A TRANSLOG COST ANALYSIS OF TURKEY PRODUCTION IN THE MID-ATLANTIC REGION

William Grisley and Kangethe W. Gitu

Abstract

The production structure of 165-hen and 200-tom turkey flocks is investigated using a translog (dual) variable cost function. The partial static equilibrium elasticities of scale, input demand, input substitution, and cross price elasticities of demand are calculated. The elasticity of scale is found to be not significantly different from one over the range of 5,900 to 9,822 birds for the hen flocks and over the range of 7,765 to 11,043 birds for the tom flocks. In general, the input demand elasticities are inelastic with the exception of the input fuel. The cross-price elasticities are in general inelastic.

Key words: turkey production, economies of scale, input substitution.

Turkey production in the Mid-Atlantic region occurs in an industry characterized by a high degree of vertical integration. Individual integrated firms, hereafter referred to as contractors, typically produce or procure inputs, contract production to individual growers, process the birds, and do their own marketing. Given the interrelationship of these steps, the decisionmaking process is expected to be integrated and simultaneous in nature. At the production stage, the contractor provides the poults, feed, fuel, medication, floor litter, and certain management and veterinary services. The grower is paid a fee, derived through a bargaining process, for his own and hired labor, management, and use of the production facility.

In the production stage, the objective of contractors is to produce turkeys at minimum cost. Production cost per pound is a function of the prices and quantities of inputs used, the genetic merit of the turkeys, and the technological endowment and capacity of the production house. Over a short-run period, the technology embodied in the turkeys and the production house are given. The important short-run decisions of contractors are selection of the input mix and flock size. Contractors can typically select among growers that have a wide range in capacity of production houses. Selecting a flock size that growers can efficiently manage and be cost efficient is important.

The purpose of this study is to estimate the substitution relationship between inputs and the economies of size from a cross-section sample of hen and tom turkey producers in the Mid-Atlantic region. Using a transcendental logarithmic (translog) cost function, elasticity of input substitution, own- and cross-price elasticities of input demand, and elasticity of scale are derived. The input procurement, processing, and marketing functions of the integrated firm are not investigated because of the inavailability of data.

The transcendental logarithmic function, introduced by Christensen et al, has been frequently used to analyze input demand and the underlying technological structure of production. Studies using the translog cost function with time series and aggregated agricultural data include those by Binswanger, Kako, Ball and Chambers, and Ray. Applications of the translog (dual) cost function using cross sectional and disaggregated United States agricultural data have not appeared in the literature. Studies investigating economies of scale in turkey production are limited. Using California data, Eidman et al. derived empirical estimates of short- and long-run average cost curves from single equation models. As expected, they found decreases in the long-run average cost curve for increases in the number of turkeys produced.

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Recent noneconometric studies of the costs of turkey production include those by Henson and Lance. However, these studies did not directly investigate the issues of input substitution and economies of size.

In applications of cost functions, an important assumption is that all inputs are in full static equilibrium. However, the firm can be assumed to be in static equilibrium with respect to a subset of inputs conditional on the observed levels of the remaining inputs. This framework is referred to as partial static equilibrium by Brown and Christensen. The variable inputs are assumed to be in static equilibrium, while the remaining inputs are designated as fixed or quasi-fixed. Applications of the variable cost function have been provided by Brown and Christensen, and Caves et al. An earlier application was provided by Lau and Yotopoulos using the variable profit function. As shown by Lau, estimates of the structure of production can be obtained from either the total or variable cost function under a set of general regularity conditions. In the present application of the translog function, the variable cost function is estimated. The total cost function could not be estimated because the prices and quantities of all inputs were unavailable. The elasticities computed are thus partial, rather than full, static equilibrium elasticities.

THE EMPIRICAL MODEL

Duality theory implies that a production technology can be represented by a cost function (Shephard). The translog (dual) cost function allows a derivation of input demand equations without placing stringent restrictions on the elasticities of substitution. Moreover, this specification allows scale economies to vary with the level of output, a feature essential to enable the unit cost curve to attain the classical U-shape (Christensen and Greene).

