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# The Dairy Industry's Derived Demand for Feed Grains and Its Effect on the Cottonseed Market

**Priscilla B. Argüello***
**Jaime Málaga**
**Benaissa Chidmi**
**Jose A. Lopez**
*Department of Agricultural and Applied Economics, Texas Tech University, TX 79409-2132*

## ABSTRACT

**Despite much research on feed grains and oilseeds, little is known about the dairy industry's influence on aggregate cottonseed demand. A transcendental logarithmic production model with regional dummy variables is used to estimate the U.S. dairy industry's derived demand for cottonseed meal, corn, alfalfa hay and other grains. Own-price and cross-price elasticities are estimated using a marginal approach. Two case analyses, selected plausible future price events in the feed grains market and increases in milk production, are investigated to determine the dairy industry's effect on aggregate demand for cottonseed and cottonseed prices.**

**KEY WORDS:** Cottonseed, derived demand, dairy industry, feed grains, oilseeds

## INTRODUCTION

Despite much research on feed grains and oilseeds, little is known about the U.S. dairy industry's influence on aggregate cottonseed demand. The growing demand for cottonseed has increased cottonseed prices substantially. Cottonseed prices have risen on average from $89.50 per ton in 2001 to $110 per ton in 2006 (USDA-NASS 2007). In September 2008, average cottonseed prices were estimated at $253 per ton, representing a 183% increase from 2000 and a 130% increase from 2006 (USDA-NASS 2008). During the first quarter of 2008, market prices in West Texas reached $270 dollars per ton.

The crushing industry and the dairy industry are the main components of demand for cottonseed in the U.S. Both determine the market price for cottonseed. According to Robinson (2001), "[t]ypically about half of the cottonseed … produced each year is used for dairy feeding." In many U.S. regions, the dairy industry pays a premium over the oil mill price. 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, price, and the substitutability and complementarities of the nutrients found in other inputs. The migration of dairy farms from traditional production states, such as California and New York, to Southern states, such as New Mexico and Texas, is expected to have a local effect on the demand for cottonseed and market price, thus making the dairy industry's role in the determination of market price for cottonseed noteworthy.

* Corresponding author: Priscilla_Arguello@yahoo.com.

There are many useful economic studies in cotton and cottonseed demand. Most studies on cottonseed analyze the U.S. crushing industry's component of demand and report the crushing industry elasticities or projected quantity demanded (Goodwin et al. 2003; Mattson et al. 2004; Food and Agricultural Policy Research Institute 2008b). Only a few studies consider external events, such as the ethanol effect on the grain commodities market and oilseed market. Such events may have a direct effect on world and U.S. demand for cottonseed and should be considered in the estimation of aggregate demand and price analysis. On the other hand, there are no studies known to the authors analyzing the U.S. dairy industry's derived demand for cottonseed. Most research conducted regarding the dairy industry and feed grains is directed towards improving production and quality, minimizing feed costs, analyzing trends in the dairy industry, and integrating management approaches, among other issues. As a result, there is a need to identify the factors that have a direct or indirect effect on aggregate demand for cottonseed, especially the dairy industry's derived demand for cottonseed which is expected to use approximately half of the cottonseed produced in the U.S. By estimating the dairy industry's demand parameters and accounting for the crushing industry's previously estimated demand, a more accurate assessment of cottonseed prices can be determined and, consequently, the level of cash funds that cotton farmers can receive during future crop years can be estimated.

This study estimates the dairy industry's derived demand for feed grains and meals using a trans-log production model and a marginal approach to estimate own-price and cross-price elasticities for the U.S. dairy industry. This study also analyzes how changes in grain prices affect the dairy industry's derived demand for cottonseed and market prices, as well as the dairy industry's effect of pulling cotton seed prices up.

**The Dairy Industry's Derived Demand for Cottonseed and Other Feeds.** The size of the U.S. dairy industry is determined by the demand for milk. In other words, the amount of milk that farmers will be able to sell, and thus need to produce, is directly determined by what consumers are willing to buy directly or indirectly. The number and size of farms are influenced by the demand for milk, the level of milk production per cow, economies of size, among other factors. The total number of dairy cows will be determined by the demand for milk and the level of milk production per cow. According to the USDA Census of Agriculture in 2007, there were about 9.267 million dairy cows in the U.S. According to a study by LaRue et al. (2003), the number of cows needed to satisfy the U.S. demand for milk would be 8,297 to 8,393 million in 2010 and 7,681 to 7,931 million in 2020, with production per cow of 21,722 pounds in 2010 and 25,352 pounds in 2020, representing a downward trend in cow numbers and an increase in production per cow. The increase in production per cow has resulted from improvements in breeding, genetics, feeding, and housing. According to FAPRI's U.S. and World Agricultural Outlook (2008a), the number of dairy cows in Texas will increase an average of 2% per year, from 367,000 heads in 2008 to approximately 432,000 heads in 2017. Milk production in Texas will increase an average 4% per year, from 7,828 million pounds to approximately 10,748 million pounds in 2017. Texas will produce approximately 5% of the national milk production by the year 2017 (FAPRI 2008a).

The reduction of feed cost and maintenance of productivity becomes a primary strategy of successful milk production. Dairy farmers minimize input costs of production by choosing feed grains, meals, and by-products that meet all the nutrient requirements of dairy cattle and yield the highest milk production. Feed grains have a certain degree of substitutability among them, but one cannot be fully substituted for another because they have different nutritional characteristics. By-

product feeding has been regarded as a substitute for more traditional feedstuffs, such as corn and soybean meal. By-product feeding has also become increasingly important given its low cost. Cottonseed, almond hull, beet pulp, citrus pulp, corn gluten feed, corn gluten meal, and rice bran are by-products that can be economically valuable over a range of market prices and regimens. According to Kaiser (2006), the increase in ethanol production to meet demand and the renewable fuels standard will significantly increase the supply of distiller grains. Distiller grains with solubles are excellent feed resources for dairy cattle. It is the fastest growing commodity feed for livestock. However, it must be competitively priced to displace feedstuffs currently included in dairy rations and there is a limit as to how much can be used in the ration of dairy cattle mainly because of its high fat content.

