ESTIMATING THE LINKAGES BETWEEN FUEL PRICES AND NITROGEN PRICES, NITROGEN DEMAND, AND COTTON PRODUCTION IN TEXAS

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Abstract

Cotton producers utilize fertilizer to enhance total production. Research has shown a correlation between fuel and fertilizer prices. This study estimates the interaction of external factors including fuel prices on the price of fertilizer and thus the demand for fertilizer and total cotton production in Texas. Equations for the price of nitrogen fertilizer used in cotton production in Texas, demand for nitrogen fertilizer in Texas cotton production, and the total production of cotton in Texas were estimated using a double-log specification. Results of the study indicated that as the U.S. diesel price multiplied by the price of natural gas in the U.S. increased by one percent, the price of nitrogen fertilizer increased by 0.3639 percent. Further, as the U.S. diesel price multiplied by the price of natural gas in the U.S. increased by one percent, the demand for nitrogen fertilizer in Texas decreased by 0.3011 percent. Finally, as the U.S. diesel price multiplied by the price of natural gas in the U.S. increased by one percent, the total cotton production in Texas decreased by 0.1289 percent. While these results do suggest that the price of fertilizer, quantity demanded of fertilizer, and cotton production are not extremely responsive to changes in fuel prices, results also indicate that changes in fuel prices are statistically significant in affecting nitrogen prices, demand, and cotton production.

Introduction

Cotton producers have utilized fertilizer to enhance total production. Economic viability is dependant on the optimal usage of this input. Research has show a correlation between fuel and fertilizer prices (Williams et al. 2005). In other words, as fuel prices change, fertilizer prices also change. However, fuel prices are not the only determinant of the price of fertilizer. Huang (2009) also suggested that costs associated with transporting the fertilizer along with the value of the U.S. Dollar can also influence the price of fertilizer. Huang (2009) also indicated that a structural shift had occurred in the U.S. with the U.S. moving from being an exporter of fertilizer in the 1980s to the world's largest importer in the 2000s.

It has also been established that natural gas prices have a direct effect on the price of nitrogen fertilizer (U.S.-GAO, 2003). Results of this study indicate that natural gas accounts for the largest proportion of the cost of producing nitrogen fertilizer. Thus, changes in the price of natural gas significantly impact the price of nitrogen fertilizer. Similarly, Huang (2007) found a stable relationship in the long-run between natural gas and ammonia prices with a long-run ammonia price elasticity with respect to natural gas prices equaling 0.79 and a short-run elasticity equaling 0.25.

Other studies have focused the relationship between nitrogen fertilizer and cotton production/yields under specific production practices such as in Sorensen, et. al., (2004) where the authors examined cotton yield response to differing nitrogen application strategies. On the other hand, studies such as Reddy, et. al., 2007 focused on cotton yield response to alternative nitrogen sources. However, Huang (2007) clearly suggests that changes in natural gas prices can impact not only the price of nitrogen fertilizer and the fertilizer industry but also cotton producers. Recent volatile fuel prices would suggest that any correlation between fuel prices and fertilizer prices can result in volatile fertilizer prices and further exacerbate the impact Huang (2007) suggested. Currently, there is a lack of research showing the linkages between fuel prices and the cotton production sector through nitrogen fertilizer prices and demand. This study estimates these interactions as well as explains the responsiveness of changes in fertilizer price and demand as well as cotton production due to changes in fuel prices.

Materials and Methods

This study analyzed data pertinent to the estimation of the price and demand of nitrogen fertilizer used in Texas cotton production between the years of 1980 and 2009. To determine the relationship between fuel prices and nitrogen fertilizer usage, three equations were estimated. The first equation explained the variation in nitrogen fertilizer prices paid by Texas cotton producers. The second equation explained the variation in the demand of nitrogen fertilizer by Texas cotton produces. The final equation explained the variation in Texas cotton production. After estimating these equations, the responsiveness of changes in fuel prices on nitrogen fertilizer price and demand as well as cotton production was then determined. A further explanation of the methods used to estimate the equations as well as determine the interrelationships between fuel prices and nitrogen fertilizer prices and demand as well as cotton production is discussed below.

