DERIVED DEMAND FOR COTTONSEED: DAIRY INDUSTRY COMPONENT
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ABSTRACT

Despite much research on feed grains and oilseeds little is known about the US dairy industry's influence on aggregate cottonseed demand. A transcendental logarithmic production model with regional dummy variables is used to estimate the US dairy industry's derived demand for cottonseed meal, corn, alfalfa hay and other grains. Own-price and cross-price elasticities for the US dairy industry are estimated using a marginal approach.

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Introduction

With the 2007 Farm Bill, WTO challenges, long-term declining cotton fiber prices, and rising production costs, cotton farmers may have to find additional sources of income. For many years cotton farmers have relied on cottonseed as a source of cash fund during harvest time. Revenue from cottonseed is often the only source of cash at harvest time for these producers and must support them until lint sales are large enough to pay off their debts (Bondurant, 1998). Cottonseed represents an average of 16.17 percent of gross value of production for 2006 (USDA, 2008)[1]. Many factors, such as the ethanol boom, the 2007 Farm bill, and the pulling-effect on behalf of the dairy industry are expected to have an effect on the aggregate demand for cottonseed and consequently affect the level of cash funds that cotton farmers can receive during future crop years.

Despite much research on feed grains and oilseeds little is known about the dairy industry's influence on aggregate cottonseed demand. The cottonseed processing industry and livestock producers are the main sources of demand for cottonseed in the U.S. Both industries determine the market price for cottonseed. The oil mill determines the price it will offer for seed based on the value of the products it can obtain from cottonseed (oil, meal, hulls, and linters). The dairy industry determines the quantity of cottonseed they will use in the ration based on the nutrient characteristics it possesses, price and the substitutability and complementarities of the nutrients found in other inputs.

[1] Gross value of production excludes government payments.

The dairy industry has shown a willingness to pay a premium over the oil mill price in many U.S. regions. In practice competition among mills and other handlers for available cottonseed often forces them to pay higher prices.

Growing demand for cottonseed has resulted in substantial increases of cottonseed prices in the last few years. US cottonseed prices have risen on average from $89.50 per ton in 2001 to $110 per ton in 2006 (USDA, 2007). In February 2008 average cottonseed prices were an estimated $168 per ton, representing a 87.7% percent increase from 2000 and a 52.7% percent increase from 2006 (USDA, 2008). Current market prices in Texas are around $270 dollars per ton.

This study will attempt to estimate the US dairy industry's derived demand for feed grains and meals using a transcendental logarithmic production model, estimate own-price and cross-price elasticities for each feed used in the regimen and analyze its implication on cottonseed prices.

Methodology

The US dairy industry's demand for cottonseed is a derived demand, that is, the amount of cottonseed that the industry consumes is based partly on the market price and quantity of milk they produce and sell, the price of other inputs, as well as the firm's characteristics and efficiencies. The dairy cow's ration requires a certain combination of nutrients for milk production such as protein, calories, fiber, calcium and phosphorus. Parts of these requirements are met by pasture and hay and the rest must be supplied by concentrated feeds including whole grains, such as corn and oats, and mill feeds, such as cottonseed meal and bran. The degrees of substitutability among feeds depend on nutrients each feed contains and market prices. Although many dairy farmers produce their own pasture and harvest their own feed, much of the ration is purchased. The feed regimen usually constitutes the largest expense per hundredweight of milk produced and must be strategically balanced to maximize milk production and profit, thus making the transcendental logarithmic production model the best estimation for the dairy industry's derived demand for cottonseed and other feed grains in the production of milk.

The transcendental logarithmic production function was first introduced by Christensen, Jorgenson and Lau (1973) as an alternate representation of a production possibility frontier by functions that are quadratic in the logarithms of the quantities of inputs and outputs, which provide a local second-order approximation of the production frontier. The transcendental logarithmic production frontier permits a greater variety of substitution and transformation patterns than frontiers based on constant elasticities of substitution and transformation, such as the Cobb-Douglas production frontier. The quadratic nature of the function also allows regularity to be held locally and the function is monotonic and convex.

Wang and Lall (1999) study provides useful starting point for the estimation of input demand using a trans-log function specified with dummies for firm's characteristics to differentiate production efficiencies among firms as well as input values. Wang and Lall (1999) examined the value of water for Chinese industries by estimating an industrial production function with a data set of approximately two thousand industrial firms. They assumed the existence of a twice differentiable aggregate production function for the industrial sector. Trans-log functions were specified with dummies for firm's characteristics such as sector, ownership and location, etc. to differentiate production efficiencies as well as water values. The quadratic function allows regularity to be held locally and the function is monotonic and convex. The elasticity of output with respect to each factor of production is calculated by taking the partial derivative of output with respect to the factor under consideration. In order to estimate price elasticity, price is set equal to marginal cost of water use and the marginal value of output would be equal to the marginal cost in a profit maximizing firm, therefore resulting in water price equal to the marginal value of water. The partial derivative of this last equation would result in the price elasticity of water. This functional form can be applied to the US dairy industry's derived demand for cottonseed.

