Multicrop Response by Sri Lankan Peasant Farmers

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Abstract· The extent to which commodity supplies and input demands are interrelated in Sri Lankan peasant agriculture is explored in this paper. Using a multiproduct dual model, a seemingly unrelated system of product supply and input demand equations is estimated for four crops and five variable inputs. Restrictions based on competitive behaviour and a twice-continuously-differentiable production function are maintained in the estimation. A large 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.

Introduction

Commodity supply estimation has played a prominent role in applied agricultural economics literature. Supply relationships have been estimated for a multitude of commodities and geographic locations (Askari and Cummings, 1977). The purpose of such estimations is highly varied and includes search for basic knowledge of production relationships, policy inference, and ultimate 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 regarding one commodity are likely to be directly associated with production decisions for others. One needs to examine the extent of production interrelationships in order to anticipate more accurately the effects of policy changes and shifts in economic conditions, particularly in many developing countries such as Sri Lanka, that are attempting to increase the contribution of the agricultural sector to 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 objective of this study is to determine the extent to which individual crop supplies and variable input demands in the Sri Lankan dry zone (Vavuniya District) are interrelated. The focus is on four crops (paddy, chillies, pulses, and onions) and five variable inputs (chemicals, fertilizer, labour, power, and seed) used in production.

Subsistence-oriented peasant farming is the rule in this district, with crops produced largely for local consumption. Eighty percent of the district's population is involved in farming. Crops are rainfed with supplementary irrigation. Given the objective of reaching self-sufficiency under the present world trade situation, the Sri Lankan government has encouraged these farming systems. Consequently, peasant farmers are increasingly adopting new farming technologies, which contribute to an increase in the complexity of resource allocation decision making (Batra, 1976; Dayal, 1984; and Herath, 1981 and 1983). To guide decisions of both policy makers and farmers, having a better understanding of the economic interrelationships associated with this sector is important.

Method of Analysis

Analytical Model

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

Assuming competitive behaviour, satisfaction of the first-order conditions for profit maximization permits profit to be written as a function of optimal output and input levels. Since optimal outputs and inputs are functionally related (in a competitive equilibrium) to output and variable input prices and fixed 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 the dual to a quadratic production function, is the normalized quadratic. Since the quadratic is a second-order Taylor expansion, these functions offer much flexibility for estimation since they do not impose restrictive assumptions (that would affect comparative statics at a point) on the underlying technology. For $x = (x_1, ..., x_n)$ representing the vector of output and input quantities and $P = (p_1, ..., p_n)$ representing the vector of output and input prices, the normalized quadratic profit function can be expressed in this multiproduct case as:

$$(1)\ \pi^{*\prime} = b_0 + {}_{i=1}\Sigma^{m-1}\, b_i p_i^{\prime} + {}_{i=m+1}\Sigma^{n}\, b_i x_i + 0.5\ {}_{i=1}\Sigma^{m-1}\ {}_{j=1}\Sigma^{m-1}\, b_{ij} p_i^{\prime} p_j^{\prime} + 0.5\ {}_{i=m+1}\Sigma^{n}\ {}_{j=m+1}\Sigma^{n}\, b_{ij} x_i x_j + {}_{i=1}\Sigma^{m-1}\ {}_{j=m+1}\Sigma^{n}\, b_{ij} p_i^{\prime} x_j\,,$$

where $\pi^{*\prime}$ is profit divided by the price of variable input m (or normalized profit), $p_i^{\prime}$ is the normalized price of commodity or input i (i.e., $p_i^{\prime} = p_i/p_m$), $i = 1, ..., k$ are outputs, $i = k+1, ..., m$ are variable inputs, and $1 = m+1, ..., n$ are fixed inputs. This function maintains the hypothesis implied by the theory of the competitive firm that profit (π^*) is homogeneous of degree one in all prices. By the envelope theorem (e.g., Silberberg, 1974), the first derivatives of a normalized profit function with respect to normalized output prices and normalized 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 normalized quadratic profit are linear in normalized product and variable input prices, fixed input quantities, and other exogenous variables:

$$(2)\ x_i = b_i + {}_{j=1}\Sigma^{m-1}\, b_{ij} p_j^{\prime} + {}_{j=m+1}\Sigma^{n}\, b_{ij} x_j\,,\ V_i = 1, ..., m-1\,.$$

The price parameters of the mth equation can be derived from the parameter estimates of the $m-1$ linear supply and demand equations, since their parameters are shared. With a total of four outputs (paddy, chillies, pulses, and onions) and five variable inputs (chemicals, fertilizer, labour, power, and seed), all product supply and variable input demand parameters are identified by estimating eight equations. The numeraire input category (i.e., x_m) is farm power; the price portion of its demand equation is derived from the estimated parameters of the other eight equations. Land is assumed to be fixed over the annual production period. Time and education level are generally expected to affect production technology. However, Herath (1981 and 1983) found such impacts on peasant farming in Sri Lanka to be nonsignificant. Hence, these variables are not included in the model. Rainfall is also excluded since annual rainfall varied little over the period of analysis.

