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Analysis of the Cost Structure for Broiler Projects in the Central Region of Saudi Arabia: A Dual Cost Function Approach

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Abstract. The broiler projects are considered one of the highest priority areas that has gained major support and incentives in the Saudi Arabian agricultural policy. However, these projects have recently experienced a wide range of technical, managerial and marketing problems that has led to a drop in the number of operating projects to more than half. The main objective of this study was to analyze the cost structure of the broiler projects in the central region of Saudi Arabia using a dual cost function approach. This approach will serve to identify a number of economic indicators that can help to design policies to solve the problems facing these projects. The study showed that the cost of feed, labor, and veterinary expenses were the main factors explaining the variation in the cost of producing broilers. Further, the study indicates that increasing return to scale is present in these projects. This study has also estimated own and cross price elasticities of input demand as well as the Allen and Morishima elasticities of factor substitutions.

Introduction

The performance of the Saudi Arabian broiler projects has been affected by a variety of managerial, technical, production, and marketing problems. These problems led to a drop in the number of operating projects from a total of 288 in 1982 to only 126 in the year of 1990 [1].

In spite of the sizable investment in these projects, the majority of the projects are not operating at full production capacity based on their invested assets due to the problems stated above. This has increased the average fixed cost of the production unit and consequently reduced the level of technical efficiency and profit of these projects.

One might contribute the source of these problems to different factors such as, the imbalance in the distribution of these projects among the provinces of Saudi Arabia. Also import competition is another factor that is a major threat to the local industry since the international companies are more technically efficient and uses more productive technologies. Finally, the structural characteristics of these projects might give some of the larger projects an advantage in size economies and restrict output expansion for the smaller projects.

Limited studies in light of the above problems have been conducted to estimate the primal cost and production function of the broiler industry in Saudi Arabia. To date no study has been done using the dual approach in examining the cost function and derive its share equations for the industry.

Objectives

This study will test the cost minimization hypothesis by using a proper translog dual cost function for the broiler projects in the central region of Saudi Arabia and obtain the following objectives:

(1) Estimate the parameters of the dual cost function as well as its derived share equations using seemingly unrelated regression (SURE) technique for the study sample.
(2) Compute the partial static equilibrium elasticities of input substitution, own - and cross - price elasticities of input demand, and scale elasticity.
(3) Test the production and cost structure, or the homotheticity of the input - output relationship.

Methodology

Because of the severe restrictions and limitations imposed by the Cobb - Douglas (CD) type of functions, researchers have tried to develop less restrictive and more flexible functional forms that do not impose any constraints a priori. An example of such function is the transcendental logarithmic function which is often referred to as the "translog" function.

The translog cost function model

This function is developed by Christensen [2,3], and considered to be a second - order approximation to an arbitrary function. This form has both linear and quadratic terms with arbitrary number of inputs. It reduces to the multiple input (CD) form as a special case. In fact, the new function does not require additivity and homogeneity or the strong separability assumption. It allows for the possibility of complementarity between any pair of factors. It is also sufficiently flexible to describe the substitution possibilities between all pairs of factors at every data point. Further it allows scale economies to vary with the level of output which enables the unit cost curve to take the classical U- Shape [4].

A translog variable cost function with three variable inputs and two fixed factors - as applied by this study - can be written as:

$$\begin{aligned} \text{Ln } C = {} & \propto_0 + \propto_y \text{Ln} Y + \Sigma_i \beta_i \text{Ln } P_i + \Sigma_k \gamma_k \text{Ln } Z_k + 1/2 \Sigma_i \Sigma_j \beta_{ij} \text{Ln } P_i \text{Ln } P_j \\ & + 1/2 \propto_{yy} (\text{Ln} Y)^2 + 1/2 \Sigma_k \Sigma_q \gamma_{kq} \text{Ln } Z_k \text{Ln } Z_q + \Sigma_i \sigma_{iy} \text{Ln } P_i \text{Ln } Y \\ & + \Sigma_i \Sigma_k \theta_{ik} \text{Ln } P_i \text{Ln } Z_k + \Sigma \phi_{ky} \text{Ln } Z_k \text{Ln } Y \end{aligned} \quad (1)$$

Where:

C : is the total cost of the three variable inputs.
Y : is the level of output per project.
Z_k: is the level of the fixed factor K.
and $\propto, \gamma, \sigma, \theta, \phi$ are parameters to be estimated.

