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RICE PRODUCTION STRUCTURES IN SRI LANKA: THE NORMALIZED TRANSLOG PROFIT FUNCTION APPROACH

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Abstract

This study attempts to estimate the output supply and input demand elasticities of rice production using the restricted normalized translog profit function for the four major paddy producing districts; Anuradhapura, Hambantota, Kurunegala and Polonnaruwa in Sri Lanka. In addition, elasticities of substitution between inputs are also estimated. The results suggest that the changes in market prices of inputs and output significantly affect the farmers' profits, rice supply and the use of resources in paddy cultivation. The supply elasticity of rice with respect to its own price is 0.5 and the supply elasticity of output with respect to fertilizer price is -0.05 on an average. Fertilizer demand in the country is inelastic but significant to its own price. Therefore, fertilizer subsidy is one of the main factors to increase fertilizer demand as well as paddy supply in the country. In addition, the low elasticity of substitution between labour and fertilizer and other inputs indicates that there is a complementary relationship among these inputs hence their combined application increases paddy production synergistically. Overall, this study suggest that farmers are price sensitive and assures prevalence of higher output price is essential for higher rice production.

Keyword: Translog profit function, demand elasticity, supply elasticity, elasticity of substitution

1. INTRODUCTION

1.1. Background of the study

The development of the agriculture sector is imperative to the wellbeing of the people since it still plays a key role in Sri Lanka in terms of employments, and main consumption expenditure. Rice is the main agricultural produce, like many other developing countries in Asia and country's staple food, and it has long been an important national target for attaining rice self-sufficiency. In the year 2014, it contributed 10 percent to the agricultural GDP and 1.1 percent to the total GDP (Central Bank of Sri Lanka 2014). The production and average yield of paddy in the country has tremendous improvement after independence in 1948, is mainly attributed the incentives provided by successive government through various measures such as huge investments in irrigation infrastructure, settlement schemes, introducing high yielding varieties (HYV), fertilizer subsidy and other input and output subsidies to farmers. As a result, Sri Lanka is almost achieved self-sufficiency in rice in good crop years. In spite of significant advances in rice production sector and various incentives provided to the sector, there is a rising concern about escalating the cost of production and declining profitability in rice cultivation. Thiruchelvum (2005) also pointed out that Sri Lanka maintains high level of self-sufficiency in rice at a cost to the economy. In addition, the current fertilizer subsidy program seems highly cost ineffective due to government spends between 1.4 and 2.4 Rupees per acre to increase farm income by only Rupees 1 per acre (World Bank,

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2013). The current subsidy accounts 4 percent of agriculture GDP and 2 percent of the total government expenditure in 2014 (Central Bank of Sri Lanka, 2014). Therefore, Fertilizer subsidy is continuing as the most controversial input subsidy programme in Sri Lanka and the subsidy cost making a huge burden to the government budget.

The main objective of this paper, therefore, is to analyze input demand and output supply parameters of paddy production with special reference to the fertilizer subsidy which has given significant interest in the recent years. In addition, study intends to estimate elasticities of the paddy supply and input demand which are vast important for the accurate prediction of the responsiveness of farmers to changes in input-output prices. Further, our analysis also aims to estimate the elasticities of substitution among different inputs used in paddy cultivation in Sri Lanka.

In order to meet the above objectives and to address the remainder of this paper is arranged as follows. Next section presents brief review of literature focusing various econometric techniques employed for the estimation of output supply and input demand functions. Section 2 presents the methodology employs to achieve the intended objectives. Section 3 discusses the results using normalized translog profit function approach that jointly estimates output supply and input demand parameters in rice production. The final section presents the concluding remarks.

1.2. Literature review

There are various econometric techniques have been employed for the estimation of demand for inputs and supply of agricultural crops. Among them production function approaches, cost function approach, profit function approach etc. are widely used. Direct or indirect application of Cobb-Douglas production function is based on highly restricted assumptions of unitary elasticity of substitution, constant returns to scale hence it yields invalid elasticities (Diewert, 1971; Christensen *et al.,* 1973). In addition, production functions with Constant Elasticity of Substitution (CES), Variable Elasticity of Substitution (VES) and the nested CES production functions are applied to estimate the production structures. However, they are based on rigid restrictions and incapable of explaining exact relationships among variables (Chaudhary *et al*., 1998). Consequently, the duality approach was widely applied to provide a comprehensive relationship among inputs and outputs (Beccera & Shuway, 1992; Siregar, 2007). The translog form is flexible because specific features of technology such as returns to scale or homotheticity may be tested by examining the estimated model parameters (Ray, 1982). Berndt and Christensen (1973), Berndt & Wood (1975), Christensen *et al.* (1975) and Binswanger (1974) also employed translog models. In addition, many authors have used profit function in empirical estimation of factor demand and output supply parameters (Yotopoulos *et al*., 1976; Sidhu & Baanante, 1979 and 1981; Bapna *et al*., 1984; Ball, 1988; Fulginiti & Perrin, 1990; Altemeier & Bottema, 1991).

Among the various functional forms a flexible functional form for the profit function is preferred (Diewert, 1973; Fuss *et al.,* 1978; Lopez, 1985) and translog, normalized quadratic and generalized Leontief are some of them. Restricted normalized translog profit function is utilized as it is able to depict input demand and output supply simultaneously. The translog profit function is a flexible functional form to estimate the input demand as it can eliminate problems related to the restrictive as required by Cobb-Douglas profit function (Diewert, 1971). Therefore, many researchers chose to start from a profit function and derive input demand and supply response functions from the profit function based on Hotelling's Lemma (Wall & Fisher, 1988; Hattink *et al*., 1998).

