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Abstract

This paper presents a duality-based model of the farm-level production of burley tobacco. A flexible translog variable-profit function for burley tobacco producers was chosen that imposes few a priori restrictions upon the values that the empirical estimates of the parameters might assume. Cost-share equations for burley tobacco producers were developed based on the translog variable-profit function. These cost-share equations were econometrically estimated using an iterative seemingly unrelated regressions estimation (ITSUR) technique. The farm-level sector was found to possess decreasing returns to scale. Hence, there was no empirical evidence to support the argument that the consolidation of burley production into fewer but larger farms would lead to greater efficiency in production and lower per unit costs in the production of burley tobacco. Certain input prices were found to exhibit substitutability, while others exhibited complementarity. All own-price elasticities of demand for variable inputs were negative whereas supply elasticity of burley was positive with respect to the price.

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This paper presents a duality-based model of the farm-level production of burley tobacco. A flexible translog variable-profit function for burley tobacco producers was chosen that imposes few restrictions upon the values that the empirical estimates of the parameters might assume. Cost-share equations for burley tobacco producers were developed based on the translog variable-profit function. These cost-share equations were econometrically estimated using an iterative seemingly unrelated regressions estimation technique.

This study is the first attempt to develop a model of farm-level burley tobacco production by employing duality theory and flexible functional forms, and is one of very few attempts to apply duality theory to the production of specific agricultural commodities at the farm level. This study follows the framework suggested by Diewert and employed by Kohli and by Woodland.

The model used in this study differs from that used in other studies employing duality theory to specific agricultural problems. First, this study estimates both the short-run and the long-run demand and supply functions for the burley tobacco industry, as suggested by Lau. For the short-run specification, the variable-profit function is a function of input and output prices and the level of the fixed factors. For the long-run specification, all inputs are treated as variable. Therefore, the variable-profit function is a function of all prices of inputs and outputs. This study employs share equations to estimate the parameters of the demand and supply functions and various price elasticities of demand and supply. The following null hypotheses were tested: (i) the long-run demand function does not significantly differ from short-run demand function (ii) the long-run and short-run supply functions are not significantly different. Other hypotheses derived from economic theory, a priori, are the usual properties of demand and supply functions, in this case derived from Hotelling's Lemma, such as $\partial(p,z)/\partial p < 0$ for input prices, and $\partial\pi(p,z)/\partial p > 0$ for product prices.

Perhaps the most similar farm-level study was the analysis of farm-level turkey production in the Northeast (Grisley and Gitu). Sidhu and Baanante estimated profit functions but for Indian farms, not for a specific agricultural commodity, and followed a different procedure suggested by Lau and Yotopoulos (1971,1972,1973). Lau and Yotopoulos, and Sidhu and Baanante estimated the profit function for the Indian farms, and primarily tested the farm relative efficiency.

This study provides empirical estimates of returns to scale and relaxes the homogeneity assumption regarding fixed inputs. Hence, one null hypothesis to be tested is that there exist constant returns to scale in burley tobacco production. The alternative hypothesis is that constant returns to scale do not exist in the burley tobacco economy.

The Theoretical Model

A Short-run Variable Profit Function

A short-run variable profit function is introduced. The short-run implies that the input of one or more productive factors is fixed (Maurice, Phillips and Ferguson, p. 175). The short-run variable profit function for the burley tobacco farmer is

$$\pi^S = \pi^S(P, V_i, z_k) \qquad (1)$$

π^S = short run profits from the sale of burley tobacco

P = price of output (burley tobacco)

V_i = price for variable inputs used in the production of burley tobacco.

z_k = quantities of fixed inputs used in burley tobacco production.

for i = 1,..., n variable inputs

k = 1,..., m fixed inputs

The burley supply function can be obtained by differentiating the short-run variable-profit function with respect to the price of output (P)(Diewert, p. 285; Silberberg, p. 265; Varian pp.31-32)

$$\partial \pi^S(P, V_i, z_k)/\partial P = Y^S \qquad (2)$$

Equation (2) is the short-run supply function for burley tobacco. Input-demand functions for burley producers can be obtained by employing Hotelling's Lemma (Varian, p. 31, Diewert, p.303):

$$\partial \pi^S/\partial V_i = - X_i(P, V_i, z_k) \qquad (3)$$

From equation (3), the partial derivatives of the variable profit function with respect to the variable prices of the input demand are the negative values for the optimal input-demand functions.

Rearranging equation (3) gives:

$$X_i(P,V_i,z_k) = -\partial\pi^s/\partial V_i \qquad (4)$$

$X_i(P,V_i,z_k)$ in equations (3) and (4) is the input-demand function for burley tobacco producers.

It follows from equations (3) and (4) that (Varian, p. 33):

$$\begin{aligned}\partial X_i(P,V_i,z_k)/\partial P &= \partial^2(-\pi^s)/\partial P\partial V_i \\ &= -\partial^2\pi^s/\partial P\partial V_i = \partial^2(-\pi^s)/\partial V_i\partial P \\ &= -\partial^2\pi^s/\partial V_i\partial P \qquad (5)\end{aligned}$$

Equation (5) implies the symmetry condition of the Hessian matrix of the second-order condition of the input demand functions.
Also by Hotelling's Lemma (Varian, p. 31):

$$\partial X_i(P,V_i,z_k)/\partial P = -\partial Y/\partial V_i \qquad (6)$$

where Y is the output of burley tobacco.

because,

$$\partial Y(P,V_i,z_k)/\partial V_i = \{[\partial\{\partial\pi^s(P,V_i,z_k)\}/\partial P]/\partial V_i\} \qquad (7)$$

Equations (6) and (7) imply that the partial derivative of the optimal input $X_i(P,V_i,z_k)$ with respect to the price of output, P, is equal to the negative of the partial derivative of output $Y(P,V,z_k)$ with respect to the price of inputs, V_i.

And by Young's Theorem (Chiang pp. 323-324, Varian p. 33):

$$[\{\partial(\partial\pi^{s}(P,V_1,z_k))/\partial P\}/\partial V_1 y]=[\{\partial(\partial\pi^{s}(P,V_1,z_k))/\partial V_i\}/\partial P]$$

$$=\partial(-X_1)/\partial P \qquad (8)$$

Equation (8) reveals that the second derivative of the variable-profit function is the (negative) partial derivative of optimal input with respect to the price of output.

By the Slutsky equation (Varian p. 95):

$$\partial X_i/\partial V_i = \partial X_i/\partial V_1|_Y + \{(\partial X_i/\partial Y)/(\partial Y/\partial V_1)\} \qquad (9)$$

Therefore,

$$-\text{sign}(\partial X_i/\partial P)=\text{sign}(\partial X_i/\partial Y)= -(\text{sign}\,\partial Y/\partial V_i) \qquad (10)$$

Equation (9) represents the partial derivatives of the input demand function $X_i(P,V_1,z_k)$ with respect to the price of inputs. This is an application of the Slutsky equation (Varian, p. 95; Silberberg, p. 248-250). From equation (10), a comparative-statics analysis of the demand functions can be made. The negative sign of equation (10) implies a gross substitute of the input-demand function, where a positive sign sign implies a gross complement. For example, by applying equation (10) to the input-demand functions for labor and machinery, the complementarity or substitutability of the inputs can be determined. Equation (10) indicates that the sign of own-price term ($\partial X_i/\partial P$) is the negative of the income term ($\partial X_i/\partial Y$) of the input demand functions. These concepts will be employed to analyze the short- and long-run supply and the input demand functions burley tobacco producers.

The short-run translog variable-profit function for the burley tobacco producer is:

$$\ln\pi^{S} = \beta_0 + \beta_P \ln P + \sum_{i=1}^{n} \beta_i \ln V_i + \tfrac{1}{2}\beta_{PP}(\ln P)^2$$

$$+ \tfrac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n}\beta_{ij}\ln V_i \ln V_j + \sum_{i=1}^{n}\beta_{Pi}\ln P \ln V_i$$

$$+ \sum_{k=1}^{m}\beta_k \ln z_k + \tfrac{1}{2}\sum_{k=1}^{m}\sum_{\ell=1}^{m}\beta_{k\ell}\ln z_k \ln z_\ell$$

$$+ \sum_{k=1}^{m}\beta_k \ln P \ln z_k + \sum_{i=1}^{n}\sum_{k=1}^{m}\beta_{ik}\ln V_i \ln z_k \qquad (11)$$

where:

π^S = short run profit to the burley tobacco producer

P = price of burley tobacco

z_k = fixed inputs

$i = 1, 2, \ldots, n$

$k = 1, \ldots, m$

Equation (11) is homogeneous of degree one in prices if and only if the the following restrictions are satisfied (Diewert, p. 581):

$$\beta_{iP} + \sum_i \beta_i = 1$$

$$\beta_{PP} + \sum_j \beta_{ij} + \sum_i \beta_{Pi} = 0$$

$$\sum_i \sum_j \beta_{ij} + \sum_i \beta_{Pi} = 0 \qquad (12)$$

A translog profit function (Diewert) fulfilling these restrictions is homogeneous of degree one in all prices of variable inputs and the output price P, non-decreasing, convex and continuous.

