Modelling the South African Agricultural Production Structure and Flexibility of Input Substitution

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Abstract

This paper evaluates the production structure of the South African agricultural sector for the period 1970-1998, using a translog function. The results show that the production structure is best represented by production technology that is Hicks-neutral and homothetic. This information is useful in evaluating the results of previous research on the structure of South African agricultural production, particularly relatively recent research on elasticities of substitution. In addition, it also provides the basis for meaningful future analysis of aspects related to the production structure of agriculture.

1. Introduction

The South African agricultural sector has gone through various stages of change and rapid growth. With democratisation in 1994, South Africa has undergone major changes in its economic policies. The country embarked on an economic restructuring programme, shifting from a relatively closed to a more free market oriented economy. In agriculture, this change is characterised by various new policies, including globalisation, market liberalisation, regional market integration, the land distribution programme and the empowerment of emerging small-scale farmers. These new policies have important effects on the structure of the agricultural sector. They also increase the need to understand these effects better.

The production structure of the South African agricultural sector has gone through several changes since World War II. Several studies attempted to analyse some of these changes, in particular how the factor inputs have substituted each other. In a series of studies, Van Zyl (1986a, 1986b, 1988, 1990) proposed and used the duality approach to evaluate the flexibly of input substitution for the South African agricultural sector. The duality approach in applied production economics often involves the estimation of a flexible functional form cost or profit function. Unfortunately, none of these studies mentioned above tested for the underlying production structure, such as whether the production technology is Hicks-neutral, homothetic or homogenous in nature. Also, it was not determined whether the estimated cost function satisfies the monotonicity, concavity and convexity conditions implied by economic theory. Thus, the analysis and conclusions derived from these studies may have lead to misleading conclusions due to using an incorrect functional form to represent the underlying production technology.

Our interest in this paper is twofold: (1) to identify the functional form of the production (cost) function that best represents the production structure of South Africa's agricultural sector; and (2) to test the properties imposed by economic theory on the cost function. The outline of the paper is as follows: In section 2, we briefly outline a translog cost function to represent producer behaviour into a system of empirical cost and factor share equations, which take the form of a seemingly unrelated regression (SUR) model. The latter model and the data are described in section 3, while the estimation results are reported in section 4. These results provide information on the parameter estimates, predicted values of the factor shares and the required test statistics. The paper is concluded in section 5, where we present a summary of our findings and the implications.

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2. The Model

We start off by assuming that the South African agricultural sector can be characterised by a twice differentiable production function $Q = Q(L, K, W, O)$, where Q is output, and L, K, W, and O are the inputs of land, capital, labour and intermediate inputs, respectively. By assuming that input prices are exogenous and farmers are minimising costs, and then applying the duality principle, we can derive the production technology from the cost function. Let the minimum cost function be $C = C(P_L, P_k, P_w, P_o, T)$, where P_j (j= L, K, W, O) are the prices of inputs, and T is used to capture exogenous technical change. So our model is predicted on the assumption that the technological possibilities faced by the South African agricultural sector can be summarised as $C(\underline{P}, Q) = \min_{X}\left\{P^{'}X:\ F(X) \geq Q,\ X \geq 0\right\}$, where X is a 4x1 vector of inputs, P is a 4x1 vector of input prices, Q is scalar output and F(X) is the underlying production function.

For our purpose, we use a flexible functional form for the cost function that places no a priori restrictions on the Allen partial elasticities of substitution (AES). The most commonly used flexible functional forms are the Generalised Leontief (Diewert, 1971), the Generalised Cobb-Douglas (Diewert, 1974) and the Translog (Christensen et al., 1971, 1973). However, we arbitrarily use a translog cost function because it has various desirable properties that the others do not have: the elasticities of substitution do need to be restricted to a particular value over time; it does not depend on the assumption of constant returns to scale and rather than assuming technological change to be non-neutral or neutral, these can be tested. Finally, in the words of Fuss, MacFadden, and Mundlak (1978), the translog function is attractive since it is a "parsimonious flexible functional form".