So far, in Sri Lanka only one study (Rajapaksha & Karunagoda, 2009) has examined the relationship among the multiple inputs used in paddy cultivation by applying the translog profit function approach using time series data. Despite that there were some previous studies which estimated the demand for fertilizer in Sri Lanka using various approaches. As example, Thusiman *et al.* (1987) estimated short run production elasticities by using micro level data and concluded that it is relatively less sensitive to increase paddy production in response to decrease in the price of

fertilizer. Meanwhile, a partial equilibrium model developed by Weerahewa (2004) to capture the changes in policy framework in demand and supply function of paddy has estimated the demand and supply elasticities for the period of 1978-2000. In that model, rice demand is a function of rice price, other crop prices and expenditure while supply is a function of paddy price and only two inputs: seed price and fertilizer price. In addition, Ekanayake (2006) has estimated the fertilizer demand elasticities for the period of 1981-2004 based on econometric method. According to his estimates fertilizer demand was relatively inelastic with respect to fertilizer prices. While, Weligamage *et al.* (2009) has estimated rice production functions in Kirindioya area using household survey data. Recently, Weerasooriya and Gunaratne (2009) examined the link between the changes in productivity and fertilizer use associated with the fertilizer subsidy using supply and area response functions for the period of 1983-2007. However, none of these studies have examined the elasticity of substitution of inputs used in paddy in Sri Lanka. Also there are no proper elasticity estimates for input demand and output supply in rice using recent input output data. Hence, our study seems to fill the knowledge gap in Sri Lanka using a normalized translog profit function approach.

2. METHODOLOGY

This study estimates the input demand and output supply functions in four selected districts in Sri Lanka for the period of 1990-2012. The selected districts are Anuradhapura, Hambantota Kurunegala and Polonnaruwa which contributed around 11%, 6%, 11% and 13% correspondingly (average of 2009-12 periods) (Department of Census and Statistics, 2012) to the national rice production annually. Anuradhapura, Hambantota and Polonnaruwa districts belong to the dry zone where paddy cultivation is mainly under the irrigation schemes while Kurunegala district belongs to the Intermediate zone where paddy cultivation is under the rain–fed and irrigated schemes. In addition, commercial level paddy cultivation is conducted in all four districts.

The demand for a production input is a derived demand based on the demand for final products. Farmers are assumed to behave rationally and the general profit function can be expressed as:

$$\pi = PQ - wx$$

Production function is given by: $Q = f(x, z)$

Where π is profit, P and w are prices of output and inputs respectively. Output quantity is Q, while x and z are the vectors of variable input quantities and fixed factor quantities. Therefore, profit function can be solved for the maximization situation.

Max $PQ - wx$ subject to $Q = f(x, z)$

The solution for this problem is a set of input demand and output supply functions given by,

$$x = x(P, w, z)$$
$$Q = q(P, w, z)$$

Substituting the above equations in general profit function gives profit maximization level of input and output.

$$\pi = P'q(P, w, z) - w'x(P, w, z)$$

Inverse input demand function and output supply functions can be obtained by differentiating the profit function with respect to the input price w and output price P.

$$X_i^* = -\frac{\partial \pi}{\partial w_i} = X^*(P, w, z) \text{ and } Q^* = \frac{\partial \pi}{\partial P} = Q^*(P, w, z)$$

A generalization of the Normalized trans-log profit function for a single output is given by Diewert (1974), Christensen *et al*. (1973).

$$\ln \pi^* = \alpha_0 + \sum_{i=1}^{n} \alpha_i \, lnP_i^* + \frac{1}{2}\sum_{i=1}^{n}\sum_{h=1}^{n} \gamma_{ih} lnP_i^* \, lnP_h^* + \sum_{i=1}^{n}\sum_{k=1}^{m} \delta_{ik} \, lnP_i^* lnZ_k + \sum_{k=1}^{m} \beta_k \, lnZ_k + \frac{1}{2}\sum_{k=1}^{m}\sum_{j=1}^{m} \emptyset_{kj} \, lnZ_k lnZ_j + \varepsilon_i \quad \text{..... (1.1)}$$

Where, $\gamma_{ih} = \gamma_{hi}, \delta_{ik} = \delta_{ki}$ and $\emptyset_{kj} = \emptyset_{jk}$ for h, i and k and the function is homogeneous of degree one in prices of all variable inputs and outputs. The definition of the variables and notation used in the profit function are as follows: π^* is the restricted profit (total revenue less total cost of variable inputs) normalized by P_q, the price of output, P_i^* is the price of variable input X_i, normalized by P_q, Z_k is the k[th]fixed inputs; $i = h = 1, \ldots n$, $k = j = 1, \ldots m$; ln is the natural logarithm; and $\alpha_{0,}\alpha_i$, γ_{ih} , δ_{ik}, β_k and $\emptyset_{kj}$ are the parameters to be estimated and ε_i is random error.

The partial derivatives of restricted profit function with respect to logs of input price yield the share equations as follows;

$$S_i = \frac{P_i^* X_i}{\pi^*} = \frac{\partial ln\, \pi^*}{\partial ln\, P_i^*} = \alpha_i + \sum_{h=1}^{n} \gamma_{ih} lnP_h^* + \sum_{k=1}^{m} \delta_{ik} \, lnZ_k \quad \text{..... (1.2)}$$

$$S_q = \frac{P_q^* X_q}{\pi^*} = 1 + \frac{\partial ln\, \pi^*}{\partial ln\, P_q^*} = 1 - (\alpha_i + \sum_{h=1}^{n} \gamma_{ih} lnP_h^* + \sum_{k=1}^{m} \delta_{ik} \, lnZ_k) \quad \text{..... (1.3)}$$

Where S_i is the share of ith input andS_q is the share of output (q). S_q is equivalent to the ratio of the total value of output to restricted profit. Since the output and input shares come from singular system of equations, their summation is equal to one and one of the share equations can be ignored. The normalized input prices and quantities of fixed factors are considered the exogenous variables under the price taking behavior. Using Hotelling Lemma, the translog profit function can be served to obtain the following share equations:

Derived factor demand function:

$$X_i = -\frac{\pi^*}{P_i}[\alpha_i + \sum_{h=1}^{n} \gamma_{ih} lnP_h^* + \sum_{k=1}^{m} \delta_{ik} \, lnZ_k] \quad \text{..... (1.4)}$$

Derived output paddy supply function:

$$X_q = \frac{\pi^*}{P_q}[1 - (\alpha_i + \sum_{h=1}^{n} \gamma_{ih} lnP_h^* + \sum_{k=1}^{m} \delta_{ik} \, lnZ_k)] \quad \text{..... (1.5)}$$

By using share equations and estimates of the profit function, output supply elasticity and input demand elasticities will be estimated simultaneously.