Supply Response to Changes in the Price of Burley Tobacco

Differentiating equation (11) with respect to lnP yields:

$$\partial \ln\pi^S/\partial \ln P = \beta_P + \beta_{PP}\ln P + \textstyle\sum_i \beta_{Pi}\ln V_i$$

$$+ \textstyle\sum_k \beta_k \ln z_k \qquad (12)$$

Equation (12) can be expressed as:

$$\partial \ln\pi^S/\partial \ln P = (\partial\pi^S/\partial P)(P/\pi^S) \qquad (13)$$

$$\partial\pi^S/\partial P = Y^S \qquad (14)$$

Therefore equation (13) can be also written as:

$$\partial \ln\pi^S/\partial \ln P = (PY^S)/\pi^S$$

$$= SY \qquad (15)$$

SY is the output share of short-run profit for the burley tobacco producer. But by equation (12), SY is also the output-price elasticity of profit, that is, the percentage change in profit with respect to change in the price of output.

From equation (14):

$$Y^S = (\pi^S/P)SY \qquad (16)$$

$$Y^S = \zeta T \qquad (17)$$

where: $\zeta = \pi^S/P$

$T = \partial \ln\pi^S/\partial \ln P = SY$

$= \beta_P + \beta_{PP}\ln P + \beta_{Pi}\ln V_i$

$$+\sum_{k=1}^{m} \beta_k \ln z_k$$

Y^S in equation (17) is the short-run supply function for the burley tobacco producer.

The Demand for Inputs by the Burley Producer

Differentiating equation (11) with respect to $\ln V_i$ yields:

$$\partial \ln\pi^S/\partial \ln V_i = \beta_i + \sum \beta_{Pi} \ln P + \sum_{j=1}^{n} \beta_{ij} \ln V_j + \sum_{k=1}^{m} \beta_{ik} \ln z_k \qquad (18)$$

or,

$$\partial \ln\pi^S/\partial \ln V_i = (\partial \pi^S/\partial V_i)(V_i)/(\pi^S) \qquad (19)$$

But,

$$\partial\pi^S/\partial V_i = -X_i \qquad (20)$$

and,

$$X_i = -\partial \pi^S/\partial V_i \qquad (21)$$

Equation (20) is the input-demand function for the ith input by the burley tobacco producer, constructed with the use of Hotelling's Lemma.

Substituting equation (21) into equation (19) gives:

$$\partial \ln\pi^S/\partial \ln V_i = -V_i X_i/\pi^S = -SX_i \qquad (22)$$

The SX_i in equation (22) is the input share of profit π^S of the burley producer, and SX_i is also the input price elasticity of profit π^S

with respect to the percentage change in the input price (V_i).

It directly follows from equation (22) that:

$$X_i = (-\pi^S/V_i)(\partial \ln \pi^S/\partial \ln V_i)$$

$$= (-\pi^S/V_i) SX_i \qquad (23)$$

or,

$$X_i = -\mu_i \Omega_i \qquad (24)$$

where,

$$\mu_i = \pi^S/V_i$$

$$\Omega_i = \partial \ln \pi^S/\partial \ln V_i = SX_i$$

$$= \beta_i + \sum \beta_{Pi} \ln P + \sum_{j=1}^{n} \beta_{ij} \ln V_j + \sum_{k=1}^{m} \beta_{ik} \ln z_k$$

Equation (24) is the short-run demand function for the i^{th} input by the burley tobacco producer.

Long-Run Translog Variable-Profit Function

The long-run translog variable-profit function differs from the short-run function in that all inputs are treated as variable, and hence there is no z_k vector in the function or terms involving interactions with the fixed input vector. The number of variable inputs (n) is increased by the m (previously fixed) inputs to r (r>n, r-n=m). The long-run function is:

$$\ln\pi^1 = \phi_0 + \phi_P \ln P + \sum_{i=1}^{r} \phi_i \ln V_i + \frac{1}{2}\phi_{PP}(\ln P)^2$$

$$+\frac{1}{2}\sum_{i=1}^{r} \phi_i \ln(V_i)^2 + \frac{1}{2}\sum_{i=1}^{r}\sum_{j=1}^{r} \phi_{ij} \ln V_i \ln V_j + \sum_{i=1}^{r} \phi_{Pi} \ln P \ln V_i \qquad (25)$$

where:

π^1 = long run profit to the burley tobacco producer

$i = 1, \ldots, n, \ldots, r$

with the following restrictions:

$\phi_P + \sum_i \phi_i = 1$

$\phi_{PP} + \sum_j \phi_{ij} + \sum_i \phi_{Pi} = 0$

$\phi_{ii} + \sum_j \phi_{ij} + \sum_i \phi_{Pi} = 0$

The derivation of long-run burley supply and factor-demand equations proceeds analogously to the short-run derivation, and is not repeated here. This derivation can be found in Pandjaitan.

The Empirical Model

The empirical model of burley tobacco production follows the theoretical derivation employing the translog profit function. The cost categories employed at the farm level follow those contained in Grise. Grise defines six main cost categories, (1) land, (2) labor, (3) machinery, (4) equipment, (5) chemicals, and (6) other inputs.

In addition to a change for land, a quota charge is also included. Labor includes hired labor, a valuation on family and exchange labor and operator labor all based on the prevailing wage rate. Machinery includes machinery ownership costs, fuel and lubricants, and repairs. Equipment includes custom operations, curing and heating equipment, irrigation and barn ownership costs. Chemicals include fertilizer, lime, pesticides, and sucker control chemicals. (Grise, 1978). All remaining inputs are classified as other inputs, for example tobacco seed, cover crop seed, plant bed canvas and other miscellaneous items. The price of burley tobacco received by the farmer is used as the output price. For the purpose of analysis, the cost of variable inputs is regrouped into four main categories, costs of land, cost of machinery and equipment, labor costs, and operating capital which includes all other variable costs. Acreage harvested of burley tobacco is treated as the quantity of the fixed input land. In the short-run, the machinery and equipment cannot be readily changed, even when the market conditions allow for a change in output (Maurice <u>et al.</u> p. 174).

Following equation (11), a translog variable-profit function at the farm level uses the price of burley tobacco received by the farmers to represent P. The acreage harvested of burley tobacco (L_F) is the single fixed input. Costs for variable inputs include two categories, the cost of labor used in the production of burley tobacco, and the cost of operating capital. A translog variable-profit function at the farm level can be written as :

$$\begin{aligned}\ln\pi_F^* = {} & \beta_{10} + \beta_{NF}\ln V_{NF} + \beta_{KF}\ln V_{KF} + \beta_{PF}\ln P_F \\ & + \beta_{LF}\ln L_F + 1/2\beta_{PFPF}(\ln P_F)^2 \\ & + 1/2\,\beta_{NFNF}(\ln V_{NF})^2 + 1/2\beta_{KFKF}(\ln V_{KF})^2 + 1/2\beta_{LFLF}(\ln L_F)^2 \\ & + \beta_{PFNF}\ln P_F\ln V_{NF} + \beta_{PFKF}\ln P_F\ln V_{KF} + \beta_{PFLF}\ln P_F\ln L_F \\ & + \beta_{NFKF}\ln V_{NF}\ln V_{KF} + \beta_{NFLF}\ln V_{NF}\ln L_F + \beta_{NFKF}\ln V_{NF}\ln V_{KF} \\ & + \beta_{NFLF}\ln V_{NF}\ln L_F + \beta_{NFKF}\ln V_{KF}\ln L_F \qquad (26)\end{aligned}$$

where π_F^* = profit at the farm level

P_F = price of burley tobacco received by the farmers.

L_F = acreage harvested of burley tobacco.

V_{NF} = labor cost used to produce burley tobacco.

V_{KF} = cost of operating capital.

