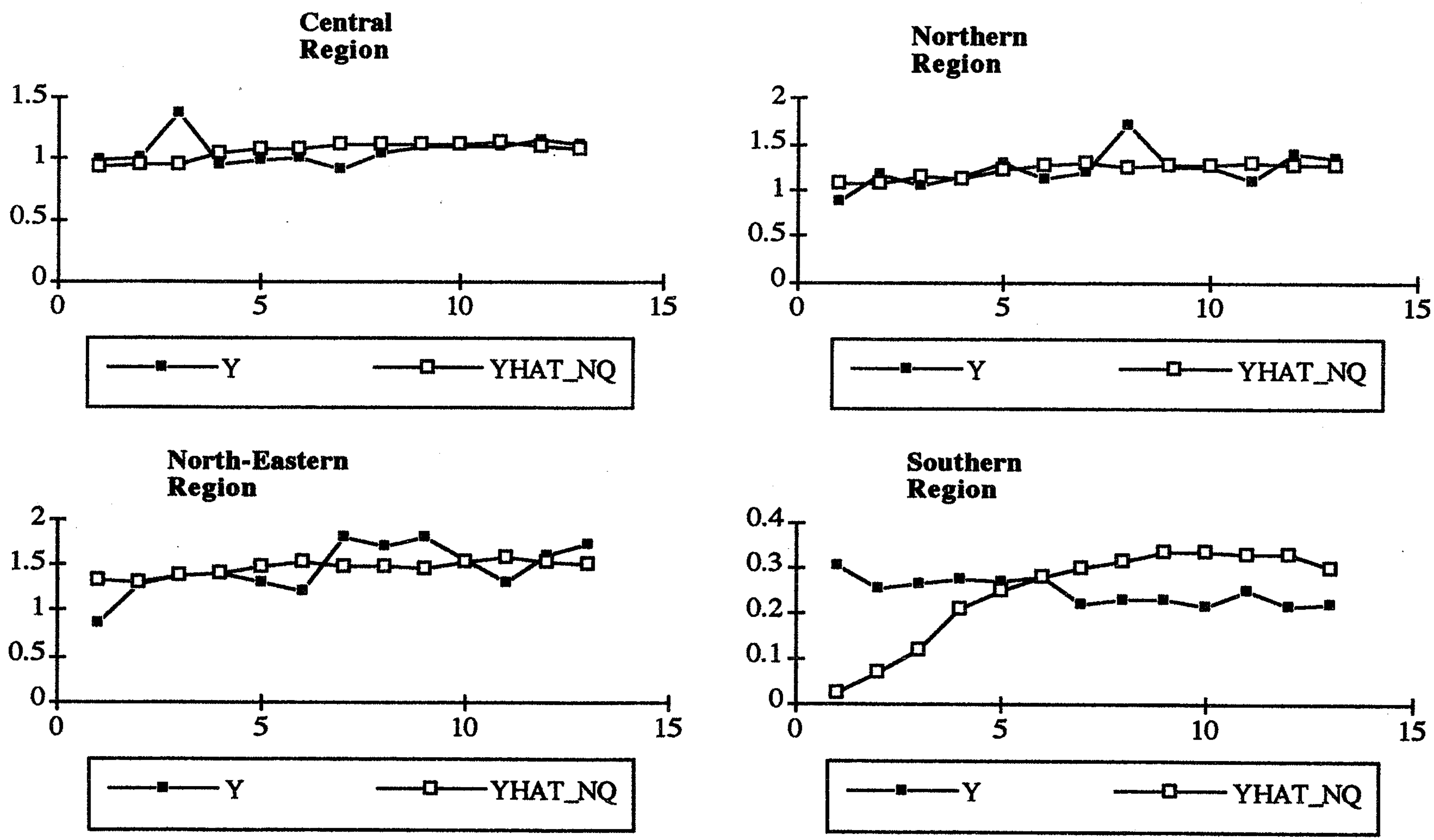
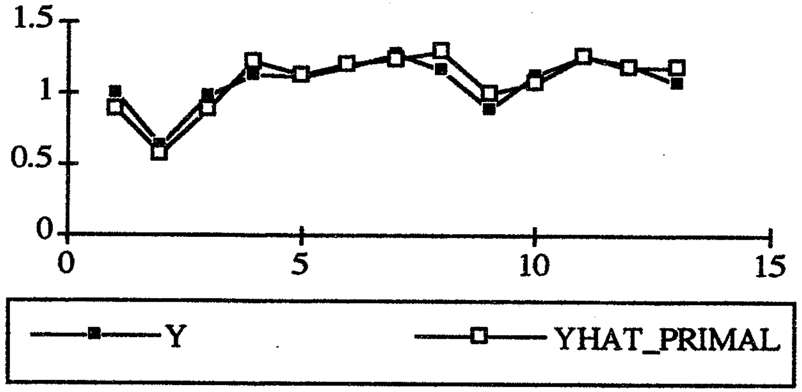