A total cost function can be written:

$$(1)\ CT = H(Q, P),$$

where CT, Q, and P are total cost, level of output, and a vector of factor prices, respectively. If cost is minimized with respect to a subset of the inputs conditional on the level of output and the remaining inputs, there exists a variable cost function:

$$(2)\ CV = G(Q, P, Z),$$

where CV is variable cost and Z is a vector of inputs (fixed or quasi-fixed), not necessarily in static equilibrium. In the model, three operating inputs (poults (t), feed (f), and fuel (b)), and three fixed factors (length of the production period (a), number of turkeys finished (d), and miscellaneous operating costs (m)) are used. The miscellaneous operating cost variable is included as a fixed factor since it was recorded in dollars per flock. The translog cost function for the three operating inputs and the three fixed factors is written as:

$$(3)\ \ln CV = \alpha_o + \alpha_q \ln Q + \sum_i \beta_i \ln P_i + \sum_k \gamma_k \ln Z_k + \tfrac{1}{2}\alpha_{qq}(\ln Q)^2 + \tfrac{1}{2}\sum_i \sum_j \beta_{ij} \ln P_i \ln P_j + \tfrac{1}{2}\sum_k \sum_r \gamma_{kr} \ln Z_k \ln Z_r + \sum_i \beta_{iq} \ln P_i \ln Q + \sum_i \sum_k \beta_{ik} \ln P_i \ln Z_k + \sum_k \gamma_{kq} \ln Z_k \ln Q,$$

where i, j = price of feed (f) and price of fuel (b); and k, r = length of the production period (a), number of turkeys (d), and miscellaneous operating costs (m). The price of poults (t) is used as the normalizing input and does not appear as a separate variable. The parameters to be estimated are α_o, α_q, β_i, γ_k, α_{qq}, β_{ij}, β_{iq}, γ_{kr}, β_{ik}, and γ_{kq}. From Young's theorem on the equality of second cross partial derivatives, the symmetry restrictions $\beta_{ij} = \beta_{ji}$ and $\gamma_{kr} = \gamma_{rk}$ are imposed on the model. Since any sensible cost function must be homogenous of degree 1 in input prices, the restrictions $\sum_i \beta_i = 1$ and $\sum_j \beta_{ij} = 0$ are imposed.

The share equations (S_i), which form the basis for estimation, are derived by differentiating equation (3) with respect to the natural log of each input price. The share equation for the i^{th} input is:

$$(4)\ S_i = \beta_i + \sum_j \beta_{ij} \ln P_j + \beta_{iq} \ln Q + \sum_k \beta_{ik} \ln Z_k.$$

The dependent variable of equation (4) is the i^{th} input's share of the variable cost or $S_i = P_i X_i / CV$, where X_i is the quantity of the i^{th} input. Since the price of poults (t) is used as the normalizing input devisor, only two linearly independent input share equations are estimated. The sum of the three operating inputs must equal the variable cost (CV).

The constant output partial static equilibrium own-price elasticities of input demand can be computed from the variable cost function (Brown and Christensen):

$$(5)\ E_{ii} = \frac{\partial \ln X_i}{\partial \ln P_i} = \frac{\beta_{ii} + S_i^2 - S_i}{S_i} = S_i\, \sigma_{ii}\,,$$

$$\text{where: } \sigma_{ii} = \frac{\beta_{ii} + S_i^2 - S_i}{S_i^2}.$$

Similarly, the constant output partial static equilibrium cross-price elasticities between inputs are:

$$(6)\ E_{ij} = \frac{\partial \ln X_i}{\partial \ln P_j} = \frac{\beta_{ij} + S_i S_j}{S_i} = S_j\, \sigma_{ij}\,,$$

$$\text{where: } \sigma_{ij} = \frac{\beta_{ij} + S_i S_j}{S_i S_j}.$$

β_{ii} and β_{ij} are parameters to be estimated from the system of equations, and S_i and S_j are the cost shares computed at the means of the respective independent variables. The term σ_{ij} is the Allen-Uzawa partial static equilibrium elasticity of substitution between inputs (Christensen et al.).