Equation (26) is homogeneous of degree one in all prices if and only if restrictions in (8) are satisfied (Diewert, p. 581) i.e.,:

$$
\begin{aligned}
&\beta_{PF} + \beta_{NF} + \beta_{KF} = 1 \\
&\beta_{PFPF} + \beta_{PFNF} + \beta_{PFKF} = 0 \\
&\beta_{LFLF} + \beta_{LFNF} + \beta_{LFKF} = 0 \\
&\beta_{NFNF} + \beta_{PFNF} + \beta_{NFKF} = 0 \\
&\beta_{KFKF} + \beta_{PFKF} + \beta_{NFKF} = 0
\end{aligned}
\tag{27}
$$

Differentiating equation (26) with respect to $\ln P_F$ (Diewert; Kohli; Woodland) gives:

$$
\partial \ln \pi_F^* / \partial \ln P_F = \beta_{PF} + \beta_{PF} \ln P_F + \beta_{PFLF} \ln L_F + \beta_{PFNF} \ln V_{NF} + \beta_{PFKF} \ln V_{KF} \tag{28}
$$

Also, differentiating equation (26) with respect to $\ln V_{NF}$ gives the share equation for labor:

$$
\partial \ln \pi_F^* / \partial \ln V_{NF} = \beta_{NF} + \beta_{NFNF} \ln V_{NF} + \beta_{PFNF} \ln P_F + \beta_{LFNF} \ln V_{LF} + \beta_{NFKF} \ln V_{KF} \tag{29}
$$

A similar equation can be derived for operating capital:

$$
\partial \ln \pi_F^* / \partial \ln V_{KF} = \beta_{KF} + \beta_{KFKF} \ln V_{KF} + \beta_{PFKF} \ln P_F + \beta_{LFKF} \ln L_F + \beta_{NFKF} \ln V_{NF} \tag{30}
$$

Equations (29) and (30) are used to develop a system of input demand functions for burley tobacco at the farm level. The derivative in (29) can be also rewritten as:

$$\partial \ln \pi_F^* / \partial \ln V_{NF} = (\partial \pi_F^* / \partial V_{NF})(V_{NF} / \pi_F^*) \qquad (31)$$

By equation (24),

$$\partial \pi_F^* / \partial V_{NF} = - X_{NF} \qquad (32)$$

and,

$$X_{NF} = - \partial \pi_F^* / \partial V_{NF} \qquad (33)$$

Equations (32) and (33) use Hotelling's Lemma. In this case X_{NF} is the demand function for labor at the farm level. Substituting equation (33) into equation (31) gives:

$$\partial \ln \pi_F^* / \partial \ln V_{NF} = -(V_{NF} X_{NF}) / \pi_F^* = SX_{NF} \qquad (34)$$

The variable SX_{NF} in equation (34) is the labor share of profit π_F^*. It is also the input (labor) price elasticity of profit π_F^*, that is, the percentage change in profit π_F^* with respect to the percentage change in labor costs (V_{NF}) by equation (32). Rearranging equation (32) yields:

$$\begin{aligned} X_{NF} &= (-\pi_F^* / V_{NF})(\partial \ln \pi_F^* / \partial \ln V_{NF}) \\ &= - (\pi_F^* / V_{NF}) SX_{NF} \qquad (35) \end{aligned}$$

Substituting equation (30) into equation (34) gives the following:

$$X_{NF} = - \mu_{NF} \Omega_{NF} \qquad (36)$$

where: $\mu_{NF} = \pi_F^*/V_{NF}$

$$\Omega_{NF} = \beta_{NF}+\beta_{NFNF}\ln V_{NF}+\beta_{PFNF}\ln V_{PF}+\beta_{LFNF}\ln V_{LF}$$
$$+\beta_{NFKF}\ln V_{KF}$$

Equation (36) is the demand function for labor at the farm level. Input-demand functions for operating capital can be derived analogously.

Equation (28) can be used to develop the supply function at the farm level:

$$\partial\ln\pi_F^*/\partial\ln P_F = (\partial\pi_F^*/\partial P_F)(P_F/\pi_F^*) \quad (37)$$

But by Hotelling's Lemma in equation (23) we can obtain:

$$\partial\pi_F^*/\partial P_F = Y_F^* \quad (38)$$

Substituting equation (38) into equation (37) yields:

$$\partial\ln\pi_F^*/\partial\ln P_F = (P_F Y_F^*)/\pi_F^* = SY_F \quad (39)$$

The variable SY_F in equation (39) is the net-output share of profit π_F^*. It is also the output price elasticity of profit π_F^* by equation (28), that is, the percentage change in profit π_F^* with respect to the percentage change in the price of burley tobacco (P_F) received by the farmers.

From equation (39),

$$Y_F^* = (\pi_F^*/P_F)SY_F \quad (40)$$

Substituting the derivative in (28) into equation (40) gives:

$$Y_F^* = \zeta_F\Psi_F \quad (41)$$

where $\zeta_F = \pi_F^*/P_F$

$$\Psi_F = \beta_{PF} + \beta_{PF}\ln P_F + \beta_{PFLF}\ln L_F + \beta_{PFNF}\ln V_{NF} + \beta_{PFKF}\ln V_{KF}$$

Equation (41) is the supply function at the farm level.

Stochastic Formulation

The first step is to incorporate disturbance terms into the translog variable-profit function and the net-output share equations. It is assumed that $E(\varepsilon_i)=0$, $E(\varepsilon_i\varepsilon_i')=\sigma_{ii}I$, $E(\varepsilon_i\varepsilon_j)=\sigma_{ij}I$, and the ε_i's are normally distributed. The short-run econometric model of the farm level is built by adding the stochastic disturbances to equation 26. The stochastic, short-run, translog variable-profit function is:

$$\begin{aligned}\ln\pi_F^S = {} & \beta_{10} + \beta_{PF}\ln P_F + \beta_{NF}\ln V_{NF} + \beta_{KF}\ln V_{KF} + \beta_{LF}\ln L_F \\ & + \tfrac{1}{2}\beta_{PFPF}(\ln P_F)^2 + \tfrac{1}{2}\beta_{NFNF}(\ln V_{NF})^2 + \tfrac{1}{2}\beta_{KFKF}(\ln V_{KF})^2 \\ & + \tfrac{1}{2}\beta_{LFLF}(\ln L_F)^2 + \beta_{PFNF}\ln P_F\ln V_{NF} + \beta_{PFKF}\ln P_F\ln V_{KF} \\ & + \beta_{PFLF}\ln P_F\ln L_F + \beta_{NFKF}\ln V_{NF}\ln V_{KF} + \beta_{NFL}\ln V_{NF}\ln L_F + \\ & + \beta_{KFL}\ln V_{KF}\ln L_F + U_F \end{aligned} \tag{42}$$

where s = short-run

All other variables and parameters are as previously defined. The share equations are

<u>Net Output Share of Profit:</u>

$$SY_F = \beta_{PF} + \beta_{PFPF}\ln P_F + \beta_{PFNF}\ln V_{NF} + \beta_{PFKF}\ln V_{KF} + \beta_{PFLF}\ln L_F + U_{PF} \tag{43}$$

Labor Share

$$SX_{NF}=\beta_{NF}+\beta_{NFNF}\ln V_{NF}+\beta_{PFNF}\ln V_{PF}+\beta_{NFKF}\ln V_{KF}+\beta_{NFLF}\ln L_{F} + U_{NF} \qquad (44)$$

Operating Capital Share

$$SX_{KF}=\beta_{KF}+\beta_{KFKF}\ln V_{KF}+\beta_{PFKF}\ln V_{PF}+\beta_{NFKF}\ln V_{KF}+\beta_{KFLF}\ln L_{F} + U_{KF} \qquad (45)$$

The model is complete since there is one equation for each endogenous variable $\pi_F{}^s$, SY_F, SX_{NF} and SX_{KF}.

Similarly, the long-run, farm-level model, treating the land and quota charge (V_{LF}) as variable is:

$$\ln\pi = \beta_{20} + \beta_{PF}\ln P_F+\beta_{LF}\ln V_{LF}+\beta_{NF}\ln V_{NF} + \beta_{KF}\ln V_{KF}+\beta_{KF}\ln K_F$$
$$+\beta_{HF}\ln V_{HF}+ \tfrac{1}{2}\beta_{PFPF}(\ln P_F)^2+\tfrac{1}{2}\beta_{LFLF}(\ln V_{LF})^2+\tfrac{1}{2}\beta_{NFNF}(\ln V_{NF})^2$$
$$+\tfrac{1}{2}\beta_{KFKF}(\ln V_{KF})^2 + \tfrac{1}{2}\beta_{HFHF}(\ln V_{HF})^2 + \beta_{PFLF}\ln P_F\ln V_{LF}$$
$$+\beta_{PFNF}\ln P_F\ln V_{NF}+\beta_{PFKF}\ln P_F\ln V_{KF}+\beta_{NFKF}\ln V_{NF}\ln V_{KF}$$
$$+\beta_{PFHF}\ln P_F\ln V_{HF}+\beta_{LFNF}\ln V_{LF}\ln V_{NF}+\beta_{LFKF}\ln V_{LF}\ln V_{KF}$$
$$+\beta_{LFHF}\ln V_{LF}\ln V_{HF}+\beta_{NFKF}\ln V_{NF}\ln V_{KF}+\beta_{NFHF}\ln V_{NF}\ln V_{HF}$$
$$+\beta_{KFHF}\ln V_{KF}\ln V_{HF} + U_F^1 \qquad (46)$$

Where V_{NF} = Labor Cost, V_{KF} = Cost of operating Capital, V_{LF}= the land and quota charge, and V_{HF} = other overhead costs.