Price of Nitrogen Fertilizer

The variation in nitrogen fertilizer prices was determined by specifying a double-log equation as presented in Equation 1.

$$lnNP2010_t = f(lnUSDP2010_t, lnPNG2010_t, lnNP2010_{t-1}, lnUSPROD_t) \quad \text{(Equation 1)}$$

where: $lnNP2010_t$ represents the natural log of the price of nitrogen fertilizer, $lnUSDP2010_t$ represents the natural log of the price of diesel in the U.S. in 2010 Dollars, $lnPNG2010_t$ represents the natural log of the price of natural gas in the U.S. in 2010 Dollars, $lnUSPROD_t$ represents the natural log of the production of nitrogen fertilizer in the U.S.

The price of diesel in the U.S. was included in the model to capture the changes in the cost of nitrogen fertilizer as the price of transporting this fertilizer changes. It was hypothesized that as the price of diesel increases in the U.S., thus increasing the cost of delivering nitrogen fertilizer, the price of nitrogen fertilizer will also increase as it is passed along to the consumer. The price of natural gas was included in the model due to the fact that natural gas is used in the production of nitrogen fertilizer. As with the price of diesel, it was also hypothesized that there is a direct relationship between the price of natural gas and the price of nitrogen fertilizer. It was also hypothesized changes price of nitrogen fertilizer in time period t-1 would be positively correlated with the price of nitrogen fertilizer in time t.

Finally, the U.S. had a major structural shift away from producing nitrogen fertilizer and towards importing greater quantities of nitrogen fertilizer in the year 2000. Specifically, the U.S. imported over twice as much (1,305.4 thousand metric tons) of nitrogen fertilizer in 2000 as in 1999 when it imported only 613.7 thousand metric tons of nitrogen fertilizer (U.S. Census Bureau, 2001). It was hypothesized that nitrogen fertilizer production shifted to foreign producers because of a lower cost of production. Thus, it is hypothesized that as the production of nitrogen fertilizer in the U.S. increases, the price of nitrogen fertilizer will also increase.

Quantity Demanded of Nitrogen Fertilizer

The quantity demanded of nitrogen fertilizer was determined by specifying a double-log equation as presented in Equation 2.

$$lnTOTN_t = f(lnETR_t, lnNP2010_t, lnPIRR_t, lnRAIN_t) \quad \text{(Equation 2)}$$

where: $lnTOTN_t$ represents the natural log of the total pounds of nitrogen fertilizer used in Texas cotton production in time t, $lnETR_t$ represents the natural log of the expected total revenue for Texas cotton producers in time t, $lnNP2010_t$ represents the natural log of the price of nitrogen fertilizer in time t in 2010 Dollars, $lnPIRR_t$ represents the natural log of the percent of planted irrigated cotton acres in Texas in time t, and $lnRAIN_t$ represents the natural log of the annual rainfall in Texas in time t.

For the use of this study, the expected total revenue for Texas cotton producer (ETR_t) was calculated by using Equation 3.

$ETR_t = EHA_t * YLD_t * MFP_t$ (Equation 3)

Where: EHA_t represents the expected harvested acres in time t (planted acres less the five year average percentage difference between planted and harvested acres), YLD_t represents expected yield in time t (the last five year average yield per harvested acre), and MFP_t represents expected price in time t (the December futures contract price of cotton in March).

It was hypothesized that changes in expected total revenue (ETR_t) will positively affect the quantity demanded of nitrogen fertilizer. This hypothesis was based on producers expecting to be able to afford to utilize more fertilizer when expected total revenues increase and less nitrogen fertilizer when expected total revenues decrease.

Economic theory suggests that an increase in the price of a good will cause the quantity demanded of that good to decrease, ceteris paribus. Thus, the hypothesized relationship between the price of nitrogen fertilizer ($lnNP2010_t$) and the quantity demanded of nitrogen fertilizer was hypothesized to be inverse.

The percentage of planted irrigated cotton acres in Texas in time t ($PIRR_t$) as well as the annual rainfall in Texas in time t ($RAIN_t$) was included to capture the hypothesized positive relationship between moisture levels and nitrogen fertilizer usage. Anguelov et al., (2010). suggested that increased need for nitrogen may be present if increases in irrigation or rainfall occur due to nitrates being moved through the soil profile with excessive water drainage.

