Fuel and Fertilizer Price Impacts on Crop Mix and Returns in the Louisiana Delta

By Michael A. Deliberto, Michael E. Salassi, and Kenneth W. Paxton

Abstract

Fuel and fertilizer price increases in 2006 have had a significant impact on crop production costs and net returns. Analysis of crop returns and enterprise selection for the Louisiana Delta, a mixed cropping area in the northeastern part of the state, indicates that increased diesel and nitrogen fertilizer prices would be expected to shift acreage away from crops with relatively high diesel and nitrogen requirements as well as increase the risk or variability of net returns above variable costs for crop enterprise combinations.

Introduction

The Louisiana Delta is a fairly diversified agricultural production region located in the northeastern part of the state. It contains alluvial soils of the Mississippi River Delta and is encompassed within the seven parishes of Morehouse, East Carroll, West Carroll, Richland, Franklin, Madison and Tensas. Cotton, corn, rice, and soybeans are the major crops produced in the region, as well as sorghum and wheat. In 2005, this region accounted for 65.7 percent of Louisiana's total cotton acreage and 66.1 percent of the state's total corn acreage. The region accounted for 42.5 percent of the total state soybean acreage and 16.7 percent of the total state rice acreage in 2005.

Acreage of the four major row crops grown in the region over the 1996-2005 period is shown in Table 1. Approximately one million acres are planted each year to cotton, corn, rice and soybeans. These crops are usually grown in rotation. Corn and soybeans are usually grown in rotation with cotton (Guidry, et al.). Soybeans are the primary rotational crop with rice. Over the past ten years, cotton has accounted for an average of 39 percent of the region's acreage, corn 24 percent, rice 7.3 percent and soybeans 29.6 percent.

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In late 2005, fuel and fertilizer prices rose dramatically in response to the significant rise in the price of oil. From 1996 to 2005, budgeted diesel prices in the LSU Agricultural Center's Projected Enterprise Costs and Returns Budgets for Northeast Louisiana increased by $0.78 per gallon, from $0.67 in 1996 to $1.45 in 2005 (Britt and Paxton, 1996; Paxton, 2005). Budgeted diesel prices for 2006 rose by $0.75 over the previous year to $2.20 per gallon (Figure 1).

Budgeted nitrogen prices according to the LSU Agricultural Center's Projected Enterprise Costs and Returns Budgets for Northeast Louisiana were $0.26 per pound of nitrogen in 1996 and rose to $0.30 per pound of nitrogen in 2005, an increase of $0.04 per pound over ten years (Figure 1). For 2006, the budgeted nitrogen price was $0.40 per pound, an increase of $0.10 per pound, or 25 percent, in one year.

Changes in diesel and nitrogen costs per acre for the four crops were estimated using 2005 and 2006 budgeted input prices. Input requirements as well as estimated costs per acre for the two years are shown in Table 2. Rice requires the largest quantity of diesel per acre since it is an irrigated crop. An estimated 27.1 gallons of diesel are required for each acre of rice to cover fuel use by tractors, harvesters, and irrigation power units. The other three crops required much less diesel per acre. Corn and rice are the heaviest users of nitrogen at 160 and 170 pounds per acre. Cotton requires approximately 90 pounds of nitrogen per acre and none for soybeans. Using 2005 projected prices of $1.45 per gallon of diesel and $0.30 per pound of nitrogen and 2006 projected prices of $2.20 per gallon and $0.40 per pound, input costs for these two items were estimated for each crop. For the 2006 crop year, budgeted fuel and nitrogen costs were projected to increase by 4.1 percent for cotton, 8.5 percent for corn, 7.9 percent for rice, and 2.3 percent for soybeans.

Since the relative importance of fuel and fertilizer costs vary across the four major crops in the region, the question arose as to what would be the impact on cropping patterns in the region from increased fuel and fertilizer costs. A research study was conducted to evaluate the impact of increased fuel and fertilizer costs on enterprise selection and net returns of cotton, corn, rice and soybeans in this region of the state.