Estimation of elasticities

The elasticities of variable input demands and output supply with respect to all exogenous variables evaluated at averages of the S_i and at given levels of variable input prices. These are the linear transformations of parameter estimates of the profit function.

From (1.2) the demand equation for the i^{th} variable input can be written as,

$$X_i = \frac{\pi}{P_i} \ln\left(-\frac{\partial ln\pi}{\partial \ln P_i}\right) \quad \text{..... (1.6)}$$

$$lnX_i = ln\pi - lnP_i + \ln\left(-\frac{\partial ln\pi}{\partial \ln P_i}\right) \quad \text{..... (1.7)}$$

The own- price elasticity of demand (η_{ii}) for X_i is,

$$\eta_{ii} = \frac{\partial \ln X_i}{\partial \ln P_i} = \frac{\partial \ln \pi}{\partial \ln P_i} - 1 + \frac{\partial ln}{\partial \ln P_i}\left(-\frac{\partial ln\pi}{\partial ln P_i}\right) \quad \text{..... (1.8)}$$

$$\eta_{ii} = -S_i^* - 1 - \frac{\gamma_{ii}}{S_i^*} \quad \text{..... (1.9)}$$

Where S_i^* is the simple average of S_i.

Similarly from (1.7), the cross price elasticity of demand (η_{ih}) for input i with respect to the price of h^{th} input can be obtained:

$$\eta_{ih} = \frac{\partial \ln X_i}{\partial \ln P_h} = \frac{\partial \ln \pi}{\partial ln P_h} + \frac{\partial ln}{\partial ln P_h}\left(-\frac{\partial \ln \pi}{\partial ln P_i}\right) \quad \text{..... (1.10)}$$

$$\eta_{ih} = -S_h^* - \frac{\gamma_{ih}}{S_i^*} \quad \text{..... (1.11)}$$

Where$i \neq h$.

The elasticity of demand for input $i(\eta_{iq})$ with respect to output price, P_q, can also be obtained from (1.7);

$$\eta_{iq} = \frac{\partial \ln X_i}{\partial \ln P_q} = \frac{\partial \ln \pi}{\partial \ln P_q} - \frac{\partial \ln P_i}{\partial \ln P_q} + \frac{\partial ln}{\partial \ln P_q}\left(-\frac{\partial \ln \pi}{\partial \ln P_i}\right) \quad \text{..... (1.12)}$$

$$\eta_{iq} = \sum_{i=1}^{n} \frac{\partial \ln \pi}{\partial \ln P_i} \cdot \frac{\partial ln}{\partial \ln P_q} - (-1) - \sum_{h=1}^{n} \frac{\gamma_{ih}}{S_i^*}(-1) \quad \text{..... (1.13)}$$

Where $i = 1, \ldots\ldots\ldots, n, h = 1, \ldots\ldots n,$

$$\eta_{iq} = \sum_{1=1}^{n} S_i^* + 1 + \sum_{h=1}^{n} \frac{\gamma_{ih}}{S_i^*} \quad \text{..... (1.14)}$$

The elasticity of demand (η_{ik}) for input (i) with respect to the k^{th} fixed factor Z_k is also obtained from (1.7):

$$\eta_{ik} = \frac{\partial \ln X_1}{\partial ln Z_k} = \frac{\partial \ln \pi}{\partial \ln Z_k} - \frac{\partial \ln P_i}{\partial \ln Z_k} + \frac{\partial ln}{\partial ln Z_k} - \left(-\frac{\partial \ln \pi}{\partial \ln P_i}\right), \quad \text{..... (1.15)}$$

$$\eta_{ik} = \sum_{i=1}^{n} \delta_{ik} \ln P_i + \beta_k - \frac{\delta_{ik}}{S_i^*} \quad \text{..... (1.16)}$$

Output supply elasticities

We evaluate the output supply elasticities with respect to output price, price of variable inputs and quantities of fixed inputs at averages of S_i and at given levels of exogenous variables. It can also be expressed as linear functions of restricted profit function parameters. Equation for output supply (q) can be written as (1.17) using the duality theory.

$$q = \pi + \sum_{i=1}^{n} P_i X_i \quad \text{..... (1.17)}$$

By using (1.4), gives the equation;

$q = \pi + \sum_{i=1}^{n} \pi\left(-\frac{\partial \ln \pi}{\partial \ln P_i}\right)$, or

$$q = \pi\left(1 - \sum_{i=1}^{n} \frac{\partial \ln \pi}{\partial \ln P_i}\right) \quad \text{..... (1.18)}$$

$$\ln q = \ln \pi + ln\left(1 - \sum_{i=1}^{n} \frac{\partial \ln \pi}{\partial \ln P_i}\right) \quad \text{..... (1.19)}$$

Elasticity of supply with respect to the price of i^{th} variable input is given by equation (1.20) where$i = h = 1, \ldots . n.$,

$$\epsilon_{qi} = \frac{\partial \ln q}{\partial \ln P_i} = \frac{\partial \ln \pi}{\partial \ln P_i} + \frac{\partial ln}{\partial \ln P_i}\left(1 - \sum_{h=1}^{n} \frac{\partial \ln \pi}{\partial \ln P_h}\right) \quad \text{..... (1.20)}$$