Elasticity of scale (ε_s) can be defined as the reciprocal of the elasticity of cost (ε_c) with respect to output along the expansion path if the total cost function is used (Hanoch). Under the variable cost function framework, the elasticity of scale is conditional on the observed levels of fixed factors. Following Caves et al., the elasticity of scale for the variable cost function can be calculated from equation (3):

$$(7)\ \varepsilon_s = (1 - \Sigma(\partial \ln CV/\partial \ln Z_k))/(\partial \ln CV/\partial \ln Q).$$

The production technology exhibits increasing, decreasing, and constant returns to scale for $\varepsilon_s > 1$, $\varepsilon_s < 1$, and $\varepsilon_s = 1$, respectively (Ball and Chambers).

The cost function in equation (3) can be tested for homothetic and homogeneous production technology by imposing further restrictions. Homotheticity implies the optimal input combination is independent of the scale of output (Denny and Fuss). The expansion path is thus linear. In equation (3), homotheticity imposes $\beta_{iq} = 0$ and $\beta_{kq} = 0$. Homogeneity requires the elasticity of cost with respect to output to be constant. Testing for homogeneity requires the same restrictions as homotheticity, plus the additional restriction, $\alpha_{qq} = 0$.

Three models are estimated after imposing the restrictions for linear homogeneity in input prices and the translog symmetry conditions. The estimated models are the unrestricted translog cost function and the homothetic and homogeneitic cost structures. The cost function in equation (3) and the share equations in (4) are estimated as a system using Zellner's seemingly unrelated regression technique. Iterating the Zellner procedure is a computationally efficient method for obtaining maximum-likelihood estimates. The share equations are for the inputs feed and fuel, and the omitted share equation is for the input poults. The estimates obtained are independent of which equation is omitted (Barten).

Data

Data used are from a survey of Mid-Atlantic States' turkey contractors and contract growers conducted by The Pennsylvania State University Experiment Station in 1982 (see Henson for a complete description of the data). All of the growers included in the survey operated under production contracts. Records for 165-hen and 200-tom flocks for the period September 1980 to September 1981 were studied. The data were segregated by sex because hen and tom turkeys are produced in separate houses and require different lengths of time for production. Up to two or three consecutive flocks were produced per grower and in some cases more than one flock was being produced during a specific time period. Seasonality in production was not considered in the model because technology did not change over this short period of time and the decision to initiate production would not be affected by prevailing input prices.

The means and standard deviations of the data used are shown in Table 1. All information except the price of fuel (LP gas) was taken from the survey questionnaires. For fuel, the average prices paid by month in the Mid-Atlantic States, as reported by the USDA,

TABLE 1. SELECTED CHARACTERISTICS OF 165-HEN AND 200-TOM TURKEY FLOCKS, MID-ATLANTIC REGION, 1980-81

Variable	Hens		Toms	
	Mean	Standard deviation	Mean	Standard deviation
Price/poult ($)	0.71	0.02	1.00	0.03
Number of poults	9,707	4,142	10,758	4,430
Price/lb. feed ($)	0.12	0.01	0.12	0.01
Pounds of feed	337,862	149,118	633,093	276,187
Price/gal. fuel ($)	0.75	0.05	0.74	0.05
Gallons fuel	1,655	1,335	2,190	1,762
Production period (days)	117	3.5	135	5.13
Pounds of turkey produced	128,732	56,315	228,815	99,164
Number of turkeys produced	9,022	3,915	9,491	4,051
Other costs/flock ($)[a]	7,468	3,334	12,341	5,589
Variable cost/flock ($)[b]	48,974	21,903	88,108	38,400
Poults cost share (%)[c]	14	1.7	12	2.1
Feed cost share (%)[c]	83	1.6	86	2.0
Fuel cost share (%)[c]	3	0.8	2	0.4

[a] Medication, litter, flock service, grower payment, and miscellaneous.
[b] Sum of poults, feed, and fuel costs.
[c] Percent of variable cost that is poults, feed, and fuel, respectively.