Methodology

A Target MOTAD modeling approach was selected to evaluate the impact of input price changes on enterprise selection. This approach utilizes a linear programming framework to determine optimal enterprise mix with the goal of maximizing net returns above variable costs while taking into account the relative return risk of each enterprise.

Target MOTAD modeling formulations were developed on the basis that decision makers desire to make choices which maximize expected returns but are also concerned about returns not meeting a predetermined "target" level (Tauer). This modeling approach has been used to evaluate a wide variety of crop production decisions including farm bill impacts on crop selection (Davis, et al.), uncertain fieldwork time (Misra and Spurlock), impacts of crop diversification and rotation on risk (Helmers, et al.), and double cropping (Burton, et al).

The general objective function utilized in the model for this study was of the form:

$$\text{Max } Z = a\,COT + b\,COR + c\,RIC + d\,SOY$$

where COT, COR, RIC, and SOY were defined as the percent of an acre planted to cotton, corn, rice, and soybeans. The parameters a, b, c and d represent the mean net return above variable production costs per acre for each commodity utilizing 2006 production cost estimates with 1996-2005 detrended crop yields, 1996-2006 actual market prices (or loan rates if higher), and 2005 and 2006 projected mean diesel and nitrogen prices. The mean diesel price in northeastern Louisiana from 1996-2005 was $0.94 per gallon. Mean nitrogen fertilizer prices during that same time span was $0.24 per pound. In order to calculate net returns above variable costs so that objective function coefficients can be determined, diesel and fertilizer prices were detrended for each year. Land arrangements, i.e., percentage of land owned and share rented, crop market price, and loan rate were unadjusted from their yearly prices/rates in an effort to isolate the sole impact of variable costs to each of the four crops. Yields were detrended from 1996-2005 to allow residuals to better reflect an overall average when considering a forecasted 2006 mean yield estimate.

By allowing the 2005 price of $1.45 per gallon of diesel fuel and $0.30 per pound nitrogen fertilizer to act as a mean price, diesel fuel and fertilizer prices from 1996 to 2005 were adjusted to reflect the actual distribution around this mean, so that net returns above variable costs could be analyzed on the magnitude of the extent to which fuel and fertilizer affect net returns per acre and crop enterprise selection. This process was then duplicated using the 2006 price of $2.20 per gallon of diesel fuel and $0.40 per pound of nitrogen fertilizer serving as the mean price. Net returns above variable costs and crop selection were analyzed based on the observed increase in input prices from 2005 to 2006.

Production costs used in the analysis were taken from projected cost estimates for the 2006 crop year in Northeast Louisiana (Paxton, 2006; Salassi, 2006). Costs for typical production systems for the four crops included: (1) solid planted stacked gene cotton; (2) stale seedbed RoundUp Ready soybeans; (3) conventional corn; and (4) water planted Clearfield rice. Variable costs for 2006 were utilized in the analysis with adjustments for alternative diesel and nitrogen input price distributions. Using regression analysis, mean 2006 trend crop yields per acre were estimated at 150 bushels for corn, 900 pounds for cotton, 38 bushels for soybeans and 66 hundredweight for rice. Estimated net returns for each crop were adjusted for average land tenure in the region with 33 percent of the cropland owned and 67 percent share rented. Share rents were 20 percent for corn, cotton, and soybeans and 30 percent for rice. These share rents are typical of northeastern Louisiana as evidenced in the LSU Ag Center's work in evaluating share rent models for various state commodities.

Estimates of mean net market returns above variable production costs, along with standard deviation and coefficient of variation, are shown in Table 3 for the two sets of diesel and nitrogen prices. Using the 2005 diesel and nitrogen prices as mean prices (NRAVC-1), net returns above variable costs average $70.91 per acre for cotton, $60.49 per acre for corn, $62.57 per acre for rice, and $73.70 per acre for soybeans using 1996-2005 market prices and detrended yields. Using the 2006 input prices as mean prices (NRAVC-2), the mean net returns of all four crops decreased, although the impact was greater for rice and corn. The increase in fuel and fertilizer prices also increased the variability of net returns as estimated by the coefficient of variation.