<u>Total Production of Cotton in Texas</u>

The total production of cotton in Texas was determined by specifying a double-log equation as presented in Equation 4.

$lnCTPRO_t = f(lnTOTN_t, lnHARCTA_t, DROUGHT_t, lnMCOST2010_t, NOTILL_t$ (Equation 4)

Where: $lnCTPRO_t$ equals the natural log of the quantity of cotton produced in Texas in time t in bales, $lnHARCTA_t$ is the natural log of the total harvested acres of cotton in Texas in time t, DROUGHT is a dummy variable representing the existence of drought in Texas in time t and is derived from the Palmer Z-index, $lnMCOST2010_t$ is the natural log of the cost of machinery for producing cotton in time t in 2010 Dollars, and $NOTILL_t$ represents a dummy variable used to denote the years that no-till production was used in cotton production in Texas.

It is hypothesized that changes in the total amount of nitrogen fertilizer used in cotton production will have a positive relationship with the production of cotton. Further, it is also hypothesized that as more acres of cotton are harvested, the total production of cotton will also increase. On the other hand, because a lack of rainfall can inhibit the cotton growth, the dummy variable $DROUGHT_t$ is hypothesized to have an inverse relationship with the total production of cotton in Texas in time t.

The cost of machinery used for cotton production was included to capture changes in technology over time. It is hypothesized that new technology will have an associated higher cost. Also economic theory suggests that positive changes in technology will increase the supply. Thus, as the cost of machinery increases in time t ($lnMCOST2010_t$), the production of cotton in Texas in time t is also hypothesized to increase. Finally, the advent of no-till represented a structural shift in the cotton production sector. This shift is hypothesized to have reduced production costs, increased acreage available for cotton production, and positively impacted yields. Thus, it is hypothesized that the existence of no-tillage options will increase cotton production in Texas.

<u>Effects of Changes in Fuel Prices on Nitrogen Fertilizer Demand and Cotton Production</u>

The coefficient associated with an independent variable in a double-log specification is the elasticity associated with that variable. Thus, the elasticity associated of nitrogen fertilizer demand as the price of fuel changes was determined by substituting Equation 1 into Equation 2 for the price of nitrogen ($lnNP2010_t$). The resulting coefficient associated with the price of fuel yielded the percentage change in nitrogen fertilizer demand associated with a one percent change in the price of fuel. Similarly, substituting Equation 1 into Equation 2 and then the expanded version of Equation 2 into Equation 4 would provide the elasticity associated with changes in the price of fuel on the production of cotton in Texas.

Model Data Sources

Data used in this study was obtained from several sources. Table 1 below shows the sources of the data obtained for use in this study and the sources of this data.

Table 1. Sources of data used in the estimation of nitrogen fertilizer price and nitrogen fertilizer demand.

Variable Name	Data Source
NP2010	USDA-ERS (2011a)
USDP2010	U.S. Energy Information Administration (2011)
PNG2010	U.S. Energy Information Administration (2011)
USPROD	U.S. Department of Commerce (2011, 2009, 2007, 2005, 2003, 2002, 2001, 2000, 1997, 1994, 1993, 1991, 1989, 1986)
TOTN	USDA-ERS (2011b)
EHA	USDA (2009, 2008, 2007, 2006, 2005, 2004, 2003, 2002, 2001, 2000, 1999, 1998, 1997, 1995-1996); Texas Agricultural Statistics Service (1995, 1993, 1992, 1990)
YLD	USDA (2009, 2008, 2007, 2006, 2005, 2004, 2003, 2002, 2001, 2000, 1999, 1998, 1997, 1995-1996); Texas Agricultural Statistics Service (1995, 1993, 1992, 1990)
MFP	Barchart (2011)
PIRR	USDA-NASS (2011)
RAIN	National Weather Service (2011)
CTPRO	USDA (2009, 2008, 2007, 2006, 2005, 2004, 2003, 2002, 2001, 2000, 1999, 1998, 1997, 1995-1996); Texas Agricultural Statistics Service (1995, 1993, 1992, 1990)
HARCTA	USDA (2009, 2008, 2007, 2006, 2005, 2004, 2003, 2002, 2001, 2000, 1999, 1998, 1997, 1995-1996); Texas Agricultural Statistics Service (1995, 1993, 1992, 1990)
DROUGHT	NOAA (2012)
MCOST	USDA-ERS (2012)
NOTILL	USDA-ERS (2010)