The Cost-Share Equations are:

Net Output Share of Profit

$$SY_F=\beta_{PF} + \beta_{PFPF}\ln P_F+\beta_{PFLF}\ln V_{LF} + \beta_{PFNF}\ln V_{NF} + \beta_{PFKF}\ln V_{KF} + \beta_{PFHF}\ln V_{HF}+ U_{PF}^1 \qquad (47)$$

Land and Quota Share

$$SX_{LF}=\beta_{LF} + \beta_{LFLF}\ln V_{LF}+\beta_{PFLF}\ln P_{F}+ \beta_{LFNF}\ln V_{NF} + \beta_{LFKF}\ln V_{KF} + \beta_{LFHF}\ln V_{HF}+ U^{1}_{LF} \quad (48)$$

Labor Share

$$SX_{NF}=\beta_{NF} + \beta_{NFNF}\ln V_{NF}+\beta_{PFNF}\ln P_{F}+ \beta_{LFNF}\ln V_{LF} + \beta_{NFKF}\ln V_{KF} + \beta_{NFHF}\ln V_{HF}+ U^{1}_{NF} \quad (49)$$

Operating Capital Share

$$SX_{KF}=\beta_{KF} + \beta_{KFKF}\ln V_{KF}+\beta_{PFKF}\ln P_{F}+ \beta_{LFKF}\ln V_{LF} + \beta_{NFKF}\ln V_{NF} + \beta_{KFHF}\ln V_{HF}+ U^{1}_{KF} \quad (50)$$

Overhead Cost Share

$$SX_{HF}=\beta_{HF} + \beta_{HFHF}\ln V_{HF}+\beta_{PFHF}\ln P_{F}+ \beta_{LFHF}\ln V_{LF} + \beta_{NFHF}\ln V_{NF} + \beta_{KFHF}\ln V_{KF}+ U^{1}_{HF} \quad (51)$$

The model is complete since there is one equation for each endogenous variable, $\pi_F{}^{S}$, SX_{LF}, SX_{NF}, SX_{KF}, and SX_{HF}, and all variables appearing on the right-hand side of each equation are treated as predetermined.

The estimation method is Iterative Seemingly Unrelated Regressions (ITSUR) to allow for the possibility that the error terms may be correlated. Parameters of the model cannot be estimated via Seemingly Unrelated Regressions (SUR) without omitting one equation, since the shares sum to one. If parameters of all share equations but one are known, then the parameters of the remaining category can be calculated without regression estimates. Therefore one share equation must be omitted. But if parameter estimates are estimated via ordinary SUR, the remaining equations are not invariant to the choice of the equation to omit. The ITSUR is used since the ITSUR method has an invariance property (SAS/ETS User's Guide:Econometrics and Time Series Library).

This means that the ITSUR produces the same parameter estimates regardless of which equation is omitted from the share equations. For a translog function with share equations such as the one used in this study, this property is desirable. Other methods of estimation are also not invariant to the equation omitted unless an iterative algorithm is used (Berndt and Wood, p. 261). The parameter estimates were derived using the SYSLIN procedure contained in SAS/ETS User's Guide.

Data

This study employs secondary data from various government sources. Appendix Table 1 provides a listing of the variables and the sources of data. Appendix Table 2 provides a listing of the data used in the analysis. Time-series data are used for all variables in the estimation. Data for output prices, input prices and quantities of fixed inputs were derived from various issues of The Tobacco Outlook and Situation.

These were available at the farm level for the period of 1976-1985. The 1976-1985 data were adjusted by the producer output index using the procedure employed by Burton and Wollo, to generate a data set consisting of 31 observations for the years 1955-1985. For example, if the 1970 index is 75.98 and the 1977 index is 100, then the adjusted–input cost for 1970 is (Index for 1970/Index for 1977)•(the 1977 input cost). Thus, the labor cost (V_{NF}) for example is, V_{NF}=(Index for 1970/Index for 1977)•(Labor cost for 1977), in this case, (75.98/100)•(44.09)=33.50.

Data were based on a survey conducted by Grise conducted for burley production in Tennessee (20 counties) and Kentucky (47 counties).

Approximately 700 farmers were interviewed in March and April 1977. Information on land use and rental arrangements, expenditures for items such as fertilizer and chemicals; field operations and practices; power and equipment inventory including size and age: family, exchange and hired labor used and wages paid for hired workers; expenditures for farm overhead items. The costs of producing burley tobacco were estimated based on this survey and subsequently used as data base for periodic updates of the estimates (Grise, 1978, p. 37). A detailed discussion of definition and estimates of labor, land, machinery, operating costs is found in Grise. The data series representing profits was computed by deducting the total variable costs from the total value of production for 100 pounds of burley tobacco for each year.

Short- and Long-Run Hypotheses

Formal tests of hypotheses for the short-run and the long-run translog variable-profit functions and the short-run and the long-run net-output share equations are derived. Tests were designed to determine whether the parameter estimates of the short-run translog variable-profit function are the same as parameter estimates of the short-run net-output share equations, based on the F distribution (Theil, Kmenta). If the null-hypotheses are rejected, then the restrictions imposed by the theory were not valid. Therefore, profit-maximizing behavior within the perfectly competitive market does not apply to the burley tobacco industry. If the null-hypotheses are not rejected, then profit-maximizing behavior cannot be rejected. The same procedure is also conducted for the long-run translog variable-profit function and net-output share equations. A test designed to determine whether comparisons can be made between the parameter estimates of the short-run and the long-run model is also conducted. A test is also used to determine whether the short-run price elasticities are the same as the long-run price elasticities.

The constant returns-to-scale hypothesis for the burley tobacco industry at the farm level is evaluated based on the parameter estimates on the quantity of the fixed input. If the coefficient is significantly greater than one, then the burley tobacco industry at the farm level has increasing-returns to scale. Constant returns-to-scale occur if the coefficient is not significantly different from one, decreasing returns-to-scale occur if the coefficient is less than one. The remaining discussion is an analysis of the estimated parameters of the model. Individual significance tests of the parameters are conducted based on asymptotic standard errors.

Tests of hypotheses are conducted to evaluate the validity of the parametric restrictions within and across the translog variable-profit function and the net output-share equations using an α level of 0.01. The null hypothesis is that there is no difference between the estimated parameters of the short-run translog variable-profit function and the short-run net-output share equations. The alternative hypothesis is that the estimated parameters of the short-run variable-profit function are greater than the estimated parameters of the short-run net-output share equations. The computed F value is 2.28 and F (0.01,14,14) is 3.69. Therefore, the null hypothesis cannot be rejected at the 0.01 level of significance. This implies that the restrictions hold for the burley tobacco industry at the farm level. In other words, the profit-maximizing behavior with respect to all prices of the variable inputs and the quantity of fixed inputs applies to the the farm level.

For the long-run translog variable-profit function, the computed F value is 2.52 and F (0.01,20,29) is 2.58. Therefore, the hypothesis that the estimated parameters of the long-run translog variable-profit function are not different from the estimated parameters of the long-run net-output share equations cannot be rejected. This implies that the profit-maximizing behavior with respect to all prices of variable inputs also applies to the farm level. However, this conclusion is conditional on the choice of an α level of 0.01, since the critical value for F (0.05,20,29) is 1.94.

Tests of hypotheses were conducted on the parameters of the short-run and the long-run translog variable-profit functions. It is hypothesized that the parameters of both functions are the same. The computed F-value is 1.28, the F (0.01,14,20) is 3.14, and therefore the null hypothesis is not rejected.

The parameter estimates of the short-run and long-run net-output share equations are also hypothesized to be the same. The alternative hypothesis is that the parameter estimates of the short-run net output share equations are greater than the parameter estimates of the long-run net output share equations. The computed F value is 1.44 and F (0.01,14,29) is 2.78. Therefore the parameter estimates of the short-run and the long-run net output share equations are not different at 0.01 level of significance.

