Marketing of Cotton Fiber in the Presence of Yield and Price Risk

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ABSTRACT

An expected-utility model and a chance-constrained linear programming model were used to analyze four marketing strategies and seven crop insurance alternatives for cotton marketing in Georgia. The results suggest that existing marketing tools and insurance alternatives can be used to reduce cotton producers' revenue risk. The optimal level of yield and price insurance coverage depends on an individual producer's risk aversion.

Key Words: *crop insurance, marketing strategies, risk aversion.*

Less government involvement in agricultural commodity programs has increased the awareness and importance of risk-management tools. The Federal Agricultural Improvement and Reform Act of 1996 (the FAIR Act) changed the link between commodity prices and direct income support, exposing producers to greater risk.

Crop insurance can be used to manage both price and output risk. Since 1995, producers have been able to obtain catastrophic coverage on insurable crops, including cotton, at a level equal to 50 percent of their established yield and 60 percent of the market price due to changes in the legislation. Producers pay an administrative fee of $50 per crop, per county, for catastrophic coverage which is fully subsidized by the government. Producers can purchase additional coverage ranging from 50 percent to 75 percent of average production history (APH), while price insurance coverage

ranges from 60 percent to 100 percent of the base price at planting time. Insurance premiums for additional coverage are partially subsidized, with the subsidy equal to 30 percent of the premium at the 65/100-percent coverage level.

Producers must decide what level of yield/price coverage is appropriate for their respective cotton acreage and what marketing strategies are appropriate given their risk preferences and/or revenue objectives. This study examines the feasibility of using existing market tools in combination with crop insurance to manage price and revenue risk for cotton producers in Georgia.

Objectives

This study analyzes several management scenarios to determine if existing marketing tools, along with crop insurance, can be used to manage revenue risk for cotton producers. Marketing tools include forward contracts, futures contracts, options, as well as cash sales. The specific objective of this research is to examine the use of alternative marketing strat-

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egies, in combination with crop insurance, to improve risk management in cotton production and marketing.

Literature Review

The choice of an optimal combination of marketing strategies requires a knowledge of the available marketing instruments and decision rules that lead to the best marketing strategy. In this section, we review recent literature on marketing tools including hedging with futures and options, firm decision making under uncertainty, and the evaluation of risky alternatives.

Hedging with Futures and Options

Futures and options markets provide producers with tools to protect themselves from price variability. Lapan, Moschini and Hanson (1991) analyzed production, hedging, and speculative decisions when both futures and options are used in an expected utility model of price and basis uncertainty. They found that options are redundant when prices are unbiased. Optimal hedging requires only futures. When prices are perceived as biased, options are used together with futures as management tools.

Vercammen (1995) investigated the possibility of using commodity options when price distributions are skewed and concluded that the usefulness of options as a price-risk management tool depends on the degree of skewness in market price distributions. Brorsen, Buck and Koontz (1998) examined hedging of hard red winter wheat using Kansas City and Chicago wheat futures. They concluded that the producer who maximizes expected utility prefers hedging over the cash market only if the producer is moderately to strongly risk averse.

Firm's Behavior under Uncertainty

A firm operating under market conditions is exposed to various kinds of risk. Holthausen (1979) analyzed the hedging strategy of the firm under price risk. Risk aversion affects the firm's optimal hedge, and if the forward price is less than the expected price, the hedge increases as the firm becomes more risk averse. For non-increasing absolute risk aversion, the optimal hedge increases as price uncertainty increases.

Feder, Just and Schmitz (1980) examined the behavior of a competitive firm under price uncertainty where a futures market exists. The distribution of cash price affects the firm's involvement in the futures market. Production decisions depend essentially on futures and input market prices. Grant (1985) analyzed producers' behavior under price and yield uncertainty. A producer facing joint price and output uncertainty, but without forward contracting opportunities, behaves in the same way as one confronting price risk only. If forward contracting opportunities exist in the presence of both price and output uncertainty, the choice of production scale and optimal forward position are interdependent. Both choices depend upon the joint distribution of price and quantity and upon the producer's degree of risk aversion.