For the objectives of this study, the trans-log production function might be the most appropriate method of estimating the US dairy industry's derived demand for cottonseed and other feed grains, given that the dairy industry consumes feed grains in response to final consumer demand for milk. The trans-log production model will provide information on the degree and nature of interrelatedness of the US dairy industry's demand for different inputs such as cottonseed meal, corn, alfalfa hay and other grains, as well as own-price and cross-price elasticities of these factors of production.

Hence, the US dairy industry's derived demand for cottonseed meal, corn, alfalfa hay and other feed grains is estimated using a trans-log production function with one output, four inputs and two dummy variables of the form,

$$\begin{aligned}\ln Q_m &= \alpha_0 + \alpha_{cs} \ln cs + \alpha_c \ln c + \alpha_g \ln g + \alpha_{ah} \ln ah \\ &+ \beta_{cs}\frac{\ln cs^2}{2} + \beta_c \frac{\ln c^2}{2} + \beta_g \frac{\ln g^2}{2} + \beta_{ah}\frac{\ln ah^2}{2} \\ &+ \gamma_{cs*c} \ln cs * \ln c + \gamma_{cs*g} \ln cs * \ln g + \gamma_{cs*ah} \ln cs * \ln ah \\ &+ \gamma_{c*g} \ln c * \ln g + \gamma_{c*ah} \ln c * \ln ah + \gamma_{g*ah} \ln g * \ln ah + \delta_1 MWsoy + \delta_2 MWdistiller \qquad (1)\end{aligned}$$

where Q_m is quantity of milk produced per cwt per year, cs is quantity of cottonseed meal purchased per cwt per year, c is quantity of corn harvested and purchased per cwt per year, g is quantity of aggregate grains including harvested and purchased soybean, distiller's grain, corn silage, commercial feeds and wheat per cwt per year, ah is the quantity of alfalfa hay harvested and purchased per cwt per year; and $MWsoy$ is a dummy variable for harvested soybean in Midwest region and $MWdistiller$ is a dummy variable for purchased distiller's grain in the Midwest region. $\alpha_{cs}, \alpha_c, \alpha_g$ and α_{ah} are first derivatives. $\beta_{cs}, \beta_c, \beta_g$ and β_{ah} are own second derivatives. $\gamma_{cs*c}, \gamma_{cs*g}, \gamma_{cs*ah}, \gamma_{c*g}, \gamma_{c*ah}$ and γ_{g*ah} are cross second derivatives.

The ARMS data set used in this study showed that the Midwest region had the most observations with soybean and distiller's grain as a factor input. The demand for soybean was most significant in the Lake States region and distiller's grain was most significant in the Corn Belt region. Dummy variables were added to the model (equation 1) to detect the shifts in quantity of milk produced for dairy farmers that used soybean and distiller's grains as factor inputs in the Midwest region.

Following Wang and Lall (1999) marginal productivity analysis, output elasticity with respect to each factor is estimated by taking the partial derivative of the trans-log production function with respect to the factor under consideration. For example,

$$\sigma_{cs} = \frac{\partial \ln Q_m}{\partial \ln cs} = \alpha_{cs} + \beta_{cs} \ln cs + \gamma_{cs*c} \ln c + \gamma_{cs*g} \ln g + \gamma_{cs*ah} \ln ah$$

$$\sigma_{c} = \frac{\partial \ln Q_m}{\partial \ln c} = \alpha_{c} + \beta_{c} \ln c + \gamma_{cs*c} \ln cs + \gamma_{c*g} \ln g + \gamma_{c*ah} \ln ah$$

$$\sigma_{g} = \frac{\partial \ln Q_m}{\partial \ln g} = \alpha_{g} + \beta_{g} \ln g + \gamma_{cs*g} \ln cs + \gamma_{c*g} \ln c + \gamma_{g*ah} \ln ah$$

$$\sigma_{ah} = \frac{\partial \ln Q_m}{\partial \ln ah} = \alpha_{ah} + \beta_{ah} \ln ah + \gamma_{cs*ah} \ln cs + \gamma_{c*ah} \ln c + \gamma_{g*ah} \ln g \qquad (2)$$