A hypothesis test is conducted on the price elasticities of the derived-input demands and the output supply. It is hypothesized that the price elasticities of the two models are not different. The computed F-value is 1.68 and F (0.01,9,24) is 3.26. Therefore, the null hypothesis cannot be rejected, and the price elasticities of derived input demands and output supply of the long-run and the short-run translog variable-profit function are not significantly different from each other at 0.01 level of significance.

Finally, the coefficient of the fixed quantity of land is 0.2406 (the asymptotic standard error is 0.0029, Table 1). Based on this value, the burley tobacco industry possesses decreasing-returns to scale at the farm level. However, this test should be interpreted with caution since land was the only fixed input. Also, the sum of the coefficients of land with other variable inputs across equations is negative. If the parameter on the land input is one and the sum of the parameters on the land input and the other variable inputs across equations is zero, then there exists constant returns-to-scale technology, but these results suggest that burley production has decreasing, not constant returns-to-scale.

The Translog Variable Profit Function and Net-Output Share Equations.

The parameter estimates for the model are presented in Tables 1-4, and derived elasticity estimates for input- demand functions and the supply of burley tobacco are presented in Tables 5 and 6. The results of the estimation indicate that for the short-run translog variable-profit function, all fifteen estimated parameters are different from zero at the 0.01 level of significance. For the long-run translog variable-profit function, all twenty-one estimated parameters are significantly different from zero at an α level of 0.01 (Tables 1 - 4). Also all estimates of own- and cross price elasticities of demand for land, labor, operating capital, and machinery are significant. Estimated own- and cross-elasticities of output supply are all different from zero at a 0.01 level of significance (Tables 5 and 6).

For the short-run translog variable-profit function all variable inputs significantly affect profit (Table 1). Also, all variable inputs of the long-run translog variable-profit function significantly affect profit (Table 2). For the share equations, all variable inputs significantly affect the share equations (Tables 3 and 4).

Land

The coefficient for the quantity of the fixed input is 0.2406 [with an asymptotic standard error of 0.0029 (Table 1)] indicating that the burley tobacco industry at the farm level possesses a technology leading to decreasing returns to scale. Theoretically, decreasing returns to scale implies that if the quantity of fixed input (land) is increased by one unit, output will increase less than proportionately, in this case, 0.2406. This finding may be due in part to constants imposed by the existing government programs for burley tobacco. However, comparisons with results of prior studies cannot be made since previous studies on burley tobacco have not explicitly estimated the returns to scale for the burley tobacco industry (Johnson; Sutton; Snell; Blackwell). Tyner and Tweeten (1966) reported decreasing returns to scale for U.S. agriculture in general. For burley tobacco, the result is consistent with their findings for all of agriculture.

However, this result must be interpreted with caution since quantities of other fixed inputs such as machinery and equipment are not included. More detailed data on quantity of other fixed inputs such as machinery and equipment, and structures (barns) should be obtained in order to investigate this further.

For the long-run translog variable profit function, the coefficient of the variable input, land, is 0.1238 (with an asymptotic standard error of 0.0002, Table 2) which is significantly different from zero. The own-price elasticity of demand for land is -2.1466 (significant at α=0.01 percent, Table 6). This implies that a 10 per cent increase in the price of land will result in a 21.466 per cent decrease in the demand for land. The cross-price elasticity of demand for land with respect to the percentage change in the price of labor is 0.1520 (significant at α=0.01 percent, Table 6). A positive value of a cross-price elasticity implies that the two inputs are substitutes (Henderson and Quandt, p. 186). The greater the (positive) value of the cross-price elasticity the closer the degree of substitutability between the two inputs. Here, a 10 percent increase in the price of labor will result in a 1.52 percent increase in the demand for land. Therefore, land and labor are substitutes, but not close substitutes for each other.

The cross-price elasticity of demand for land with respect to the percentage of the price of operating capital is 0.1070 (significant at α=0.01, Table 6) which implies that land and operating capital are substitutes. A 10 per cent increase in the price of operating capital will result in 1.07 per cent increase in the demand for land. The cross-price elasticity of demand for land with respect to the percentage change in the price of machinery and equipment is -0.0281 (significant at α=0.01 percent). This implies that land and machinery and equipment are complements. (Maurice et al. p. 380; Henderson and Quandt, p. 186). A 10 percent increase in the price of machinery and equipment brings about a 0.281 percent decrease in the demand for land. The low degree of complementarity is consistent with the argument that small burley farms do not lend well to mechanization (Johnson).The output-price elasticity of demand for land with respect to the percentage change in the price of burley tobacco is 0.7900 (significant at α=0.01 percent, Table 6) and indicates that a 10 per cent increase in the price of burley tobacco will result in a 7.9 percent increase in the demand for land. This result is theoretically consistent since an increase in the price of output will encourage farmers to increase their acreage of burley tobacco. A positive sign of price elasticity of demand for land indicates that land is a normal input. (Ferguson, pp. 197-204).

To summarize, the parameter estimates for the land variable are theoretically consistent with the previous studies (Tweeten and Tyner; Johnson). The cross-price elasticity estimates indicate that land complements machinery and equipment but substitutes for labor and operating capital. The result indicates that land is a normal input relative to the price of burley tobacco since an increase in the price of burley tobacco results in an increase in the demand for land.

Labor

For the short-run translog variable-profit function, the coefficient for labor is 0.1298 (significant at α=0.01, Table 1). The magnitude of the own-price elasticity of demand for labor is -2.1035 (significant at α=0.01 percent, Table 5), implying that a 10 percent increase in the price of labor will result in a 21.035 percent decrease in the demand for labor. The output-price elasticity of demand for labor with respect to the percentage change in the price of operating capital is 0.0333 (significant at α=0.01 percent, Table 5), implying that labor and operating capital are substitutes. However, labor and operating capital are not close substitutes since a 10 percent increase in the price of operating capital will result in 0.333 percent increase in the demand for labor. The cross-price elasticity of demand for labor with respect to the percentage change in the price of burley tobacco is 1.3492 (significant at α=0.01 percent, Table 5). This is consistent with Johnson's study which argues that because of the nature of harvesting and stripping the burley leaves, burley tobacco production is highly labor intensive. Price increases for burley tobacco encourage farmers to produce more and, in turn, demand more labor.

For the long-run translog variable-profit function, the coefficient of the variable input, labor, is 0.1238 (significant at α=0.01 percent Table 2). The own-price elasticity of demand for labor is -2.1192 (significant at α=0.01 percent, Table 6), implying that a 10 percent increase in the price of labor will result in a 21.192 percent decrease in the demand for labor. The cross-price elasticity of demand for labor with respect to the percentage change in the price of land is 0.1364 (significant at α=0.01 percent, Table 6), implying that labor and land are substitutes. A ten percent increase in the price of land will result in a 1.364 percent increase in the demand for labor. The cross price elasticity of demand for labor with respect to the price of machinery and equipment is 0.0882 (significant at α=0.01 percent, Table 6), implying that labor and machinery and equipment are substitutes. However the degree of substitution is low since a 10 per cent increase in the price of machinery and equipment will result in a 0.882 percent increase in the demand for labor. The cross-price elasticity of demand for labor with respect to the percentage change of the price of operating capital is 0.1070 (significant at α=0.01, see Table 6). This means that labor and operating capital are substitutes. Finally, the output-price elasticity of demand for labor with respect to the price of burley tobacco is 0.8329 (significant at α= 0.01 percent, Table 6). A 10 percent increase in the price of burley tobacco will result in a 8.329 percent increase in the demand for labor.

Hence, labor is a significant regressor in both the short-run and long-run translog variable-profit function. The own-price elasticity of demand for labor is negative. Labor is a subtitute for land, operating capital, and machinery and equipment. A positive cross-price elasticity of demand for labor with respect to the price of output implies that labor is a normal input (Ferguson, pp. 197-204).

Operating Capital

The coefficient of operating capital for the short-run translog variable profit function is 0.0700 (significant at α=0.01, Table 1). The own-price elasticity of operating capital is -1.9773 (significant at α=0.01, Table 5) which implies that a 10 percent increase in the price of operating capital will result in a 19.8 percent decrease in the demand for operating capital. The cross- price elasticity of operating capital with respect to labor is 0.0521 (Table 5) implying that operating capital and labor are substitutes. However, the small cross-price elasticity indicates that labor and operating capital are not close substitutes. A ten percent increase in the price of capital will result in a 0.521 percent increase in the demand for labor. The cross-price elasticity of operating capital with respect to the the price of output is 1.2080 (significant at α=0.01, Table 5), which implies that a 10 percent increase in the price of burley tobacco will result in a 12.08 percent increase in the demand for operating capital.

For the long-run translog variable-profit function, the coefficient of the variable input, operating capital, is 0.0713 (significant at α=0.01, Table 6). Therefore, operating capital influences long-run profit, but but not to the degree of the other variable inputs, including land and labor.