Evaluation of Risky Alternatives

A firm makes a decision under price and output uncertainty based on limited information. The outcomes of a particular decision are revealed ex post, i.e., after the uncertainty is resolved. Since the decision has to be made ex ante (i.e., before the uncertainty is resolved) it has to be evaluated based on ex ante information.

Markowitz (1952) provided a theoretical foundation for portfolio selection employing the first two moments of returns distributions. Given various combinations of mean (E) and variance (V), there exists a set of efficient E-V combinations. If a decision maker can state which E-V combination from an attainable set that she/he prefers, a portfolio can be found which gives the desired combination.

Paris (1979) used quadratic programming to generalize the traditional mean-variance approach originated by Markowitz's portfolio analysis to farm planning under uncertain revenues. This formulation admits nonzero co-

variances between revenues and the costs of limiting inputs. It also allows computation of risk coefficients associated with a companion chance-constrained programming model.

Balkeslee (1997) developed a method to find a sequence of expected utility maximizing decisions under risk aversion when random elements are time-dependent. A Taylor-series approximation of expected utility was used along with dynamic programming to find the optimal sequence of marketing decisions. Balkeslee found that the optimal sequence of sell-hold marketing decisions depends on the level of wheat prices and the risk aversion of the decision maker. Information from this literature review was used to develop risk-management models for Georgia cotton producers.

Risk-Management Models and Assumptions

Chance-constrained linear programming and expected utility maximization can deal with n risky alternatives and choose the combination of those alternatives that gives the highest returns for a given confidence level (a chance-constrained programming model) or the highest expected utility (an expected-utility model). Assume that the representative producer grows 500 acres of cotton in south Georgia. The producer chooses a level of yield and price insurance coverage and a combination of marketing strategies which may include 1) cash sale at harvest, 2) forward contracting, 3) futures hedging, and 4) buying put options.

Seven Multiple Peril Crop Insurance (MPCI) levels were considered for yield-risk protection. These alternative yield/price coverages in percentages were 50/60, 50/100, 55/100, 60/100, 65/100, 70/100, and 75/100.

The first model assumes that the decision maker has a continuous, twice differentiable, and concave utility function. He/she chooses a combination of marketing strategy and insurance level that maximizes expected utility. The second model uses chance-constrained linear programming to find an optimal combination of marketing strategy and insurance level, subject to the constraint that the revenue

should be greater than variable costs at a chosen confidence level. Both decision models use price and yield distributions which were estimated from time-series data.

Historical distributions of prices and yields were used to calculate expected revenue in the case of the chance-constrained model and expected utility in case of the expected-utility model. Producers evaluate different futures prices in the spring which include a range of expected prices for all marketing strategies except cash sale at harvest. Thus, there were different payoffs and risk levels for different futures prices.

Both the expected-utility model and the chance-constrained utility model find the optimal insurance level and marketing strategy. The objective function in the expected-utility model is measured in utility whereas in the chance-constrained model, the objective function is measured in revenue. In the light of Von Neuman-Morgenstern work, revenue can be reparametrized to reflect utility level.

The main difference between these two models is that the expected-utility model is an unconstrained optimization problem. There is always a solution even if it is below the acceptable utility level. Chance-constrained programming requires minimum revenue at a given confidence level to arrive at a solution, which may not always exist. In both models, 5000 random drawings from the estimated distributions of yield and prices were used to calculate expected returns.

Expected-Utility Model

Under the expected-utility model, the representative agent has a continuous, twice differentiable, and concave utility function with a Arrow-Pratt constant absolute risk-aversion (CARA) coefficient. The utility function is:

$$U = -\exp(-\alpha R)$$

where U is the utility function, α is the coefficient of risk aversion, and R is revenue from a given marketing strategy or combinations of marketing strategies and insurance level. The representative producer chooses the combina-

tion of marketing strategies and insurance level that maximizes expected utility of revenue. Three risk-aversion coefficients commonly used in the literature were used in this analysis: 0.01, 0.03, and 0.1 (e.g. Balkeslee; Brorsen *et al.*, Rolfo).