Accordingly, the U.S. dairy industry's derived demand analysis must take into consideration traditional feed grains and meals, such as corn and soybean meal, as well as by-products such as cottonseed and distiller's grain, in their maximization of profits. The feed regimen usually constitutes the largest expense per hundredweight of milk produced and thus must be strategically balanced to optimize milk production.

## MATERIALS AND METHODS

For the objectives of this study, input demand is the most appropriate method of estimating the U.S. dairy industry's derived demand for cottonseed meal and other feed grains, given that the dairy industry consumes feed grains in response to final consumer demand for milk. Similarly, the crushing industry consumes cottonseed in response to final consumer demand for cottonseed oil, meal, and hulls. Input demand analysis provides information on the degree and nature of interrelatedness of the U.S. dairy industry's derived demand for different inputs such as cottonseed meal, corn, alfalfa hay, and feed grains in their maximization of profits, as well as own-price and cross-price elasticities of these factors of production.

Following Wang and Lall's (1999) marginal productivity approach, a transcendental logarithmic functional form is implemented. Wang and Lall (1999) provide a useful starting point for the estimation of input demand using a marginal productivity approach and a trans-log production function. The marginal productivity approach is dual to the cost function approach as the marginal input cost should equal the marginal value of production given the assumption that firms are maximizing profits. The trans-log form and marginal approach are implemented in the estimation of the U.S. dairy industry's derived demand for cottonseed. Hence the U.S. dairy industry's derived demand for cottonseed meal, corn, alfalfa hay, and other feed grains and forages is estimated using a trans-log production function with one output, four inputs, and two dummy variables of the form,

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

where $Q_m$ is quantity of milk produced (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. In other words, the ARMS data set indicated that the Midwest region had the most observations with soybean and distiller's grain as a factor input. The dummy variables measure any 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's (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,

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

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

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

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

Assuming perfect competition and a profit maximizing firm where the marginal cost of a factor equals the market price and the marginal value of output is equal to marginal cost, then marginal values of each factor of production $\rho_{cs}$, $\rho_c$, $\rho_g$, and $\rho_{ah}$ are equal to the market price of that factor, where

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

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

$$\varepsilon_{ii} = \frac{\sigma_i}{\beta_i + \sigma_i^2 - \sigma_i}, \quad (4)$$

$$\varepsilon_{ij} = \frac{\sigma_j}{\gamma_{ij} + \sigma_j}, \quad (5)$$

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

U.S. dairy industry data is obtained from the Agricultural Resource Management 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). This data set includes feed operating costs such as purchased feed, homegrown harvested feed, and grazed feed. Purchased feed types include feed grains and by-products that are essential to the feed regimen, including distiller's grains. Homegrown feed types include feed grains which are later broken down by the amount actually fed to the dairy cows during that year. All these alternative feeds data are essential to the estimation of the U.S. dairy industry's derived demand for cottonseed.

In the ARMS data, each observation represents itself and many other farms through a weight or expansion factor, which is based on sales value. Through the weight variable, the sample estimates the population. A dataset with both small and large dairy farms may be heavily represented by small dairy farms and with few observations for large dairy farms. Table 1 below shows the weighted aggregate quantities of feeds used in hundred weights per year. Since the ARMS data use weights as in complex surveys, the means have to be computed incorporating the weight variable. The sampling weight can be thought of as the number of units in the population represented by the sample unit while the sum of weights can be thought as the population size.

Table 1. Descriptive Statistics of Variables in the Study.

| Variable | Number of Obs. | Weighted Mean (cwt/year) | Std. Dev. (cwt/year) |
|---|---|---|---|
| Alfalfa Hay | 179 | 81,509 | 74,451 |
| Commercial Feed | 57 | 9,538 | 6,075 |
| Corn | 179 | 86,118 | 74,517 |
| Corn Silage | 167 | 33,493 | 4,081 |
| Cottonseed Meal | 179 | 40,438 | 37,236 |
| Distiller's Grain | 56 | 19,686 | 13,539 |
| Grains | 179 | 36,314 | 4,844 |
| Milk | 179 | 37,301 | 4,066 |
| Soybean | 25 | 1,912 | 484 |
| Wheat | 11 | 4,121 | 2,458 |

Note: Sum of weights = 6,940.61.
Source: Prepared by the Author based on ARMS data.

NASS recommends the delete-a-group jackknife variance estimator to analyze the ARMS data. NASS divides the sample data into 15 nearly equal and mutually exclusive different parts and creates replicate weights by setting the full sample weight of every 15$^{th}$ observation to zero (Dubman 2000), such that each observation's greatest effect is measured when it is deleted from the replicate. The delete-a-group jackknife variance is estimated as

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

where $\beta$ is the full sample estimate and $\beta_k$ 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 as

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

Joint linear hypothesis testing of the form $D\beta = d$ (Brick et al. 1997) are conducted as

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

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) are conducted as

$$T_d^2 = (D\beta - d)'(D * Cov(\beta) * D')^{-1}(D\beta - d). \quad (9)$$

The ARMS data is pooled for the years 2000 and 2005. The sub-sample consists of 179 observations which report cottonseed meal, corn, alfalfa hay, and grains as a factor of production. These inputs are either harvested or purchased, and used on farm (hundred weights per year).

According to Dubman (2000), at least 30 observations are needed for jackknife variances estimation, and 60 observations are needed for hypothesis testing. As a result, a grains and forages variable is created to account for feeds that are not reported across all observations (Table 1). The grains and forages variable includes commercial feeds, corn silage, distiller's grain, grains, soybean, and wheat.

In this study, aggregate demand consists of the dairy industry's derived demand plus the crushing industry's demand for cottonseed. According to the National Cottonseed Products Association (NCPA), approximately 5% is set aside to plant next year's crop. FAPRI (2008a) has already estimated the crushing industry's demand for cottonseed using their World Trade Model, which lists the forecasted total domestic use and total crushed cottonseed through the year 2017. This facilitates the derivation of the dairy industry's demand for cottonseed which can be estimated as U.S. production of cottonseed minus the crushing industry's demand for cottonseed minus the 5% estimate for replanting next year's crop.

