RISK EFFICIENCY OF ALTERNATIVE PRE-HARVEST MARKETING STRATEGIES FOR SOUTH TEXAS COTTON

Shahin Bahrami
John Robinson
Texas A&M University
College Station, TX

Abstract

Three risk management strategies were simulated for a representative dryland cotton farm in the Texas Coastal Bend. The strategies included purchasing Revenue Protection insurance (RP), purchasing Yield Protection insurance (YP), and purchasing put options pre-harvest. The combination of coverage level for each insurance policy and the time of purchasing put options yields five separate strategies. Each marketing strategy was ranked based on the certainty equivalent (CE) of net returns associated with it. Monte-Carlo simulation model was used to simulate the stochastic yield, stochastic futures prices, and stochastic basis values, and these simulated values were implemented for the calculation of net returns linked with each strategy. The rankings of strategies were consistent across different levels of coefficient of relative risk aversion (CRRA) for a decision maker. Buying a put option in May plus purchasing YP insurance with the coverage level of 60 percent had the highest CE across all risk aversion coefficients from zero to four. Buying a put option later in June with YP of 60 percent coverage level and buying a put option in July with YP of 60 percent coverage level were ranked second and third, respectively. The analysis shows that the earlier marketing of South Texas cotton could be a risk efficient risk management strategy.

Introduction

The marketing of agricultural commodities plays a substantial role in overall farm profitability. The variability in yield because of stochastic weather influences, and the irregularity in prices due to inconsistent market conditions, can both impact farm profitability. There are several different marketing and risk management strategies that farmers use such as forward pricing, insurance policies, or storing the products for deferred sale. There are some levels of risk associated with each strategy, but an efficient combination of them may preserve more income of field crop farmers. The efficiency of financial markets including the commodity futures market has been a debating topic in academia. A financial market is efficient when it can accurately incorporate all available information about the price (Fama, 1970). Efficient market theory (EMT) supporters believe that today's prices of assets reflect all obtainable data available to the participants in the market. That being said, it is not achievable for an individual decision-maker (DM) to make a considerable profit from speculating about the future prices, since the information that DM is taking its position based on is also available to all others in the market. However, this view of an efficient market has been disputed by several scholars, believing that Fama's assumptions of no transaction costs and the costless information are not common characteristics of modern financial markets (Grossman and Stiglitz, 1980).

There are also several studies that specifically focus on the efficiency of the cotton futures market. Brorsen, Bailey, and Richardson (1984) investigated the price discovery and the efficiency of cash and futures cotton prices. Unlike the previous studies, they compared current cash and current futures prices rather than comparing future cash prices with current futures prices. They defined the efficient market as the one that can adjust itself instantaneously by new information. Based on this restrictive definition of efficient market, their model suggested that both futures market and the cash market for cotton are inefficient. However, they asserted that this cannot be conclusive without having more information about the transaction cost. Wood, Shafer, and Anderson (1989) examined the profitability of hedging for Texas High Plains cotton producers and concluded that profitable hedging opportunities are available for a considerable duration of time both before and after planting season. Bailey and Richardson (1985) evaluated selected marketing strategies using a whole-farm dynamic Monte Carlo simulation for cotton farmers in the southern high plains of Texas. They recursively simulated the annual yield, farm policy, financial management, growth, and income tax functions of a farm over a ten-year horizon to rank the farm's net worth using stochastic dominance for the set of alternative strategies. Bailey and Richardson (1985) concluded that hedge and hold marketing strategies are preferred to the discretionary hedging strategies by risk-averse decision maker. Coble, Zuniga, and Heifner (2003) studied the interaction of alternative insurance designs with futures hedging and the purchase of options for cotton and soybeans. They concluded that insurance policies and forward pricing strategies are not separable for an expected utility maximizing producer, but crop insurance can provide bigger risk reduction in comparison with other risk management tools. Curtis, Isengildina-Messa, and Hummel (2007) analyzed the variables affecting the premiums of options on ICE cotton futures to identify a period in time that would be preferred for the purchasing of December put option contract for corn and cotton. They used the Black-Scholes (1973) model to evaluate option premiums and concluded that March may be the best time to purchase pre-harvest put options, noting that March displayed plenty amount of time to maturity, low amount of implied volatility, and highest observed futures price. Elrod (2008) evaluated three marketing strategies for a representative west Texas High Plains cotton farm. The strategies he evaluated were forward pricing with put options, cash selling at harvest time, and selling the crop in June of the following year through storing.