TABLE 2. ESTIMATED COEFFICIENTS OF THE UNRESTRICTED TRANSLOG COST FUNCTION FOR HEN AND TOM TURKEYS PRODUCED IN THE MID-ATLANTIC REGION, 1980-81

Parameter[a]	Coefficient estimates[b] Hens	Toms	Parameter (cont'd)	Coefficient estimates (cont'd) Hens	Toms
α_0	10.791***	11.375***	β_{ta}	−0.030***	−0.014*
	(0.002)	(0.002)		(0.010)	(0.009)
α_q	1.108***	1.216***	β_{td}	0.141***	0.140***
	(0.032)	(0.032)		(0.004)	(0.006)
β_t	0.142***	0.124***	β_{tm}	0.023***	0.021***
	(0.001)	(0.001)		(0.002)	(0.002)
β_f	0.834***	0.858***	β_{ff}	0.083***	0.076***
	(0.001)	(0.001)		(0.007)	(0.006)
β_b	0.024***	0.017***	β_{fb}	0.041***	0.033***
	(0.001)	(0.001)		(0.007)	(0.006)
γ_a	0.174***	0.023	β_{fa}	0.098***	0.007
	(0.059)	(0.064)		(0.025)	(0.018)
γ_d	0.089***	−0.009	β_{fd}	−0.143***	−0.151***
	(0.024)	(0.020)		(0.009)	(0.006)
γ_m	−0.197***	−0.201***	β_{fm}	0.011**	−0.010**
	(0.014)	(0.017)		(0.006)	(0.005)
α_{qq}	2.020***	1.293***	β_{bb}	0.043***	−0.037***
	(0.266)	(0.228)		(0.007)	(0.006)
β_{qt}	−0.164***	−0.162***	β_{ba}	−0.068***	−0.121***
	(0.005)	(0.004)		(0.026)	(0.018)
β_{qf}	0.131***	0.159***	β_{bd}	0.002	0.010*
	(0.013)	(0.010)		(0.009)	(0.006)
β_{qb}	0.033***	0.003	β_{bm}	−0.034***	−0.010**
	(0.013)	(0.010)		(0.006)	(0.005)
γ_{qa}	0.043	0.557	γ_{aa}	−2.331**	−0.303
	(0.466)	(0.389)		(1.116)	(0.885)
γ_{qd}	−1.848***	−1.323***	γ_{ad}	−0.306	−0.275
	(0.072)	(0.127)		(0.338)	(0.264)
γ_{qm}	−0.149	−0.009	γ_{am}	−0.261	−0.266
	(0.128)	(0.132)		(0.205)	(0.217)
β_{tt}	0.122***	0.101***	γ_{dd}	1.752***	1.301***
	(0.013)	(0.012)		(0.130)	(0.102)
β_{tf}	−0.124***	−0.107***	γ_{dm}	0.091	0.017
	(0.002)	(0.002)		(0.087)	(0.074)
β_{tb}	−0.002	0.006***	γ_{mm}	0.038	0.006
	(0.003)	(0.002)		(0.069)	(0.081)

[a] The subscripts q, t, f, b, a, d, and m refer to output, poults, feed, fuel, production period length, number of turkeys finished, and miscellaneous operating expenses, respectively.
[b] Estimated standard errors are in parentheses. Single, double, and triple asterisks indicate significance at the 0.10, 0.05, and 0.01 probability levels, respectively. The method used to calculate the standard errors of the omitted parameters follows Kmenta, p. 444.

were used. These prices are thus only approximations. Actual prices may differ by contractor and the geographical location of the grower.

RESULTS

Estimated results for the unrestricted cost function for sex flocks are shown in Table 2. The model fits the data quite well for both the cost and the feed share equations for both sex flocks. Coefficients of determination for the hen and tom cost functions and the feed share equations were 0.998 and 0.995 and 0.771 and 0.870, respectively. The R-squares for the fuel share equation were lower, 0.475 for hens and 0.224 for toms, which could be the result of using average monthly rather than actual contractor fuel prices. The system R-square for both sex flocks approached one. The parameter estimates in Table 2 are not of direct use by themselves, but are used in calculating the elasticity of scale, elasticity of input substitution, and the own- and cross-price elasticities.

Results of the hypothesis tests for homothetic and homogeneous cost structures are reported in Table 3. Both were rejected at the 0.01 probability level. Rejection of homotheticity implies the underlying production technology cannot be written as a separate function of input prices and output. Homogeneity is a special case of homotheticity and it was rejected by the strong rejection of homotheticity.