The own-price elasticity of demand for operating capital is -1.9939 (significant at α=0.01, Table 6). The sign is theoretically correct. The result implies that a 10 percent increase in the price of operating capital will result in a 19.94 percent decrease in the demand for operating capital. The cross-price elasticity of demand for operating capital with respect to land is - 0.0239 (significant at α=0.01, Table 6), indicating that operating capital and land are complements. However, the degree of complementarity is low, since a 10 percent increase in the price of land results in only a 0.239 percent decrease in the demand for operating capital. The variable input, labor, is a substitute for operating capital since the cross-price elasticity of demand for operating capital with respect to the price of labor is 0.0521 (significant at α=0.01, Table 6). This implies that a 10 percent increase in the price of labor results in a 0.521 percent increase in the demand for operating capital. The cross-price elasticity of demand for operating capital with respect to the percentage change in the price of machinery and equipment is -0.0814 (significant at α=0.01, Table 6) which is an indication that operating capital and machinery and equipment are complements.

The cross-price elasticity of demand for operating capital with respect to the price of burley tobacco is 0.5547 (significant at α=0.01, Table 6) indicating that a 10 percent increase in the price of burley tobacco will result in a 5.547 percent increase in the demand for operating capital.

The results suggest that operating capital is a significant variable affecting both the short-run and long-run profit. Operating capital and land are complements (as indicated by the negative sign of cross-price elasticity) whereas labor and machinery are substitutes for operating capital. Operating capital is a normal input since an increase in the price of burley tobacco results in an increase in the demand for operating capital.

Machinery and Equipment

The coefficient of machinery and equipment is 0.1116 (significant at α=0.01, Table 2). The own-price elasticity of demand for machinery is -2.1129 (significant at α=0.01, Table 6) implying an inverse relationship with its own price which is theoretically correct. A 10 percent increase in the price of machinery will result in a 21.129 percent decrease in the demand for machinery.

The cross-price elasticity of demand for machinery with respect to the price of labor is 0.1061 (significant at α=0.01, Table 6). This implies that machinery and labor are substitutes. A 10 percent increase in the price of labor will result in a 1.061 increase in the demand for machinery. A low degree of substitutability between machinery and labor is consistent since the production of burley does not lend itself to mechanization (Johnson, p. 85). Machinery is primarily used for field preparation, transplanting, spraying and leaf transportation. Other activities such as harvesting and stripping off burley leaves are done by manual labor.

The cross-price elasticity of demand for machinery with respect to the percentage change in the price of operating capital is -0.0584 (significant at α=0.01, Table 6) implying that machinery and equipment and operating capital are complements. The cross-price elasticity of demand for machinery with respect to the percentage change in the price of burley tobacco is 0.8015, indicating a positive relationship between machinery and equipment and the price of burley tobacco. Machinery is a normal input since an increase in the price of output by 10 percent will result in a 8.015 percent increase in the demand for machinery.

There are no direct comparisons of these results with other studies dealing with tobacco. However, a study on the demand for U.S. farm wheel tractors (Mui) found a negative relationship between the demand response and the change in the price of the output. Mui contended that the crop price index was inappropriate and was the most plausible explanation for obtaining the wrong sign. An alternative explanation is that, farm-wheel tractors were an inferior input. This study concludes that machinery is an important inputaffecting profit,is inversely related to its own price, is a complement with operating capital, and is a substitute for land and labor.

Supply

For the short run, the own-price elasticity is 0.6061 (significant at α=0.01, Table 5), implying a positive relationship between burley tobacco and its own price. The result indicates that a 10 percent increase in the price of burley tobacco will result in a 6.061 percent increase in the supply of burley tobacco. This result contradicts with a previous study (Sutton, p. 127) where a price elasticity was estimated to be - 0.031. Sutton's result implies that a 10 percent increase in the price of burley tobacco received by the farmers will result in a 0.31 percent decrease in the quantity of burley tobacco produced. The result is a highly inelastic response. However, the negative sign contradicts the theory since the own-price effect of supply is positive (Varian, 1978, p. 33). Using the price equation from Sutton's regression simulation, the response of the quantity of burley tobacco produced with respect to the real price of burley tobacco received by the farmers was reestimated and the estimated value was -4.3225. This indicates an elastic response, but the sign is theoretically incorrect. Thus, our estimate of own-price elasticity of +0.6061 is more plausible.

The cross-price elasticity of supply with respect to the price of labor is -0.5956 (significant at α=0.01, Table 5), implying that labor is a normal input (Ferguson, pp. 197-204). A 10 percent increase in the price of labor will result in a 5.956 percent decrease in the output supply. Comparisons with previous studies cannot be made because this relationship has not been explicitly investigated before for burley tobacco industry at the farm level. The supply elasticity of operating capital is -0.5047 which also implies that operating capital is a normal input. A positive relationship exists between supply and the quantity of fixed input, which is 0.2357 (significant at α=0.01, Table 5). If land is expanded by 10 percent, the burley supply will increase by 2.357 percent. This finding is consistent with the coefficient of the short-run translog function where a 10 percent expansion of land will increase the profit by 2.406 percent.

For the long run, there is an analogous interpretation of own- and cross-price elasticities of output supply with respect to changes in the price of burley tobacco received by the farmers and the price of variable inputs. For example, the own-price elasticity of supply is 0.8353 (significant at α= 0.01, Table 6), implying a positive response between supply of burley tobacco and the price of burley tobacco. In this case, a 10 percent increase in the price of burley tobacco results in a 8.353 percent increase in the supply of burley tobacco. All cross-price elasticities of supply with respect to the price of variable inputs are negative (Table 6). For example, cross-price elasticity with respect to price of labor is -0.5218 (significant at α=0.01 Table 6). A 10 percent increase in the price of labor will result in a 5.218 percent decrease of the supply of burley tobacco.

In summary, the short-run and long-run supply of burley tobacco is positively related to its own price but inelastic, as indicated by the estimated own-price elasticity of supply. For the short-run, all variable inputs are negatively related to the output supply. The short-run supply elasticity with respect to the percentage change of the quantity of the fixed input is consistent with the decreasing returns to scale. Long-run supply is negatively related to all variable inputs.

Conclusions and Implications

The results of the study support the usefulness of a duality-based build a model of burley tobacco production. Tests of hypotheses on the restrictions imposed on the short-run and long-run translog variable-profit functions and the net-output share equations indicate that profit-maximizing behavior applies to the farm level. Tests on the coefficient of the quantity of the fixed input suggest that decreasing returns to scale occur at the farm level.

Parameter estimates of the short- and long-run translog variable-profit functions indicate that the price of burley tobacco and the prices of all of variable inputs significantly affect profit. The price has the greatest statistical impact, but the wage rate for labor is the most important variable input price. This is not surprising given that labor comprises approximately 30 percent of total costs of burley tobacco production (Grise).

Estimates of the short and long-run own-price elasticities of burley supply suggest that the burley supply response was inelastic and positive relative to its own price. The negative values of the supply responses relative to the prices for variable inputs indicate that all variable inputs are normal.

Estimates of the short- and long-run cross-price elasticities suggest that either substitutability or complementarity can occur among variable inputs used in burley tobacco production. For example, operating capital and machinery are complements, but labor and machinery are substitutes. This finding is consistent with Berndt and Wood. Given a specific technology, a small cross-price elasticity for labor relative to the price of machinery indicates that labor and machinery are not close substitutes for each other. Labor remains comparatively inexpensive. While efforts have been made at the University of Kentucky to develop mechanical harvesters, this equipment would require a large capital investment by the farmer and would need large acreages for harvest to be economically justifiable. All derived input demands had negative responses relative to their own prices. For example, own-price elasticity of labor is - 2.1192, indicating that a 10 percent increase in the price labor will result in with a 21.192 percent decrease in the demand for labor. Analogous interpretations can be also made for other variable inputs.

The results of the study can also be linked to the possible implications for the methodology and methods used in the analysis, and to the policy issues currently affecting the burley tobacco industry. The discussion on methodology will focus on both the usefulness and problems with duality theory in specifying a model for the burley tobacco industry. The discussion on methods presents some ideas for the use of ITSUR for future studies. Policy implications arising from the results of the study are presented. Finally, additional research needs will be outlined.

Applicability of Duality Theory
To Other Components of the Industry

The application of duality to the farm level suggests that building an econometric model for the entire burley tobacco economy based on duality theory is feasible. A disaggregated model for burley tobacco industry including the farm level, the cigarette manufacturer level, the cigarette wholesaler level, the cigarette retailer, and the consumers of cigarettes was built using duality theory (Pandjaitan). However, it was not possible to estimate the entire model at all levels because of lack of data.