Results

The results and findings presented in below are the outcome of the methods and procedures used to accomplish the objectives of this study. This section is separated into four sections. The first section presents the estimated nitrogen fertilizer price model. The estimated equation of the nitrogen fertilizer demand is reported in the second section. The third section presents the estimated total cotton production model. Finally, the forth section presents the findings regarding the responsiveness of nitrogen fertilizer price, the nitrogen fertilizer demand, and cotton production due to changes in the price of fuel.

Nitrogen Fertilizer Price Estimation

Descriptive statistics for the dependent variable and the predictor variables of the price paid by cotton farmers for nitrogen fertilizer is presented in Table 2. The estimated double log model representing the price of nitrogen paid by cotton farmers explained about 76 percent of the total variation in nitrogen price over the study period. Specifically, the price of diesel in 2010 dollars ($USDP2010_t$), the price of natural gas in 2010 dollars ($PNG2010_t$), the lag of nitrogen prices ($NP2010_{t-1}$), and the production of nitrogen fertilizer in the U.S. ($USPROD_t$) were reasonably successful in explaining the total variation in nitrogen fertilizer prices. This measure indicated that the model had satisfactory explanatory power and fit the data well.

Table 2. Nitrogen fertilizer price estimates from Maximum Likelihood Procedure.

Independent Variables	Coefficient Estimates	t-statistic	P-Value
Intercept	-2.1060		
$lnUSDP2010_t*lnPNG2010_t$	0.3639	5.57	7.58E-6
$lnNP2010_{t-1}$	0.3412	2.89	0.0077
$lnUSPROD_t$	0.5101	2.87	0.0081
R-Squared	76.63		
F-Statistic	28.42		
VIF	4.57		
Durbin-Watson	1.68		

Estimation results indicated that the multiplicative of the U.S. diesel price and price of natural gas ($lnUSDP2010_t*lnPNG2010_t$), the lag of the price of nitrogen fertilizer ($lnNP2010_{t-1}$), and the production of nitrogen fertilizer in the U.S. ($lnUSPROD_t$) were all statistically significant and direct in explaining the variation in the price of nitrogen fertilizer. Specifically, results indicated that a one percent change in the multiplicative of the U.S. diesel price and the price of natural gas caused a 0.3639 percent change in the price of nitrogen fertilizer in the same direction. Likewise, as the price of nitrogen fertilizer increases by one percent in time t-1, the current nitrogen fertilizer price was found to increase by 0.3412 percent. Finally, as the production of nitrogen fertilizer in the U.S. increases by one percent, the price of nitrogen fertilizer increases by 0.5101 percent.

Nitrogen Fertilizer Demand Estimation

Descriptive statistics for the dependent variable and the predictor variables of the model representing the demand for nitrogen fertilizer by cotton farmers in the U.S. is presented in Table 3. The estimated double log demand equation had satisfactory explanatory power and fit the data well as 76 percent of the total variation in nitrogen fertilizer demand over the study period was explained by the independent variables. These independent variables included the natural log of the: total pounds of nitrogen used in cotton production (lnTOTN), expected total revenue for Texas cotton producers (lnETR), the price of nitrogen (lnNP2010), percent of irrigated Texas cotton acres (lnPIRR), and the annual rainfall in Texas (lnRAIN).

Table 3. Nitrogen fertilizer demand estimates from Maximum Likelihood Procedure.