At the mean level of output (pounds of live turkey per flock), the scale elasticity was 0.84 for hens and 0.98 for toms. Converting the pound values at the mean level output to live birds gives flock sizes of 9,022 for hens and 9,491 for toms. The number of birds at an elasticity of one was 8,277 for hens and 9,276 for toms. To determine if the variable cost curve was statistically flat over some range of output, the confidence interval around the point where the elasticity of scale was not significantly different from one was calculated at the 0.05 probability level. This range can be defined as the "flat" portion of the cost curve over which there are no statistically significant economies or diseconomies of size. For the hen flocks, the range of this interval was 65 to 109 percent of the mean flock size. In terms of the number of turkeys harvested, these percentages correspond to a range of 5,900 to 9,822 hens, Table 4. Thirty-nine percent (64 flocks) of the total number of flocks produced fell within this range. Twenty-two percent (36 flocks) of the flocks fell in the range with economies of size and 39 percent (65 flocks) fell in the range of diseconomies of size.

The statistically flat portion of the variable cost curve for toms ranged from 82 to 116 percent of the mean flock size. This corresponds to a flock size range of 7,765 to 11,043 toms. Thirty-two percent (63 flocks) of the 200 flocks fell within this range. Forty-one percent (81 flocks) showed economies of size and 28 percent (56 flocks) showed diseconomies of size.

TABLE 3. CHI-SQUARE STATISTICS FOR HYPOTHESIS TESTS FOR HOMOTHETICITY AND HOMOGENEITY, HEN AND TOM TURKEY FLOCKS, MID-ATLANTIC, 1980-81

Model	Calculated value		Number of restrictions	Critical value	
	Hens	Toms		5%	1%
Homotheticity	233.50	276.31	7	14.07	18.48
Homogeneity	214.74	224.07	8	15.51	20.09

TABLE 4. RANGES OF RETURNS TO SIZE FOR 165-HEN AND 200-TOM TURKEY FLOCKS, MID-ATLANTIC REGION, 1980-81

Item	Hens	Toms
Bounds of the region with no significant economies or diseconomies:		
Flock size - number of turkeys		
Lower	5,900	7,765
Upper	9,822	11,043
Number of flocks	64	63
Percent of flocks	39	32
Significant size economies:		
Number of flocks	36	81
Percent of flocks	22	41
Significant size diseconomies:		
Number of flocks	65	56
Percent of flocks	39	28

These results imply the variable cost curve for sex flocks is U-shaped. In terms of the number of turkeys produced, the cost curve for toms lies to the right of that for hens. Contractors can exploit size economies of the variable factors conditional on the observed level of the fixed factors by selecting flock sizes that fall within the statistically flat portion of the cost curve.

A description of the production technology is provided by the Allen-Uzawa elasticities of substitution and the elasticities of factor demand. These elasticities are shown in Table 5, with own-price elasticities of demand on the diagonal and elasticities of substitution on the off-diagonal. The elasticities and cross-price elasticities reported here are calculated at the mean of the individual flock elasticities.[1] For hens, the own price elasticity of demand for poults was not significantly different from zero. The own-price elasticities for feed and fuel were both negative and significantly different from zero (see Binswanger for a calculation of the approximate standard error). The demand for feed was highly inelastic (−0.067), while that for fuel was elastic with a value of −3.024. For the tom flocks, the own-price elasticity was significantly different from zero for feed and fuel, but not poults. The elasticity for feed was −0.055 and that for fuel was −3.248. The small elasticities estimated for feed implies the quantity demanded does not respond greatly to a change in price. This result is as expected since the turkeys are fed *ad libitum*. The elasticities estimated for fuel were larger than expected. One explanation may be that the heat retaining capacity of the houses are different. Information on the quality of the houses was not available.

The elasticity of substitution between poults and feed was found to be complementary and significant for hen flocks, but not significant for tom flocks. The substitution rate was small and inelastic for hens. Poults and fuel and feed and fuel were found to be substitutes and statistically significant for both sex flocks. The large and elastic values found are not easily explainable, but may be a result of differences in housing quality.