The purpose of this project is to evaluate the trade-offs in net returns versus risk for different strategies for marketing Texas Coastal Bend cotton. The objective is to identify the risk efficient combination of the following strategies: 1) Revenue Protection (RP) insurance with coverage levels of 60 percent, and 70 percent. 2) Yield Protection (YP) insurance with coverage levels of 60 percent, and 70 percent and 3) purchasing a put option in May, June, and July to short hedge against price fluctuation. A dynamic, recursive, Monte Carlo simulation is used to simulate the ending net returns for a cotton grower in a representative farm in South Texas region. Assuming there is a weak form of market efficiency in the cotton futures market, this paper analyzes the tradeoff in net returns versus risk. It investigated the interchangeability of insurance policies with put options. The results from this project will inform the value of ongoing improvements in Precision Agriculture (PA), which develops a machine learning-based cotton yield estimation framework using multi-temporal data from unmanned aircraft systems (Ashapure, et al, 2020).

Materials and Methods

A Monte Carlo simulation model was used to evaluate marketing and risk-mitigating strategies for a representative dryland cotton farm in Texas Coastal Bend. The model simulated the net returns associated with different combinations of strategies. Yield and prices were generated stochastically by the model, and these random values were used to create the components of the stochastic net returns.

The model simulated stochastic yield based on the historical yield data of Texas Coastal Bend. The yield values were not identically, independently distributed (iid), and could not be used for the purpose of resampling and simulation. The model obtained residuals (ε_Y) for the regression of the yield values over time, and these residuals passed the iid criteria required for the resampling. The study investigated the distribution of these new variables and found the log-gamma distribution as the best fit and obtained the Percent Point Function (PPF) of this distribution. Independent standard uniform draws were generated, and through plugging them into the PPF by multiple iterations, the model simulated stochastic deviates from the mean. Stochastic yield then was obtained by adding these random deviates to the mean value of the yield for a representative Coastal Bend cotton farm.

(1) Expected Yield = $ß_0 + ß_1$ * Time
(2) Stochastic Yield = Expected Yield + ε_Y

The study did not account for the correlation between the yield and prices, since the production level in Coastal Bend area was substantially smaller in comparison with the overall cotton production.

To simulate the futures price values, this study used a Geometric Brownian Motion (GBM) process, which itself is a Markov process with assumptions that are consistent with weak-form market efficiency. GBM is capable of using the current state of price variables to characterize its future path considering that the logarithm of the price variable follows a Brownian motion with drift. A discrete-time representation of the GMB was used for the changes in the natural logarithm of December cotton futures prices. Stochastic values for December cotton futures prices were obtained by reverse transformation of logarithm function. The study simulated the values of futures for 106 consecutive business days starting from a representative planting time of mid-March.

(3) $\text{Log}(P_t) - \text{Log}(P_{t-1}) = ”\ \log(P_t) = (-0.5 * \sigma^2)\ ”\, t + \sigma_p * z_{kt} * ”\, t^{0.5}$

P_t = Future Price at time t
σ_p = Annualized standard deviation of volatility
$”\, t$ = Time period
z_{kt} = Joint Standard Normal draw accounting for correlation matrix between futures price and Basis value
Basis values were simulated using mean-reverting benchmark price procedure introduced by Ross (1978) to generate

stochastic spot prices for cotton in May, June, July, and harvest time in mid-August.

(4) $\text{Basis}_{(t)} = \text{Spot Price}_{(t)} - \text{Futures Price}_{(t)}$

(5) $B_t - B_{t-1} =$ ” $B = \gamma * (ß - B_{t-1}) *$ ” $t + \sigma * z_{kt} *$ ” $t^{0.5}$

B_t = Basis Value at time t
γ & ß = Estimated Parameters
z_{kt} = Joint Standard Normal draw

Stochastic spot prices were simulated by adding the stochastic basis values to the stochastic futures as follows:

(6) $\text{Stochastic Spot Price}_{(t)} = \text{Stochastic Basis}_{(t)} + \text{Stochastic Futures}_{(t)}$

Stochastic option premiums were generated using the Black-Scholes (1973) model, using the simulated values of futures prices. The model evaluated “at-the-money” put options which defined the strike price the same as the futures values.

