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PRODUCTION INTERRELATIONSHIPS IN SRI LANKAN PEASANT AGRICULTURE

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Technical change and the extent to which commodity supplies and input demands are interrelated in Sri Lankan peasant agriculture are explored in this paper. Using a multiple-product dual model, a seemingly unrelated system of product supply and input demand equations is estimated for four crops and four variable inputs. Restrictions based on competitive behaviour and a twice-continuously-differentiable production function are maintained in the non-linear least squares estimation. A number of important interrelationships in individual product supplies and input demands are identified, further documenting the need to account for intercommodity production relationships in econometric and simulation studies and in policy formulation. Non-joint production and Hicks-neutral technical change are both rejected.

Commodity supply models are prominent in the applied agricultural economics literature. Supply relationships have been estimated for a multitude of commodities and geographic locations (Askari and Cummings 1977). The purposes of such estimation are highly varied and include the search for basic knowledge of production relationships, policy inference and price prediction. Most studies have focused on supply relationships for single commodities, particularly with regard to changes in own-product price.

Many firms produce several commodities and others are capable of doing so. Thus, production decisions about one commodity are likely to be associated directly with production decisions for others. It is important to examine the extent of production interrelationships in order to anticipate more accurately the effects of policy changes and shifts in economic conditions. This is particularly crucial in many developing countries, such as Sri Lanka, that are attempting to increase the contribution of the agricultural sector to the nation's economic development. Such information can also play a vital role in guiding subsequent econometric specifications and simulations within the agricultural sector as well as in policy formulation and price prediction.

The objectives in this study are: (a) to determine the extent to which individual crop supplies and variable input demands in the Sri Lankan dry zone (Vavuniya District) are interrelated; and (b) to examine technical change. The focus will be on four crops (paddy, chili, pulse and vegetables) and four variable inputs (chemicals, fertiliser, power and seed) used in production. The four crops are the major ones produced in the Vavuniya District. Little livestock production occurs here and consequently is not addressed in this study.

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Semi-commercial peasant farming is the rule, with crops produced largely for domestic consumption. Few crops produced in the district are exported from Sri Lanka. There is an active rural market for farm inputs and most outputs. All households participate in the labour market as buyers, sellers and/or self-employers of labour, and 80 per cent of the district's population is involved in farming. Because of the presence of the local input and output markets, production and consumption decisions of the household appear to be effectively separable. Production decisions are thus examined in this study without regard to possible interrelationships with consumption decisions.

Individual firms are price takers and produce non-differentiated products. With a semi-commercial orientation, they exhibit standard characteristics of the competitive firm. Because of the small size of the district, it is not likely that output or most input prices are affected substantially by the quantities produced or used in the district. Thus, it appears reasonable to model the district as though it were a competitive firm, with few quasi-fixed inputs, requiring several production periods to adjust to equilibrium levels.

Crops in the district are rain fed with supplementary irrigation. Given the objective of reaching agricultural self-sufficiency under the present world trade situation, the Sri Lankan government has encouraged the modernisation of peasant farming systems. Consequently, peasant farmers are increasingly adopting new farming technologies. This is contributing to an increase in the complexity of resource allocation decision making (Batra 1976; Herath 1983; Dayal 1984). To guide decisions of both policy makers and farmers, it is important to have a better understanding of the economic interrelationships associated with this sector.

Method of Analysis

Analytical model

Important methodological advances have been made during the past decade that permit coherent direct estimation of product supply and input demand relationships for firms producing multiple products. Labelled dual models, systems of profit, product supply, and input demand equations are estimated consistent with a behavioural assumption. From these models, important information about production relationships can be derived (Weaver 1977, 1983; Lau 1978*a*; Varian 1978; Berndt and Wood 1982).

Assuming competitive behaviour, satisfaction of the first-order conditions for profit maximisation permits profit to be written as a function of optimal output and input levels. Since optimal outputs and inputs are functionally related in competitive equilibrium to output and variable input prices and fixed input quantities, so is profit. Known as the indirect profit function, it is a reduced-form equation dependent only on the exogenous variables in the economic system.