Independent Variables	Coefficient Estimates	t-statistic	P-Value
Intercept	1.1235		
$\ln ETR_t$	0.8793	7.47	6.27E-8
$\ln NP2010_t$	- 0.8273	- 5.21	1.94E-5
$\ln(PIRR_t{*}RAIN_t)$	0.5945	2.86	0.0082
R-Squared	76.54		
F-Statistic	28.28		
VIF	3.17		
Durbin-Watson	1.55		

The estimated coefficient for the expected total revenue for Texas cotton producers was found to have a statistically significant relationship with the nitrogen fertilizer demand. The coefficient suggests that a one percent increase in the expected total revenue of cotton farmers would result in a 0.8793 percent increase in the demand for nitrogen fertilizer. The coefficient associated with the price of nitrogen fertilizer was also found to have a statistically significant but inverse relationship with the demand of nitrogen fertilizer suggesting that as the price of nitrogen fertilizer increases by one percent, the quantity demanded of nitrogen fertilizer decreases by 0.8273 percent. Finally, the coefficient associated with the multiplicative of the percent of irrigated acres in Texas and the annual rainfall in Texas was found to have a statically significant and direct relationship with the demand for nitrogen fertilizer. Results suggest as the percent of moisture available increases by one percent, the quantity demanded of nitrogen fertilizer increases by 0.5945 percent.

Total Texas Cotton Production Estimation

Descriptive statistics for the dependent variable and the predictor variables of the model representing the total production of Texas cotton is presented in Table 4. The independent variables of the estimated double log supply equation explained 80 percent of the total variation in cotton production suggesting the model had satisfactory explanatory power and fit the data well. These independent variables included the natural log of the: total pounds of nitrogen fertilizer used in Texas cotton production ($\ln TOTN_t$), the total harvested acres of cotton in Texas ($HARCTA_t$), the dummy variable representing the existence of drought in Texas (DROUGHT), the cost of machinery for producing cotton ($MCOST2010_t$), and the dummy variable used to denote the years that no-till production was used in cotton production in Texas ($NOTILL_t$).

Table 4. Total Texas cotton production estimates from Maximum Likelihood Procedure.

Independent Variables	Coefficient Estimates	t-statistic	P-Value
Intercept	-2.3149		
$\ln TOTN_t$	0.4280	4.84	6.24E-5
$\ln HARCTA_t$	0.5503	3.45	0.0021
$DROUGHT_t$	-0.1090	-1.62	0.1193
$\ln MCOST2010_t$	0.2041	1.53	0.1387
$NOTILL_t$	0.3199	4.32	0.0002
R-Squared	80.99		
F-Statistic	20.45		
VIF	6.44		
Durbin-Watson	2.22		

The estimated coefficient for the total pounds of nitrogen fertilizer used in Texas cotton production ($\ln TOTN_t$) was found to have a statistically significant and direct relationship with the production of cotton suggesting that as the total amount of nitrogen fertilizer used in cotton production increases by one percent, cotton production in Texas increases by 0.4280 percent. Similarly, the coefficient associated with the number of harvested Texas cotton acres ($\ln HARCTA_t$) suggested that a one percent increase in harvested acres resulted in a 0.5503 percent increase in total cotton production in Texas. The dummy variable representing the existence of drought in Texas in time t (DROUGHT) and the cost of machinery cost for producing cotton in time t in 2010 Dollars ($MCOST2010_t$) were found to be statistically significant in explaining the production of cotton in Texas at the 0.15 level and had corresponding coefficients of 0.5503 and -0.1090, respectively. This suggests cotton production in Texas is 0.1090 percent lower in years that experience some level of drought as opposed to years without drought. On the other hand, as the machinery cost used for cotton production increases by one percent, the total production of cotton in Texas increases by 0.5503 percent. Finally, the dummy variable used to denote the years that no-till production was used in cotton production in Texas ($NOTILL_t$) was found to be statistically significant and possessed a direct relationship. It was found that in years where no-till production was used in Texas, cotton production in Texas was 0.3199 percent higher than in years where no-till production was not used.

<u>Effects of Changes in Fuel Prices on Nitrogen Fertilizer Demand and Texas Cotton Production</u>

The resulting equation from inserting the estimated nitrogen fertilizer price equation (Table 1) in to the estimated nitrogen fertilizer demand equation (Table 2) is presented in Equation 5 below.

$$\ln TOTN = 1.1235 + 0.8793 * \ln ETR_t - 0.8273 * [-2.1060 + 0.3639 * \ln(USDP2010_t * PNG2010_t) + 0.3412 * \ln NP2010_{t-1} + 0.5101 * \ln USPROD_t] + 0.5945 * \ln(PIRR_t * RAIN_t) \quad \text{(Equation 5)}$$

Reducing Equation 5, yields the results of Equation 6 below.