For the translog profit function:

$$\epsilon_{qi} = -S_i - \sum_{h=1}^{n} \gamma_{hi} / (1 + \sum_{h=1}^{n} S_h^*) \quad \text{..... (1.21)}$$

The own price elasticity of supply (ϵ_{qq}) and elasticity of output supply (ϵ_{qk}) with respect to the fixed inputs Z_k is calculated by using following equations.

$$\epsilon_{qq} = \sum_{i=1}^{n} S_i^* + \sum_{i=1}^{n} \sum_{h=1}^{n} \gamma_{ih} / (1 + \sum_{h=1}^{n} S_h^*) \quad \text{..... (1.22)}$$

$$\epsilon_{qk} = \sum_{i=1}^{n} \delta_{ik} \ln P_i + \beta_K - \sum_{i=1}^{n} \delta_{ik} / (1 + \sum_{h=1}^{n} S_h^*) \quad \text{..... (1.23)}$$

Partial elasticities of substitution

The partial elasticities of substitution are normalized price elasticities, represents how factor income shares change as the ratio of the factors change.

Atkinson & Halvorsen (1976) defined the Partial elasticities of substitution as:

$$\sigma_{ii} = \frac{1}{S_i} \eta_{ii} \quad \text{..... (1.24)}$$

and

$$\sigma_{ih} = \frac{1}{S_h} \eta_{ih} \quad \text{..... (1.25)}$$

Where σ_{ii} is the own elasticity of substitution and σ_{ih} is the cross elasticity of substitution.

2.1. Data

To estimate the model, labour, seeds, fertilizer and agro chemicals are included as variable factors of production of paddy. In addition the machinery cost and land are included as fixed factors of production. The profit function analysis is based on the data obtained from the biannual Cost of Cultivation Surveys conducted by the Socio Economics and Planning Centre of the Department of Agriculture for the period of 1990 to 2012. Weighted average price of urea, TSP and MOP are used as fertilizer price for the analysis. GDP deflator index values obtained from the Annual Reports of Central Bank are used as proxy to calculate the machinery price index and Real price index values are obtained compared to Year 2000 values. Total cost of each inputs are calculated for the districts by multiplying per acre input cost from the paddy extent harvested area in each districts obtained from the Department of Census and Statistics for the each year. *Yala* and *Maha* season cost data are aggregated to obtain the total annual cost. Farm gate price of paddy is obtained from the Department of Agriculture and one year lagged farm gate price is used for the model.

All the time series variables are tested for the presence of stationary prior to perform the econometric analysis. In order to test for unit root at its level or first difference, all the variables are subjected to Augmented Dickey Fuller (ADF) unit root test. Since the variables of the time series are stationary their variances and auto covariances are independent of time.

2.2. Model estimation

From the general function (1.1), the normalized restricted translog profit function can be specified in actual variables as:

$$\ln \pi^* = \alpha_0 + \alpha_L \ln P_L^* + \alpha_S \ln P_s^* + \alpha_F \ln P_F^* + \alpha_C \ln P_C^* + \frac{1}{2}\gamma_{LL} \ln P_L^* \ln P_L^* + \frac{1}{2}\gamma_{SS} \ln P_S^* \ln P_S^* + \frac{1}{2}\gamma_{\mathrm{FF}} \ln P_F^* \ln P_F^* + \frac{1}{2}\gamma_{\mathrm{CC}} \ln P_C^* \ln P_C^* + \frac{1}{2}\gamma_{\mathrm{LS}} \ln P_L^* \ln P_S^* + \frac{1}{2}\gamma_{\mathrm{LF}} \ln P_L^* \ln P_F^* + \frac{1}{2}\gamma_{\mathrm{LC}} \ln P_L^* \ln P_C^* + \frac{1}{2}\gamma_{SF} \ln P_S^* \ln P_F^* + \frac{1}{2}\gamma_{SC} ln P_S^* \ln P_C^* + \frac{1}{2}\gamma_{FC} \ln P_F^* \ln P_C^* + \delta_{LZm} \ln P_L^* \ln Z_m + \delta_{LZa} \ln P_L^* \ln Z_a + \delta_{SZm} \ln P_S^* \ln Z_m + \delta_{SZa} \ln P_S^* \ln Z_a + \delta_{FZm} \ln P_F^* \ln Z_m + \delta_{FZa} \ln P_F^* \ln Z_a + \delta_{CZm} \ln P_C^* \ln Z_m + \delta_{CZa} \ln P_C^* \ln Z_a + \beta_{Zm} \ln Z_m + \beta_{Za} \ln Za + \frac{1}{2}\emptyset_{ZmZm} \ln Z_m \ln Z_a + \frac{1}{2}\emptyset_{ZaZa} \ln Z_a \ln Z_a + \emptyset_{ZmZa} \ln Z_m \ln Z_a \quad \ldots\ldots\ldots\ldots\ldots (1.26)$$

Where π^* is the restricted profit (real value) from paddy production: total revenue less total cost of labour, seeds, fertilizer and agro chemicals normalized by the farm gate price of paddy; P_L^* is the wage rate of labour per man day normalized by farm gate price of paddy; P_S^* is the seed price normalized by farm gate price of paddy, P_F^* is the fertilizer farm gate price normalized by farm gate price of paddy, P_C^* is the agro chemical price normalized by farm gate price of paddy (import value of pesticides is included as a proxy for agro chemical price). Fixed inputs included in the specifications of the profit function are Z_m machinery price (obtained by dividing the machinery cost by GDP deflator index) and Z_a is the land area index. All the price indices are in real value (2000=1).

The parameters α_0, α, β, δ, and θ are to be estimated and subscripts L, S, F, and C stand for the variable input of production labour, seeds, fertilizer and agro chemicals respectively.