The translog cost function used in this paper is similar to the one used by Van Zyl (1986a, 1986b, 1988, 1990). The unrestricted four-input translog can be written as:

$$\begin{aligned}\text{Ln}\, C = {} & \alpha_0 + \alpha_Q \text{Ln Q} + \frac{1}{2}\alpha_{QQ}(\text{Ln}\, Q)^2 + \alpha_T T + \alpha_{TT}(T)^2 + \sum_{i}^{4}\gamma_i \text{Ln}P_i + \frac{1}{2}\sum_{i}^{4}\sum_{j}^{4}\gamma_{ij}\text{Ln}P_i \text{Ln}P_j \\ & + \sum_{i}^{4}\delta_{iQ}\text{Ln}\, P_i \text{Ln}Q + \sum_{i}^{4}\varphi_{iT}\text{Ln}P_i\ T\end{aligned} \tag{1}$$

For the underlying production function to satisfy the general requirements of production theory, the following restrictions are imposed, symmetry i.e., $\gamma_{ij} = \gamma_{ji}$ for i,j = L, K, W and O, linear homogeneity in prices requires $\sum_{i}^{4}\gamma_i = 1$ and $\sum_{i}^{4}\gamma_{ij} = \sum_{i}^{4}\partial_{iQ} = \sum_{i}^{4}\varphi_{iT} = 0$.

Accordingly, these restrictions imply that a proportional increase in the cost of all factors of production will cause an increase in output. Using the notion that factor market is competitive, and assuming that input prices are fixed and farmers are cost minimising agents, then input demand functions are derived by differentiating the log transformation of the translog cost function:

$$\frac{\partial\, \text{Ln}\, C}{\partial\, \text{Ln}\, P_{\text{i}}} = \frac{\partial\, C}{\partial\, P_{\text{i}}}\frac{P_{\text{i}}}{C} = \gamma_i + \sum_{j}\gamma_{\text{ij}}\text{Ln}\, P_j + \sum_{j}\delta_{jQ}\text{Ln}\, Q + \varphi_{iT}T \succ 0,\ \forall\, \text{i}. \tag{2}$$

Since equation 2 is the input share, it must be positive, which implies that the monotonicity condition (in prices) is satisfied. Monotonicity in output requires that the cost function is non-decreasing in output, i.e.,

$$\frac{\partial\, \text{Ln}\, C}{\partial\, \text{Ln}\, \text{Q}} = \alpha_Q + \alpha_{\text{QQ}}\ \text{Ln}\, \text{Q} + \sum_{i}\delta_{iQ}\text{Ln}\, \text{P} \succ 0 \tag{2a}$$

The factor share equation is obtained by using Shephard's Lemma, so that the ith factor demand is

$$\text{X}_{\text{i}} = \frac{\partial\, C}{\partial\, P_i} \tag{3}$$

Hence, from equation 2 and equation 3, we obtain the following factor share equations,

$$\frac{X_L P_L}{C} = S_L = \gamma_L + \sum_j \gamma_{ij} \text{Ln } P_j + \partial_{LQ} \text{Ln } Q + \varphi_{LT} T$$
$$\frac{X_K P_K}{C} = S_K = \gamma_K + \sum_j \gamma_{ij} \text{Ln } P_j + \partial_{KQ} \text{Ln } Q + \varphi_{KT} T \qquad (4)$$
$$\frac{X_W P_W}{C} = S_W = \gamma_W + \sum_j \gamma_{ij} \text{Ln } P_j + \partial_{WQ} \text{Ln } Q + \varphi_{WT} T$$
$$\frac{X_O P_O}{C} = S_O = \gamma_O + \sum_j \gamma_{ij} \text{Ln } P_j + \partial_{OQ} \text{Ln } Q + \varphi_{OT} T$$

where the total cost $C = P_L L + P_K K + P_W W + P_o O$ and S_i is the cost share of input i.

In our case, neutral or non-neutral technological change is embodied in the translog cost function, i.e. after estimating if $\varphi_{iT} = 0$, then time alone affects factor shares. However, if $\varphi_{iT} > 0$, then the technological change is non-neutral(i.e. factor-i using).