The dairy industry's derived elasticities are used to determine the sensitivity of the dairy industry's demand for cottonseed from changes in own price and the price of other grains. For example, the sensitivity of the dairy industry's demand for cottonseed based on a percentage increase or decrease in the price of other grains and forages holding all other factors constant can be determined. Similarly, the output elasticity helps determine how a percentage increase in the production of milk will respond to increases or decreases in inputs demanded on behalf of the dairy industry holding all other factors constant.

The simulation of the U.S. cottonseed market generates a forecasted stream of quantities of cottonseed demanded on behalf of the dairy industry holding all other factors constant. The analysis takes into consideration external variables that have a direct effect on cottonseed prices, such as the long-term trend of increases in national milk production, as well as increases in the national price of grains due to the increased demand for grains from the increased production of ethanol.

## RESULTS AND DISCUSSION

The trans-log production function is 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 is significant at the 1% level in favor of the unrestricted model in equation (1). Table 2 below presents the results of the estimated model in equation (1). Standard errors are estimated using the delete-a-group jackknife variance formulas described in the conceptual framework. These were estimated by taking the square root of the diagonal of the covariance matrix estimated with equation (7). Standard errors are expressed in parenthesis.

The White's (1980) test is 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 is applied for quantity of milk produced depending on the seventeen explanatory variables. The test rejects the null hypothesis (< 0.001) showing evidence in favor of homoskedasticity in the model.

Table 2. Translog Production Function with One Output, Four Inputs, and Two Dummy Variables.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| $\alpha_0$ | 0.2803 (5.3191) | $\beta_{cs}$ | -0.0695* (0.1973) | $\gamma_{cs*c}$ | -0.0963* (0.1280) | $\delta_1$ | -0.0571* (0.1721) |
| $\alpha_{cs}$ | -0.5441 (1.4853) | $\beta_c$ | 0.0830** (0.5009) | $\gamma_{cs*g}$ | -0.0122* (0.1044) | $\delta_2$ | -0.1788* (0.1403) |
| $\alpha_c$ | -0.5416*** (0.9716) | $\beta_g$ | 0.1302* (0.0966) | $\gamma_{cs*ah}$ | 0.0943* (0.1551) | | |
| $\alpha_g$ | 0.7929 (0.4132) | $\beta_{ah}$ | 0.0226* (0.1577) | $\gamma_{c*g}$ | 0.0371* (0.2836) | | |
| $\alpha_{ah}$ | 0.9049 (0.9511) | | | $\gamma_{c*ah}$ | -0.0327* (0.1999) | | |
| | | | | $\gamma_{g*ah}$ | -0.0181* (0.1607) | | |

| | |
|---|---|
| Number of Observations: 179 | White's Test: 0.1280 |
| R-square: 0.8363 | Breusch-Pagan: < 0.0001 |
| Adjusted R-square: 0.8202 | Durbin Watson: 2.0825 |

Note: Parameter estimates significance levels of 1%, 5%, and 10% are denoted by *, **, and *** respectively. Standard errors are reported in parenthesis.

A Durbin Watson test for first-order autocorrelation is also estimated to test the hypothesis of no auto regression against a one-sided alternative – positive regression – at the 5% significance level. The lower and upper critical statistics 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, which means the test fails to reject the hypothesis of no autocorrelation. First-order autocorrelation in the model does not appear to be statistically significant.

The *F*-test or joint linear hypothesis testing of all seventeen coefficients plus the intercept being 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. 1997, p.188) are estimated with equation (9) and reported in Table 2. As can be noted in Table 2, own-second derivatives and cross-second derivatives are all significant at the 1 or 5% level. First derivatives are not as significant for $\alpha_{cs}$ and $\alpha_c$ with a value at 20% and 10% significance level, but are insignificant for $\alpha_0$, $\alpha_g$, and $\alpha_{ah}$.

Analysis of the sub-dataset shows that as quantity of milk produced increases during the years 2000 to 2005, the demand for feeds also increases. This proportionate increase is reflected in all five regions (Atlantic, South, Midwest, Plains, and West) of the U.S. There also seems to be a relationship between regional crops and the local demand for feed grains. The Midwest region has the most observations with soybean and distiller's grain as a factor input. The demand for soybean is most significant in the Lake States region and distiller's grain is most significant in the Corn Belt region. Dummy variables are added to the model, equation (1), to detect shifts in quantity of milk produced for dairy farmers that use soybean and distiller's grains as factor inputs and are in the Midwest region. The coefficient $\delta_1$, which represents dairy farmers in the Midwest region that reported

harvesting and using soybeans in their dairy operations, estimates -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 1% level. The coefficient $\delta_2$, which represents dairy farmers in the Midwest region that reported purchasing distiller's grains for their dairy operations, estimates -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 1% level.

Output elasticities measure how a 1% change in the input being considered affects the quantity of milk produced. Output elasticities with respect to each factor of production are 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 1% change in quantity of cottonseed meal or corn or alfalfa hay does not have a large effect on the quantity of milk produced. However, a 1% increase in the amount of grains and forages used will increase quantity of milk produced by 0.3055%. Aggregate grains and forages include harvested and purchased soybean, distiller's grain, commercial feeds, wheat and corn silage, where commercial feeds also include custom feeds.

Table 3. U.S. Dairy Industry Output Elasticities.

| Cottonseed Meal | Corn | Grains & Forages | Alfalfa Hay |
|---|---|---|---|
| 0.0471 | 0.0340 | 0.3055 | 0.0440 |

Own-price and cross-price elasticities for each factor of production are estimated using equation (4) and equation (5) and are presented in Table 4. The derived demand for cottonseed meal is inelastic with respect to its own-price implying that 1% change in the price of cottonseed meal will change the quantity demanded by -0.4120%. The derived demand for feed grains and forages, and alfalfa hay are elastic with respect to own-price meaning that a percentage change in each factor's own-price will change the quantity demanded by -3.7288% and -2.2644% respectively. Grains and forages 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 1% increase in the price of corn will increase the quantity demanded by 0.6784%.