Assuming perfect competition and a profit maximizing firm where the marginal cost of a factor equals the market price, and $\rho_{cs}, \rho_c, \rho_g$ and ρ_{ah} are the marginal values of each factor of production,

$$\rho_i = \frac{\partial Q_m}{\partial i} = \frac{\partial \ln Q_m}{\partial \ln(i)} * \frac{Q_m}{i} = \sigma_i * \frac{Q_m}{i} \tag{3}$$

where i are factor inputs: cottonseed meal, corn, grains or alfalfa hay. Correspondingly, own-price elasticity and cross-price are estimated by,

$$\varepsilon_{ii} = \frac{\sigma_i}{\beta_i + \sigma_i^2 - \sigma_i} \tag{4}$$

$$\varepsilon_{ij} = \frac{\sigma_j}{\gamma_{ij} + \sigma_j} \tag{5}$$

where i and j are factor inputs: cottonseed meal, corn, grains or alfalfa hay.

Data

US dairy industry data was obtained from the Agricultural Management Resource Survey (ARMS) *2000 Dairy Production Practices and Costs and Returns Report* and the *2005 Dairy Cost and Returns Report* conducted by the National Agricultural Statistics Service (NASS)[2]. In the ARMS data each observation represents itself and many other farms through a weight. ARMS weights are based on a value of sales.

The delete-a-group jackknife variance estimator is applied to the ARMS data. NASS divided the sample data into 15 nearly equal and mutually exclusive different parts and created replicate weights by setting the full sample weight of every 15th observation to zero (Dubman, 2000). The jackknife variance is therefore estimated by,

[2] Any interpretations and conclusions derived from the ARMS data represent the authors' views and not necessarily those of NASS.

$$Var(\beta) = \frac{14}{15}\sum_{k=1}^{15}(\beta_k - \beta)^2 \tag{6}$$

where β is the full sample estimate and β_k is a replicate estimate with part *k* removed. This formula adjusts the degrees of freedom for each weight used. Similarly, the jackknife covariance of regression coefficients are estimated by,

$$COV(\beta) = \frac{14}{15}\sum_{k=1}^{15}(\beta_k - \beta)(\beta_k - \beta)' \tag{7}$$

Joint linear hypothesis testing of the form $D\beta = d$ (Brick, *et al,* 1997) is estimated with the statistic,

$$F_{d,16-d} = \frac{16-d}{15*d}(D\beta - d)'(D*COV(\beta)*D')^{-1}(D\beta - d) \tag{8}$$

where *d* is the rank of the matrix D equal to the number of linearly independent restrictions. Individual T-tests for each variable equal zero of the form $D\beta = d$ (Brick, *et al,* 1997) is estimated with the statistic:

$$T_d^2 = (D\beta - d)'(D*COV(\beta)*D')^{-1}(D\beta - d) \tag{9}$$

The ARMS data was pooled for the years 2000 and 2005. The aggregate grains variable was created to account for those feeds that were not reported across all observations. The aggregate grains variable includes quantities of soybean, distiller's grain, corn silage, commercial feeds and wheat used in production. The sub-sample used in this study consisted of 179 observations which reported cottonseed meal, corn, alfalfa hay and grains as a factor of production. These inputs were either harvested or purchased, and used on farm per hundred weights per year.

Results

The trans-log production function was estimated under different nested hypotheses to test the validity of nonlinear restrictions. The log-likelihood ratio test which is approximated by a chi-square distribution resulted significant at the one percent level in favor of the unrestricted model in equation (1). Table 1 below presents the results of the estimated model in equation (1). Standard errors were estimated by taking the square root of the diagonal of the covariance matrix estimated with equation (7). Standard errors are expressed in parenthesis.

Table 1 : Translog Production Function with One Output, Four Inputs and Two Dummy Variables.

α_0	0.2803 (5.3191)	β_{CS}	-0.0695 (0.1973)	γ_{cs*c}	-0.0963 (0.1280)
α_{CS}	-0.5441 (1.4853)	β_C	0.0830 (0.5009)	γ_{cs*g}	-0.0122 (0.1044)
α_C	-0.5416 (0.9716)	β_g	0.1302 (0.0966)	γ_{cs*ah}	0.0943 (0.1551)
α_g	0.7929 (0.4132)	β_{ah}	0.0226 (0.1577)	γ_{c*g}	0.0371 (0.2836)
α_{ah}	0.9049 (0.9511)			γ_{c*ah}	-0.0327 (0.1999)
				γ_{g*ah}	-0.0181 (0.1607)
				δ_1	-0.0571 (0.1721)
				δ_2	-0.1788 (0.1403)

Number of Observations:	179	White's Test:	0.1280
R-square:	0.8363	Breusch-Pagan:	<.0001
Adjusted R-square:	0.8202	Durbin Watson:	2.0825

The White's (1980) test was used to examine the presence of heteroskedasticity. The White's test failed to reject the null hypothesis of no heteroskedasticity with a value of 0.1280, meaning there is evidence of homoskedasticity. In the same manner the Breusch-Pagan test for homoskedasticity was applied for quantity of milk produced as depending on the seventeen explanatory variables. The test also rejects the null hypothesis (<.001) showing evidence that there is homoskedasticity present in the model.