For the estimated cost function to be consistent with economic theory, it must be concave, requiring that the estimated Hessian matrix of the second order derivatives be negative semi-definite. For a singular matrix, a necessary and sufficient condition for negative semi-definiteness is that the maximum Eigenvalues are exactly equal to zero. Note that singularity implies that at least one of the Eigenvalues must be zero. In other words, the Hessian matrix should be semi-negative

3. Estimation procedure and Data

Using the Seemingly Unrelated Regressions (SUR) estimation procedure, we estimate a system of equations (equation 3). Because there may be simultaneous equation bias present, the four inputs should be treated as endogenous variables. An additive disturbance term is added to each equation to represent any deviation of the cost shares from the logarithmic derivatives of the translog cost function as result of cost minimising behaviour (Berndt and Wood, 1975). The share and cost equation error is assumed to be independently and identically distributed over time, with mean zero and constant variance, i.e., the error terms in each equation are homoskedastic and non-autocorrelated. Moreover, contemporaneous error terms across equations have non-zero correlation.

Since factor cost share adds to one, and to avoid singularity of the error covariance matrix, one of the four factor share equations is discarded during estimation and the required parameters are computed residually. According to Berndt and Wood (1975), any share equation can be dropped. In this analysis, the intermediate inputs equation is dropped. The remaining equations are estimated, including the total cost function as a system of equations using SUR. The use of the SUR estimation procedure to estimate equation 5 and equation 6 reduces possible multicollinearity problems.

$$S_L = \gamma_L + \sum_j \gamma_{ij} \text{Ln } P_j^N + \partial_{LQ} \text{Ln } Q + \varphi_{LT} T + \varepsilon_L$$
$$S_K = \gamma_K + \sum_j \gamma_{ij} \text{Ln } P_j^N + \partial_{KQ} \text{Ln } Q + \varphi_{KT} T + \varepsilon_k \qquad (5)$$
$$S_W = \gamma_W + \sum_j \gamma_{ij} \text{Ln } P_j^N + \partial_{WQ} \text{Ln } Q + \varphi_{WT} T + \varepsilon_W$$

Where $P_j^N = \frac{P_j}{P_o}, j = L, K, W$.

$$\text{Ln } C = \alpha_0 + \alpha_Q \text{Ln Q} + \frac{1}{2}\alpha_{QQ}(\text{Ln } Q)^2 + \alpha_T T + \alpha_{TT}(T)^2 + \sum_i^3 \gamma_i \text{Ln} P_i^N + \frac{1}{2}\sum_i^3 \sum_j^3 \gamma_{ij} \text{Ln} P_i^N \text{Ln} P_j^N$$
$$+ \sum_i^3 \delta_{iQ} \text{Ln } P_i^n \text{Ln} Q + \sum_i^3 \varphi_{iT} \text{Ln} P_i^N \; T + \varepsilon_c \qquad (6)$$

Equation 5 and 6 are similar to those used by Van Zyl (1986a, 1896b, 1988) in his studies mentioned earlier. The simpler structure of the model is in line with assumptions used in most empirical work of this type (Pope and Just, 1998).

As stated previously, the translog function allows for the estimation of the cost function without any *a priori* restrictions, such as Hicks-neutral technological change and homotheticity, etc. The structure of the underlying production function is tested by imposing restrictions (specifically Hicks-neutrality, homotheticity, homogeneity and technological change) on the parameters of the cost function. Each time a set of restrictions is imposed, a new system of equations is created that is nested in the unrestricted model. For our purpose, we first test for Hicks-neutrality, followed by respectively testing for homotheticity, combined homotheticity and Hicks-neutrality, technological change, and finally restricting the parameters for homogeneous conditions. The validity of the different restrictions is tested by applying the log-likelihood ratio test to each of the restricted and unrestricted models. This procedure creates a form of sequential ordering of nested models within the unrestricted model. Finally, we evaluate whether the selected structure of the underlying production function satisfies the monotonicity, concavity and convexity conditions implied by economic theory.