Following Binswanger [5], through the use of shephard's lemma, the derived demand functions can be found by differentiating the cost function in equation (1) with respect to the input prices, so that the share equations are given by:

$$S_i = \frac{\partial \text{Lnc}}{\partial \text{Ln } P_i} = \frac{P_i X_i}{C} \quad (2)$$

or

$$S_i = \beta_i + \Sigma_j \beta_{ij} \text{Ln } P_j + \Sigma_i \sigma_{iy} \text{Lny} + \Sigma_k \theta_{ik} \text{ Ln } Z_k \quad (3)$$

where

S_i = is the ith factor cost share.
X_i = is the quantity of the ith input.

The constant output own - price elasticity of factor demand, as well as the cross - price elasticity of factor demand can be computed following Binswanger [5], using this formula:

$$E_{ii} = \beta_{ii}/S_i + S_i - 1 \quad (4)$$

$$E_{ij} = \beta_{ij}/S_i + S_j \quad (5)$$

We can also examine the substitutability and complementarity between inputs by deriving the Allen partial elasticity of substitution (AES) and the Morishima elasticity of substitution (MES) which is according to (Binswanger) equal to:

$$\sigma_{ii}^{A} = \frac{\beta_{ii} + S_i^2 + S_i}{S_i} \tag{6}$$

$$\sigma_{ij}^{A} = \beta_{ij} / S_{ij} + 1 \tag{7}$$

$$\sigma_{ij}^{m} = S_j(\sigma_{ij}^{A} - \sigma_{jj}^{A}) = E_{ij} - E_{jj} \tag{8}$$

where

σ_{ii}^{A} = is the Allen elasticity of substitution.

σ_{ij}^{m} = is the Morishima elasticity of substitution.

Following Caves *et al.* [6], the elasticity of scale for the variable cost function - which is the reciprocal of the elasticity of cost with respect to output - can be calculated as:

$$E_s = (1 - \Sigma_k (\partial Lnc / \partial Ln\, Z_k))/(\partial Lnc / \partial Ln\, Y) \tag{9}$$

In the case of E_s equal to 1, the production technology exhibits constant return to scale, however, decreasing and increasing return to scale requires $E_s < 1$, and $E_s > 1$ respectively.

Shoemaker [7] has developed the theoretical implications for homotheticity of the production and cost functions. Theoretically, homotheticity implies the separability between output and input prices which imply that the production expansion in the aggregate is not constrained by relative factor prices. Thus the cost function in equation (1) is homothetic if:

$$\sigma_{iy} = 0 \ldots \quad \forall_i \tag{10}$$

Since any valid cost function has to be homogeneous of degree one in input prices, the cost function in (1) has to have the following restrictions before estimation:

$$\Sigma_i \beta_i = 1 \ ; \ \Sigma_i \beta_{ij} = 0 \ ; \ \Sigma_i \sigma_{iy} = 0 \tag{11}$$

Another important restriction is the symmetry condition, which is implied by the young theorem. This requirs that:

$$\beta_{ij} = \beta_{ji} \tag{12}$$

Area of study and variable specification

This study is based on the data collected by Al-Fuhaid [8]. This area contains the largest number of projects in the Kingdom, and its production accounts for over 52% of the Kingdom's total production. The sample consists of 38 broiler projects which accounts for about 88% of total number of projects in the area.

The use of translog cost function requires information about unit prices and quantities of each operating input plus the quantity of output produced. This study will consider three variable inputs (P) and two fixed factors (Z).

Based on the specification in equation (1), the definition of the variables used in this study are:

Y = Total production of life and prepared broilers for each project in tons.
P_1 = Unit price of chicks for each project in Saudi riyals.
P_2 = Unit price of feed for each project in riyal.
P_3 = Average per hour wage rate of workers for each project in riyal.
Z_k = Total veterinary expenses of each project in riyal.
Z_q = Total annualized flow of capital services including machinery and equipment per project in riyal.