The indirect profit function which is dual to a quadratic production function is the normalised quadratic. Since the quadratic is a second-order Taylor's series expansion, these functions offer much flexibility for estimation as they do not impose restrictive assumptions on the underlying technology which affect comparative statics at a point (Fuss, McFadden and Mundlak 1978, p. 231). The restricted normalised quadratic profit function can be expressed in this multiple product case as:

$$(1) \quad \pi^* = a_0 + \sum_{i=1}^{7} a_i p_i + \sum_{i=9}^{12} a_i x_i + 0.5 \sum_{i=1}^{7} \sum_{j=1}^{7} b_{ij} p_i p_j + 0.5 \sum_{i=9}^{12} \sum_{j=9}^{12} b_{ij} x_i x_j + \sum_{i=1}^{7} \sum_{j=9}^{12} b_{ij} p_i x_j$$

where π^* is profit divided by price of input 8 (that is, normalised profit); p_i is the price of output or variable input i divided by price of input 8 (or normalised price); x_i is the quantity of output or input i; $i = 1, \ldots, 4$ are outputs; $i = 5, \ldots, 8$ are variable inputs; and $i = 9, \ldots, 12$ are fixed inputs and other exogenous variables. This function maintains the hypothesis implied by the theory of the competitive firm that profit is homogeneous of degree one in all prices.[1]

By the envelope theorem (Silberberg 1974), the first derivatives of a normalised profit function with respect to normalised output prices and normalised variable input prices are the output supply and (negative of) variable input demand equations. Except for the numeraire output, all product supply and negative input demand equations derived from the normalised quadratic profit function are linear in normalised product and variable input prices and fixed input quantities:

$$(2a) \quad x_i = a_i + \sum_{j=1}^{7} b_{ij} p_j + \sum_{j=9}^{12} b_{ij} x_j \qquad i = 1, \ldots, 4$$

$$(2b) \quad -x_i = a_i + \sum_{j=1}^{7} b_{ij} p_j + \sum_{j=9}^{12} b_{ij} x_j \qquad i = 5, \ldots, 7$$

The numeraire (input 8) demand equation can be derived also via the envelope theorem as the first derivative of the profit function with respect to the numeraire price. Because the profit function is normalised profit multiplied by the numeraire price, the numeraire demand equation is quadratic in prices and fixed input quantities:

$$(3) \quad x_8 = a_0 + \sum_{i=9}^{12} a_i x_i - 0.5 \sum_{i=1}^{7} \sum_{j=1}^{7} b_{ij} p_i p_j + 0.5 \sum_{i=9}^{12} \sum_{j=9}^{12} b_{ij} x_i x_j$$

[1] The normalised quadratic is only one of an infinite set of second-order Taylor's series expansions (also commonly labelled flexible functional forms). The translog and generalised Leontief are other popular versions of such flexible forms. Since none impose restrictions on comparative statics at a point, choice among these functional forms is generally regarded as arbitrary. Lopez (1985) and Blackorby, Primont and Russell (1977) note, however, that they are not all equally suitable as dual representations of technology. The normalised quadratic was chosen for this study because of its capacity to maintain globally the theory of the competitive firm and because it leads to simplicity of interpretation. Both of these properties occur because its Hessian matrix is a matrix of constants.

The linear equations (2) consist of supplies of pulse, paddy, chili and vegetables and negative demands of the variable inputs — chemicals, fertiliser and seed. The numeraire input is farm power and its demand equation is the quadratic function (3). The independent variables in each equation include normalised prices of all output and variable inputs and quantities of inputs presumed quasi-fixed or outside the control of the producer during the production period (that is, labour, land, rainfall and time). By treating labour and land as quasi-fixed, the hypothesis that the first-order conditions for profit maximisation are satisfied for these inputs is not maintained. Time is included as a proxy for technology.

The supply and demand equations are homogeneous of degree zero in all prices as each is a function of price ratios. A proportionate change in all prices thus has no impact on optimal quantities supplied or demanded. Because the second partial derivatives of equation (1) are invariant to order of differentiation, the seven linear output supply and input demand equations are symmetrical in normalised prices, that is, $b_{ij} = b_{ji}$ in the set of supply and demand equations (2). Their magnitudes are the same as the b_{ij} parameters in the quadratic equations (1) and (3) since these parameters are shared by the various equations.