Annual data for the period 1970 to1998 from the National Department of Agriculture is used to estimate the equation. The price of labour, i.e. the wage rate, is computed by dividing the total wage bill by total employment in the agricultural sector. The prices of capital, land and intermediate inputs are indices from the *Abstract of Agricultural Statistics*

4. Empirical Results

The SUR estimates of the structural parameters are reported in Table 1. The estimations were done using Micro TSP software. The first column of the table in Table 1 reports the results of the unrestricted equation. The second column reports the estimated results when Hicks-neutral technology is imposed, that is by setting $\varphi_{iT} = 0, \ \forall i$. The third column provides the estimated results when homotheticity is imposed i.e., $\partial_{iQ} = 0, \ \forall i$. Column 4 gives the estimated results when both homotheticity and Hicks-neutral technology are imposed simultaneously. Column 5 is the estimated result when no technological change applies, i.e., both $\alpha_T = 0,$ and $\alpha_{TT} = 0$. Finally, column six reports the result when homogeneity is imposed. The validity of these restrictions can be tested using the log-likelihood ratio test, maximum likelihood test or Wald test.

The regularity conditions for a well-behaved cost function, homogeneity in prices, positivity and concavity, were examined for each model. Linear homogeneity was imposed *a priori,* thus all the estimated models satisfies the linear homogeneity condition. The estimated results are examined in terms of the estimated parameters, predicted factor shares, Eigenvalues of the estimated Hessian matrix of second order derivatives of the cost function, and estimates of the own and cross elasticities of inputs of the selected underlying production function.

The last two rows of the Table 1 give the calculated and tabulated value of the likelihood ratio test statistics, respectively. The number of restrictions is in parenthesis. Based on the reported results in Table 1, the underlying production function that gives the best representation South African agriculture best is Hicks-neutral and homothetic. The estimated parameters of the selected model are significantly different from zero at usual levels of significance. Monotonicity requires that the predicted cost of factor shares is positive. The predicted shares are reported in Table 2, which indicates that the monotonicity condition is satisfied. To be consistent with economic theory, the cost function associated with selected underlying production must be non-decreasing and concave. Concavity requires that the estimated Hessian matrix of second-order derivatives is negative. Semi-definiteness implies that the maximum Eigenvalues is exactly zero, while non-decreasing in output requires equation 2a to be positive. The predicted value of equation 2a is reported in Table 3. This model was accepted at the 1% level of significance. On an individual basis the respective models with Hicks-neutral and homothetic restrictions were plausible candidates. However, we chose the model that satisfies both Hicks-neutral and homothetic restrictions, since the estimated parameters φ_{iT} and $\partial_{iQ} \forall i$ are not statistically significant]. The fitted shares are all positive at every point of the selected model, which implies that the positivity condition is also satisfied.

The predicted factor shares are reported in Table 2. Monotonicity in output is also satisfied by the cost function for the selected model at every point. In the model, the technical change is Hicks-neutral; factor shares are unaffected by technical change, while unit cost decreases at a constant percentage rate. The estimated parameter for the time variable in the cost function indicates that there is a proportional reduction in unit costs as a result of technical change (see Table 3). For concavity, the principal minors of the Hessian matrix of the second order partial derivative should be negative semi-definite (see Table 3). The reported modified Hessian matrix is a negative semi-definite; which implies that the translog cost function associated with the selected production function, is quasi-concave (see Table 3). The estimated reduction in unit cost is reported in Table 4. The results in column one of Table 4 indicate that there has been a decrease in unit cost. Reduction in unit cost is occurring at a decreasing rate.

5. Elasticities of Substitution

The Allen elasticities of substitution (AES) between the different input pairs, which is the cross price factor demand elasticity, were calculated for different segments of the period 1970-98 from the equation estimated above (Table 5). A positive value implies the inputs are substitutes, in which case an increase in price of one input results in an increase the use of the other. When the value is negative, the inputs are complements. When the price of one input increases, it will lead to a decrease in the use of the other in this latter case.

The estimated results presented in Table 5 indicate that capital is a substitute for all other inputs. On the contrary, labour and land, and labour and intermediate inputs, are complements. The AES of substitution between capital and labour increased, in 1994-1998 and for capital and land it decreased far the same period, which indicate that there have a relative change in degree of substitutability between capital and labour, but between capital and land the degree of substitutability decrease in the same period.

For land and labour the AES is negative for the whole period, but changes from –1.0781 to –1.1572, which indicates that dealing with input prices variation increased from 1990-1993 to 1994-1998. The result for labour and intermediate inputs is quite different: they are substitutes for the period 1970-1977, turning to complements for the period 1978-1989 and switching back to substitutes for the remaining period, though the degree of substitutability differ in the period 1990-1993 and 1994-1998.