Cross-price elasticities of input demand contain much the same information as the elasticities of substitution and own-price elasticities. Between pairs of inputs, cross-price elasticities are not symmetric as in the case of elasticities of substitution since they depend on the input share weights. All of the cross-price elasticities between pairs of inputs were significant for both sex flocks except those for poults and feed and feed and poults in the tom flocks, Table 6. The hen flock elasticity for poults and feed was inelastic with a negative sign, implying that

TABLE 5. ALLEN-UZAWA PARTIAL ELASTICITIES OF SUBSTITUTION, UNRESTRICTED COST FUNCTION FOR HEN AND TOM TURKEYS, MID-ATLANTIC REGION, 1980-81

	Hens			Toms		
Inputs	Poults	Feed	Fuel	Poults	Feed	Fuel
Poults	0.004 (0.094)[a]		(Symmetry)	−0.047 (0.093)		(Symmetry)
Feed	−0.053 (0.017)	−0.067 (0.008)		−0.018 (0.020)	−0.055 (0.007)	
Fuel	1.807 (0.871)	3.319 (0.333)	−3.024 (0.296)	3.874 (1.114)	3.231 (0.389)	−3.248 (0.345)

[a] Approximate standard errors are in parentheses.

TABLE 6. CROSS-PRICE ELASTICITIES OF INPUT DEMAND, UNRESTRICTED COST FUNCTION FOR HEN AND TOM TURKEYS, MID-ATLANTIC REGION, 1980-81

	Hens			Toms		
Inputs	Poults	Feed	Fuel	Poults	Feed	Fuel
Poults	—	0.006 (0.002)	0.259 (0.125)	—	0.005 (0.003)	0.482 (0.003)
Feed	−0.046 (0.019)[a]	—	2.265 (0.278)	−0.018 (0.981)	—	2.767 (0.335)
Fuel	0.041 (0.021)	0.073 (0.008)	—	0.065 (0.020)	0.054 (0.007)	—

[a] Approximate standard errors are in parentheses.

[1] Elasticities calculated at the mean of the individual flock elasticities may not correspond exactly to elasticities calculated using the parameter estimates reported in Table 1.

as the price of one increased the quantity demanded of the other decreased. The fuel and poults and feed and poults elasticities were inelastic and positive for both sex flocks. An increase in the price of one input resulted in an increase in the quantity demanded of the other. Results for fuel and feed and feed and fuel were similar in sign but different in magnitude. The elasticity between fuel and feed was highly elastic.

Cross-price elasticities are of direct use in policy formulation. A relative increase in the price of one input can result in changes in the quantity demanded of other inputs. From the results reported, changes in the prices of inputs did not result in large changes in the quantity demanded of other inputs except for the case of fuel and feed. Policies that cause an increase in the price of fuel can result in a large increase in the quantity demanded of feed.

CONCLUSIONS

This study investigated the structure of production for hen and tom turkey flocks being produced under contract agreements from vertically integrated turkey firms in the Mid-Atlantic region. A short-run translog variable cost function was used for this purpose. An important decision of contracting firms is to select the flock size and input mix that will give minimum cost per pound of turkey produced. The flocks studied ranged in size from 4,000 to 22,000 birds, with an average of 9,022 for hens and 9,491 for toms. A classical U-shaped average variable cost curve was isolated for both sex flocks. The elasticity of scale at the mean level of output was 0.84 for hens and 0.98 for toms. The curves were found to be statistically "flat" over the range of 5,900 to 9,822 birds for hens and 7,765 to 11,043 birds for toms. These results are potentially useful to both contracting firms and contract growers. Contractors could achieve size economies by contracting with growers who have production houses with capacities falling in the statistical "flat" portion of the average variable cost curve. Contract growers could use these results in their decisions concerning the optimum size of production facility to construct. The fee paid by contractors to growers is, in general, a function of the cost efficiency in production. From the growers' point of view, this fee is a return to labor and the production facility. Assuming no changes in production technology, constructing facilities with capacities that fall in the range of the statistical "flat" portion of the average variable cost curve would result in minimum variable cost per pound of turkey produced. Growers fees per pound of turkey could thus be maximized. However, the grower would also have to consider efficiency in labor utilization and fixed construction costs.