Table 4. U.S. Dairy Industry Own-price and Cross-Price Elasticities.

| Quantity | Price | | | |
|---|---|---|---|---|
| | Cottonseed Meal | Corn | Alfalfa Hay | Grains & Forages |
| Cottonseed Meal | -0.4120 | -0.9581 | 0.3333 | 1.3497 |
| Corn | -0.5457 | 0.6784 | 25.3301 | 0.4782 |
| Alfalfa Hay | 0.3182 | 3.8798 | -2.2644 | 1.6962 |
| Grains & Forages | 1.0416 | 0.8917 | 1.0628 | -3.7288 |

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 -0.9581% and a substitute for grains and forages, and alfalfa hay with a cross-price elasticity of 1.3497% and 0.3333% respectively (Table 4). A 1% change in the price of cottonseed meal will affect the quantity demanded of corn by -0.5457%, slightly more than it affects quantity demand of cottonseed meal, which has an own-price elasticity of -.4120. However, grains and forages have an elastic demand with respect to the price of cottonseed meal with an elasticity of 1.0416%. Alfalfa hay on the

other hand has an inelastic demand with respect to the price of cottonseed meal with an elasticity of 0.3182%. 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 and forages 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 -0.5457% and a substitute for grains and forages and alfalfa hay with elasticities of 0.4782% and 25.3301% respectively (Table 4). However, a 1% change in the price of corn will change quantity demanded for cottonseed meal by -0.9581% but will change the quantity demanded for corn by 0.6784%, as well as change quantity demanded for grains and forages by 0.8917% and alfalfa hay by 3.8798%.

The estimated cross-price elasticities for grains and forages imply that it is a substitute of all other inputs (Table 4). Grains and forages have a cross-price elasticity of 1.0416% with respect to the price cottonseed meal, 0.8917% with respect to the price of corn, and 1.0628% with respect to the price of alfalfa hay. A 1% increase in the price of grains and forages, which contains harvested and purchased soybean, distiller's grain, commercial feeds, wheat and corn silage, will significantly increase the quantity demanded for alfalfa hay by 1.6962% and cottonseed meal by 1.3497%.

The simulation analysis generates a forecast of quantities of cottonseed demanded on behalf of the dairy industry holding all other factors constant. The case analysis takes into consideration external variables that have a direct effect on the quantity demanded of cottonseed or cottonseed prices. Two cases are analyzed using the dairy industry's derived price elasticities and output elasticities such as the long-term trend of increases in national milk production and increases in the national price of grains.

**Increases in National Milk Production.** FAPRI (2008b) estimates national milk production to increase from 185,599 million pounds in 2007 to 212,385 million pounds in 2017 with an average 1.4% increase per year. Taking these projections and the estimated output elasticities (Table 3), the dairy industry's demand for cottonseed and its relationship with milk production can be derived holding all other factors constant. Figure 1 reports the simulated quantities of milk produced on behalf of the dairy industry given changes in input use of cottonseed, holding all other factors constant.

Figure 2 depicts the stream of cottonseed demanded on behalf of the dairy industry using the simulated quantities of milk produced. Simulations are estimated for an additional 1.5% increase and 2.9% increase above estimated quantities of milk produced and 1.5% below estimated quantities of milk produced. As can be noted from Figure 2, the quantity of cottonseed demanded on behalf of the dairy industry's increases at an increasing rate given higher increases in milk production, holding all other factors constant. That is, if milk production increases at an average rate of 4.3% annually (plus 2.9% per year) the quantity of cottonseed demanded would increase beyond 6 million tons (plus 66%). Using the World Cotton Fiber Model's forecasted cotton production; cottonseed production would reach approximately 6.95 million tons for the year 2016. This would imply that the dairy industry would demand all of the cottonseed produced by 2016 if milk production increased at an average rate of 4.3%. Similarly, if milk production increased at an average rate of 1.5% annually above the FAPRI (2008b) milk production estimates the demand for cottonseed on behalf of the dairy industry would be 5.7 million metric tons in 2016 (34% increase). This represents approximately 82% of the estimated cottonseed produced. On the other hand, if milk production were to decrease 1.5% the demand for cottonseed

would be 2.9 million metric tons in 2016, which represents 41% of the estimated cottonseed produced in 2016.

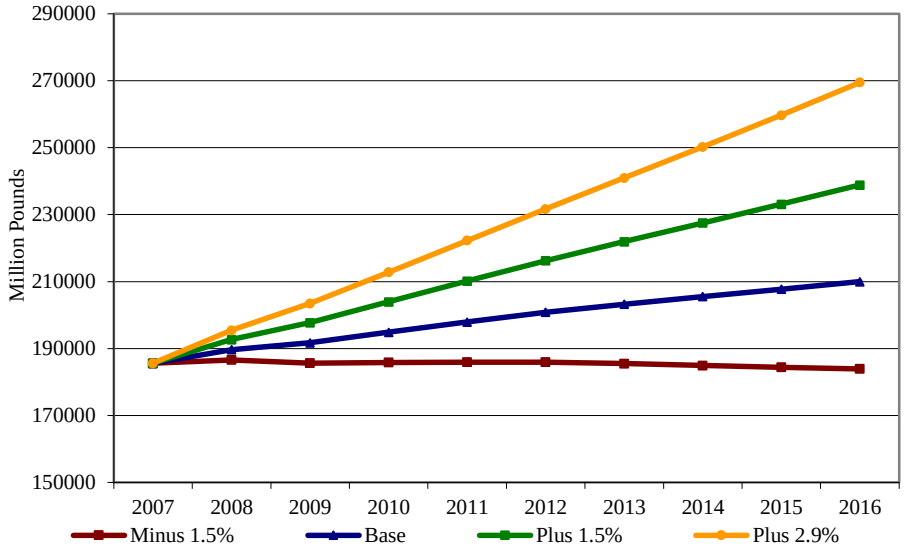


Figure 1. Projected Quantities of Milk Produced Under Different Scenarios.