The changes in magnitude of the AES estimates over time provide an indication of whether policy changes have resulted in increases in the flexibility or rigidity of the production process. The relative small changes to the magnitude of the AES between input pairs over time for most periods and input pairs, is rather surprising given the relative large shifts in policy encountered over the period. In particular, one would have expected the market liberalisation process to result in much more flexibility in input substitution. This seems not to have been the case.

6. Conclusion

The main purpose of this paper is to evaluate the characteristics of the underlying production technology for the South African agricultural sector using a flexible function form, i.e., the translog cost function. Our empirical application has been motivated by various recent studies for the South African agricultural sector, where the regularity conditions implied by economic theory were not tested. The empirical results presented in this paper include parameter estimates, predicted factor shares and the Hessian matrix. The results suggest that the production structure of the South African agricultural sector is best represented by a production function which is Hicks-neutral and homothetic.

These results imply that previous research on the structure of South African agriculture should be interpreted with care. The previous research did not fully test the characteristics of the underlying production function and technology. Neither did they impose all the restrictions implied by the theory underpinning the analyses. In most cases, however, these results are not completely incorrect as the restrictions imposed and the underlying production technology are reasonably approximated by the approaches followed. The point is that the results would have been better approximations had the production function been Hicks-neutral and homothetic.

Table 1: Critical value of χ^2 (*; **; * indicate significance at 1%, 5% and 10%, respectively)**

Coefficient	Unrestricted Model	Hicks-Neutral	Homothetic	Hicks-neutral and Homothetic	No technological change	Homogenous
α_0	15.9802***	4.9124	12.2202**	12.9259***	-4.8722**	8.0302***
α_Q	-2.9920***	-0.2972	-2.1671	-2.3887***	1.6110***	
α_{QQ}	0.1481***	0.0168	0.1196	0.3494***	-0.0159	
α_T	-0.4314**	-0.2548***	-0.3532**	- 0.3919***		
α_{TT}	0.0047***	0.0020	0.0039***	0.0045***		
γ_L	-0.3247**	-0.0386	0.1278**	0.1200***	0.1202***	0.0621***
γ_K	-0.2105	-0.1989	0.0955	0.3072***	0.3069***	0.2600***
γ_W	0.3798	0.2059	0.2812**	0.1890***	0.1892***	0.2142***
γ_{LL}	-0.0017	0.0433	0.0414	0.0650***	0.0759***	0.1208***
γ_{LK}	-0.0492**	-0.0248	-0.0492**	-0.0624***	-0.0614***	-0.0234***
γ_{LW}	-0.0437**	-0.0597**	-0.0704**	-0.0616***	-0.0550***	-0.0512***
γ_{KK}	0.1170***	0.1118***	0.1220***	0.0641***	0.0629***	0.0856***
γ_{KW}	0.0469**	0.0517**	0.0291	0.0508***	0.0470***	0.0225***
γ_{WW}	0.0582	0.0719**	0.0666**	0.0500***	0.0483***	0.0634***
∂_{LQ}	0.0884**	0.0155				
∂_{KQ}	0.545	0.0492				
∂_{WQ}	-0.0330	-0.0014				
φ_{LT}	-0.0136**		-0.0003			
φ_{KT}	-0.0135		0.0062			
φ_{WT}	0.0043		-0.0026			
Calculated χ	----------------	7.81835	7.45584	7.961676	30.7779	287.604
Critical χ^2	-----------------	11.3449(3)	11.3449(3)	11.3449(3)	9.21034(2)	9.21304(2)