Because of shared parameters and because production decisions on one crop may be affected by or associated with decisions on another, contemporaneous correlation among the product supply and input demand equations is likely. To account for this correlation properly, the seven linear product supply and input demand equations and the numeraire equation were estimated as a system of seemingly unrelated regressions using generalised least squares. The errors were assumed to be additive and independently and identically distributed with mean zero and constant contemporaneous covariance matrix. Generalised least squares was used to obtain parameter estimates for the stacked eight-equation system, (2) and (3), subject to the symmetry constraints. Global homogeneity was maintained by the process of normalisation. Because of limited degrees of freedom, parameters on the squared terms of rainfall and time and interaction terms of rainfall and time with all fixed inputs were constrained to be zero.

The profit function was not included in the system of equations to be estimated. At first glance, one is tempted to include it on the grounds that since the supply and demand equations were derived from it, it surely constitutes additional information which should be brought to the estimation problem. This, however, is not the case. All information (that is, quantities and prices) needed to determine profit exactly is already included in the problem as it stands. Since profit in any time period is a linear combination of outputs and inputs, it can be shown that the full covariance matrix of a system in which the profit function is included is singular. Further, since prices are time dependent, the variance of profit will also be time dependent.

This problem differs from that of a translog estimation which also exhibits a singular covariance matrix for the full system. In a translog model, each equation can be assumed to have homogeneous variance. The difficulty is that the dependent share variables, all of which are in the same units and measure the same concept, sum identically to unity for every observation. In that framework, an equation of fundamental interest, one of the share equations, must be dropped from the system in order to perform generalised least squares estimation. That is true whether or not the profit function is included in the estimation system. In the present case, however, the supply and demand equations do not constitute a linearly dependent system. Each equation of fundamental interest can be estimated as an integral part of the system. The profit function is not included since it is just one of an infinite number of arbitrary linear combinations of the dependent variables which might be calculated, none of which adds any new information.

Using the generalised least squares estimates to obtain an initial starting point, parameter estimates subject to homogeneity, symmetry and convexity of the profit function were obtained by constrained non-linear least squares using the Cholesky factorisation procedure to maintain convexity (Lau 1978*b*). A reduced-gradient non-linear programming procedure (Talpaz, Alexander and Shumway 1986) utilising algorithm code MINOS (Murtagh and Sanders 1978, 1983) was used to obtain these parameter estimates consistent with the theory of the competitive firm. Results of an eight-equation system of linear supply and demand functions for chili, paddy, pulse, vegetables, chemicals, fertiliser, labour, and seed in their prices normalised by the price of farm power and estimated by generalised least squares with homogeneity and symmetry maintained are reported in Jegasothy (1985) and in Jegasothy and Shumway (1987).

Data

Annual time-series data were collected for the Vavuniya District for the period 1969–82.[2] Except for the price of chemicals, all quantity and price information with respect to farm inputs and products was gathered from the records and publications of the Agricultural Extension Service of the Vavuniya District, the Agricultural Division of the Vavuniya Secretariat, and the Agrarian Research and Training Institute of Sri Lanka. The national chemical price index was used as a proxy for district chemical prices. Expected prices that affect production decisions were assumed to be current input prices and lagged output prices.[3] Rainfall data were from weather measurement stations in the Vavuniya District (see Table 1 for units of measurement).

Results and Discussion

Estimates of product supply and input demand functions

The non-linear least squares estimates maintaining symmetry, homogeneity and convexity are reported in Table 1. Monotonicity is

[2] With only 13 annual observations on each variable, it is obviously impossible to estimate independently all parameters of equation (3) by ordinary least squares. All equations were estimated as a stacked system with symmetry restrictions maintained in each step. With eight equations in the system and 71 parameters requiring estimation, 33 system degrees of freedom are left. While this is not a large number, it does not constitute a statistical problem in estimation.

[3] Use of expected prices is consistent with an objective function that maximises expected rather than actual profit. Under risk neutrality, all duality properties of profit maximisation that apply in the certainty case for *ex ante* choices also apply to expected profit maximisation in the uncertainty case with expected prices substituted for the presumed known prices (Pope 1982, p. 349).

violated at three observations but is not statistically rejected at the 1 per cent level. The χ^2 statistic is 8.3 with a critical value for $\chi^2_{.01,3}$ of 11.4.