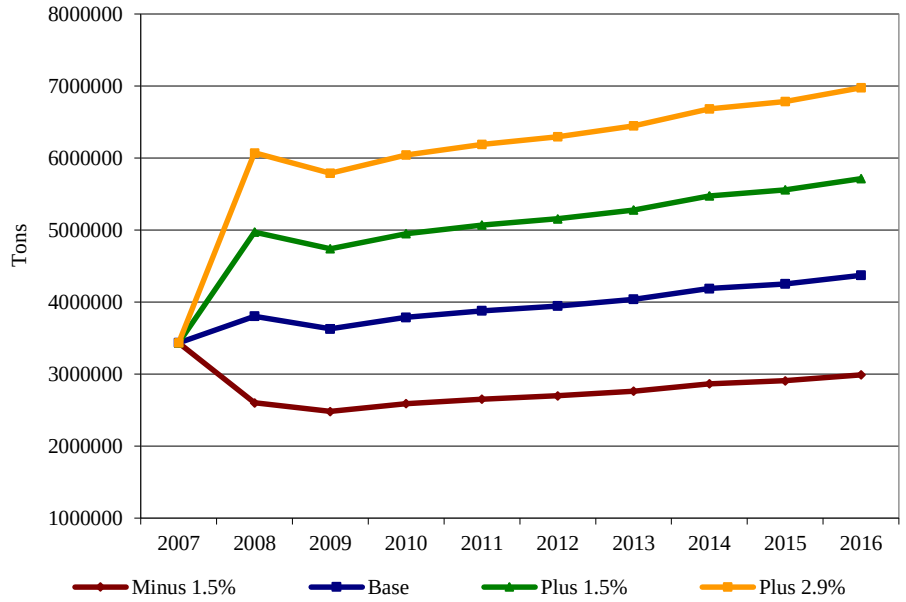


Figure 2. Dairy Industry Demand for Cottonseed Given Various Changes in Milk Production.

This simulation analysis has shed some light into the influence that the dairy industry has on quantity of cottonseed demanded. The migration of dairy farms from traditional production states such as California and New York, to Southern states such as New Mexico and Texas, may have a significant effect on the local demand for cottonseed. Texas milk production is expected to increase an average 4% per year, from 7,828 million pounds to approximately 10,748 million pounds in 2017. This is expected to have significant increases in the local demand for cottonseed.

These projected quantities of cottonseed demanded on behalf of the dairy industry given changes in milk production can be used to simulate its effect on cottonseed prices. Aggregate quantities demanded for cottonseed are the summation of the dairy industry's simulated demand for cottonseed and the FAPRI (2008a) forecasted crushing industry's demand for cottonseed plus 5% of cottonseed production that is set aside to plant next year's crop. Figure 3 shows the stream of aggregate cottonseed demanded from the simulation of changes in quantities demanded on behalf of the dairy industry given changes in milk production. Figure 3 illustrates that, holding all other factors constant, increases in milk production at a rate higher than 1.4% would imply that the dairy industry and the crushing industry demand more than exceeds the forecasted cottonseed supply for 2016. This implies that the shortage of cottonseed supply may result in increasing cottonseed prices as both industries demand more than what is produced.

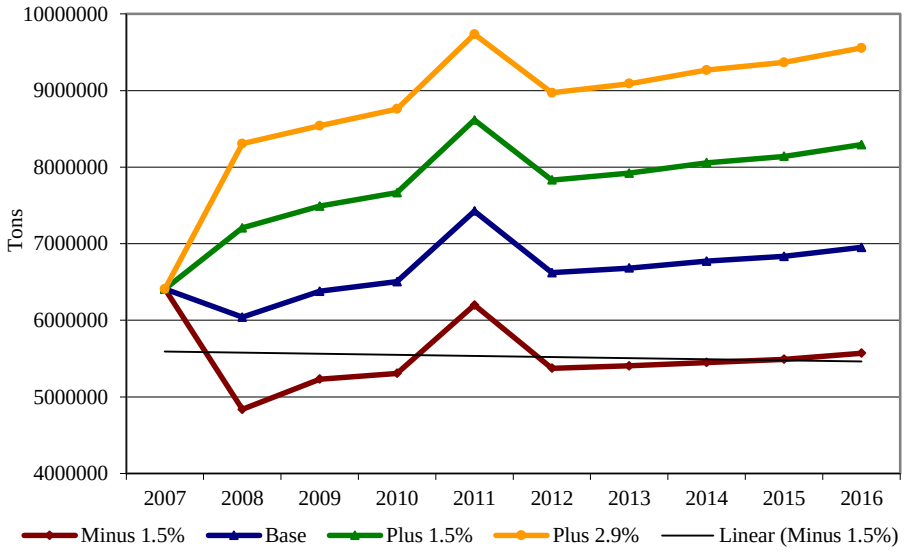

Figure 3. Aggregate Quantities of Cottonseed Demanded Given Changes in Milk Production.

Consequently, the effect that these changes in aggregate quantities demanded would have on cottonseed prices can be simulated, holding all other factors constant. Figure 4 illustrates the estimated price of cottonseed given changes in milk production. It demonstrates that given increases in quantities demanded by the dairy industry the price of cottonseed will also increase, holding all other factors constant. If milk production were to increase at an average rate of 4.3% then cottonseed prices would increase 105% by the year 2016. This implies that there is a demand increase (pulling-effect) by the dairy industry.

**Increases in the Price of Grains.** In order to simulate how changes in the price of grains affect the demand for cottonseed, an A-index is created using the FAPRI (2008a) forecasted prices for distiller's grains and wheat, and NASS' (USDA-NASS 2008, 2007) forecasted soybean prices. NASS also has historical data on dairy feed prices in their annual report "Agricultural Prices" (USDA-NASS 2008, 2007). Dairy concentrated feeds are forecasted using a linear regression of dairy feeds as a

function of the price of corn, price of soybean and the price of wheat.[1] The corn silage price is also forecasted using a linear regression of corn silage as a function of the yield of corn production per acre, price of soybean and alfalfa hay.[2] Corn silage gross value per acre for the period 1996-2006 is obtained from the USDA-ERS annual reports on corn production costs and returns (USDA-ERS 2008). Although there is much literature that encourages using corn prices as a base price to determine corn silage price per acre, the variable resulted insignificant and is therefore dropped from the model. After estimating the A-index it was evident that corn silage price per ton was pulling the A-index price down. Corn silage represents 48.72% of the aggregate grains variable and it has the least cost per metric ton. Corn silage is dropped from the A-index in order to have an accurate estimate for grains. Figure 5 depicts the grains index estimation.