Table 2: Predicted Shares of Factor Inputs

Year	Capital	Land	Labour	Year	Capital	Land	Labou
1970	0.34702	0.098	0.21619	1985	0.37013	0.021591	0.1348
1971	0.33711	0.123	0.20459	1986	0.35041	0.043101	0.1690
1972	0.32306	0.152	0.21883	1987	0.31679	0.113579	0.2140
1973	0.31966	0.154	0.24054	1988	0.31730	0.113579	0.2125
1974	0.30555	0.181	0.26857	1989	0.34397	0.059134	0.1690
1975	0.33843	0.110	0.2029	1990	0.31860	0.111602	0.2003
1976	0.34023	0.101	0.21709	1991	0.32089	0.105513	0.1769
1977	0.35230	0.082	0.19021	1992	0.27304	0.208921	0.2143
1978	0.36501	0.044	0.15848	1993	0.28384	0.175338	0.2089
1979	0.33468	0.040	0.13644	1994	0.27023	0.201146	0.2167
1980	0.35280	0.053	0.15945	1995	0.29008	0.183778	0.1800
1981	0.33053	0.092	0.21040	1996	0.28964	0.159342	0.1705
1982	0.36336	0.044	0.14853	1997	0.28513	0.159242	0.1786
1983	0.33468	0.095	0.19217	1998	0.28321	0.170185	0.1695
1984	0.35295	0.064	0.15976				

Table 3: Predicted Values for Equation 2a (Monotonicity in Output)

Year	Predicted Values	Year	Predicted Values	Year	Predicted Values
1970	0.186209	1980	0.635250	1990	1.174099
1971	0.239547	1981	0.733725	1991	1.204058
1972	0.291190	1982	0.794598	1992	1.206870
1973	0.307843	1983	0.826520	1993	1.260835
1974	0.446629	1984	0.835950	1994	1.293327
1975	0.462468	1985	0.953627	1995	1.314190
1976	0.487680	1986	0.967982	1996	1.390343
1977	0.517276	1987	1.025296	1997	1.404472
1978	0.564414	1988	1.094351	1998	1.425081
1979	0.595403	1989	1.158476		

Table 4: Reduction in Unit Cost Due to Technical change

Year	RUC	D(RUC)	Year	RUC	D(RUC)
1970	-3.469		1985	-6.985	0.171
1971	-3.766	0.297	1986	-7.147	0.162
1972	-4.055	0.288	1987	-7.300	0.153
1973	-4.334	0.279	1988	-7.445	0.144
1974	-4.604	0.270	1989	-7.580	0.135
1975	-4.866	0.261	1990	-7.707	0.126
1976	-5.118	0.252	1991	-7.824	0.117
1977	-5.361	0.243	1992	-7.932	0.108
1978	-5.596	0.234	1993	-8.032	0.099
1979	-5.821	0.225	1994	-8.122	0.090
1980	-6.038	0.216	1995	-8.204	0.081
1981	-6.245	0.207	1996	-8.276	0.072
1982	-6.443	0.198	1997	-8.339	0.063
1983	-6.633	0.189	1998	-.8.390	0.059
1984	-6.813	0.180			

RUC = Reduction in Unit cost due to Technical Change, D(RUC) = Change in RUC (RUC_t – RUC_{t-1})

Hessian Matrix

$$|H| = \begin{vmatrix} -0.406 & -0.039 & -0.0256 \\ -0.039 & -0.103 & -0.108 \\ -0.0256 & -0.108 & -0.301 \end{vmatrix}$$