The large number of price and quantity variables included as regressors led to serious collinearity problems (the condition index of the stacked system was 2041).[4] Even so, standard errors are generally low relative to parameter estimates. Forty-three of the 71 parameter estimates are asymptotically significant at the 5 per cent level.

The hypothesis of no serial correlation was tested and not rejected for any supply or demand equation (see Table 2). The Durbin-Watson statistic was inconclusive only for power demand.

Consistent with the findings of Jegasothy and Shumway (1987), considerable evidence of joint production (that is, significant cross-price parameters on other outputs, Lau 1978*a*, p. 183) among the four outputs emerge from the output supply equations. In fact, stronger evidence of jointness is found in these estimates than in Jegasothy and Shumway (1987). All output–output cross-price parameters are asymptotically significant at the 5 per cent level. Non-jointness in production of all four crops is strongly rejected at the 1 per cent level. The χ^2 statistic for $b_{12}=b_{13}=b_{14}=b_{23}=b_{24}=b_{34}=0$ is 136.1. The critical value for $\chi^2_{.01,6}$ is 16.8.

This jointness may be due to technical interdependence and/or to the presence of a constraining allocatable input such as land (Shumway, Pope and Nash 1984). It is not uncommon for all four of these crops to be grown on the same farm in a given year. Thus, they often compete for the same land, labour and managerial resources. Differences in the relative importance of technical interdependence and constraining allocatable inputs may result in the economic interdependence between any pair of products being either complementary (positive alternative product price parameter) or competitive (negative parameter). Further, such weightings may change over time. For the data period, the economic interdependence between pulse and chili, chili and vegetable, and vegetable and paddy production are all complementary. They are competitive between pulse and vegetable, pulse and paddy, and chili and paddy production. Thus, for half of the interrelationships, the econometric evidence suggests that constraining (quasi-fixed) allocatable inputs are a major cause of jointness.

Pulse and vegetable production are significantly related to own prices at the 5 per cent level. Output of chili and paddy are not significantly related to own prices, but both own-price parameters exceed their standard errors.

Output of each crop is significantly related to the price of chemicals. Except for chili, crop outputs are also significantly related to seed price. Only pulse and vegetable supplies are significantly related to fertiliser price. Output of each crop is positively and significantly related to the quantity of land. Most supplies are also significantly related to rainfall and time. Although two of the four parameter estimates exceed their standard errors, the quantity of labour is not a significant variable in any output supply equation. Output supplies are generally strongly related

[4] The most severe collinearity is between four variables: labour, land, labour × land, and land × land. The last two variables appear only in the quadratic numeraire equation. The square root of the ratio of the biggest to second smallest eigen value is 439.

TABLE 1

Constrained Nonlinear Least Squares Estimates of the Normalised Profit Function for Sri Lankan Agriculture Maintaining Symmetry and Convexity