(7) $\text{Premium} = e^{-r*t} * [f * N(d_1) - s * N(d_2)]$

$d1 = (\boldsymbol{ln}\,(\boldsymbol{f}/\boldsymbol{x}) + (\mathbf{0.5} * \boldsymbol{\sigma}^2)\,\boldsymbol{t}) / (\boldsymbol{\sigma} * t^{0.5})$
$d2 = d1 - \boldsymbol{\sigma} * t^{0.5}$
Ln = Natural Logarithm
f = current underlying futures price
s = At-the-money strike price
r = Risk free interest rate
$\boldsymbol{\sigma}$ = Standard Deviation of the underlying futures price
N = Standard Normal CDF

For different times of purchasing options, the premiums were different because of the component of Black-Scholes equations such as strike price, futures values, and time to maturity were all time specific.

The study used representative insurance premium data from 2021 obtained from New Frontier Capital Markets, LLC to calculate the net revenue of insurance policies (Table 1).

Table 1. Insurance premiums

Coverage Level	60%	70%
Yield Protection	$22.21	$35.29
Revenue Protection	$24.75	$39.06

Insurance indemnities for both yield and revenue protection policies were obtained from the following equations:

(8) YP Indemnity = Projected price * Max(0, APH *Cover level – Yield)

(9) RP Indemnity = Max (0, Revenue Guarantee – Yield * Capped Harvest Price)

Projected Price = Planting time new-crop futures price
APH = Actual Proven History
Cover level = Level of coverage that producer selects
Yield = Realized yield
Capped Harvest Price = Min (Harvest Price, 2 * Projected Price)
Revenue Guarantee = Cover Level * Approved Yield * Max (Projected Price, Capped Harvest Price)

The study assumed that farmers sell their crops at the spot price in cash during harvest time in August. The components of net returns were the market receipts through selling in cash, revenue from insurance, revenue from options, cost of options and insurance, and the variable cost of growing cotton.

(10) Option Revenue = Max (0, Strike Price – Futures at Harvest Time)

(11) Option Cost = Yield * Option Premium

(12) Stochastic Spot Price = Stochastic futures – Stochastic Basis

(13) Stochastic Market Receipts = Stochastic Yield * Stochastic Spot

(14) Variable Cost = (Picking cost + Ginning cost) * Stochastic Yield

(15) Net Returns = Market Receipts + Option Revenue + Insurance Revenue – Option Cost – Insurance Cost – Variable Cost

Data

Historical yield data for Coastal Bend cotton was collected from USDA-NASS website for twenty years. Cotton futures price data were obtained from Intercontinental Exchange (ICE) to simulate November settlement prices for a December cotton contract. Historical spot price data were obtained from USDA-AMS data compiled at Texas A&M University (Gleaton 2021). Insurance premium data was provided by the New Frontier Capital Markets, LLC which contain the quotes from 2021 insurance year in Nueces County, Texas.

Results and Discussion

The Monte Carlo model simulated the net returns over 500 trials of each strategy for 104 business days from planting in mid-March to harvest time mid-August. The model estimated the net returns of the following strategies:

- Strategy (1): Revenue protection insurance with the coverage level of 60% (RP, 60%)
- Strategy (2): Revenue protection insurance with the coverage level of 70% (RP, 70%)
- Strategy (3): Yield protection insurance with the coverage level of 60% (YP,60%) and purchasing put option in early May
- Strategy (4): Yield protection insurance with the coverage level of 60% (YP,60%) and purchasing put option in early June
- Strategy (5): Yield protection insurance policy with the coverage level of 60% (YP,60%) and purchasing put option in early July

The summary statistics for net returns per acre include mean, standard deviation, minimum, median, and maximum. The model showed that strategy (3) has the highest mean value of $362.53 for the net returns among the five strategies (Table 2). Strategy (4) and (5) comes next respectively with the mean of $360.81 and $356.97. Strategy (1) and (2) had the lowest mean and highest standard deviation. Strategy (3) also had the lowest standard deviation at $96.94.