Elasticities of input substitution and own- and cross-price elasticities of input demand provide information regarding producers' input mix decisions and responses to input price changes given the production technology employed. These elasticities may not be of direct use by producers, but they provide policymakers with estimates of producers' production behavior. The own-price elasticity of demand for poults and feed was highly inelastic and that for fuel was elastic. Given the short time frame investigated, the former result was expected. The latter result was larger than expected and, in part, may have been due to use of average monthly prices, rather than actual prices paid. Poults and feed were found to be complements and fuel with both poults and feed were found to be substitutes in both sex flocks. The cross-price elasticities were, in general, found to be highly inelastic. An increase in the price of one input does not result in large changes in the quantity demanded of another input.

The results have application to production decisions by contractors. However, the production decision is only one of several decisions an integrated firm must make. It would be expected that the production decision would be integrated and made simultaneously with decisions at other stages. Given the complex nature of a vertically integrated firm, contractors may not be able to select a flock size that is cost efficient. Requirements in the input processing and turkey processing and marketing stages may not allow for sufficient flexibility in the production decision to take advantage of size economies.

REFERENCES

Ball, V. E. and R. G. Chambers. "An Economic Analysis of Technology in the Meat Products Industry." *Amer. J. Agr. Econ.,* 64(1982):699-709.

Barten, A. P. "Maximum Likelihood Estimation of a Complete System of Demand Equations." *Europ. Econ. Rev.,* 1(1969):7-73.

Binswanger, H. P. "A Cost Function Approach to the Measurement of Factor Demand and Elasticities of Substitution." *Amer. J. Agr. Econ.,* 56(1974):377-86.

Brown, R. S. and L. R. Christensen. "Estimating Elasticities of Substitution in a Model of Partial Static Equilibrium: An Application to U.S. Agriculture, 1947 to 1974." *Modeling and Measuring Natural Resource Substitution,* eds. E. R. Berndt and B. C. Field. The MIT Press, Cambridge, Massachusetts, 1981.

Caves, D. W., L. R. Christensen and J. A. Swanson. "Productivity Growth, Scale Economies, and Capacity Utilization in U.S. Railroads, 1955-74." *Amer. Econ. Rev.,* 71(1981):994-1,002.

Christensen, L. R. and W. H. Greene. "Economies of Scale in U.S. Electric Power Generation." *J. Pol. Econ.,* 84(1976):655-76.

Christensen, L. R., D. W. Jorgenson and L. R. Lau. "Transcendental Logarithmic Production Frontiers." *Rev. Econ. Stat.,* 55(1973):28-45.

Denny, M. and M. A. Fuss. "The Use of Approximation Analysis to Test for Separability and the Existence of Consistent Aggregates." *Amer. Econ. Rev.,* 67(1977):404-18.

Eidman, V. R., H. O. Carter and G. W. Dean. "Decision Models for California Turkey Growers." Giannini Foundation Monograph Number 21, University of California, Berkeley, 1968.

Hanoch, G. "The Elasticity of Scale and the Shape of Average Cost." *Amer. Econ. Rev.,* 65(1975):492-7.

Henson, W. L. "Turkey Production Practices and Costs in Virginia and Pennsylvania, 1981." A.E. and R.S. 162, Department of Agricultural Economics and Rural Sociology, The Pennsylvania State University, 1983.

Kako, T. "Decomposition Analysis of Derived Demand for Factor Inputs: The Case of Rice Production in Japan." *Amer. J. Agr. Econ.,* 60(1978):628-35.

Kmenta, J. *Elements of Econometrics,* New York, New York: Macmillan Publishing Co., 1971.

Lance, G. C. "Economic Evaluation of Total Confinement and Open Range Turkey Production Systems in Georgia." *Poultry Sci.,* 62(1983):1142-54.

Lau, L. J. "A Characterization of the Normalized Restricted Profit Function." *J. Econ. Theory,* 12(1976):131-63.

Lau, L. J. and P. A. Yotopoulos. "A Test for Relative Efficiency and Application to Indian Agriculture." *Amer. Econ. Rev.,* 61(1971):94-109.

Ray, S. C. "A Translog Cost Function Analysis of U.S. Agriculture, 1939-77." *Amer. J. Agr. Econ.,* 64(1982):490-8.

Shephard, R. W. *Cost and Production Functions,* Princeton, New Jersey: Princeton University Press, 1953.

USDA, SRS. *Agricultural Prices: Annual Summary,* 1980 and 1981.