To increase the efficiency of estimation, the collected data of each variable and fixed inputs plus the total quantity of output produced are divided by its mean before taking the logarithm. Further, each of the variable inputs are normalized by the unit price of chicks.

A disturbance term has been specified for the cost equation (1) and for each share equation of the three variable inputs such as the one in equation (3). The disturbance can be interpreted as a random error in achieving cost - minimizing behavior by each project. We expect the disturbances for each project to be correlated since errors involving one input will affect the cost shares of other inputs and total cost. However, we assume that errors made by one project are not correlated with the errors made by any other project. Therefore, we jointly estimate equation (1) and the share equations after excluding one of them since they add up to unity. Also the Zellner - iterative seemingly unrelated regression (ITSUR) procedure is used to estimate the system of equations Zellner [9].

Results and Discussion

The estimated parameters of the translog cost function are shown in Table 1. The estimated translog cost function fits the data reasonably well, explaining a large proportion of the variance in the costs of producing broilers. The adjusted R^2 as shown in the table was 0.96. All the first order output and input price coefficients in the model are positive and significantly different from Zero at $\alpha = 0.01$. The estimated value of α_q (the parameter for the annualized flow of capital) shows a negative sign, however it is not significant. On the other hand, the estimated coefficient for the fixed factor of veterinary expenses is highly significant representing the high level of spending on disease control at these projects. The second - order coefficients, however, are mixed in signs and significance level as expected since some are complement factors and others are substitutes.

Table 1. Estimated coefficients of the restricted translog cost function

Variable	Parameter estimate	t - Ratio
Intercept	7.723	199.282*
α_y	0.645	10.462*
β_1	0.268	9.395*
β_2	0.439	28.22*
β_3	0.291	12.16*
γ_k	0.271	4.058*
γ_q	-0.025	0.350
β_{11}	0.200	2.246*
β_{12}	-0.149	2.78*
β_{13}	-0.05	0.71
β_{22}	0.216	6.003*
β_{23}	0.067	1.688***
β_{33}	0.117	1.98**
α_{yy}	0.085	0.374
γ_{kk}	0.290	4.567*
γ_{kq}	-0.114	1.187
γ_{qq}	0.066	0.412
σ_{1y}	0.0170	0.312
σ_{2y}	0.05	1.68***
σ_{3y}	-0.067	1.47
θ_{1k}	-0.002	0.06
θ_{1q}	0.003	0.064
θ_{2k}	-0.013	0.722
θ_{2q}	-0.007	0.26
θ_{3k}	0.015	0.551
θ_{3q}	0.004	0.093
ϕ_{ky}	0.142	1.98**
ϕ_{qy}	-0.15	0.822
R^2 - Adjusted	0.96	

*, **, *** are 1%, 5%, and 10% degree of significance respectively.

The test of the hypothesis about the structure of the cost and production function - namely Homotheticity, is done by using a likelihood ratio test as such:

$$\lambda = L(R) - L(\mu) \tag{13}$$

where: $L(R)$ and $L(\mu)$ are the log likelihood values under the restricted and unrestricted versions, respectively. Then, - 2λ is distributed asymptotically as a chi - squared Maddala, [10 p.180]. This hypothesis was rejected at the 0.01 probability level. This implies that the production technology cannot be written as a separable function of input prices and output.

The elasticity of scale was calculated by using equation (9) and the parameters from equation (1). At the sample mean the calculated elasticity of scale was 1.14. This implies that increasing returns to scale happened at the sample mean level of production of 283.8 tons of broilers per project.