If the data for the entire industry could be gathered, estimation procedures would be comparatively routine following the basic procedures used for the farm level. However, a survey procedure could be costly and time consuming. These data requirements are not unique to burley tobacco but apply to most other agricultural commodities as well. For example, Grisley and Gitu, in their study of the turkey industry, could not investigate the input procurement, processing, and marketing functions of the integrated firm because of unavailability of data.

An alternative to a model that requires secondary, time-series data is a model that employs primary, cross-sectional data obtained from a sample survey. Questionnaires could be designed such that the required primary data for each level of the tobacco economy could be collected. Questionnaires, in this case, could follow the theoretical models developed in this study. The major problem is that firms at some levels, such as cigarette manufacturers, may be unwilling to release cost data, particularly for items such as machinery investment.

Difficulties may also arise in the applicability of duality theory when a particular level violates the assumptions of perfectly-competitive pricing behavior (producers are price takers). Several studies have shown that the tobacco industry does not operate in an environment of perfect competition in which firms are atomistic. At the farm level, burley tobacco producers perhaps come closer to being atomistic than nearly any other group of farmers. However, this is clearly not the case at the cigarette manufacturing level.

For example, Sumner found that the atomistic competition hypothesis was rejected at the 0.01 level of significance, implying that the cigarette industry is not perfectly competitive. The study also provided evidence against the operation of an effective cartel.

Approaches suggested in studies by Appelbaum and by Lopez might be applicable at the cigarette-manufacturer level. Appelbaum, in a study of the U.S. rubber, textile, electrical machinery and tobacco industries, found that tobacco industry had the highest degree of oligopolistic power. So far, very few studies employed duality theory to an oligoplistic industry. Lopez, using the theoretical framework suggested by Stigler and estimation procedures similar to those employed by Appelbaum, estimated the demand for food and price elasticities of demand for variable inputs enroute to measuring the oligopoly power of the Canadian food-processing industry.

Applicability of ITSUR

The Iterative Seemingly Unrelated Regressions (ITSUR) procedures are advantageous in terms of the invariance property and because restrictions within and across equations can easily be imposed. However, ITSUR requires long data series for sufficient degrees of freedom. As a rule, the number of observations should be greater than the number of predetermined variables and restrictions including intercepts. Hence, the number of predetermined variables and restrictions within and across equations should be carefully considered in order to obtain sufficient degrees of freedom. This analysis suggests that systems of equations with five predetermined variables in each equation should have, at minimum, 30 observations in order to obtain satisfactory results in terms of convergence and the number of iterations. If shorter data series are used, the results should be interpreted with extreme caution since the standard errors are approximations of the true standard errors of the population, and become less reliable as the sample size decreases.

Since the translog function is a second-degree approximation of a Taylor series, model convergence should be obtained. In this study, the convergence is assumed at the 0.0001 convergence value within fifty iterations. The convergence also depends on the starting values for the iterations, and the starting values are specified by trial and error. The SAS procedure suggests that the user make an initial run without specifying starting values. In subsequent runs, these initial estimates are used as starting values. An alternative approach uses OLS parameter estimates for the translog variable-profit function as the starting values for the iterations. The final parameter estimates using either approach were the same. The more restrictions and the fewer the number of observations, the more difficult it is to obtain convergence in a specified number of iterations. (The default value for the SYSLIN routine is 30 iterations.)

Policy Implications

Returns-to-Scale estimates and the various estimates of own- and cross-price elasticities have policy implications. It is important to know whether the farm level has decreasing, constant or increasing returns to scale, for it is of policy interest to determine if large-scale production of burley tobacco is economically feasible. If increasing returns to scale prevail, large-scale production can lead to efficiencies.

If large-scale production is feasible, burley producers may no longer be price takers, but have a degree of monopolistic power. Small burley producers will quit producing burley tobacco, or merge to become larger producers. If constant returns to scale exist, the number of burley producers and the scale of production are variable. If decreasing returns to scale occur, the number of burley producers and the scale of production remain small since large-scale production will lead to inefficiencies (Nicholson, pp. 142-147).

The empirical results of the study reveal that farm- level production exhibits decreasing returns to scale. Hence, large-scale production of burley tobacco is not economically feasible. Given the state of burley tobacco production technology represented by the data set used in this analysis, there is no evidence to support the notion that a smaller number of producers, each with larger acreages, would reduce aggregate production costs.

Elasticity estimates indicate that substitution between each variable input pair is usually possible. Therefore with changing relative input prices, less expensive inputs can be substituted for high priced inputs. Cheaper inputs may be also obtained via bulk purchases even if the producers remain small. For example, a group of farmers might cooperate to purchase inputs such as fertilizer and chemicals in large quantities which results in a lower per-unit cost, increasing profits to individual burley producers.

Table 1. **The ITSUR Parameter EstimatesThe Short-run Translog Variable-Profit Function.**[a/]

$$\ln\pi_F^S = -0.5702 + 0.5619\ \ln P_F + 0.1298\ \ln V_{NF} + 0.0700 \ln V_{KF} +$$
$$(.1859)\quad (0.0043)\quad (0.0008)\quad (0.0013)$$

$$0.2406 \ln TH_F + [0.1173(\ln P_F)^2]/2 + [0.6890(\ln V_{NF})^2]/2 +$$
$$(0.0029)\quad (0.0024)\quad (0.0034)$$

$$[0.0830(\ln V_{KF})^2]/2 - [0.0083(\ln TH_F)^2]/2 - 0.0420 \ln P_F \ln V_{NF}$$
$$(0.0024)\quad (0.0062)\quad (0.0005)$$

$$-0.0472 \ln P_F \ln V_{KF} - 0.0045 \ln P_F \ln TH_F - 0.0061 \ln V_{NF} \ln TH_F$$
$$(0.0022)\quad (0.0016)\quad (0.0026)$$

$$-0.0152 \ln V_{NF} \ln V_{KF} - 0.0130 \ln V_{KF} \ln TH_F$$
$$(0.0019)\quad (0.0027)$$

a/ All parameter estimates are significant at α=0.01 level. Asymptotic Standard Errors are in parentheses. P_F = Price of Burley, V_{NF} = Labor Cost, V_{KF}= Operating Cost, TH_F = Tobacco Harvested (000).

Table 2. **The ITSUR Parameter Estimates of The Long-run Translog Variable-Profit Function.**[a/]

$$\ln\pi_F^1 = \underset{(0.1863)}{-0.5730} + \underset{(0.0043)}{0.5614}\ln P_F + \underset{(0.0002)}{0.1238}\ln V_{LF} + \underset{(0.0001)}{0.1319}\ln V_{NF} +$$

$$\underset{(0.0010)}{0.0713}\ln V_{KF} + \underset{(0.0011)}{0.1116}\ln V_{HF} + [\underset{(0.0142)}{0.1742}(\ln P_F)^2]/2 +$$

$$[\underset{(0.0018)}{0.0938}(\ln V_{LF})^2]/2+[\underset{(0.0018)}{0.1176}(\ln V_{NF})^2]/2+[\underset{(0.0027)}{0.0875}(\ln V_{KF})^2]/2$$

$$+[\underset{(0.0008)}{0.0962}(\ln V_{HF})^2]/2 \underset{(0.0004)}{-0.0402}\ln P_F \ln V_{LF} \underset{(0.0004)}{-0.0405}\ln P_F \ln V_{NF}$$

$$+\underset{(0.0012)}{0.0410}\ln P_F \ln V_{KF} \underset{(0.0047)}{-0.0347}\ln P_F \ln V_{HF} \underset{(0.0010)}{-0.0357}\ln V_{LF}\ln V_{NF}$$

$$\underset{(0.0010)}{-0.0077}\ln V_{LF}\ln V_{KF} \underset{(0.0022)}{-0.0102}\ln V_{LF}\ln V_{HF} \underset{(0.0006)}{-0.0146}\ln V_{NF}\ln V_{KF}$$

$$\underset{(0.0018)}{-0.0269}\ln V_{NF}\ln V_{HF} \underset{(0.0021)}{-0.0243}\ln V_{KF}\ln V_{HF}$$

a/ All parameter estimates are significant at $\alpha=0.01$ level. Asymptotic Standard Errors are in parentheses. P_F = Price of Burley, V_{NF} = Labor Cost, V_{KF}= Operating Cost, TH_F = Tobacco Harvested (000), V_{HF}= Overhead Cost, V_{LF} = Land and Quota Cost

Table 3. **Parameter Estimates of The Short-run Net-Output Share Equations.**[a/]

Shares	Intercept	$\ln P_F$	$\ln V_{NF}$	$\ln V_{KF}$	$\ln TH_F$
SY_F	0.5619	0.1173	-0.0420	-0.0472	-0.0045
	(0.0015)	(0.0024)	(0.0005)	(0.0022)	(0.0016)
SX_{NF}	0.1298	-0.0420	0.0689	-0.01520	-0.0061
	(0.0008)	(0.0005)	(0.0034)	(0.0019)	(0.0026)
SX_{KF}	0.0700	-0.0472	0.0152	0.0830	-0.0130
	(0.0013)	(0.0022)	(0.0022)	(0.0024)	(0.0027)

a/ All parameter estimates are significant at α=0.01 level. Asymptotic Standard Errors are in parentheses. P_F = Price of Burley, V_{NF} = Labor Cost, V_{KF}= Operating Cost, TH_F = Tobacco Harvested (000). SY Denotes the output share, SX the input share.