Chance-Constrained Linear Programming Model

The chance-constrained programming chooses the best combination of marketing strategies and insurance levels given a minimum revenue requirement and a confidence level within which the minimum revenue objective is achieved. The objective function is:

$$\max\left(\sum_{i=1}^{n} P_i Y_i - Ip + Id\right)$$

subject to:

$$Y_i \geq 0, \quad \forall I$$

$$\sum_{i=1}^{n} Y_i \leq EP$$

$$\sum_{i=1}^{n} P_i Y_i - Ip + Id - K_\alpha\left[\mathrm{Var}\left(\sum_{i=1}^{n} P_i Y_i\right)\right]^{1/2}$$
$$\geq R_{\min}$$

where P_i is the expected price received under marketing strategy i, Y_i is a share of marketing strategy i, Ip is the insurance premium paid, Id is the indemnity payment received, K_α is constant for given confidence level α, $Var(\sum_{i=1}^{n} P_i Y_i)$ is the variance of revenue numerically calculated, EP is the expected production, and $R_{\min}$ is the minimum revenue equal to the variable costs of production which was assumed to be $300/acre (Givan and Shurley).

Estimating Distributions of Cotton Yields and Prices

In order to apply the expected-utility model or the chance-constrained linear programming model, price and yield distributions are required. Once price and yield distributions are

estimated, random draws from those distributions can be used to simulate prices and yields, which are then used in both the chance-constrained linear programming model and expected-utility model.

Eighteen years of average county data for 53 counties in Georgia were regressed on the annual trend and a dummy variable for the different counties in order to estimate the distribution of cotton yield. The residuals from this regression were plotted and examined for nonnormality by calculating skewness and kurtosis. Then residuals were used to estimate the variance of cotton yield.

To estimate the distribution of cash price, 18 years of average monthly cotton prices at Memphis, Tennessee were regressed against the annual trend and dummy variables representing the different months. Then, the residuals from this regression were examined and used to estimate the variance of cotton cash price. Memphis cotton prices were assumed to be a good proxy for Georgia spot prices since a consistent set of state wide prices were unavailable.

Empirical Results

Expected-Utility Model

The optimal combination of marketing strategies was independent of the insurance level for risk-averse producers (0.01). The optimal strategy was to sell two futures contracts (100,000 lbs.), forward contract 250,000 lbs., and sell the remaining balance (18,500 lbs.) in the November cash market. The optimal insurance level was to elect the 50/60 yield/price option that is available for the minimal subsidized processing fee of $50 per crop, per county.

The optimal result for risk-aversion coefficients of 0.03 and 0.1 differed only by the insurance option selected. The insurance coverages were the 65/100 and 75/100 yield/price options for the 0.03 and 0.1 risk-aversion coefficients, respectively. The associated marketing strategy included signing four forward contracts, purchasing three put options and

Table 1. Optimal Marketing Strategies and Optimal Insurance Coverage for a Risk-Aversion Coefficient of 0.01 Under the Expected-Utility Model at Different Futures Price Levels[1]

Expected Utility	Insurance Coverage Level	Number of Futures Contracts	Number of Forward Contracts[2]	Number of Put Options	Cash Sale (1000 lbs.)	Futures Price Level ($/lb)
--- Risk-Aversion Coefficient of 0.01 ---						
−0.110261	50/60	0	0	0	368.5	0.65
−0.109919	50/60	0	0	3	218.5	0.66
−0.108771	50/60	0	0	6	68.5	0.67
−0.107105	50/60	0	0	7	18.5	0.68
−0.105348	50/60	0	0	7	18.5	0.69
−0.103304	50/60	0	2	5	18.5	0.70
−0.100716	50/60	0	4	3	18.5	0.71
−0.097913	50/60	0	5	2	18.5	0.72
−0.094986	50/60	0	5	2	18.5	0.73
−0.092061	50/60	1	5	1	18.5	0.74
−0.088946	50/60	2	5	0	18.5	0.75

[1] The expected cotton yield was 737 lbs/acre while the expected futures price was equal to $0.7505/lb.
[2] One forward contract was assumed to be equal to 50,000 lbs. Futures and options contracts are in 50,000 lbs. units.

selling the remaining 18,500 lbs in the cash market (Wojciechowski 1998, p. 65).