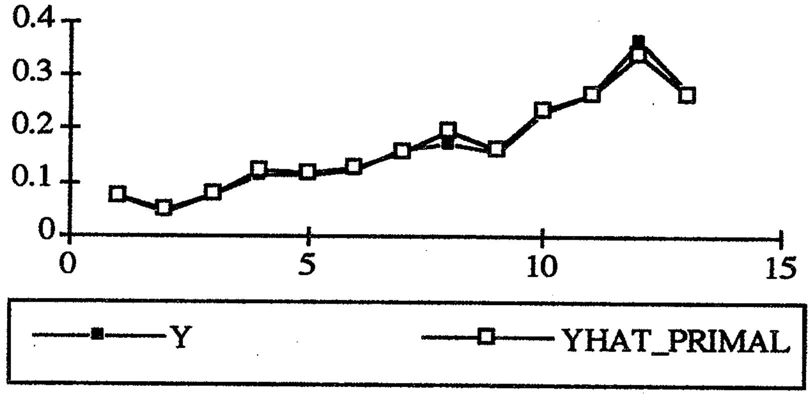
Figure 2 CASSAVA: Actual Output vs Simulated Output

(a) Simulation Using Primal (Translog) Estimation Results

Central Region



Northern Region



North-Eastern Region

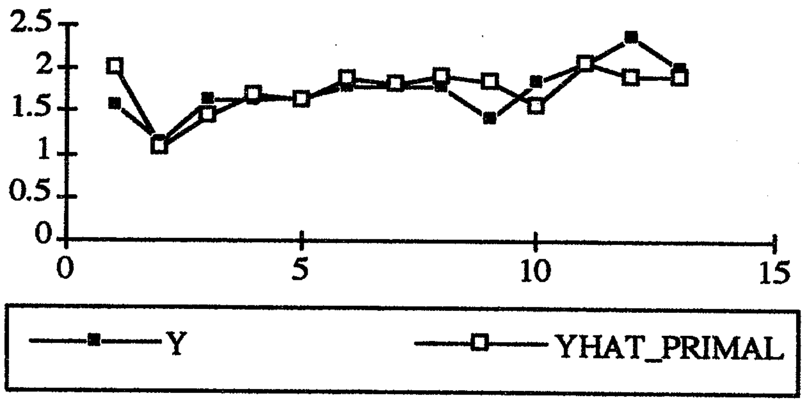
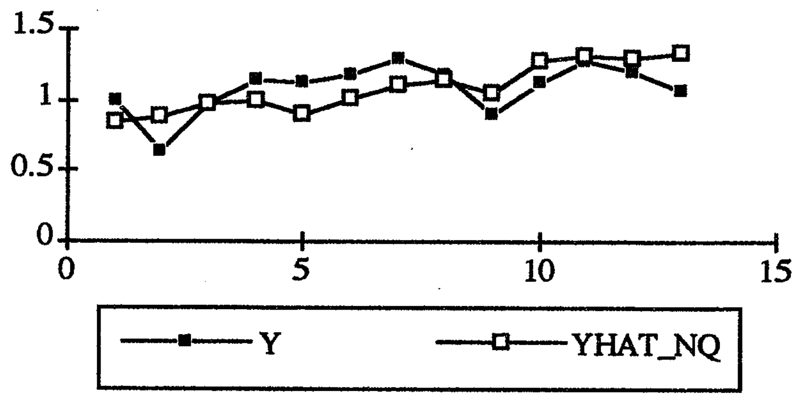