TABLE 5: ALLEN CROSS ELASTICITY OF SUBSITUTION

YEAR	CAPITAL_ LABOUR	CAPITAL LAND	CAPITAL INTER	LAND LABOUR	LAND INTER	LABOUR INTER
1970	1.2470	0.1233	0.2646	-1.8826	0.5458	-1.0575
1971	1.2543	0.2058	0.3026	-2.1083	0.4873	-1.0437
1972	1.2587	0.2714	0.2704	-1.6312	0.5051	-0.7790
1973	1.3065	0.0519	0.1827	-1.2205	0.6404	-0.4195
1974	1.2872	0.0925	0.2519	-1.5862	0.5996	-0.6147
1975	1.3077	0.0357	0.2926	-1.9324	0.5959	-0.6159
1976	1.3128	0.0304	0.2927	-1.9354	0.5977	-0.5911
1977	1.3163	0.0495	0.2917	-1.8812	0.5967	-0.5466
1978	1.4129	0.5240	0.2439	-0.8956	0.4345	0.1679
1979	1.4374	0.4197	0.2980	-1.3147	0.4740	0.1094
1980	1.4352	0.4198	0.3267	-1.5261	0.4493	0.0631
1981	1.4254	0.4113	0.3336	-1.5912	0.4490	0.0269
1982	1.3927	0.5106	0.3217	-1.4074	0.3733	0.0032
1983	1.3682	0.5451	0.3145	-1.3869	0.3245	-0.0652
1984	1.3736	0.4870	0.2698	-1.0594	0.4494	0.0352
1985	1.4013	0.4558	0.2405	-0.9316	0.4936	0.1236
1986	1.3845	0.4558	0.2446	-0.9489	0.4919	0.0821
1987	1.3814	0.4437	0.2382	-0.9297	0.5036	0.0761
1988	1.3997	0.4399	0.2114	-0.8193	0.5189	0.1397
1989	1.3590	0.4320	0.2310	-0.9114	0.5140	0.0185
1990	1.3464	0.4688	0.2465	-0.9624	0.4771	-0.0233
1991	1.3413	0.4750	0.2569	-1.0211	0.4627	-0.0549
1992	1.3380	0.4625	0.2648	-1.0808	0.4654	-0.0849
1993	1.3950	0.3043	0.2698	-1.2737	0.5517	-0.0076
1994	1.4041	0.2790	0.2640	-1.2806	0.5627	0.0043
1995	1.4153	0.2565	0.2938	-1.5127	0.5517	-0.0243
1996	1.4375	0.2168	0.3232	-1.8282	0.5410	-0.0487
1997	1.4543	0.2095	0.3467	-2.0528	0.5261	-0.0523
1998	1.4740	0.1996	0.3678	-2.3087	0.5092	-0.0577

TABLE 5 A: ALLEN CROSS ELASTICITY OF SUBSITUTION

YEAR	CAPITAL LABOUR	CAPITAL LAND	CAPITAL INTER	LAND LABOUR	LAND INTER	LABOUR INTER
1970-1973	1.2628	0.1776	0.2654	-1.6747	0.5512	-0.7927
1974-1977	1.3056	0.0526	0.2827	-1.8277	0.5979	-0.5907
1978-1981	1.4273	0.4485	0.3022	-1.3032	0.4526	0.0984
1982-1985	1.3813	0.5028	0.2910	-1.1804	0.4160	0.0281
1986-1989	1.3806	0.4434	0.2319	-0.9003	0.5074	0.0807
1990-1993	1.3537	0.4338	0.2631	-1.0781	0.4920	-0.0379
1994-1998	1.3670	0.3900	0.2697	-1.1572	0.5149	-0.0292

Reference

Berndt, R. E., and Wood, D., O., (1975): "Technology, Prices, and the Derived Demand For Energy." *The Review of Economics and Statistics*, August 1975:259-267

Christensen *et al.,* (1971): "Conjugate Duality and the Transcendental Logarithmic Production Function." *Econometrica*, 39: 255-256.

Christensen *et al.,* (1973): " Transcendental Logarithmic Production Frontiers." *The Review of Economics and Statistics*, Feb. 1973: 28-45

Diewert, W. E., (1971): " An Application of the Shepard Duality Theorem: A Generalised Leontief Production Function." *Journal of Political Economy*, 79: 481-507

---------------- , (1974): " Applications of Duality Theory." In M. Intrilligator and David Knedrick(Eds) *Frontiers of Quantitative Economics*, Vol., 2, Amsterdam, North-Holland

Fuss, M., MacFadden,.D., and Mundlak, Y., (1978): " A Survey of Function Forms in the Economic Analysis of Production." In Fuss., M., & McFacdden, D. (eds). *Production Economics: A Dual Approach to theory and Application.*, Vol I. Amsterdam, North-Holland.

Pope, R. D., and Just, R. E (1998): " Cost Function Estimation Under Risk Aversion." *American Journal of Agricultural Economics*, 80: 288-295

Van Zyl, J., (1986b): "Duality and Elasticities of Substitution II: *Agrekon* 25(3):65-69

Van Zyl, J., (1986a): "Duality and Elasticities of Substitution I: *Agrekon* 25(3)

Van Zyl, J., and Groenewald J. A., (1988): Flexibility in Inputs Substitution: A case Study of South African Agriculture." *Development Southern Africa*, Vol.5(1)