A sensitivity analysis of different strategies and insurance alternatives was performed to evaluate a change in pre-planting futures price levels on the optimal marketing strategies. The spring futures price level was allowed to range from 60 to 75 cents per pound. The results for different levels of futures prices are summarized in Tables 1, 2 and 3.

For risk-averse preferences (0.01), the optimal strategy is to purchase the basic 50/60 crop insurance coverage while the optimal marketing strategies vary from cash sale at

Table 2. Optimal Marketing Strategies and Optimal Insurance Coverage for a Risk-Aversion Coefficient of 0.03 Under the Expected-Utility Model at Different Futures Price Levels[1]

Expected Utility	Insurance Coverage Level	Number of Futures Contracts	Number of Forward Contracts[2]	Number of Put Options	Cash Sale (1000 lbs.)	Futures Price Level ($/lb)
--- Risk Aversion Coefficient of 0.03 ---						
−0.002766	50/60	0	0	0	368.5	0.62
−0.002759	50/60	0	0	1	318.5	0.63
−0.002729	50/60	0	0	2	268.5	0.64
−0.002677	50/60	0	0	3	218.5	0.65
−0.002608	50/60	0	0	4	168.5	0.66
−0.002523	50/60	0	0	5	118.5	0.67
−0.002428	50/60	0	0	6	68.5	0.68
−0.002327	50/60	0	0	7	18.5	0.69
−0.002223	50/60	0	0	7	18.5	0.70
−0.002117	50/60	0	1	6	18.5	0.71
−0.001974	65/100	0	4	3	18.5	0.72
−0.001825	65/100	0	4	3	18.5	0.73
−0.001678	65/100	0	4	3	18.5	0.74
−0.001539	65/100	0	4	3	18.5	0.75

[1] The expected cotton yield was 737 lbs/acre while the expected futures price was equal to $0.7505/lb.
[2] One forward contract was assumed to be equal to 50,000 lbs. Futures and options contracts are in 50,000 lbs. units.

Table 3. Optimal Marketing Strategies and Optimal Insurance Coverage for a Risk-Aversion Coefficient of 0.1 Under the Expected-Utility Model at Different Futures Price Levels[1]

Expected Utility	Insurance Coverage Level	Number of Futures Contracts	Number of Forward Contracts[2]	Number of Put Options	Cash Sale (100 lbs.)	Futures Price Level ($/lb)
		Risk Aversion Coefficient 0.1				
−7.975E-8	75/100	0	2	2	168.5	0.60
−6.944E-8	75/100	0	2	2	168.5	0.61
−6.058E-8	75/100	0	2	2	168.5	0.62
−5.170E-8	75/100	0	2	3	118.5	0.62
−4.346E-8	75/100	0	2	3	118.5	0.63
−3.626E-8	75/100	0	3	2	118.5	0.64
−2.986E-8	75/100	0	3	2	118.5	0.65
−2.986E-8	75/100	0	3	2	118.5	0.66
−2.454E-8	75/100	0	3	2	118.5	0.67
−2.001E-8	75/100	0	3	3	68.5	0.68
−1.620E-8	75/100	0	3	3	68.5	0.69
−1.307E-8	75/100	0	3	3	68.5	0.70
−1.037E-8	75/100	0	4	3	18.5	0.71
−8.150E-9	75/100	0	4	3	18.5	0.72
−6.354E-9	75/100	0	4	3	18.5	0.73
−4.881E-9	75/100	0	4	3	18.5	0.74
−3.693E-9	75/100	0	4	3	18.5	0.75

[1] The expected cotton yield was 737 lbs/acre while the expected futures price was equal to $0.7505/lb.
[2] One forward contract was assumed to be equal to 50,000 lbs. Futures and options contracts are in 50,000 lbs. units.

low levels of futures prices to using the options market as futures prices rise. Forward contracts become optimal at higher levels of futures prices. Futures contracts were included in the optimal strategy only at the highest levels of cotton futures prices and in conjunction with a combination of forward contracts and put options (Table 1).

At the risk-aversion coefficient of 0.03, the optimal combination of marketing strategies and insurance coverage changes. For this level of risk aversion the optimal marketing strategy is to sell the output in the cash market at harvest for low levels of futures prices while the preferred insurance level is the 50/60 yield/price coverage. As the futures price levels increase, the optimal marketing strategy includes options and then forward contracts. At higher futures prices the optimal insurance coverage increases to 65/100 percent coverage (Table 2).