Each of the supply and demand equations is homogeneous of degree zero in all prices, since one price (farm power) is used as a denominator. 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 output supply and input demand equations are symmetrical in normalized prices; i.e., b_{ij} in the set of supply and demand equations *(2)*.

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 properly for this correlation, the eight linear product supply and input demand equations were estimated as a system of seemingly unrelated regressions using generalized least squares. Homogeneity and symmetry restrictions were maintained in the estimation.

Data

Annual time series data were collected for Vavuniya District for the 1969-82 period. Except for the price of chemicals, all quantity and price information with respect to farm inputs and farm products were gathered from the records and publications of the Agricultural Extension Service of Vavuniya District, the Agricultural Division of the Vavuniya Secretariat, and the Agrarian Research and Training Institute in Colombo. The chemical price index at the national level is used as a proxy for district chemical prices.

Results and Discussion

Estimates of Product Supply and Input Demand Functions

Parameter estimates for the product supply and (negative of) input demand functions normalized with farm power price are reported in Table 1 (page 372) (see Jegasothy, 1985, for further details).

Table 1—Estimated Normalized Quadratic Profit Function Parameters

Variables	Chillies	Onions	Pulses	Paddy	Seed	Chemicals	Fertilizer	Labour
Intercept	-14.99 (10.38)	103.94 (90.11)	-323.2 (328.22)	236.45 (201.54)	-98.6 (128.0)	75.6 (96.6)	-82.64 (40.23)	-548.4 (280.6)
Chilli price	0.00002 (0.00006)							
Onion price	0.003 (0.001)	-0.05 (0.06)						
Pulse price	-0.004 (0.001)	0.05 (0.02)	-0.11 (0.13)					
Paddy price	0.021 (0.003)	-0.107 (0.104)	-0.06 (0.08)	1.4 (0.5)				
Seed price	-0.012 (0.001)	0.065 (0.05)	-0.124 (0.03)	-0.67 (0.16)	-0.3 (0.5)			
Chemical price	-0.01 (0.001)	-0.08 (0.03)	0.14 (0.02)	-0.41 (0.1)	0.14 (0.05)	0.24 (0.3)		
Fertilizer price	-0.01 (0.001)	0.1 (0.04)	0.03 (0.01)	0.7 (0.4)	-0.13 (0.05)	-0.15 (0.03)	0.05 (0.06)	
Farm labour price	-0.1 (0.3)	-1.8 (0.003)	-0.002 (0.47)	0.88 (0.28)	-2.5 (0.11)	-1.93 (0.17)	3.13 (3.9)	1.53 (0.56)
Land quantity	0.0003 (0.0001)	0.003 (0.0011)	0.028 (0.003)	0.07 (0.004)	0.017 (0.004)	0.035 (0.012)	0.014 (0.008)	-0.008 (0.005)

[Note: Degrees of freedom = 76.]

Although a large number of price variables were included as regressors, collinearity proved not to be a major problem, as evidenced by the generally low standard errors relative to parameter estimates. Thirty-one of the 52 parameter estimates are significant at the 5 percent level.

R^2 statistics from OLS estimation of each of the eight equations ranged from 0.79 for farm labour to 0.95 for the paddy equations. No evidence of autocorrelation was observed at the 5 percent level for these OLS estimated equations; Durbin-Watson statistics ranged from 2.22 for the pulse equation to 2.48 for the paddy equation.

Three of eight own-price parameters have negative signs. Thus, this estimated production system is not fully consistent with the convexity condition of profit maximization. However, none of the unexpected own-price parameter signs is significant. The lack of full support by the estimated model parameters for the expectations of the theory may be due to a problem with the theory, the econometric specification, the data, estimation procedure, or some combination of these. While clearly sorting out the cause of the apparent discrepancies is not possible, a great many important interrelationships clearly exist in the supply of these four crops and the demand for variable inputs. Statistically significant relationships between variables are identified in Table 1. Several of these relationships are of particular consequence.