Functional linear programming constraints specified in the Target MOTAD model included the following:

$$
\begin{array}{llr}
(1) & COT + COR + RIC + SOY & \leq 1.0 \\
(2) & COT & \geq 0.10 \\
(3) & COT & \leq 0.70 \\
(4) & COR & \geq 0.00 \\
(5) & COR & \leq 0.55 \\
(6) & RIC & \geq 0.00 \\
(7) & RIC & \leq 0.40 \\
(8) & SOY & \geq 0.00 \\
(9) & SOY & \leq 0.60
\end{array}
$$

Constraint 1 ensures the sum of the percentages of each of the four crops does not exceed 100 percent. Constraints 2-9 specify a minimum and maximum percentage for each specific crop which allows the percentage of regional acreage accounted for by each crop to vary within the range of plus or minus 30 percent of the historical acreage average of the region. Over the past ten years, cotton has accounted for an average of 39 percent of the region's acreage, corn 24 percent, rice 7.3 percent, and soybeans 29.6 percent. The basic purpose of these constraints is to model the general direction of acreage change in response to fuel and fertilizer price increases while maintaining some measure of asset fixity for specialized production equipment.

Risk constraints were also included for 10 years of historical return data. The Target MOTAD equally weights net return risk across the ten year period. Coefficients for each crop in these constraints represented net returns above variable costs using 1996-2005 actual market prices (or loan rates if higher), detrended crop yields with a mean of projected trend 2006 yield levels, and 2006 variable production costs with variable diesel and nitrogen input prices based on 1996-2005 input price variation and 2005 and 2006 mean price levels.

The goal of Target MOTAD is to maximize net returns around a specified target level of income. Since the crop decision variables in the model were defined as the percent of an acre devoted to each crop, target income levels of $40, $60, and $80 were specified, representing a likely range of market net returns per acre across all four crops. Model results provide multiple sets of optimal crop enterprise solutions with alternative net returns objective function values and associated levels of net return risk. The measure of risk for each solution is the mean absolute deviation which is defined as the average deviation per year around the specified target income for each solution enterprise mix.

Results

Results from the analysis of fuel and fertilizer input price changes on crop enterprise mix are shown in Table 4 for the three levels of target income analyzed. Specifying the target level of net returns at $40 per acre yielded three enterprise mix solutions for each set of input prices. With mean fuel and fertilizer prices set at 2005 levels (NRAVC-1), the first solution devoted 10 percent of the crop mix to cotton, 14.7 percent to corn, 15.3 percent to rice, and 60 percent to soybeans. The higher crop mix value for soybeans results from its relatively high net returns above variable cost per acre compared to the other three crops. Mean net returns for this crop mix were $69.78 per acre with a mean absolute deviation (risk measure) of $10.90. The other two solutions represent crop mixes with higher expected net returns and higher associated levels of net return risk. Acreage originally in corn and rice shifted out of these crops and into cotton, yielding expected mean net returns in excess of $70 per acre.

With the higher 2006 fuel and fertilizer input prices, three solutions were obtained for the $40 target net return level (NRAVC-2). The first solution had 10 percent of the crop mix devoted to cotton and 60 percent in soybeans, similar to the first analysis. However, the remaining 30 percent of the crop mix was devoted all to corn. This shift out of rice and into corn resulted from the fact that with the higher input prices, average market net returns above variable costs for corn exceeded average net returns for rice. Expected mean net returns for this solution as lower, at $59.53 per acre, reflecting the higher diesel and nitrogen costs. The other two solutions were similar in that crop mixes generating higher net returns shift acreage out of corn and into cotton. An important difference is noted in the risk measure. Higher fuel and fertilizer costs not only reduce expected net returns but also increase the risk or variability of those net returns.