Table 4. **Parameter Estimates of The Long-run Net-Output Share Equations.**[a/]

Shares	Intercept	lnP_F	lnV_{LF}	lnV_{NF}	lnV_{KF}	lnV_{HF}
SY_F	0.5614	0.1742	-0.0402	-0.0405	-0.0410	-0.0347
	(0.0043)	(.0143)	(0.0004)	(0.0004)	(0.0012)	(0.0047)
SX_{LF}	0.1238	-0.0402	0.0938	-0.0357	-0.0077	-0.0102
	(0.0002)	(0.0004)	(0.0018)	(0.0010)	(0.0008)	(0.0022)
SX_{NF}	0.1319	-0.0405	-0.0357	0.1176	-0.0146	-0.0269
	(0.0001)	(0.0005)	(0.0010)	(0.0018)	(0.0006)	(0.0009)
SX_{KF}	0.0713	-0.0410	-0.0077	-0.0146	0.0875	-0.0243
	(0.0011)	(0.0012)	(0.0008)	(0.0006)	(0.0027)	(0.0043)
SX_{HF}	0.1116	-0.0347	-0.0102	-0.0269	-0.0243	0.0962
	(0.0011)	(0.0047)	(0.0008)	(0.0018)	(0.0021)	(0.0008)

a/ All parameter estimates are significant at $\alpha=0.01$ level. Asymptotic Standard Errors are in parentheses. P_F = Price of Burley, V_{NF} = Labor Cost, V_{KF}= Operating Cost, TH_F = Tobacco Harvested (000), V_{HF}= Overhead Cost, V_{LF} = Land and Quota Cost SY denotes the output share, SX, the input share.

Table 5. **Estimates of the Short-run Own- and Cross-Price Elasticities of The Derived Input Demands For Labor and Operating Capital and Supply of Burley Tobacco At The Farm Level.**[a/]

Description	Supply	Labor	Operating Capital
Price of Labor	-0.5956	-2.1035	0.0597
	(0.0043)	(0.0134)	(0.0059)
Price of Operating Capital	-0.5407	-0.0333	-1.9773
	(0.0060)	(0.0033)	(0.0213)
Price of Burley Tobacco	0.6061	1.3492	1.2080
	(0.0060)	(0.0045)	(0.0035)
Quantity of Fixed-Input	0.2357	-	-
	(0.0034)	-	-

a/All elasticity estimates are significant at α=0.01 level. Asymptotic Standard Errors are in parentheses.

Table 6. **Elasticity Estimates of the Long-run Own- and Cross-Price of The Derived Input Demands For Land, Labor, Operating Capital and Machinery and Equipment and Supply of Burley Tobacco At The The Farm Level.**[a/]

Description	Price of: Land	Labor	Operating Capital	Machinery/ Equipment	Supply of Burley Tobacco
Land	-2.1466	0.1520	0.0165	-0.0281	0.7900
	(0.0200)	(0.0079)	(0.0024)	(0.0034)	(0.0098)
Labor	0.1364	-2.1192	0.1070	0.0882	0.8329
	(0.0062)	(.0137)	(0.0071)	(0.0050)	(0.0070)
Operating Capital	-0.0239	0.0521	-1.9939	-0.0814	0.5547
	(0.0031)	(0.0057)	(0.0217)	(0.0021)	(0.0167)
Machinery And Equipment	-0.0311	0.1061	-0.0584	-2.1129	0.8015
	(0.0038)	(0.0061)	(0.0028)	(0.0150)	(0.0071)
Supply of Burley Tobacco	-0.5220	-0.5218	-0.5218	-0.5258	0.8353
	(0.0061)	(0.0060)	(0.0061)	(0.0060)	(0.0030)

a/ All elasticity estimates are significant at $\alpha=0.01$ level. Asymptotic Standard Errors are in parentheses.

Appendix Table 1. Description and Sources of Variables Used in Empirical Analysis.

Symbol	Description	Unit	Source
P_F	Price of burley tobacco received by the farmer	Cent/pound	Tobacco Outlook and Situation, (TS) 1955-1986
V_{LF}	Cost of land to produce burley tobacco	$/100 pounds of burley tobacco	Tobacco Outlook and Situation, (TS) 1978-1986
V_{NF}	Cost of labor to produce burley tobacco	$/100 pounds of burley tobacco	Tobacco Outlook and Situation, (TS) 1978-1986
V_{KF}	Cost of operating capital to produce burley tobacco	$/100 pounds of burley tobacco	Tobacco Outlook and Situation, (TS) 1978-1986
V_{HF}	Cost of machinery and equipment to produce burley tobacco	$/100 pounds of burley tobacco	Tobacco Outlook and Situation, (TS) 1978-1986
L_F	Harvested acreage of burley tobacco	thousand acres	Tobacco Outlook and Situation, (TS) 1955-1986
π_F	Profit of the producer	$/100 pounds	computed

Producer Output Indices used to deflate the data were obtained from Economic Indicators of the Farm Sector Production and Efficiency Statistics, 1982 and 1984, USDA Washington D.C.

Appendix Table 2. Data Used in the Analysis.

Year	PBF	π	VNF	VOF	VLF	VHF	THF	YA
1955	58.6	2.7	36.1	19.8	33.9	30.2	310.6	1513
1956	63.6	6.9	36.6	20.1	34.4	30.6	309.8	1635
1957	60.3	5.0	35.7	19.6	33.5	29.9	306.6	1592
1958	66.1	4.6	39.7	21.8	37.3	33.2	297.1	1567
1959	60.6	1.9	37.9	20.8	35.6	31.7	301.0	1669
1960	64.3	5.6	37.9	20.8	35.6	31.7	295.7	1639
1961	66.5	3.6	40.6	22.3	38.1	33.9	318.9	1820
1962	58.6	3.9	35.3	19.4	25.7	29.5	339.0	1894
1963	59.2	8.1	32.6	17.9	30.6	27.3	339.0	2231
1964	60.3	5.0	35.7	19.6	33.5	29.9	306.6	2002
1965	64.6	10.7	34.8	19.1	32.7	29.1	277.1	2116
1966	66.9	21.2	29.5	16.2	27.7	24.7	240.7	2437
1967	71.8	26.7	29.1	16.0	27.3	24.3	237.7	2274
1968	73.7	34.0	25.6	14.1	24.0	21.4	237.6	2372
1969	69.6	32.7	23.8	13.1	22.4	19.9	237.7	2488
1970	72.2	20.2	33.5	18.4	31.5	28.0	216.4	2590
1971	80.9	18.0	40.6	22.3	38.1	33.9	213.5	2213
1972	79.2	26.6	33.9	18.7	31.9	28.4	235.6	2553
1973	92.9	39.7	34.3	18.9	32.3	28.8	227.0	2093
1974	113.7	61.3	33.5	18.4	31.5	28.0	261.0	2350
1975	105.6	51.1	37.5	17.0	35.19	31.3	282.0	2265
1976	114.2	54.98	38.56	20.66	36.89	33.74	286.0	2376
1977	120.0	51.68	44.09	24.23	41.40	36.68	269.0	2296
1978	131.2	59.65	46.73	24.82	42.38	37.40	261.0	2396
1979	145.2	49.73	62.41	33.06	46.92	47.48	238.0	1873
1980	165.9	74.36	55.36	36.18	47.14	44.22	277.0	2027
1981	180.7	86.50	54.98	39.22	51.16	44.85	331.0	2203
1982	181.0	90.36	51.79	38.85	49.88	44.22	346.0	2374
1983	177.3	57.48	64.71	55.11	49.51	61.51	293.0	1645
1984	187.5	81.24	57.87	48.39	48.49	46.53	316.0	2256
1985	160.1	31.27	60.02	68.81	43.24	46.43	266.0	2278

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