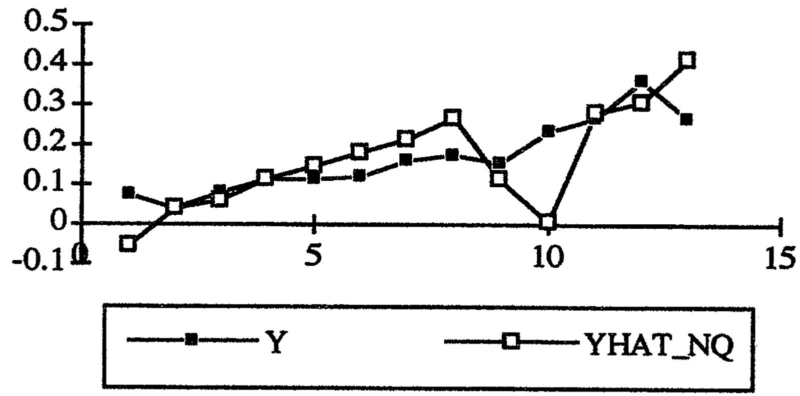
Figure 2 CASSAVA: Actual Output vs Simulated Output

(b) Simulation Using Dual (Normalised Quadratic) Estimation Results

Central Region



Northern Region



North-Eastern Region

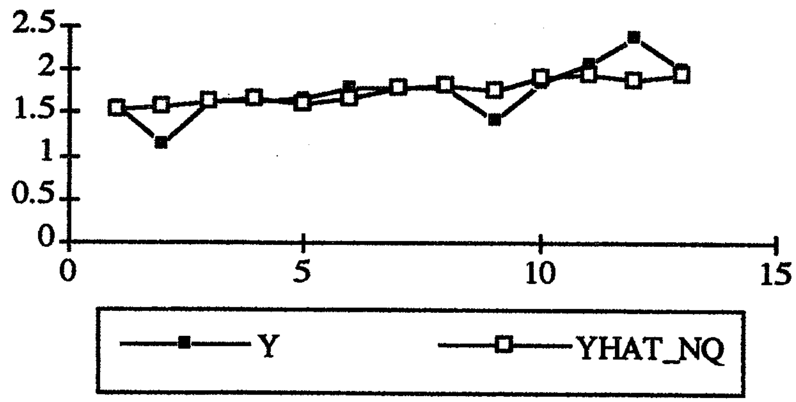