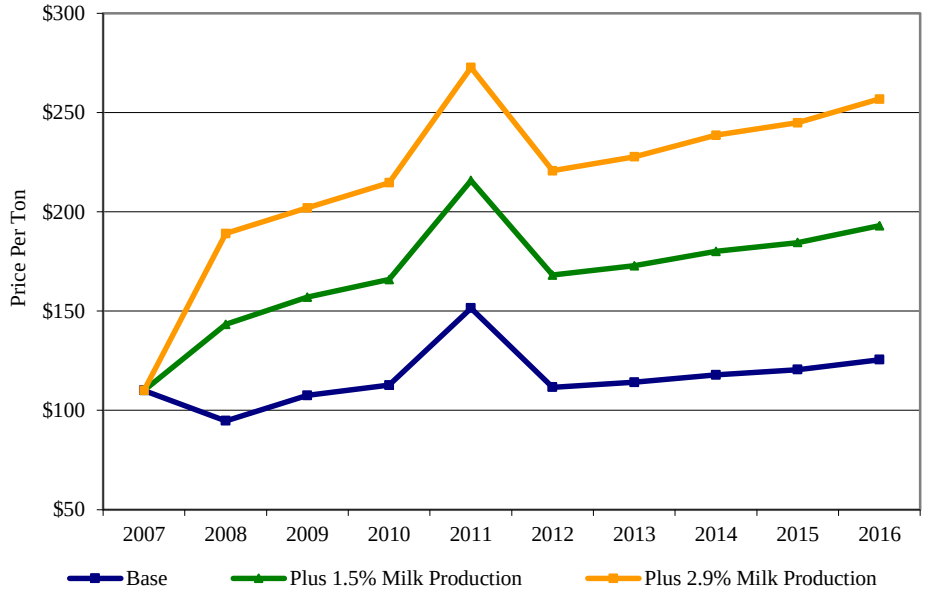


Figure 4. Price of Cottonseed Given Increases in Milk Production.

Taking the A-index projections and the cross-price elasticity of demand estimates (Table 4), the dairy industry's demand for cottonseed is derived, holding all other factors constant. Figure 6 depicts the stream of cottonseed demanded on behalf of the dairy industry using the projected grains index (base) which has an average growth rate of 1.6%. Simulations are estimated for a 0.5% increase and a 0.5% decrease in the rate of grains index prices. As can be noted from Figure 6 an additional 0.5% increase above the average grains price index rate increases the quantity demanded of cottonseed significantly, holding all other factors constant. Using the World Cotton Fiber forecast for cotton production, cottonseed production is derived. Cottonseed production is expected to reach approximately 6.9 million

[1] The linear regression explained 89.10% of the variation in the price of dairy feeds. Soybean price was significant at the 1% level, corn price was significant at the 5% level, and wheat price was significant at 20% level.

[2] The linear regression explained 82.69% of the variation in corn silage price. Corn yield and soybean price were significant at the 1% level, and alfalfa hay price was significant at 10% level.

metric tons by 2016. If grains prices were to increase at an average rate of 2.1% per year the dairy industry would demand almost all cottonseed production by the year 2016 holding all other factors constant. On the other hand, if projected grains prices were to decrease 0.5% per year the dairy industry would demand 2.6 million metric tons or approximately 38% of the estimated cottonseed production by 2016 holding all other factors constant.

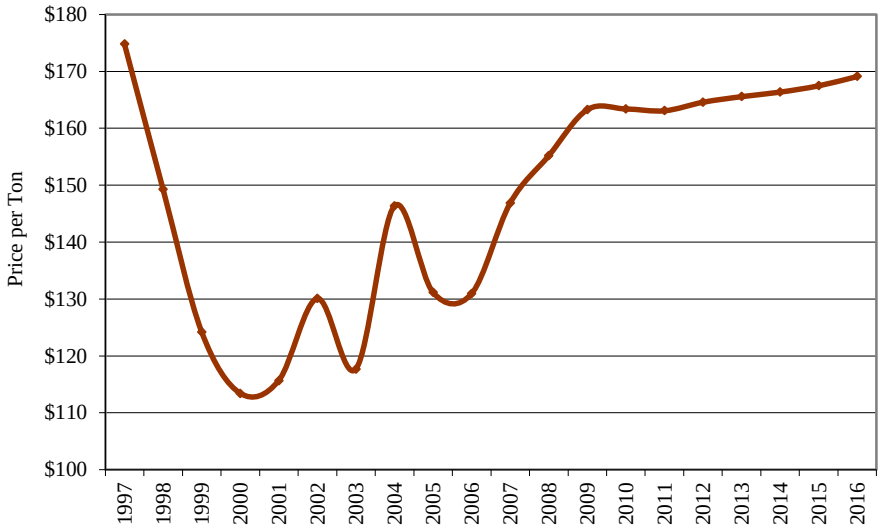


Figure 5. Grains Price Index.
Source: Prepared by the Author using the FAPRI (2008a) and USDA-NASS's (2008, 2007) Forecasted Price Estimates for Distiller's Grain, Wheat, Soybean and Historical Prices for Dairy Feeds.