The partial derivatives of normal restricted translog profit function (1.26) with respect to log of input price are the negative share equations for labour, seeds, fertilizer and agro chemicals as follows:

$$-\frac{P_L X_L}{\pi^*} = \alpha_L + \gamma_{LL} \ln P_L^* + \gamma_{\mathrm{LS}} \ln P_S^* + \gamma_{LF} \ln P_F^* + \gamma_{\mathrm{LC}} \ln P_C^* + \delta_{LZm} \ln Z_m + \delta_{LZa} \ln Z_a \ldots\ldots (1.27)$$

$$-\frac{P_S X_S}{\pi^*} = \alpha_S + \gamma_{SS} \ln P_S^* + \gamma_{\mathrm{LS}} \ln P_L^* + \gamma_{SF} \ln P_F^* + \gamma_{SC} \ln P_C^* + \delta_{SZm} \ln Z_m + \delta_{SZa} \ln Z_a \ldots\ldots (1.28)$$

$$-\frac{P_F X_F}{\pi^*} = \alpha_F + \gamma_{FF} \ln P_F^* + \gamma_{\mathrm{LF}} \ln P_L^* + \gamma_{SF} \ln P_S^* + \gamma_{FC} \ln P_C^* + \delta_{FZm} \ln Z_m + \delta_{FZa} \ln Z_a \ldots\ldots (1.29)$$

$$-\frac{P_C X_C}{\pi^*} = \alpha_C + \gamma_{CC} \ln P_C^* + \gamma_{\mathrm{LC}} \ln P_L^* + \gamma_{SC} \ln P_S^* + \gamma_{FC} \ln P_F^* + \delta_{CZm} \ln Z_m + \delta_{CZa} \ln Z_a \ldots\ldots (1.30)$$

WhereX_L,X_S,X_F and X_C are the quantities of variable inputs of labour, seeds, fertilizer and agro chemicals, respectively. Other variables and parameters are same as defined earlier.

Under the assumptions of profit maximizing and price taking behaviour, the parameters in equation (1.26) must be equal to the corresponding parameters in equation (1.27), (1.28), (1.29), (1.30) and must fulfil the symmetry restriction. This concept will provide testing the hypothesis of profit maximization.

Since the input and output shares come from a singular system of equations (since by definition $S_q - \sum S_i$=1), one of the share equations, the output share is dropped and the profit and factor demand equations are estimated as simultaneous system.

An error term of the profit function and share equations are likely to be correlated contemporaneously due to large number of common explanatory variables. Thus Ordinary Least Square (OLS) is not applicable to estimate the equation in the system. OLS is also not appealing as we need to impose cross equation restrictions. This problem can be overcome by using Zellner's estimation procedure for Seemingly Unrelated Regression (SUR) to obtain estimates which are asymptotically equivalent to Maximum Likelihood Estimation (MLE) when iterated to convergence and invariant to which share equation is deleted. In addition to the symmetry constraints ($\gamma_{LS} = \gamma_{SL}$,$\gamma_{LF} = \gamma_{FL}$, $\gamma_{LC} = \gamma_{CL}$, $\gamma_{SF} = \gamma_{FS}$, $\gamma_{SC} = \gamma_{CS}$, $\gamma_{CF} = \gamma_{FC}$), the linear parametric constraints are also imposed across equations.

Before proceeding to the estimated parameter of normalized restricted translog profit and share equations, two hypothesis tests are carried out. They are test for the validity of profit maximization and Cobb Douglas hypothesis. The first empirical test checks the validity of symmetry and homogeneity restrictions across profit and share equations. The null hypothesis in the first test indicates that the parameters of the input share equations 1.27, 1.28, 1.29 and 1.30 are equal to the corresponding same parameters on the profit equation 1.26. An F test statistic with good asymptotic properties is conducted to test this hypothesis (Theil, 1971). F test statistics indicates that the null hypothesis cannot be rejected at 0.05 level of significance. This means that the profit maximization assumption is valid for all four districts.

The second statistical test is conducted in order to check the Cobb-Douglas (C-D) hypothesis where the coefficients of all second order terms in profit function (1.26) should be zero. Therefore, an *F*-test is conducted to test the null hypothesis that all γ_{ih} equal zero and all δ_{ik} equal zero. Based on the F-test, the hypothesis on Cobb-Douglas is rejected, suggesting that the translog profit function is more suitable for the data.

The Stata 12 statistical software is used for the analysis.

3. RESULTS AND DISCUSSION

The parameter estimates of translog profit function for each district is presented in Table 1 and output supply and demand elasticities derived are presented in Table 2, 3, 4 and 5 for the selected districts of Anuradhapura, Hambantota, Kurunegala, and Polonnaruwa respectively. These elasticities are evaluated at simple averages of the S_i and at geometric means of the variable input prices and of levels of fixed inputs.

Table 1: Estimated normalized translog profit function for paddy

Variable	Polonnaruwa	Anuradhapura	Hambantota	Kurunegala
Lnpl	-0.810*	-0.982*	-0.955*	-1.212*
	(0.114)	(0.145)	(0.129)	(0.109)
Lnps	-0.086*	-0.114*	-0.174*	-0.124*
	(0.010)	(0.015)	(0.023)	(0.015)
Lnpf	-0.227*	-0.244*	-0.243*	-0.279*
	(0.031)	(0.029)	(0.038)	(0.037)
Lnpc	-0.125*	-0.117*	-0.171*	-0.149*
	(0.024)	(0.016)	(0.034)	(0.020)
Lnplpl	-0.745*	-1.089*	-0.941*	-1.548*
	(0.143)	(0.155)	(0.141)	(0.133)
Lnpsps	-0.060*	-0.212*	-0.024	-0.092*
	(0.007)	(0.031)	(0.037)	(0.019)
Lnpfpf	-0.118*	-0.129*	-0.168*	-0.150*
	(0.014)	(0.020)	(0.026)	(0.017)
Lnpcpc	0.017	-0.073	0.179*	-0.082