When the expected-utility model with a risk-aversion coefficient of 0.1 is used, the optimal crop insurance coverage increases to 75/100 percent which is the maximum possible

(Table 3). The optimal marketing strategies consisted of a combination of put options, forward contracts, and cash sale. The amount of output under forward contract increases from two to four contracts with an increase in futures prices (Table 3). The producer's optimal marketing strategy is to lock in the price through forward contracting for 27 to 54 percent of production depending on the level of futures prices. Put options protect 150,000 lbs or 41 percent of expected production against price declines but allow for upside price appreciation. The balance of expected production is sold in the cash market.

Chance-Constrained Linear-Programming Model

The chance-constrained linear-programming model was applied to 1997 cotton data. The base data included a futures price of 75.05 cents/lb, a yield of 737 lbs./acre, and a put option price of 3.01 cents per pound with a strike price of 75 cents/lb. As in the previous model, the

Table 4. Chance-Constrained Linear Programming Results for 1997 Cotton Data and 95 Percent Confidence Level

Expected Revenue[1]	Insurance Coverage Level	Number of Futures Contracts	Number of Forward Contracts	Number of Put Options	Cash Sale (1000 lbs.)
258.542	00/00	2	5	0	18.5
258.690[2]	50/60	2	5	0	18.5
255.008	50/100	2	5	0	18.5
253.351	55/100	2	5	0	18.5
251.378	60/100	2	5	0	18.5
250.334	65/100	2	5	0	18.5
246.265	70/100	2	5	0	18.5
240.273	75/100	2	5	0	18.5

[1] Expected revenue from 500 acres of cotton in thousands of dollars.
[2] The base data included a futures price of 75.05 cents/lb, yield of 737 lbs./acre, and a put option price of 3.01 cents per pound.

expected production on 500 acres was equal to 368,500 lbs. For the 1997 data at the 95-percent confidence level, the optimal level of insurance coverage was 50/60 with the following combinations of marketing strategies: two futures contracts (100,000 lbs) and five forward contracts (250,000 lbs), with the remainder of expected production (18,500 lbs.) to be sold in the cash market at harvest. The optimal combination of marketing strategies was the same for other insurance levels (Table 4).

At the 99-percent confidence level the optimal level of insurance coverage was the 65/100 insurance alternative. The optimal marketing strategy included one futures contract (50,000 lbs), five forward contracts (250,000 lbs), one put option (50,000 lbs), with the remainder of the expected production (18,500 lbs.) to be sold in the cash market at harvest (Table 5).

As with the expected-utility model, the response to a change in cotton futures price levels was analyzed. Sensitivity of the solution to a change in futures price levels in the spring was analyzed by varying futures price levels from 65 to 75 cents/lb. The confidence levels were kept the same at 95 and 99 percent, respectively.

Regardless of the level of futures prices, the optimal insurance option was 50/60 at the 95-percent confidence level where expected

Table 5. Chance-Constrained Linear Programming Results for 1997 Cotton Data at 99-Percent Confidence Level

Expected Revenue[1]	Insurance Coverage Level	Number of Futures Contracts	Number of Forward Contracts	Number of Put Options	Cash Sale (1000 lbs.)
ns[2]	0/0	ns	ns	ns	ns
ns	50/60	ns	ns	ns	ns
ns	50/100	ns	ns	ns	ns
ns	55/100	ns	ns	ns	ns
247.844	60/100	0	4	2	68.5
249.992[3]	65/100	1	5	1	18.5
246.265	70/100	2	5	0	8.5
240.273	75/100	2	5	0	18.5

[1] Expected revenue from 500 acres of cotton in thousands of dollars.
[2] ns—no solution found.
[3] The base data included a futures price of 75.05 cents/lb, yield of 737 lbs./acre, and a put option price of 30.1 cents per pound.