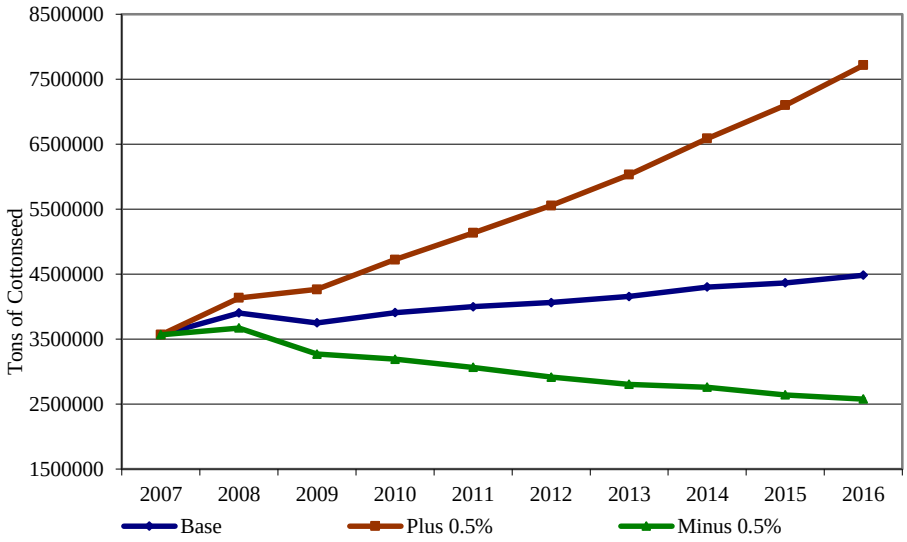


Figure 6. Dairy Industry Demand for Cottonseed Given Changes in the Grains Price Index.

These projected quantities of cottonseed demanded on behalf of the dairy industry given changes in the price of grains are then used to simulate its effect on cottonseed prices. This simulation is estimated using the changes in aggregate

quantities demanded and the inverse of the derived own-price elasticity (Table 4), holding all other factors constant. Aggregate quantities demanded for cottonseed is the summation of the dairy industry's simulated demand for cottonseed and the FAPRI (2008a) forecasted crushing industry's demand for cottonseed plus 5% of cottonseed production that is set aside to plant next year's crop. Figure 7 shows the stream of aggregate cottonseed demand from the simulation of changes in quantities demanded on behalf of the dairy industry given changes in grains index prices. Figure 7 illustrates that holding all other factors constant the dairy industry and the crushing industry demand more than what the forecasted cottonseed supply will be for 2016. This implies that the shortage of supply may result in increasing cottonseed prices.

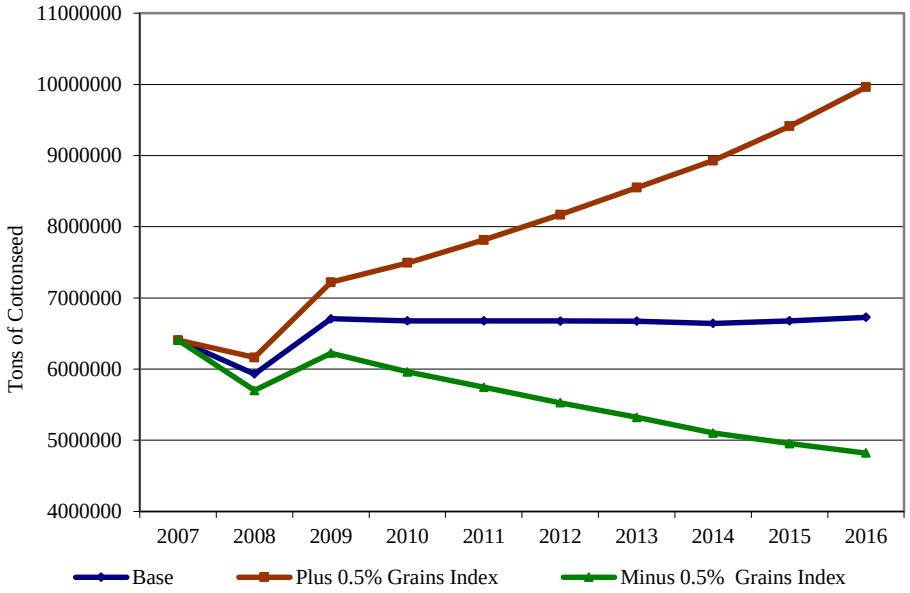


Figure 7. Aggregate Quantity of Cottonseed Demanded Given Changes in Grains Index.

Consequently, the effect that these changes in aggregate quantities demanded would have on cottonseed prices is simulated, holding all other factors constant. Figure 8 illustrates the estimated price of cottonseed given changes in the grains index. The figure demonstrates that given increases in quantities demand on behalf of the dairy industry the price of cottonseed also increases, holding all other factors constant. That is, a 2.1% increase in the gains price index (0.5% above base estimate) will lead to a 152% increase in the price of cottonseed holding all other factors constant. Yet again, this implies that there may be a demand (pulling) effect on behalf of the dairy industry. This correspondence is also expected given increases in milk production, where the dairy industry demands significantly more cottonseed, holding all other factors constant.

Finally, taking the estimated cottonseed price projections (two simulations and the FAPRI forecast), as well as quantities of cotton and cottonseed produced from the World Cotton Fiber Model, and the FAPRI (2008a) forecasted cotton prices, the aggregate gross value of production for U.S. cotton farmers can be estimated. Following USDA calculations, gross value of production for the cotton farmer is equal to the revenues from cottonseed (lbs per acre times dollars per lb) plus the revenues from cotton (lbs per acre times dollars per lb). Figure 9 illustrates that gross value of production from cottonseed may represent a significant portion of farmer's

revenues by 2011. If milk production increases 4.3% cottonseed may represent 40% of gross value of production; similarly if grain prices increase 2.1% cottonseed may represent 30% of gross value of production by 2011. Using the FAPRI (2008a) price projections, cottonseed may represent 24% of gross value of production. This implies that cottonseed may switch from a minor byproduct to a significant percentage of gross value of cotton production.