	(0.029)	(0.052)	(0.089)	(0.056)
Lnplps	-0.034*	-0.027	-0.167*	-0.059*
	(0.012)	(0.028)	(0.044)	(0.022)
Lnplpf	-0.093*	-0.195*	-0.199*	-0.257*
	(0.035)	(0.037)	(0.046)	(0.038)
Lnplpc	-0.202*	-0.119*	-0.372*	-0.130*
	(0.042)	(0.045)	(0.085)	(0.042)
Lnpspf	-0.009*	-0.032*	0.001	-0.018*
	(0.003)	(0.005)	(0.013)	(0.006)
Lnpspc	-0.031*	0.025	-0.102*	-0.102*
	(0.007)	(0.027)	(0.041)	(0.024)
Lnpfpc	0.007	0.009	-0.070*	-0.022*
	(0.011)	(0.010)	(0.025)	(0.009)
Lnplzm	-0.078	-0.081	0.064	0.621*
	(0.207)	(0.150)	(0.073)	(0.176)
Lnplza	-0.836*	-0.747*	-0.786*	-1.538*
	(0.270)	(0.153)	(0.111)	(0.212)
Lnpszm	-0.039	-0.029	0.073*	-0.023
	(0.012)	(0.022)	(0.021)	(0.022)
Lnpsza	-0.043*	-0.065*	-0.242*	-0.106*
	(0.019)	(0.022)	(0.029)	(0.025)
Lnpfzm	-0.145*	-0.024	-0.151*	-0.069
	(0.053)	(0.064)	(0.045)	(0.058)
lnpfza	-0.284*	-0.101	-0.144*	-0.198*
	(0.082)	(0.069)	(0.071)	(0.064)
Lnpczm	0.020	-0.033	-0.109*	-0.021
	(0.059)	(0.039)	(0.041)	(0.036)
Lnpcza	-0.175	-0.012	-0.060	-0.132*
	(0.096)	(0.040)	(0.060)	(0.041)
Cons	7.658	7.303*	6.777*	7.207*
	(0.099)	(0.162)	(0.136)	(0.102)

Note: Standard errors are in parenthesis. * Significant at 5%

As shown in Table 1, coefficient of factor prices of labour, seeds, fertilizer and agro chemicals and their interaction terms are negative in the profit function. Based on the results, price of labour, seeds, fertilizer and agro chemicals are significantly influence the profit function. Therefore, cheaper input prices increase the profit obtained from paddy cultivation. However, the coefficients values are less than unity, indicate the input prices affect inelastic on the profit. Moreover, the highest coefficient values for the labour wage rate, followed by fertilizer price indicate the profit is highly depending on labour wage rate and fertilizer price.

As shown in Table 2, 3, 4 and 5, the farm gate price of paddy has a significant positive effect on paddy supply while variable factor prices have negative effects as expected. The supply elasticity with respect to previous year farm gate price is found to be positive and inelastic; a one percent rise in the paddy price would expand the supply of paddy ranging between 0.4 to 0.6 and on an average it is 0.5 percent. Therefore, results indicate that the effect of paddy price is more important to determine the country's paddy supply than the price of fertilizer. And also our supply elasticity is in line with recent study findings of Weerahewa (2004) that estimated supply elasticity with respect to own price is 0.6 and with respect to fertilizer price is -0.07 for the 1978-2000 periods. But our elasticity values are smaller than the results obtained by Rajapaksha & Karunagoda (2009) that estimated own price elasticity of paddy supply raging between 0.85 in Polonnaruwa district to 2.37 in Kalutara district. Meantime, the aggregate paddy output elasticities with respect to price were relatively low in Sri Lanka in early years, with short-run supply elasticity falling between 0.09 and

0.13 and long-run elasticity 0.11-0.19 (Gunawardana & Oczkowski, 1992; Bogahawatte, 1983; Samaratunga, 1984).

The negative supply elasticities with respect to variable inputs imply that the input use will decline with the increased input price thus would reduce the paddy yield and output. Moreover, the results show that wage rate and fertilizer price are the influencing variable inputs on paddy supply while fixed factor of land also affect significantly. The results show that the output supply with respect to fertilizer price is significant and -0.05 on an average. Therefore, fertilizer subsidy has a significant positive effect on paddy output in the country and the effect is relatively small compared to paddy price. According to the figures, supply elasticity with respect to fertilizer price is quite comparable in absolute values in Anuradhapura and Kurunegala districts (-0.05) whereas values are less than unity in all four districts. Thus, the paddy supply with respect to fertilizer price is inelastic as estimated. In addition, one percent rise in wage rate will decrease the paddy supply by 0.18 percent on an average.

Moreover, expansion of cultivable area would enhance paddy supply significantly and positively in all the districts. The largest supply elasticity in Kurunegala with respect to land area may be due to the fact that farmers in Kurunegala district cultivate paddy using rain-fed as well as irrigated system and when the irrigated water is available adequately so that increasing in land area would expand the paddy production significantly. But in other three districts paddy cultivation largely depends on irrigated water and supply is limited. Moreover, fixed input of machinery has slight positive impact in all the districts except in Kurunegala.

The own price elasticity of demand for inputs have negative signs as expected and are statistically significant except own price elasticity of agro chemical in Anuradhapura andprice elasticity of seed and chemical in Kurunegala district. Elasticity values are less than unity in absolute value for all the inputs in all four districts (except agro chemical in Hambantota and Polonnaruwa).