Parameter	Estimate	Parameter	Estimate	Parameter	Estimate	Parameter	Estimate
a_0	3.12	b_{14}	−0.307	b_{47}	0.174	b_{710}	−0.0268
	(1.46)		(0.0981)		(0.0777)		(0.0512)
a_1	−8.06	b_{24}	−0.308	b_{57}	−0.154	b_{910}	0.0259
	(0.835)		(0.189)		(0.0182)		(0.0979)
a_2	10.1	b_{34}	0.707	b_{67}	0.0467	b_{1010}	−0.111
	(1.20)		(0.105)		(0.0600)		(0.213)
a_3	6.07	b_{44}	0.384	b_{77}	0.129	b_{111}	9.80
	(0.654)		(0.208)		(0.0459)		(1.15)
a_4	−0.899	b_{15}	0.0467	b_{19}	−0.0655	b_{211}	−13.8
	(1.57)		(0.0202)		(0.0356)		(1.63)
a_5	−1.32	b_{25}	−0.639	b_{29}	−0.0494	b_{311}	−14.5
	(0.423)		(0.0530)		(0.0465)		(0.828)
a_6	−3.03	b_{35}	−13.1	b_{39}	0.000427	b_{411}	−1.64
	(1.20)		(0.116)		(0.0245)		(2.18)
a_7	0.394	b_{45}	−0.116	b_{49}	0.0511	b_{511}	3.90
	(0.648)		(0.0337)		(0.0688)		(0.0580)
a_9	−0.512	b_{55}	4.06	b_{59}	−0.0342	b_{611}	3.99
	(0.609)		(0.0720)		(0.0163)		(1.60)
a_{10}	0.218	b_{16}	−0.226	b_{69}	−0.0391	b_{711}	−0.680
	(0.562)		(0.0711)		(0.0433)		(0.882)
a_{11}	−1.77	b_{26}	−0.125	b_{79}	−0.0303	b_{112}	0.0869
	(0.900)		(0.175)		(0.0277)		(0.0146)
a_{12}	−0.0412	b_{36}	−0.631	b_{99}	0.0686	b_{212}	−0.0337
	(0.0120)		(0.105)		(0.0179)		(0.0223)
b_{11}	0.360	b_{46}	0.0988	b_{110}	0.207	b_{312}	0.334
	(0.0579)		(0.116)		(0.0668)		(0.0191)
b_{12}	0.259	b_{56}	−0.0171	b_{210}	0.270	b_{412}	−0.0761
	(0.0847)		(0.0447)		(0.0909)		(0.0277)
b_{22}	0.384	b_{66}	1.02	b_{310}	0.231	b_{512}	−0.123
	(0.306)		(0.158)		(0.0572)		(0.00773)
b_{13}	−0.328	b_{17}	−0.106	b_{410}	0.729	b_{612}	−0.00118
	(0.0826)		(0.0321)		(0.130)		(0.225)
b_{23}	1.85	b_{27}	−0.113	b_{510}	−0.0351	b_{712}	0.00474
	(0.265)		(0.112)		(0.0300)		(0.0110)
b_{33}	44.0	b_{37}	0.778	b_{610}	−0.0495		
	(2.25)		(0.0603)		(0.0806)		

Notes to Table 1

Standard errors are in parentheses. MSE = 11.2 with 33 system degrees of freedom.
Variable numbers: 1–normalised pulse price (Rs/10 kg),
2–normalised chili price (Rs/lb),
3–normalised vegetable price (Rs/lb),
4–normalised paddy price (Rs/bu),
5–normalised chemical price (Rs/0.1 fl. oz.),
6–normalised fertiliser price (Rs/10 lb),
7–normalised seed price (Rs/lb),
9–labour quantity (10^6 days),
10–land quantity (10^3 ha),
11–rainfall (100 in/year),
12–time (69, . . ., 82).
Normaliser is power price (Rs/hr).

TABLE 3

Price Elasticities of Output Supply and Input Demand, 1982

Output or input	Elasticity with respect to the price of							
	Pulse	Chili	Vegetables	Paddy	Chemicals	Fertiliser	Power	Seed
Pulse	0.20	0.02	−0.003	−0.16	0.01	−0.12	0.09	−0.04
Chili	0.18	0.04	0.02	−0.20	−0.10	−0.09	−0.19	−0.05
Vegetables	−0.35	0.27	0.80	0.69	−3.11	−0.65	1.84	0.51
Paddy	−0.12	−0.02	0.005	0.14	−0.01	0.04	−0.07	0.04
Chemicals	−0.12	0.23	0.60	0.29	−2.41	0.04	1.12	0.25
Fertiliser	0.63	0.05	0.03	−0.25	0.01	−2.76	2.38	−0.08
Power	−0.16	−0.04	−0.03	0.17	0.09	0.80	−0.92	0.08
Seed	0.25	0.04	−0.03	−0.38	0.08	−0.11	0.34	−0.19

TABLE 2

Durbin-Watson Statistics, NLS Estimates

Equation	Durbin-Watson
Pulse supply	1.60
Chili supply	2.22
Vegetable supply	2.07
Paddy supply	2.56
Chemical demand	1.48
Fertiliser demand	2.07
Power demand	2.92
Seed demand	1.67

to variable input prices and exogenous input levels, with the exception of labour.