Figure 3 MAIZE: Actual Output vs Simulated Output

(a) Simulation Using Primal (Translog) Estimation Results

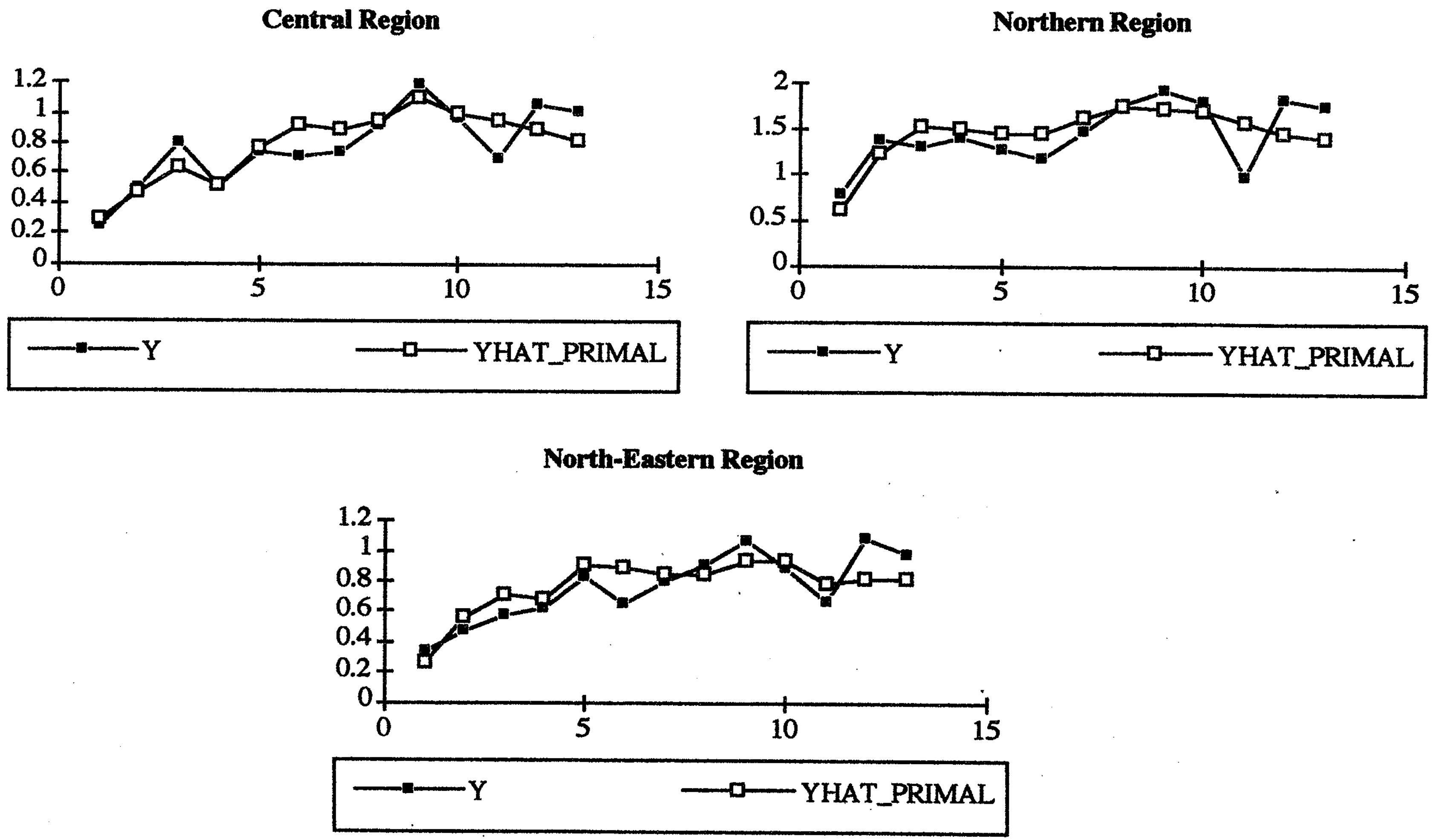
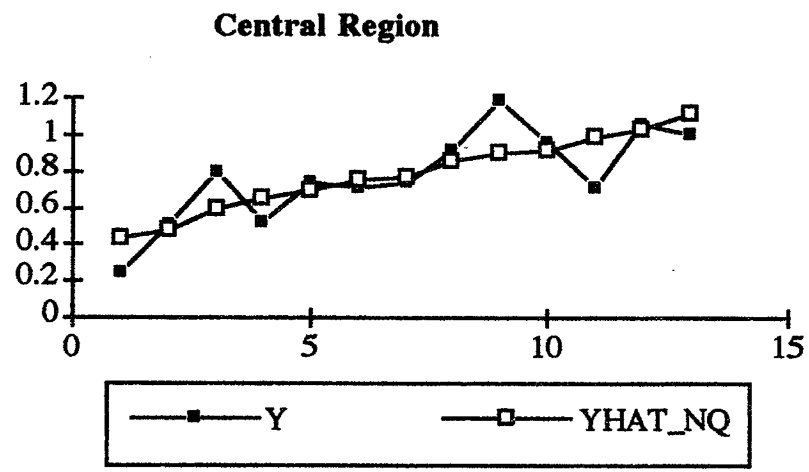
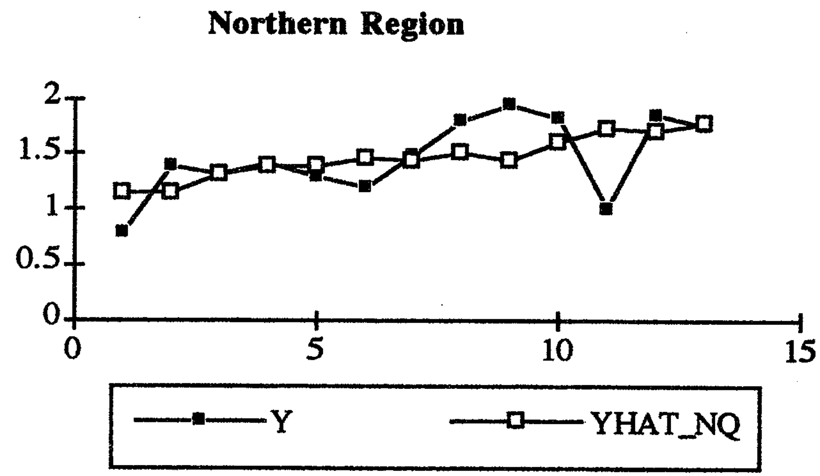