Derived elasticity estimates for paddy supply and demand for variable inputs in rice production

Table 2: Elasticity values – Anuradhapura district

Output/input	Price of Paddy	Price of Labour	Price of Seed	Price of Fertilizer	Price of Chemical	Machinery	Land
Paddy supply	0.478*	-0.231*	-0.001	-0.054**	-0.042	0.089	0.503*
Labour demand	0.617*	-0.588*	-0.078*	0.022	0.027	0.044	0.404*
Seed demand	0.031	-0.609*	-0.830*	0.087	-0.339	0.013	0.028
Fertilizer demand	0.596**	0.090	0.047	-0.578*	-0.155*	.015	0.065
Agro-chemical demand	0.868	0.210	-0.334	-0.286*	-0.457	0.016	0.006

Note: The figures are calculated at the mean value of shares. Significance test for each estimated elasticity can be conducted by making use of estimated standard errors as follows: $SE(\eta_{ih}) = SE(\gamma_{ih})/S_i$ and t statistics can be calculated by $t_{ih} = \eta_{ih}/SE(\eta_{ih})$ where η_{ih} is elasticity of factor demand
* Significant at 5%, ** Significant at 10%

Table 3: Elasticity values – Hambantota district

Output/input	Price of Paddy	Price of Labour	Price of Seed	Price of Fertilizer	Price of Chemical	Machinery	Land
Paddy supply	0.422**	-0.019	-0.002	-0.009	0.012	0.095	0.667*
Labour demand	0.056	-0.535*	0.086	0.057	0.336*	-0.034	0.378*
Seed demand	0.040	0.499	-0.948*	-0.215*	0.623*	-0.035	0.116
Fertilizer demand	0.100	-0.505*	-0.140	-0.374*	0.198	0.109	0.104
Agro-chemical demand	0.521	1.708*	0.547*	0.267	-2.339*	0.055	0.030

Note: The figures are calculated at the mean value of shares. Significance test for each estimated elasticity can be conducted by making use of estimated standard errors as follows: $SE(\eta_{ih}) = SE(\gamma_{ih})/S_i$ and t statistics can be calculated by $t_{ih} = \eta_{ih}/SE(\eta_{ih})$ where η_{ih} is elasticity of factor demand
* Significant at 5%, ** Significant at 10%

Table 4: Elasticity values –Kurunegaladistrict

Output/input	Price of Paddy	Price of Labour	Price of Seed	Price of Fertilizer	Price of Chemical	Machinery	Land
Paddy supply	0.462*	-0.168**	-0.001	-0.060*	0.006	-0.298*	1.205*
Labour demand	0.422**	-0.396*	-0.051*	0.021	0.003	-0.374*	0.928*
Seed demand	0.024	-0.444*	-0.285	-0.079	0.785*	0.012	0.054
Fertilizer demand	0.607*	0.086	-0.037	-0.618*	-0.038	0.052	0.148
Agro-chemical demand	0.120	0.022	0.670*	-0.070	-0.501	0.012	0.076

Note: The figures are calculated at the mean value of shares. Significance test for each estimated elasticity can be conducted by making use of estimated standard errors as follows: $SE(\eta_{ih}) = SE(\gamma_{ih})/S_i$ and t statistics can be calculated by $t_{ih} = \eta_{ih}/SE(\eta_{ih})$ where η_{ih} is elasticity of factor demand
* Significant at 5%, ** Significant at 10%

Table 5: Elasticity values-Polonnaruwa District

Output/input	Price of Paddy	Price of Labour	Price of Seed	Price of Fertilizer	Price of Chemical	Machinery	Land
Paddy supply	0.653*	-0.281*	-0.033	-0.113*	-0.052	0.085	0.971*
Labour demand	0.795**	-0.837*	-0.003	-0.101*	0.145	-0.053	0.676**
Seed demand	0.827	-0.022	-0.439*	-0.062	-0.304	0.012**	0.036
Fertilizer demand	1.143*	-0.361*	-0.025	-0.679*	-0.079	0.109	0.185
Agro-chemical demand	0.905	0.897	-0.214	-0.136	-1.452**	0.016	0.074

Note: The figures are calculated at the mean value of shares. Significance test for each estimated elasticity can be conducted by making use of estimated standard errors as follows: $SE(\eta_{ih}) = SE(\gamma_{ih})/S_i$ and t statistics can be calculated by $t_{ih} = \eta_{ih}/SE(\eta_{ih})$ where η_{ih} is elasticity of factor demand
* Significant at 5%, ** Significant at 10%

Increase in output price would also encourage direct and significant expansion in demand for variable inputs especially labour and fertilizer in paddy cultivation. In quantitative terms, the percent increases in demand for labour, associated with one percent increase in output price are 0.62, 0.06, 0.42 and 0.80 for the Anuradhapura, Hambantota, Kurunegala and Polonnaruwa districts, respectively. Meantime, the results also indicate that labour and agro chemicals in all four districts are substitute inputs in paddy production. Elasticity of labour with respect to fixed inputs of land is positive and significant for all the districts and the average elasticity value is 0.60. Therefore, degree of responsiveness to labour absorption is significant but inelastic. The significant negative elasticity value of labour demand with respect to machinery in Kurunegala district indicates that labour and machinery are complementary inputs and their combined application will increase paddy production. This might be due to the fact that in Sri Lanka the majority of the paddy lands are small plots of less than one hectare, thus mechanization in large scale cannot apply and consequently labour and small equipment are jointly use in paddy cultivation.