Chilli production is highly interrelated with all other crops. Prices of all alternative products have an important impact on chilli production. So does pulse price on onion production. Nonzero parameters on alternative product prices imply jointness in production (Lau, 1978, p. 183). This jointness may be due to technical interdependence and/or the presence of a constraining allocation input such as land (Shumway, Pope, and Nash, 1984). For all four of these crops to be grown on the same farm in a given year is not uncommon. 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 our data period, the economic interdependence between chillies and onions and between chillies and paddy are both complementary. They are competitive between chillies and pulses and between onions and pulses. Only paddy production is significantly related to its own price.

Output of each crop is positively related to the quantity of land. Except for paddy, these relationships are all significant.

Demand for every variable input is strongly related to nearly all expected product and input prices, and crop supplies are strongly related to input prices. Chemical demand is highly related to all other input and product prices and land quantity. Seed demand is highly related to all prices except its own and onion prices; labour demand is highly related to all prices except pulse and land quantity; and fertilizer demand is highly related to all prices except its own, paddy, and labour prices and land quantity. Nearly all inputs are economic substitutes, since an increase in the price (quantity) of one causes the demand for the other to decrease (increase). Only seed and chemicals are significantly complementary.

Elasticities of Product Supply and Input Demand

Input demand and product supply elasticities for 1982 are presented in Table 2. Elasticities for farm power are computed using the homogeneity and symmetry conditions.

Own-price input demand elasticities range from -2.0 to 0.1. All are negative, as expected, except for seed. Although its parameter estimate was nonsignificant, chemical demand is the most elastic. Input demand elasticities range from -0.5 to 2.7 with respect to alternative input prices and from -3.0 to 1.3 with respect to product prices. The larger absolute elasticities are also statistically significant.

Own-price product supply elasticities range from -0.3 to 0.7. Both negative elasticities are nonsignificant. Paddy supply is the most elastic, positive, and significant. Product supply elasticities range from -0.4 to 0.5 with respect to alternative product prices and from -0.8 to 0.5 with respect to input prices. The larger absolute elasticities are generally also statistically significant.

Table 2—Price Elasticities of Output Supply and Input Demand, 1982

Price	Paddy	Chillies	Onions	Pulses	Seed	Chemicals	Fertilizer	Power	Labour
Paddy	0.70	0.28	0.36	-0.03	0.02	0.24	-0.34	0.23	-0.62
Chilli	0.42	0.34	0.34	-0.23	0.07	0.85	0.68	0.17	1.03
Onion	0.46	0.37	-0.30	-0.40	-0.06	1.34	-0.85	0.16	-3.00
Pulse	-0.02	-0.02	-0.06	-0.04	0.01	-0.10	-0.03	-0.10	0.00
Seed	-0.75	-0.11	0.02	-0.30	0.05	-0.50	0.39	0.00	0.96
Chemical	-0.65	-0.31	-0.34	0.45	-0.05	-2.04	0.98	-0.30	2.69
Fertilizer	0.34	-0.14	0.09	0.05	0.01	0.17	-0.08	-0.02	-0.30
Farm power	-0.56	-0.30	-0.51	0.50	-0.08	-0.06	-0.14	-0.11	-0.26
Farm labour	0.06	-0.13	0.40	0.00	0.03	0.10	-0.01	-0.04	-0.50

Summary and Conclusions

A systematic economic examination of crop production in Vavuniya District, Sri Lanka, was conducted using a dual model and statistical analysis. Important information learned about the nature of this industry includes the following:

- Crop supplies and input demands are highly interrelated.
- Most inputs are economic substitutes.
- Outputs are more evenly divided between economic substitutes and economic complements, but no evidence exists of nonjoint production of any crop.

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. Supply response of one crop apparently cannot in general be correctly examined while ignoring decisions made on competitive or complementary crops. Crop production in the Sri Lankan dry zone is highly interrelated. While specific interrelationships vary from area to area, the same can probably be said for much of the world's agricultural production. The magnitudes and importance of these interrelationships warrant both econometric estimation and judgmental interpretation to achieve more accurate simulations, policy analyses, and price predictions for individual commodities or inputs.