Two-thirds of output supplies are negatively related to the prices of variable inputs and three-quarters of them are positively related to the quantities of exogenous input levels. By symmetry, it is obvious that two-thirds of variable input demands are positively related to output prices.

The estimates of all input demands show significant own-price effects. Contrary to the findings of Jegasothy and Shumway (1987), fewer input–input than output–output cross-price parameters are asymptotically significant.[5] The only variable inputs that are significantly interrelated are chemicals and seed. They are economic substitutes. Chemical demand is also significantly related to quantity of labour as an economic complement. As rainfall increases, chemical and fertiliser demand decrease. Chemical demand increases with time.

Elasticities of product supply and input demand

Input demand and product supply elasticities are presented in Table 3 for the data year 1982. Own-price input demand elasticities range from −0.2 to −2.8. All are negative, so estimated input demands slope downward as required for convexity of the profit function. Fertiliser demand is the most elastic and seed demand is the least elastic. Input demand elasticities range from −0.1 to +2.4 with respect to alternative input prices and from −0.4 to +0.6 with respect to product prices. The larger absolute elasticities tend also to be statistically significant.

Own-price product supply elasticities range from +0.04 to +0.8. All have the required sign such that product supplies slope upward. Vegetable supply is the most elastic and chili supply is the least elastic. Product supply elasticities range from −0.4 to +0.7 with respect to alternative product prices and from −3.1 to +1.8 with respect to input prices. The larger absolute elasticities are generally also statistically significant.

The output–output elasticities are remarkably similar to those

[5] Some minor errors were discovered in the Jegasothy-Shumway (1987) data and have been corrected in this study. However, the major differences in empirical conclusions are due to model specification, that is, including rainfall and time as explanatory variables, treating labour as quasi-fixed, including the quadratic demand equation in the estimation system, stacking all equations prior to the first step (OLS estimation) in the generalised least squares procedure, and maintaining convexity.

recently reported by Behrman and Murty (1985) for semi-arid tropical Indian agriculture. They report elasticities computed at data means for six output categories: sorghum, superior cereals, other coarse cereals, pulses, oilseeds, and other crops. Their estimates are also based on a normalised quadratic profit function but exclude input demands because of inadequate data. The data are a pooled time-series (1957–73) cross section (13 regions). They report own-price output supply elasticities ranging from 0.16 to 0.87 (this study: 0.04 to 0.80). Their output–output cross-price elasticities (in absolute values) range from 0.02 to 0.35 (this study: 0.003 to 0.69). Fifty-three per cent of their output–output cross-price elasticities are negative (this study: 50 per cent), also suggesting that constraining allocatable inputs are an important cause of joint production.

Technical change

Technical change is indirectly Hicks neutral in variable inputs (outputs) if all ratios of variable input (output) demands are independent of time (Lau 1978*a*, p. 202):[6]

$$(4)\quad \partial(x_i/x_j)/\partial x_{12}=0$$

where the variable x_{12} is time. For Hicks neutrality in outputs, equation (4) applies to all $i,j=1,\ldots,4$, which for non-zero x_j is satisfied by:

$$(5)\quad b_{i12}x_j-b_{j12}x_i=0 \qquad \text{for all } i,j=1,\ldots,4$$

For Hicks neutrality in variable inputs, the index for i,j in (4) is $5,\ldots,8$. For non-zero x_j, (4) is satisfied by:

$$(6)\quad \begin{aligned} &b_{i12}x_j-b_{j12}x_i=0 \\ &a_{12}x_j-b_{j12}x_8=0 \qquad \text{for all } i,j=5,\ldots,7 \end{aligned}$$

By a dual transformation, technical change is directly Hicks neutral in the exogenous inputs, labour and land, if:

$$(7)\quad \partial[(\partial\pi^*/\partial x_9)/(\partial\pi^*/\partial x_{10})]/\partial x_{12}=0$$

Since the interaction terms between x_{12} and the exogenous inputs were deleted from the model to conserve degrees of freedom, direct Hicks neutrality in those inputs is maintained by the model specification.