Figure 3 MAIZE: Actual Output vs Simulated Output

(b) Simulation Using Dual (Normalised Quadratic) Estimation Results





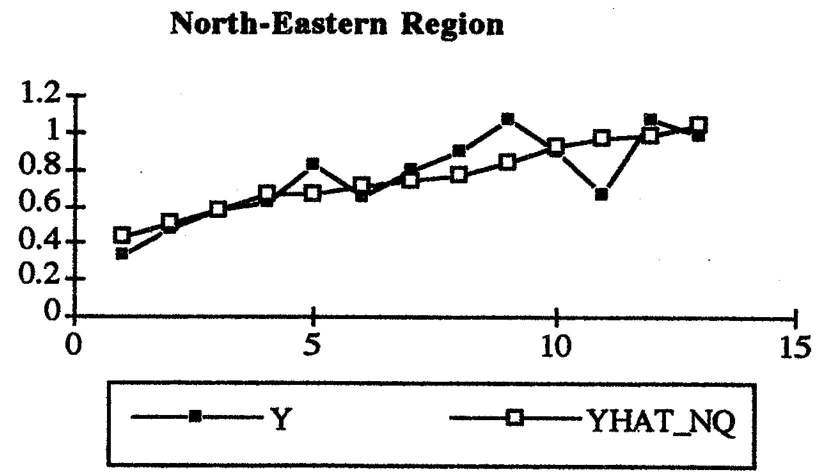
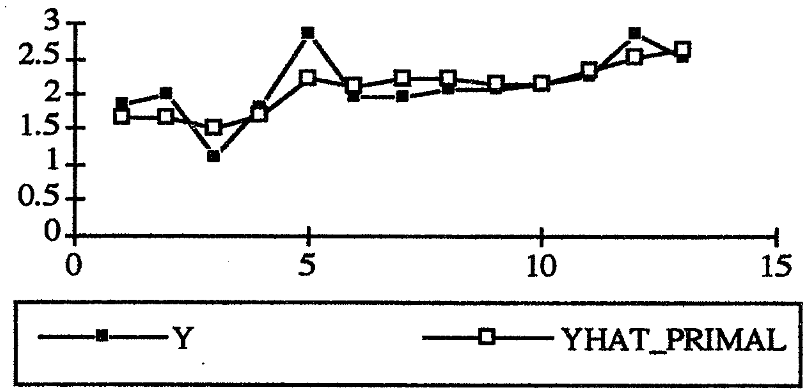


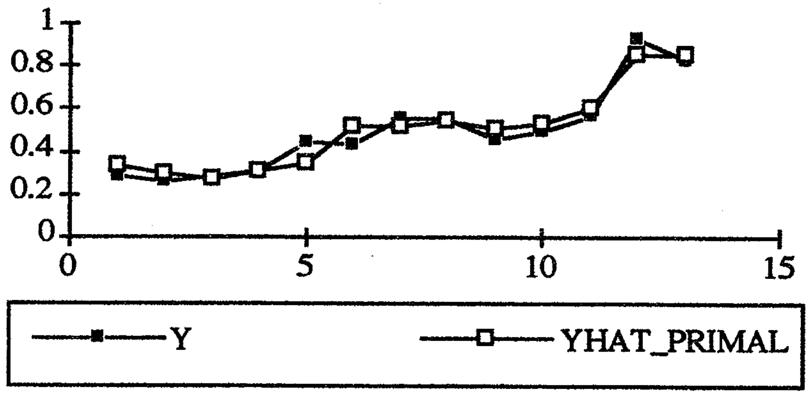
Figure 4 SUGAR: Actual Output vs Simulated Output

(a) Simulation Using Primal (Translog) Estimation Results

Central Region



Northern Region



North-Eastern Region

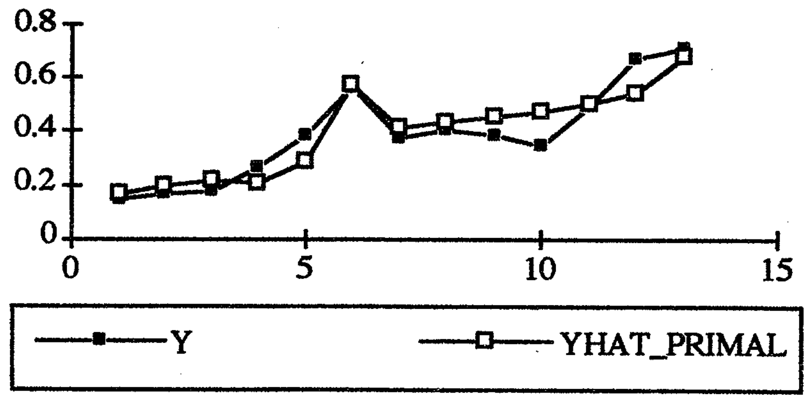


Figure 4 SUGAR: Actual Output vs Simulated Output

(b) Simulation Using Dual (Normalised Quadratic) Estimation Results