Note

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Discussion Opening–*Max R. Langham*

The paper by Sastry and Ramanna represents an attempt at measurement without theory. One might characterize their paper as a search for hypotheses among a set of variables. Factor analysis has not proved very useful in economics because it is nearly always the case that one factor (dimension) explains most of the generalized variation in the observed variables. Sastry and Ramanna's first factor explains approximately four times as much of the generalized variance as does the second factor for the more developed region and about three times as much for the less developed region. As a consequence, interpretation is at best very difficult. They interpreted their first factor as "irrigated or modern technology" and the second factor as "rainfed technology." Those interpretations seem quite arbitrary.

The Livingstone paper seems to both embrace and reject the common property explanation of pastoralism with major reference to Africa. However, if an underlying theoretical construct exists, I would characterize it as this explanation. Concern is expressed that the common property explanation does not cover all dimensions of the problem. Useful theoretical constructs, however, are in most cases great abstractions from reality. And if we had a theory that offered a precise explanation of the real world, it would be as obscure to us as the phenomena we wish to explain, and we would need to begin again in search of an explanation.

Both the descriptive information and the critique of some of the issues with regard to the pastoral problem are useful. The paper gives one a sense of the complexities of the climatological, biological, and institutional forces operating within the pastoral system. The paper demonstrates that different ways exist to view aspects of the pastoral problem. The demonstrations are useful, although they do give the paper a bit of a *Fiddler-on-the-Roof* character; i.e., on the one hand this and on the other hand that. Good analysis must derive from good description, and the Livingstone paper makes a contribution.

The Jegasothy and Shumway paper is based on the neoclassical theory of the firm, and their estimation procedure utilizes more recent developments of the indirect profit function. An early lesson in microeconomic theory is that whether acting as a consumer or, as in the case of the Jegasothy and Shumway paper, as a producer, one faces two kinds of markets. In one market, the actor is a buyer and, in the other, a seller. In formulating economic policies, knowledge of the fundamental economic behaviour in these markets, though essential, is often quite inadequate. I support the kind of research reported in this paper. Their paper is carefully done and I have no conflict with their reported results. Their reported objective and their first conclusion did, however, seem a little nonsensical. One does not need to determine the extent to which individual crop supplies and input demands are interrelated. The theory they use gives a one-to-one correspondence among these relationships. And their specification of a quadratic profit function was perhaps more restrictive than a translog specification would have been.

The Livingstone paper comes closest to the spirit of the conference theme—agriculture in a turbulent world economy. His description of pastoral agriculture in Africa provides an account of the turbulent environment of the pastoral setting. Among the environmental factors, climatic conditions dominate the scene, but in reading the paper one gets a sense of the other forces at work.

The other two papers essentially represent static analyses. Sastry and Ramanna did, however, look across two periods in an attempt at comparative statics analysis. They also looked at two levels of development within the two time periods. Even so, comparative statics does not give one a very good sense of turbulence in the agricultural system being studied. Jegasothy and Shumway could have generalized further with the benefit of dynamic duality to recognize that we operate in a nonstatic world. This generalization may not, however, have significantly changed their results.

General Discussion–*K.L. Sharma*, Rapporteur

A comment was made on the Sastry and Ramanna's paper on the arbitrary distinction between rainfed and irrigated zones. In reply, Sastry pointed out that the main indicators, such as soil type, rainfall, and cropping patterns, were used in making a distinction between these two zones.

The discussion from the floor centred on Livingstone's paper. The treatment of pastoral resources as common property is a real problem in Africa, yet not one fact or figure was cited by Livingstone, nor did he relate the problem to any particular country in Africa. A need exists to draw a distinction between common property and open-access resources. One needs to devise some institutional rules to overcome problems of overuse of pastoral or reef fishery resources. Also, one should explore the impact of alternative investment opportunities on livestock in relation to other forms of entitlements, such as sugar quotas and vegetable contracts. In areas where sugar quotas were granted to smallholders, livestock numbers were apparently reduced. We are perhaps dealing here with a shift in security and entitlement of holding. What is the generality of the results concerning the common property concept? Could they hold for fisheries? Are taxes imposed on common property? Going by past experience, a tax solution may not be acceptable to subsistence farmers. Moreover, the transaction costs involved in imposing taxes will perhaps defeat the main purpose of solving the common property problem. Could grazing rights be transferable?

Few comments were made on the paper by Jegasothy and Shumway. Concern was expressed on the multicollinearity problem among independent variables included in regression analysis. Also, significant response has been seen with respect to multiple cropping to water management, which should be considered as an input specifically in profit functions.

Participants in the discussion included H.I Behrmann, L. Drake, E. Fleming, A.D Indraratna, W.L. Nieuwoudt, J. van Rooyen, and T.O Williams.