Technical change is globally indirectly Hicks neutral in variable inputs (outputs) if all parameters in (6) (or (5)) are zero. Global indirect Hicks neutrality was tested by computing a χ^2 statistic for each case. Neutrality in variable inputs is rejected at the 1 per cent level. The χ^2 statistic is 20.7 with a critical value for $\chi^2_{.01,4}$ of 13.3. Neutrality in outputs is also rejected. The χ^2 statistic is 199.8 with the same critical value. Global neutrality in both inputs and outputs would have implied no technical change at all in this specification. Since global neutrality is

[6] Indirect Hicks neutrality implies and is implied by direct Hicks neutrality only if either the production function is homothetic or it is additive in time (Lau 1978*a* p. 202).

rejected both in outputs and in variable inputs, it is concluded that production over the data period has been characterised by technical change of some form.

Although global neutrality is rejected both in outputs and variable inputs, local indirect Hicks neutrality can be tested by (5) for outputs and (6) for variable inputs at the data points. Chi-square statistics were computed at each observation for each form of neutral technical change, and the largest (19.3 for variable inputs and 199.5 for outputs) constitutes the test statistic. By using a test size of 0.01/13, where 13 is the number of observations, the probability of rejecting local Hicks neutrality when it is a true hypothesis is at most 1 per cent by Bonferroni's inequality. The critical value of $\chi^2_{.01/13,3}$ is 17.0. Consequently, local indirect Hicks-neutral technical change is rejected at the 1 per cent level both in outputs and in variable inputs. The evidence consistently suggests that production over the data period was characterised by technical change that was not Hicks neutral.

Summary and Conclusions

The theory of the competitive firm has been fully maintained in this econometric estimation of crop production in the dry zone of Sri Lanka. Parameters of a normalised quadratic profit function were estimated by non-linear least squares using a stacked system of four product supply equations and four variable input demand equations. Homogeneity was maintained by the functional form, symmetry was maintained by the shared parameter structure of the stacked system, and curvature (convexity) properties were maintained by Cholesky factorisation. The estimates violated monotonicity conditions at three observations, but the violations were not statistically significant (1 per cent level).

Many important interrelationships were found to exist in crop production by these Sri Lankan peasant farmers. The output of every crop was significantly related to the prices of all other outputs. Thus joint production is the rule. The evidence also suggested that constrained (quasi-fixed) allocatable inputs were an important cause of at least half the jointness in production.

Important economic interrelationships were also evident among some inputs and between outputs and inputs. The strength of these interrelationships was further documented by several large cross elasticities of crop supplies and input demands computed for the last year of the observation period. With one exception, the largest absolute elasticity values were for own-price input demands, but many of the cross elasticities were also substantial. More than a third were greater than 0.2 (in absolute value) and several were greater than unity (in absolute value).

Hicks-neutral technical change was examined and rejected. No evidence of either global or local Hicks neutrality was found.

These findings are important in understanding behaviour in this peasant industry. They are also important in designing policies and more detailed economic analyses of crop production decisions. It is apparent that supply response of one crop cannot in general be correctly examined while ignoring the nature of technical change and decisions made on competitive and complementary crops and on inputs. Yet agricultural commodity policies are all too often formulated without sufficient consideration of such interrelationships. Sri Lankan policies such as the guaranteed price scheme are no exception. Designed to increase marketed output from peasant agriculture and decrease national dependence on food imports, this policy has established price floors on many of the commodities produced in the dry zone, including paddy, chili and four of the pulse crops. They have had little direct effect, however, because in only three years (1969–71) of the data period were any of the guaranteed prices higher than actual average market prices. Even then they were higher only for paddy and one pulse crop.

Technical change in the Sri Lankan dry zone is not Hicks neutral and crop production is highly interrelated. Although specific interrelationships vary from area to area, it is likely that the same can be said for much of the world's agricultural production. The magnitudes and importance of these interrelationships warrant both econometric estimation and judgmental interpretation in order to achieve more accurate simulations, policy analyses and price predictions for individual commodities and inputs. The estimated parameters reported in this paper provide at least rudimentary assessment of the importance of these relationships for one district in the Sri Lankan dry zone. They are historical statistical measures of the impact on output supplies and input demands from expected price changes. They warrant careful consideration in anticipating future effects of changes in guaranteed prices and other agricultural commodity and input policies.

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