A Durbin Watson test for first-order autocorrelation was also estimated to test the hypothesis of no auto regression against a one-sided alternative – positive regression – at the 5% significance level. From the Durbin Watson table the appropriate values for 200 observations and 16 explanatory variables (excluding the intercept) are d_L 1.599 and d_U 1.943. The calculated d statistic is 2.0825 such that the test failed to reject the hypothesis of no auto regression. The absence of first-order autocorrelation in the model is confirmed.

The F-test or joint linear hypothesis testing of all seventeen coefficients including the intercept are equal to zero could not be estimated. The rank of the D matrix does not conform to equation (8) and therefore could not be tested.

Nonetheless, individual T-tests for each variable equal zero of the form $D\beta = d$ (Brick, *et al,* p.188) were estimated with equation (9). Table 2 below presents the estimated T-calculated values. As can be noted, own-second derivatives and cross-second derivates are all significant at the 1% level. First derivatives are not as significant for α_{CS} and α_C, but were insignificant for α_0, α_g and α_{ah}.

Table 2: Estimated T-calculated Values.

α_0	0.1353	β_{CS}	5.4205	γ_{cs*c}	8.5621
α_{CS}	1.0396	β_C	1.8306	γ_{cs*g}	9.6980
α_C	1.5866	β_g	9.0008	γ_{cs*ah}	5.8403
α_g	0.5011	β_{ah}	6.1984	γ_{c*g}	3.3956
α_{ah}	0.1000			γ_{c*ah}	5.1639
				γ_{g*ah}	6.3337
				δ_1	6.1415
				δ_2	8.4002

Analysis of the sub-dataset showed that as quantity of milk produced increased during the year 2000 to 2005, the demand for feeds also increased. This proportionate increase was reflected in all five regions – Atlantic, South, Midwest, Plains and West – of the U.S. There also seemed to be a relationship between regional crops and the local demand for feed grains. The Midwest region had the most observations with soybean and distiller's grain as a factor input. The demand for soybean was most significant in the Lake States region and distiller's grain was most significant in the Corn Belt region. Dummy variables were added to the model (equation 1) to detect the shifts in quantity of milk produced for dairy farmers that used soybean and distiller's grains as factor inputs and were in the Midwest region. δ_1 which represents dairy farmers in the Midwest region that reported quantities of soybean used in production have -0.0571 quantity of milk produced per hundred weight per year with a standard error of 0.1721 and a t-value significant at the one percent level. δ_2 which represents dairy farmers in the Midwest region that reported quantities of distiller's grains in production have -0.1788 quantity of milk produced per hundred weight per year with a standard error of 0.1403 and a t-value significant at the one percent level.

Output elasticities measure how a one percent change the input being considered affects the quantity of milk produced. Output elasticities with respect to each factor of production were estimated using equation (2) and are presented in table 3 below. Each factor, cottonseed meal, corn and alfalfa hay, by itself does not explain much of the variation in quantity of milk produced implying that a one percent change in quantity of cottonseed or corn or alfalfa hay will not have a significant affect on the quantity of milk produced. However, a one percent increase in the amount of grains used will increase quantity of milk produced by 0.305540. Aggregate grains include harvested and purchased soybean, distiller's grain, corn silage, commercial feeds and wheat, where commercial feeds also include custom feeds.

Table 3: US Dairy Industry Output Elasticities.

Cottonseed Meal	Corn	Grains	Alfalfa Hay
0.047126	0.034004	0.305540	0.044003

Own-price and cross-price elasticities for each factor of production were estimated using equation (4) and equation (5); and are presented in Table 4 below. Own-price elasticity for cottonseed meal is inelastic implying that an increase in the price of cottonseed meal will decrease quantity demanded by -0.412032. Grains and alfalfa hay have an elastic own-price elasticity meaning that a percentage change in each factor's price will decrease the quantity demanded by -3.728773 and -2.264414 respectively. Grains have the highest negative percentage change in quantity demanded given a change in own-price out of the four inputs studied. Corn on the other hand has a positive own-price elasticity implying that the output effect supersedes the substitution effect of other inputs for corn, such that a one percent increase in the price of corn will increase the quantity demanded by 0.678439.