With target net returns set at higher levels, similar enterprise mixes were obtained for both input price sets, although expected net returns and measures of risk were different. Two enterprise solution sets were obtained for each input price set. The first solution allocated 10 percent of the crop mix to cotton, 30 percent to rice, and 60 percent to soybeans with no acreage devoted to rice. Expected net returns for this enterprise mix was estimated at $69.46 per acre under the 2005 input price level and $59.3 per acre under the 2006 input price level. A second solution was obtained which moved acreage out of corn and into cotton, yielding a high expected net return per acre and a higher measure of net return risk. Although the risk measures are estimating deviations from higher target levels of income, $60 and $80 per acre, results show that impact of higher fuel and fertilizer prices on net return variability. Deviations of net returns from target income levels increase by more than $10 per acre with higher input prices.

Conclusions

Fuel and fertilizer input prices have risen dramatically over the past couple of years. These input price increases have had a significant impact on the net returns of major crops produced in the Louisiana Delta. Changes in net returns above variable costs were directly related to the quantity of diesel fuel required for tillage and irrigation and the quantity of nitrogen fertilizer required by the crops. Soybean average net returns were reduced by $2.94 per acre, as soybeans require no direct nitrogen fertilization as well as a relatively small amount of tillage passes over the field. Cotton and corn average net returns were reduced by $17.31 and $21.45, resulting from higher field tillage and fertilization. Average net returns for rice were reduced by $27.65 per acre, as rice is a heavy user of nitrogen as well as being an irrigated crop utilizing primarily diesel irrigation power units. The variability of net returns were also increased for those crops which required larger uses of diesel and nitrogen as inputs.

A linear programming methodology incorporating net return risk across four major crops was utilized to evaluate potential directional changes in regional enterprise mix resulting from the increase in input prices. Results of the linear programming analysis incorporating income risk indicated that the higher fuel and fertilizer prices tended to shift acreage out of rice in into corn, cotton, and soybeans which had higher net returns. The results also indicated that for growers with higher income risk preferences, the predicted changes in crop mix were about the same for the lower 2005 input prices as they were for the higher 2006 input prices. Results indicated acreage shifts into cotton and soybeans which had relatively higher net returns given historical commodity market prices.

Results from this analysis showed that not only are market net returns above variable production costs reduced for all crops resulting from increased fuel and fertilizer input costs but the income risk or variability around a mean net return is increased for all crops. This is most significant for crops such as corn and rice which are heavy users of nitrogen. The analysis also suggests that for a given grower income risk preference, the enterprise mix would not be expected to change substantially as the result of increased fuel and fertilizer inputs costs alone. This observation is partly substantiated by observing crop acreage changes. State level acreage data for the three dominant crops (cotton, corn, and soybeans) in the region showed relatively minor changes in acreage 2006 compared to 2005, while rice acreage decreased substantially.

References

Britt, D. W., and K. W. Paxton, *Projected Costs and Returns – Cotton, Soybeans, Corn, Milo and Wheat, Northeast Louisiana, 1996*, LSU Agricultural Center, Dept. of Ag. Economics and Agribusiness, AEA Information Series No. 138, January 1996.

Burton, Jr., R. O., M. F. Crisostomo, P. T. Berends, K. W. Kelley, and O. H. Buller, "Risk/Return Analysis of Double-Cropping and Alternative Crop Rotations With and Without Government Programs," *Review of Agricultural Economics*, 18:681-692 (1996).

Davis, T., Curtis, C., Shumaker, G., and N. Smith. "The Effect of the 2002 farm bill on Crop Enterprise Selection in the Southeast Region," selected paper abstract, *Journal of Agricultural and Applied Economics*, Vol. 35, No. 2, p. 434, August 2003.

Guidry, K., A. Bechtel, S. Hague, R. Hutchinson, and D. Boquet, "Profitability of Cotton Crop Rotation Systems in Northeast Louisiana," *Louisiana Agriculture*, Summer 2001, pp. 22-24.