The estimated Partial price elasticities for the model is shown in Table 2. The t-rations corresponding to these estimates are approximated by the following equation and reported in parentheses.

$$SE\ (\sigma_{ij}) = SE\ (\beta_{ij} / S_i\ S_j) \tag{14}$$

where

SE is the standard error of the estimated parameters. The calculated input price elasticities - as shown in tables are not symmetric, hence we have nine own and cross price elasticities. All the own price elasticities of input demand are negative as expected. However none is significantly different from Zero at 10% level. Further, all the own price elasticities are significantly lower than one. On the other hand, two of the cross price elasticities are unexpectedly negative, however they are not significant. In general, the calculated price elasticities of demand show that the demand for inputs is inelastic, which means that the cost of producing broilers is likely to escalate as input prices of feed and labor increases.

Table 2. Estimated partial price elasticities of factor demand for the model

Input	Chicks (C)	Feed (F)	Labor (L)
Chicks (C)	-0.0140	-0.117	0.103
	(0.42)	(0.58)	(0.39)
Feed (F)	-0.071	-0.0673	0.139
	(0.589)	(0.819)	(1.54)
Laber (L)	0.095	0.209	-0.305

	(0.391)	(1.54)	(1.506)

The estimated parameters of the Allen clasticity of substitution (AES), and Morishima elasticities of substitution (MES) are presented in Table 3. Theoritically, these elasticities are positive for substitutes and negative for complements. The calculated AES shows that chicks and feed are complements while chicks and labor are substitutes. However, their calculated elasticities are not significantly different from Zero. Further, the AES between labor and feed shows a good substitutability with a strong confidence level.

Table 3. Estimates of Allen elasticity of substitution (AES) and Morishima elasticity of substitution (MES) of the model variables

Input	Chicks (C)	Feed (F)	Labor (L)
A. Allen partial elasticities of substitution			
Chicks (C)	-0.052	-0.267	0.35
	(0.042)	(0.36)	(0.36)
Feed (F)		-0.153	0.477*
		(0.819)	(2.31)
Labor (L)			-1.045
			(1.506)
B. Morishima elasticities of substitution			
Chicks (C)	0	-0.05	0.408
		(0.17)	(0.87)
Feed (F)	-0.086	0	0.444
	(0.189)		(1.516)
Labor (L)	0.081	0.276	0
	(0.14)	(1.26)	

*, is 1% degree of significance.

The estimated values of the Morishima elasticities of factor substitution shows a similar result with the exception that feed can be more easily substituted for labor than vice versa.

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تحليل الهيكل الإنتاجي لمشروعات إنتاج دجاج اللحم في المنطقة الوسطى من المملكة العربية السعودية: بطريقة دالة التكلفة الازدواجية

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(قدم هذا البحث في ١٤١٨/١١/٢٠هـ؛ وقُبل للنشر في ١٤١٩/٦/٣٠هـ)

ملخص البحث. تعد مشروعات دجاج اللحم أحد المجالات التي تدعمها السياسة الزراعية للمملكة العربية السعودية، وفي السنوات الأخيرة عانت هذه المشروعات من مشكلات عديدة سواء كانت تقنية أو إدارية أو تسويقية مما أدى إلى توقف أكثر من نصف هذه المشروعات عن الإنتاج.

وتهدف هذه الدراسة إلى تحليل الهيكل الإنتاجي لمشروعات إنتاج دجاج اللحم في المنطقة الوسطى من المملكة العربية السعودية، وذلك باستخدام طريقة دالة التكلفة الازدواجية. ويمكن من خلال هذه الطريقة استنباط بعض المؤشرات الاقتصادية التي تساعد على وضع السياسات المناسبة لمعالجة المشكلات التي تواجه مثل هذه المشروعات.

وقد اتضح من نتائج هذه الدراسة أن تكاليف التغذية والعمالة إضافة إلى النفقات البيطرية هي أهم بنود تكاليف إنتاج دجاج اللحم في هذه المشروعات. وتبين من نتائج الدراسة، أيضاً، وجود ظاهرة تزايد العائد للسعة، مما يشير إلى ان زيادة عناصر الإنتاج في هذه المشروعات ستؤدي إلى زيادة أكبر في الإنتاج. كما تم في هذا البحث احتساب كل من المرونة السعرية الذاتية والتقاطعية لعناصر الإنتاج. إضافة إلى اشتقاق مرونة آلن وموروشيما الإحلالية لهذه العناصر الإنتاجية.