Table 2	Mean	Std	Min	Max	Median
Strategy 1	354.71	105.72	144.18	681.47	344.40
Strategy 2	343.08	102.14	147.19	667.16	331.16
Strategy 3	362.53	96.94	154.21	656.64	362.09
Strategy 4	360.81	100.59	138.26	656.57	354.73

Strategy 5	356.97	101.83	116.30	658.55	351.50

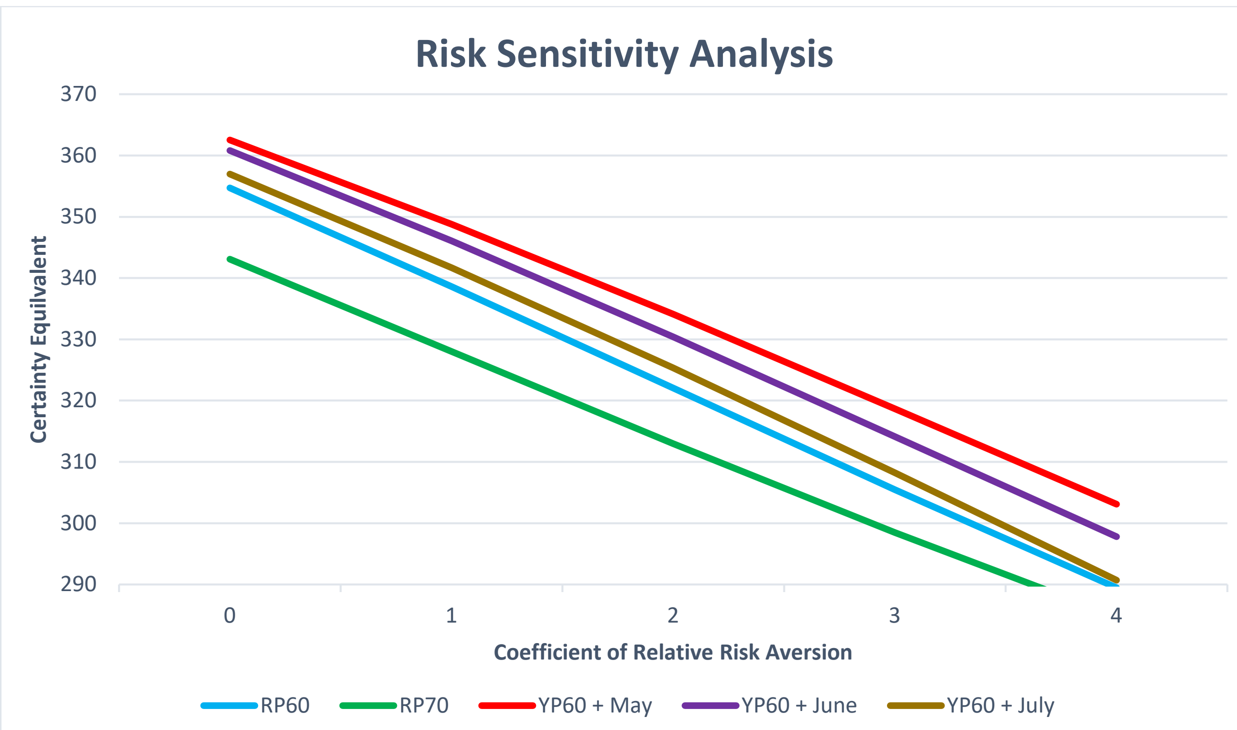
The study used Isoelastic utility function for the purpose of sensitivity analysis over the risk aversion levels of decision makers. Four levels of coefficient of relative risk aversion (CRRA) from zero to four were used to obtain the certainty equivalent value of net returns for each strategy. The decision maker becomes more risk averse as the CRRA increases.

Assuming that cotton farmers are expected utility maximizers, the following equation was used to calculate the certainty equivalent values of net return for each strategy over five levels of attitude towards risk.

$$U(Y) = \begin{cases} Y^{(1-crra)} - 1 \,/\, 1 - crra & \text{for crra } \epsilon \ [0, \infty] \backslash 1 \\ Log(y) & \text{for crra} = 1 \end{cases}$$

where y = monetary outcome and CRRA = coefficient of relative risk aversion.

The sensitivity analysis results were consistent among all coefficient of relative risk aversion, and the ranking of strategies did not change. Strategy (1) kept the highest mean of net returns among all strategies, which can be interpreted that earlier purchasing of put options can play a role of a cheap insurance compared with other strategies. Figure 1 shows the certainty equivalent values for each strategy across five levels of CRRA. Higher coefficient of risk aversion leads to a lower certainty equivalent as the agent become more risk averse.



Summary

This study used Monte-Carlo simulation to estimate and rank the net return associated with several risk management strategies. The model suggested that earlier marketing of cotton-purchasing put options in May appears risk efficient strategy for decision makers regardless of their risk attitudes.

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