Table 4: US Dairy Industry Own-price and Cross-Price Elasticities.

	Cottonseed Meal	Corn	Grains	Alfalfa Hay
Cottonseed Meal	-0.412032	-0.958083	1.349685	0.333284
Corn	-0.545721	0.678439	0.478185	25.330141
Grains	1.041625	0.891706	-3.728773	1.062827
Alfalfa Hay	0.318226	3.879797	1.696233	-2.264414

The estimated cross-price elasticities of demand for cottonseed meal imply that it is considered a complement of corn with a cross-price elasticity of -0.958083 and a substitute for grains and alfalfa hay with a cross-price elasticity of 1.349685 and 0.333284 respectively (table 4). A one percent increase in the price of cottonseed meal will affect the quantity demanded of corn by -0.545721, slightly more than it will affect quantity demand of cottonseed meal, which has an own-price elasticity of -0.412032. A one percent increase in the price of cottonseed meal will increase the quantity of grains by 1.041625 and alfalfa by 0.318226. In summary, the quantity demanded for cottonseed meal is sensitive to changes in own-prices and corn prices; nonetheless, an increase in the price of grains helps augment demand for cottonseed.

The estimated cross-price elasticities for corn imply that corn is a complement of cottonseed meal with an elasticity of -0.545721 and a substitute for grains and alfalfa hay with elasticities of 0.478185 and 25.330141 respectively (table 4). However, a one percent increase in the price of corn will decrease quantity demanded for cottonseed meal by -0.958083 but will increase the quantity demanded for corn by 0.678439, as well as increase quantity demanded for grains by 0.891706 and alfalfa hay by 3.879797. The quantity demanded for alfalfa hay will increase the most, meaning that corn may loose some of its share in total inputs as will cottonseed meal. Conversely, a one percent increase in the price of alfalfa hay will increase the quantity demanded for corn by 25.330141.

The estimated cross-price elasticities for grains imply that it is a substitute of all other inputs (table 4). Grains have a cross-price elasticity of 1.041625 with respect to the price cottonseed meal, 0.891706 with respect to the price of corn, and 1.062827 with respect to the price of alfalfa hay. An increase in the price of grains, which contains harvested and purchased soybean, distiller's grain, corn silage, commercial feeds and wheat, will significantly increase the quantity demanded for alfalfa hay by 1.696233 and cottonseed meal by 1.349685.

Conclusion

Despite much research on feed grains and oilseeds little is known about the US dairy industry's influence on aggregate cottonseed demand. A transcendental logarithmic production model with regional dummy variables was used to estimate the US dairy industry's derived demand for cottonseed meal, corn, alfalfa hay and other grains. Following Wang and Lall (1999) marginal productivity analysis own-price and cross-price elasticities were estimated for the US dairy industry.

The results of the estimated model demonstrate that cottonseed meal has a small output elasticity of 0.047126, which implies that if the US dairy industry continues to grow as it has been over the past few years, it will not have a significant effect on the demand for cottonseed meal. The demand for cottonseed meal is more susceptible to an increase in the price of other feed grains and alfalfa hay. An increase in the price of other feeds can increase the demand for cottonseed meal by way of substitution in the feed ration. Feed expenses in 2008 are forecast to have the largest increase of all expenses as they rise $6.9 billion (18.2 percent) to a record-high

$45.0 billion (USDA, 2008). A one percent increase in the price of grains will significantly increase the quantity demanded for cottonseed meal by 1.349685. On the other hand, a one percent increase in the price of corn will decrease quantity demanded for cottonseed meal by -0.958083. This predisposition in the feed grains market may significantly alter cottonseed meal share in the US dairy ration and consequently the demand for cottonseed.

The estimated US dairy industry's own-price and cross-price elasticities of demand for cottonseed will allow the forecasting of cottonseed prices and its implications for U.S. cottonseed policies. Taking both the dairy industry's and crushing industry's cross-price and own-price elasticities of demand and forecasted aggregate supply of cottonseed, for example Texas Tech University's World Cotton Fiber Model, the modeling of a forecasted pricing structure of the U.S. cottonseed market is possible. There have been various studies on the crushing industry's demand for commodities; for example, Goodwin, Harper and Schenepf's (2002) estimated demand relationships for vegetable oils and meals. An additional simulation analysis of plausible future price events will help explore future probability distribution of cottonseed prices and their implication on US farm policy.

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