The study result suggests that the demand for seeds with respect to labour and fertilizer are complementary in inputs. Meanwhile, seed demand increase slightly with fixed inputs of machinery and land. Demand for fertilizer with respect to labour is negative and significant in the Hambantota and Polonnaruwa districts, while the elasticity values are positive but insignificant in Anuradhapura and Kurunegala districts. Hence, fertilizer and labour inputs in Hambantota and Polonnaruwa districts act as complementary inputs. Fertilizer demand elasticity with respect to land is in around 0.1. As can be seen from Tables 2, 3, 4 and 5, the own price elasticities of fertilizer are -0.58, -0.37, -0.62 and -0.68 for Anuradhapura, Hambantota, Kurunegala and Polonnruwa districts respectively. Furthermore, fertilizer demand elasticity to the output price is highest in Polonnaruwa (1.14). Contrary, one percent increase in paddy price will increase the fertilizer demand only by 0.10 percent in Hambantota district. This is due to the fact that in Polonnaruwa district fertilizer use in paddy farming is noticeably higher than that of Hambantota district. Therefore, findings of our results show that fertilizer demand in the country is significantly affected by both farm gate price of paddy and fertilizer price. However, Ekanayake (2006) using a simple regression model, found that changes in the prices of fertilizer do not have a significant effect on fertilizer usage and own price elasticity of fertilizer demand is -0.1. Rajapaksha & Karunagoda (2009) also concluded that the fertilizer demand in the country is highly responsive to the paddy price rather than fertilizer price. According to their estimation, fertilizer demand is elastic with respect to its own price and paddy price. However, normalized translog profit function estimated by them seems to be unclear since they used interaction between paddy price and variable inputs in their model. Based on simple Cobb Douglas approach using individual farm level data, Weligamage *et al.* (2009) also found that the elasticity of paddy yield with respect to fertilizer application is 0.15 and this estimate implies that the elasticity of fertilizer demand with respect to fertilizer price is approximately -1.2.

Study results indicate that agro chemical demand with respect to output price is positive but not significant. Similarly, agro chemical demand with respect to fixed inputs is positive and relatively small. Moreover, the effect of wage rate on agro chemical demand is positive in all the districts indicates labour and agro chemicals are substitutes in paddy cultivation. This might be because instead of using more labour in general land preparation activities, weedicides can be used intensively to reduce the labour inputs. In addition, seed is also substitute to agro chemicals in Hambantota and Kurunegala districts.

The analysis also suggests that the expansion of capital in the form of agricultural machineries, decreases labour demand (except in Anuradhapura district) contributes positively to paddy production. In addition, exogenous increases in land area also increase the paddy production and demand for all variable inputs of production in the country. The expansion of land has relatively large influence on output supply and labour demand while seed, fertilizer and agro chemical demand have small impact.

The estimated elasticities of substitution between pairs of inputs are presented in the Table 6 for four districts. Labour is a substitute for agro chemicals and the highest substitutability value can be observed in Hambantota district. Nonetheless, labour is complement to the seed except in Hambantota district. The estimates also indicate that seed and fertilizer are complementary except in Anuradhapura district. In addition elasticity of substitution values between fertilizer and agro chemicals are also negative (except Hambantota). As seen from Table 6, the largest substitutability relation is between seeds and agro chemicals and the value is higher than the unity. However, the low elasticity of substitution between labour and fertilizer and other input pairs indicates that there is a complementary relationship among these inputs hence combined application of such inputs will synergistically increase the paddy production in the country.

Table 6: Estimated elasticities of substitution

Anuradhapura			
σ_{LL}=-0.69	σ_{Ls}= -0.71	σ_{LF}=0.11	σ_{LC}=0.24
σ_{ss}=-7.56	σ_{SF}=0.43	σ_{SC}=-3.05	
σ_{FF}=-2.81	σ_{FC}=-1.39		
σ_{CC}=-4.1			
Hambantota			
σ_{LL}=-0.70	σ_{Ls}=0.65	σ_{LF}=0.28	σ_{LC}=2.23
σ_{ss}=-7.17	σ_{SF}=-1.06	σ_{SC}=4.14	
σ_{FF}=-1.84	σ_{FC}=1.31		
σ_{CC}=-15.53			
Kurunegala			
σ_{LL}=-0.40	σ_{Ls}=-0.45	σ_{LF}=0.09	σ_{LC}=0.02
σ_{ss}=-2.55	σ_{SF}=-0.33	σ_{SC}=5.99	
σ_{FF}=-2.56	σ_{FC}=-0.29		
σ_{CC}=-3.83			
Polonnaruwa			
σ_{LL}=-1.06	σ_{Ls}=-0.03	σ_{LF}=-0.46	σ_{LC}=1.14
σ_{ss}=-4.91	σ_{SF}=-0.28	σ_{SC}=-2.39	
σ_{FF}=-3.09	σ_{FC}=-0.62		
σ_{CC}=-11.41			

Note: Elasticities of substitution values are evaluated at the means of the data. The subscripts L, S, F and C stand for Labour, Seeds, Fertilizer and Agro chemicals respectively. The own elasticities of substitution has little economic meaning.

From the analysis, following broad conclusions may be drawn about the paddy production in Sri Lanka.

4. CONCLUSION

The overall estimations suggest that the changes in market prices of inputs and output affect significantly on farmer profit, rice supply and the resource use in paddy cultivation. Meanwhile, farmers maximize profit in paddy farming subject to given inputs (labour, seeds, fertilizer and agro chemicals), paddy prices and fixed factors of production (machinery and land).

The results show that paddy output in the country is more responsive to the increase in output price than change in fertilizer price. The impact of fertilizer price on paddy supply is relatively small (supply elasticity with respect to fertilizer price is -0.05) but significant.Generally fertilizer demand is thought to be more elastic in developing countries; this study outcome confirms that in Sri Lanka fertilizer demand is inelastic but significant to its own price. Consequently, fertilizer subsidy is one of the main factors to increase the fertilizer demand as well as output supply in the country. As indicated by the elasticity, fertilizer demand in the country is also significantly depend on the output price of supply. Therefore, paddy price has strong incentive to promote the fertilizer demand as well as paddy production in the country. In addition, the analysis shows that labour demand in paddy cultivation is more responsive to the wage rate while fertilizer price has fair degree of responsiveness.

The low substitutability between labour and fertilizer and other input pairs indicates combined application of such inputs increase the paddy production in the country.Overall, this study suggests that farmers are price sensitive and assures prevalence of high output price is essential for higher production.

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