Table 6. Chance-Constrained Linear Programming Results for 1997 Cotton Data at 95-Percent Confidence Level and Different Level of Futures Prices

Expected Revenue[1]	Insurance Coverage Level	Number of Futures Contracts	Number of Forward Contracts	Number of Put Options	Cash Sale (1000 lbs.)	Level of Futures Price ($/lb)
238.587	50/60	0	0	1	318.5	0.65
238.762	50/60	0	0	1	318.5	0.66
238.959	50/60	0	0	1	318.5	0.67
240.192	50/60	0	0	7	18.5	0.68
241.741	50/60	0	0	7	18.5	0.69
243.450	50/60	0	0	7	18.5	0.70
245.474	50/60	0	4	3	18.5	0.71
248.480	50/60	0	5	2	18.5	0.72
251.616	50/60	0	6	1	18.5	0.73
255.041	50/60	1	6	0	18.5	0.74
258.512	50/60	2	5	0	18.5	0.75

[1] Expected revenue from 500 acres of cotton in thousands of dollars.

revenue is equal to or greater than the variable costs. The combination of marketing alternatives is different for alternative levels of futures prices. At low levels of futures prices it is optimal to buy put options for only part of the expected production. As the level of futures prices increases beyond 65 cents/lb., the number of put options purchased goes up. For futures prices above 70 cents/lb., it becomes optimal to use four, five, or six forward contracts. Only at futures prices above 73 cents/lb. does it become optimal to purchase futures contracts (Table 6).

The optimal insurance coverage for the 99-percent confidence level and a futures price equal to or greater than 70 cents/lb. is 65/100 percent. At futures prices below 70 cents/lb., the optimal yield coverage increases to 70–75 percent and price coverage to 100 percent (Table 7). For the futures prices of 65 cents/lb. and below, no feasible solution was found that would guarantee the expected revenue to be equal to or greater than variable costs at the 99-percent confidence level.

The most popular insurance level bought by cotton producers is 65/100 according to the data obtained from Rain and Hail Crop Insurance Company (1998). Results from the

Table 7. Chance-Constrained Linear Programming Results for 1997 Cotton Data and at 99-Percent Confidence Level and Different Level of Futures Prices

Expected Revenue[1]	Insurance Coverage Level	Number of Futures Contracts	Number of Forward Contracts	Number of Put Options	Cash Sale (1000 lbs)	Level of Futures Price ($/lb)
219.164	75/100	0	2	4	68.5	0.66
225.928	70/100	0	2	4	68.5	0.67
229.208	70/100	0	0	7	18.5	0.68
230.596	70/100	0	0	7	18.5	0.69
234.006	65/100	0	3	2	118.5	0.70
236.814	65/100	0	3	3	68.5	0.71
240.464	65/100	0	4	3	18.5	0.72
243.628	65/100	0	5	2	18.5	0.73
246.642	65/100	0	5	2	18.5	0.74
250.031	65/100	1	5	1	18.5	0.75

[1] Expected revenue from 500 acres of cotton in thousands of dollars.

expected-utility model as well as the chance-constrained linear programming model correspond very closely to actual producer behavior in Georgia.

Conclusions

This study examined the feasibility of using existing marketing tools to manage price and output risk in the marketing of cotton products in Georgia. The significance of this research is increased by the fact that the 1996 Farm Bill reduces protection for agricultural producers, exposing them to more price and revenue risk than at any time since the 1930s. Two major practical implications result from this research.

First, existing marketing tools can be used in price-risk management as demonstrated in this study. A combination of marketing strategies can be used to reduce price and revenue risk for cotton producers. This is of particular importance in a period of changing farm programs. The optimal marketing strategy or combination of marketing strategies depends, for the most part, on the level of the futures prices prior to planting in the spring.

Second, crop yield insurance coverage can complement marketing tools to provide better protection for producers' revenues. The optimal insurance level depends on the level of producers' risk aversion which varies for individual cotton farmers. As producers become more risk averse, their level of yield and price coverage increases, especially at higher pre-planting futures price levels.

Under the 1996 Farm Bill, with its emphasis on less government intervention in farm commodity prices, the importance of marketing strategies increases in a more volatile environment. The results of this study demonstrate that existing marketing tools, in combination with crop insurance, can be used to reduce price and output uncertainty. Moreover, through the use of crop insurance, government intervention in the agricultural product market can be reduced without exposing agricultural producers to full price and output risk.

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