Helmers, G. A., C. F. Yamoah and G. E. Varvel, "Separating the Impacts of Crop Diversification and Rotations on Risk," *Agronomy Journal*, 93:1337-1340, 2001.

Misra, S. and S. Spurlock. "Incorporating the Impacts of Uncertain Fieldwork Time on Whole-Farm Risk-Return Levels: A Target MOTAD Approach." *Southern Journal of Agricultural Economics*. Vol 23, No. 2, pp. 9-17,1991.

Paxton, K. W., *Projected Costs and Returns – Cotton, Soybeans, Corn, Milo and Wheat, Northeast Louisiana, 2005*, LSU Agricultural Center, Dept. of Ag. Economics and Agribusiness, AEA Information Series No. 226, January 2005.

Paxton, K. W., *Projected Costs and Returns – Cotton, Soybeans, Corn, Milo and Wheat, Northeast Louisiana, 2006*, LSU Agricultural Center, Dept. of Ag. Economics and Agribusiness, AEA Information Series No. 234, January 2006.

Salassi, M. E., *Projected Costs and Returns – Rice, Louisiana, 2006*, LSU Agricultural Center, Dept. of Ag. Economics and Agribusiness, AEA Information Series No. 236, January 2006.

Tauer, L. W. "Target MOTAD". *American Journal of Agricultural Economics*. Vol. 65. No. 3. 606-610. 1983.

Figure 1. Average diesel and nitrogen prices in Louisiana, 1996-2006

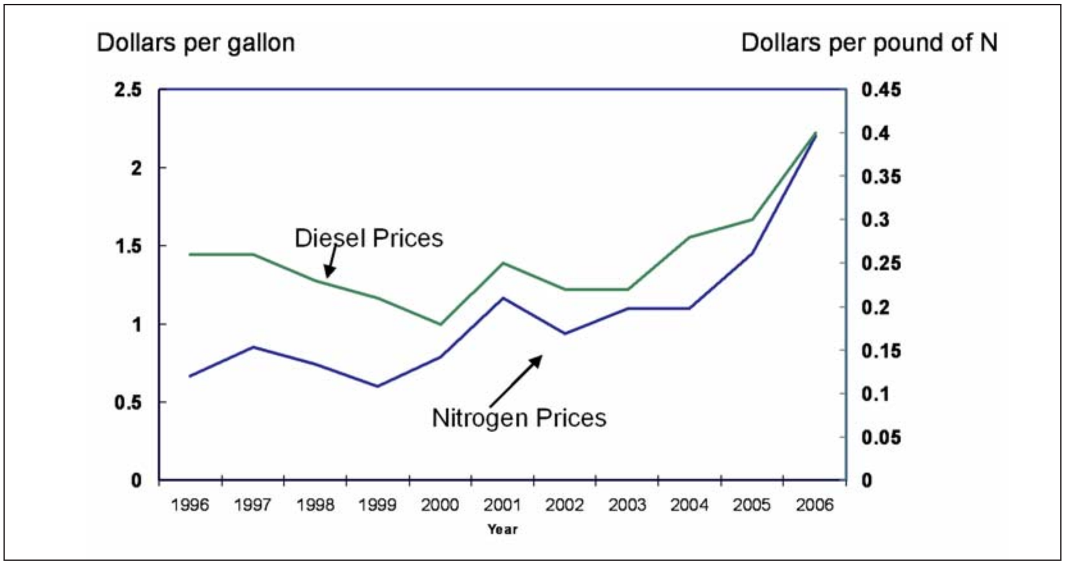

Table 1. Harvested acreage of major crops in northeast Louisiana, 1996-2005

		Percent of Total Acreage in:			
Year	**Total Acreage**	**Cotton**	**Corn**	**Rice**	**Soybeans**
1996	1,229,700	49.3	22.4	6.0	22.4
1997	1,220,700	37.4	19.5	6.7	36.5
1998	1,115,000	33.6	26.9	9.0	30.5
1999	1,074,000	39.6	16.3	9.2	34.9
2000	1,017,000	45.6	21.8	6.0	26.5
2001	992,600	56.4	19.7	7.8	16.1
2002	975,000	33.3	37.4	7.2	22.1
2003	1,128,200	28.6	30.6	5.8	35.0
2004	1,071,400	29.4	25.3	7.3	38.0
2005	1,062,700	37.3	20.5	8.3	34.0
Average	1,088,640	39.0	24.0	7.3	29.6