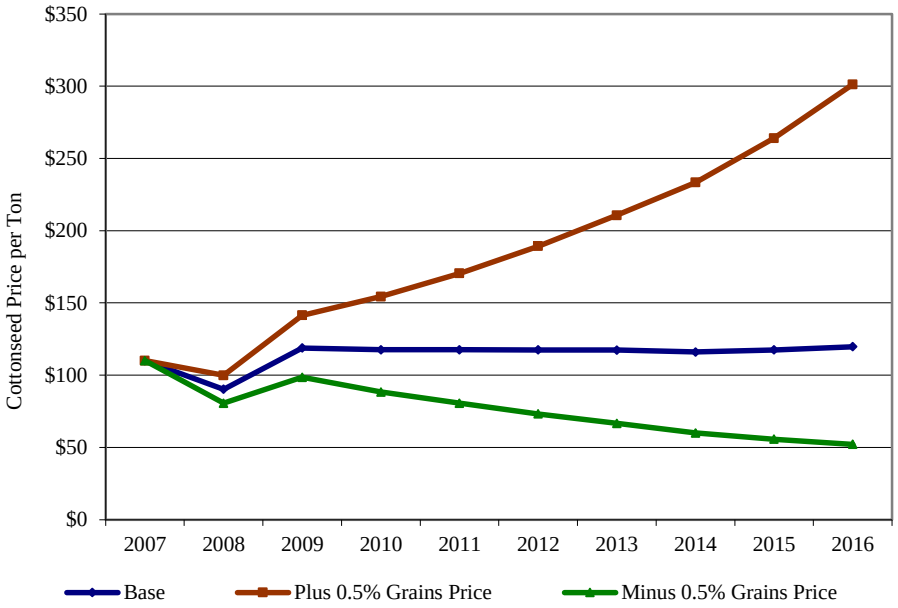


Figure 8. Price of Cottonseed Given Changes in Grains Price Index.

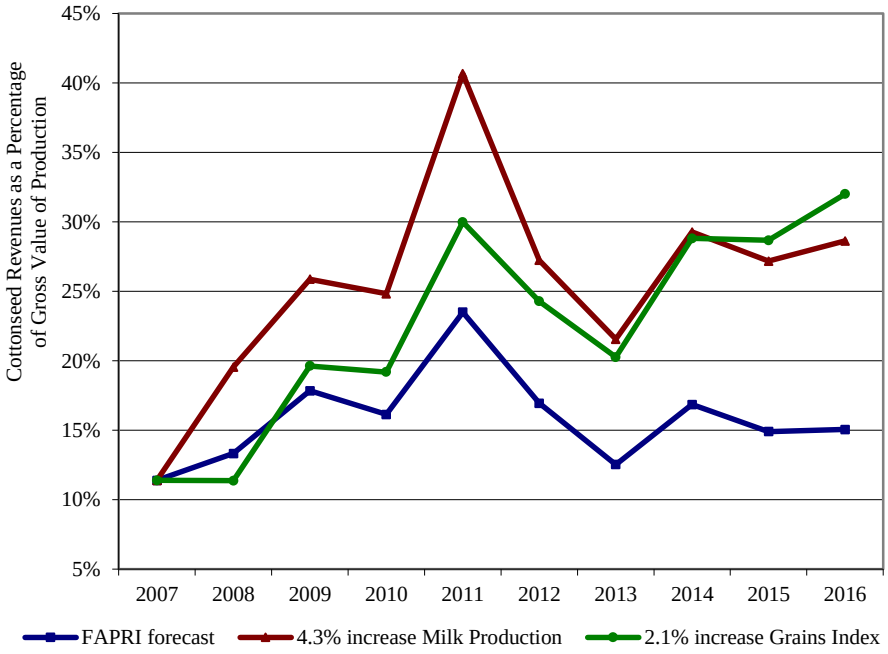


Figure 9. Simulated Cottonseed Revenues as a Percentage of Total Gross Value of Production for the Cotton Enterprise.

## CONCLUSION

This study focuses mainly on the U.S. dairy industry's derived demand for cottonseed, and other feed grains and forages by estimating the industry's price elasticities as well as its output elasticities. A transcendental logarithmic production model with regional dummy variables is used to estimate the U.S. dairy industry's derived demand for cottonseed meal, corn, alfalfa hay, and other grains and forages. Following Wang and Lall's (1999), marginal productivity analysis, own-price and cross-price elasticities are estimated for the U.S. dairy industry using data from the Agricultural Resource Management Survey (ARMS).

The study provides useful insight into the sensitivity of prices and quantities demanded by the dairy industry. Output elasticities and price elasticities are further used to analyze the factors that have an effect on aggregate demand for cottonseed. Two case analyses, plausible future price events in the feed grains market and increases in milk production, are estimated to help determine its effect on aggregate demand for cottonseed and consequently its effect on forecasted cottonseed prices.

Case analyses of plausible long-term increases in dairy industry production demonstrate that the dairy industry will demand proportionately more cottonseed given increases in milk production holding all other factors constant. This implies that the migration of dairy farms to Southwestern states such as Texas, where milk production is expected to increase an average 4% per year, from 7,828 million pounds to approximately 10,748 million pounds in 2017 (FAPRI 2008a). This growth in dairy production will proportionately increase local demand for cottonseed, which means that the gross value of production of cottonseed for the cotton farmer may also increase. Regional cotton farmers can expect bigger cash revenue from cottonseed as dairies migrate to southern states.

Nonetheless, the quality of the cottonseed produced also influences the market price. According to Robinson (2001), the size and quality of the seed has decreased. Robinson (2001) states that cottonseed production per bale of cotton has decreased from 780 pounds per bale of cotton in the 1980s to 740 pounds per bale of cotton in 2001. Cotton farmers naturally focus on maximizing cotton production given that it represents 83.8% of gross value of production, while cottonseed represents only 16.2% (USDA-ERS 2008). However, if cottonseed prices continue to increase, more emphasis on the size and quality of the cottonseed will be brought to the attention of cotton farmers, meaning that future studies will now not only focus on maximizing cotton production but also maximize the size and quality of the cottonseed as its value increases. Cotton models may eventually include cottonseed. The role of cottonseed in cotton production may switch from a minor by-product to a significant part of gross value of cotton production. Revenues from cottonseed may eventually be the determining factor as to whether cotton farmers finished the crop year with profitable returns.

## DISCLAIMER

The conclusions reported here are those of the authors and do not necessarily represent those of the National Agricultural Statistics Service.

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