$$\ln TOTN = 2.8658 + 0.8793 * \ln ETR_t - 0.3011 * \ln(USDP2010_t * PNG2010_t) - 0.2823 * \ln NP2010_{t-1} - 0.4220 * \ln USPROD_t + 0.5945 * \ln(PIRR_t * RAIN_t) \quad \text{(Equation 6)}$$

Given that the coefficients associated with each independent variable in Equation 6 represent the elasticities, it can be concluded that a one percent change in the price of the multiplicative of the U.S. diesel price and the price of natural gas ($\ln(USDP2010_t * PNG2010_t)$) results in a 0.3011 percent change in the opposite direction of the quantity demanded of nitrogen fertilizer used in cotton production in Texas.

The resulting equation from inserting the estimated nitrogen fertilizer demand equation (Equation 6) in to the supply of Texas cotton equation (Table 4) is presented in Equation 7 below.

$$\begin{aligned} lnCOTPRO = & -2.3149 + 0.4280*[2.8658 + 0.8793 * lnETR_t \\ & - 0.3011 * ln(USDP2010_t*PNG2010_t) - 0.2823 * lnNP2010_{t-1} - 0.4220 * lnUSPROD_t \\ & + 0.5945 * ln(PIRR_t * RAIN_t)] + 0.5503*lnHARCTA_t - 0.1090*DROUGHT_t \\ & + 0.2041*lnMCOST2010_t + 0.3199*NOTILL_t \end{aligned} \quad \text{(Equation 7)}$$

Reducing Equation 6, yields the results of Equation 8 below.

$$\begin{aligned} lnCOTPRO = & -1.0883 + 0.3763 * lnETR_t - 0.1289 * ln(USDP2010_t*PNG2010_t) \\ & - 0.1208 * lnNP2010_{t-1} - 0.1806 * lnUSPROD_t + 0.2544 * ln(PIRR_t * RAIN_t)] \\ & + 0.5503*lnHARCTA_t - 0.1090*DROUGHT_t + 0.2041*lnMCOST2010_t + 0.3199*NOTILL_t \end{aligned} \quad \text{(Equation 8)}$$

Equation 8 would suggest that a one percent change in the price of the multiplicative of the U.S. diesel price and the price of natural gas ($ln(USDP2010_t*PNG2010_t)$) results in a 0.1289 percent change in the opposite direction of the production of cotton in Texas.

Conclusion

The results of this study indicate that the price of nitrogen fertilizer is directly dependent on the price of fuel. This price of nitrogen fertilizer was also found to be important in determining the quantity demanded of nitrogen fertilizer used in Texas cotton production and had an inverse relationship. Finally, the quantity demanded of nitrogen fertilizer used by Texas cotton producers was found to be directly related to the production of cotton in Texas. This establishes that the price of fuel not only impacts the price of nitrogen fertilizer used by cotton producers, but also the quantity demanded of nitrogen fertilizer and production of cotton in Texas. These linkages made it possible to determine the elasticity of a change in fuel prices as it relates to the price of nitrogen fertilizer, the quantity demanded of nitrogen fertilizer in Texas, and production of cotton in Texas. Specifically, this study found that a one percent change in the price of the multiplicative of the diesel price and price of natural gas increases by one percent, the price of nitrogen fertilizer increases by 0.3639 percent, the quantity demanded of nitrogen fertilizer decreases by 0.3011 percent, and the total production of cotton lint decreases by 0.1289 percent.

The magnitude of the elasticities estimated in this study being less than one suggests that the price of nitrogen fertilizer, quantity demanded of nitrogen fertilizer in Texas, and production of cotton in Texas are relatively inelastic in regards to changes in the price of fuel. However, results also indicate that changes in fuel prices are significant in affecting all of these variables. This would suggest that the increasingly volatile fuel prices can result in significant changes to the production of cotton in Texas.

Most factors affecting production agriculture have long windows of time for the market to adjust to the changes. For instance, changes in planted acreage and even weather have an entire growing season for the industry to factor in to final production estimates. However, fuel prices have been extremely volatile even within short windows of time such as within a growing season. The relationships found in this study would suggest that fuel price volatility adds another level of complexity to the industry with the unique characteristic of being able to affect total production over a short time span.

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