Table 2. Diesel and nitrogen requirements and costs per acre

	Units	Cotton	Corn	Rice	Soybeans
Diesel use:					
Tractors	gal / acre	7.4	5.8	5.2	3.0
Harvesters	gal / acre	3.7	1.4	2.6	1.2
Irrigation	gal / acre	--	--	19.3	--
Total	gal / acre	11.1	7.2	27.1	4.2
Diesel cost:					
@ $1.45/gal.	$ / acre	16.10	10.44	39.30	6.09
@ $2.20/gal.	$ / acre	24.42	15.84	59.62	9.24
Nitrogen use	lbs / acre	90	160	170	--
Nitrogen cost:					
@ $0.30/lb.	$ / acre	27.00	48.00	51.00	--
@ $0.40/lb.	$ / acre	36.00	64.00	68.00	--
Combined cost increase as percent of total variable costs		4.1%	8.5%	7.9%	2.3%

Table 3. Estimated enterprise net returns above variable costs (NRAVC)

	Units	Cotton	Corn	Rice	Soybeans
NRAVC-1 1/					
Mean	$ / acre	70.91	60.49	62.57	73.70
Standard dev.	$ / acre	87.29	67.91	82.74	46.64
Coef. of Var.	percent	123.1%	112.3%	132.2%	63.3%
NRAVC-2 2/					
Mean	$ / acre	53.60	39.04	34.92	70.76
Standard dev.	$ / acre	87.29	67.91	82.74	46.64
Coef. of Var.	percent	162.8%	174.0%	237.0%	65.9%

1/ Diesel mean price of $1.45 per gallon and nitrogen mean price of $0.30 per pound.
2/ Diesel mean price of $2.20 per gallon and nitrogen mean price of $0.40 per pound.

Table 4. Target MOTAD enterprise mix solution for alternative target net returns per acre

	Percent of Acreage					
	Cotton	**Corn**	**Rice**	**Soybeans**	**Mean NRAVC**	**Risk Measure 3/**
			Target Net Returns of $40 per Acre			
NRAVC-1 1/						
Solution A	10.0	14.7	15.3	60.0	69.78	10.90
Solution B	33.0	7.0	0.0	60.0	71.85	12.84
Solution C	40.0	0.0	0.0	60.0	72.58	14.40
NRAVC-2 2/						
Solution A	10.0	30.0	0.0	60.0	59.53	19.66
Solution B	36.0	4.0	0.0	60.0	63.31	20.62
Solution C	40.0	0.0	0.0	60.0	63.90	21.00
			Target Net Returns of $60 per Acre			
NRAVC-1 1/						
Solution A	10.0	30.0	0.0	60.0	69.46	30.20
Solution B	40.0	0.0	0.0	60.0	72.58	34.58
NRAVC-2 2/						
Solution A	10.0	30.0	0.0	60.0	59.53	42.10
Solution B	40.0	0.0	0.0	60.0	63.90	45.00
			Target Net Returns of $80 per Acre			
NRAVC-1 1/						
Solution A	10.0	30.0	0.0	60.0	69.46	54.20
Solution B	40.0	0.0	0.0	60.0	72.58	58.58
NRAVC-2 2/						
Solution A	10.0	30.0	0.0	60.0	59.53	67.46
Solution B	40.0	0.0	0.0	60.0	63.90	70.38

1/ Mean diesel and nitrogen input price of $1.45/gallon and $0.30/pound, respectively.
2/ Mean diesel and nitrogen input price of $2.20/gallon and $0.40/pound, respectively.
3/ Risk measure is defined as mean absolute deviation.