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# Performance of the Producer Accumulator in Corn and Soybean Commodity Markets

*This research quantifies risk reduction and performance of the producer accumulator contract in corn and soybean markets. To quantify performance, we use three alternative theoretical pricing models to estimate historical producer accumulator contract specifications in corn and soybean markets. We then compare the performance of the producer accumulator to eight alternative agricultural marketing strategy portfolios that are also used in new generation grain contracts.*

*The performance measures we compare are: average bushel price that would be received by the producer, daily portfolio risk, and the Sharpe ratio. The period we examine performance was between 2008 and 2017. We investigate performance of the producer accumulator executed during each year, month, whether the contract was executed during the growing season or non-growing season, and beginning and following an uptrend, neutral trend, and downtrend ranging in length from 25 to 100-days. Specific to the producer accumulator, we also quantify bushels accumulated during the contract period.*

*We find the average price the producer would expect to receive adopting an accumulator to slightly underperform the average price they would receive with a long futures portfolio in corn and slightly outperform long futures in soybeans. Nevertheless, the accumulator significantly reduces daily risk compared to the long futures portfolio. Indeed, producer accumulator portfolios produced average daily Sharpe ratios exceeding all other simulated risk management strategies in corn and soybeans on an average annual and average aggregate basis from 2008-2017. Consequently, the producer accumulator portfolio offered corn and soybean producers the best risk adjusted return to hedge production during this time-frame.*

**Key words:** agricultural risk management, marketing contracts, producer accumulator.

## Introduction

### *Background*

The accumulator is an over-the-counter derivative product that originated in Hong Kong equity markets in 2002. Accumulator contracts were introduced to the commodity futures market by INTL FCStone Trading, and were first offered to corn and soybean producers in 2005. The producer accumulator is currently offered across the Midwest through local cooperatives, and commodity purchasing firms such as CHS, ADM, and Cargill. Producer accumulator contracts are dominantly concentrated in the Midwestern states of Iowa, Nebraska, and Illinois. The producer accumulator functions as an averaging contract that is time-path dependent due to weekly bushel accumulation over the duration of the contract. The dual intent of commodity purchasing firms and local cooperatives offering the accumulator was to provide an alternative grain marketing product and to increase the amount of grain sales originated from large scale corn and soybean operations (Johnson, 2006).

The producer accumulator offers pricing benefits to producers' conditional on the price time-path of the underlying futures contract. For producers, the incentive includes an offer to sell corn or soybean bushels above the current CBOT futures price. To obtain the incentivized futures price, producers must agree to the doubling up conditions associated with crossing the accumulation strike price and the termination terms affiliated with breaching the knock-out barrier. Consequently, if the CBOT futures price rises above the accumulation strike price, doubling up of contracted bushels to accumulate occurs at some interval that the price remains above the strike price. For example, when doubling up occurs, producers must sell twice the weekly bushel quantity that is sold under normal circumstances where price is spatially between the accumulation strike price and knock-out barrier price. In effect, the producer sells more bushels as price increases and remains above the at the accumulation strike price, but would be limited to twice as many bushels as contracted. Selling more bushels than originally intended can present risk for the producer as potential bushels sold could be greater than the expected bushels to be sold when the producer accumulator was originated. Conversely, when the CBOT futures price falls below the knock-out barrier, the producer accumulator contract immediately terminates and bushels accumulated prior to knock-out are priced at the accumulation strike price, while no remaining contracted bushels will be priced. Thus, the remaining bushels offered under the accumulator contract will assume full risk of daily price movements that would occur with a long futures portfolio (Johnson, 2006).

The producer accumulator is offered in varying contract durations ranging from a minimum of 16 weeks to a maximum of 67 weeks. Duration is largely dependent on the structural agreement between the offering firm and the producer. To assemble an accumulator contract, the producer contracts with their local grain buying firm. Upon executing, or beginning an accumulator contract, the total bushel quantity offered in the contract, designated weekly day, accumulation period, accumulation strike price, knock-out barrier price, delivery timeline, and service charge are determined and agreed upon. As with accumulators in equities, these contracts conventionally come with a zero-cost structure—meaning there are no 'out-of-pocket expenses' to execute an accumulator. However, some commodity firms may charge a servicing fee (Johnson, 2006).

*Justification for Research and Contribution*

Accumulator contracts have been referred to as the "I-Kill-You-Later" contract. The general assumption of the accumulator is that it can present unfair risk management. This notion arises from prior academic research and literature that focuses on the buy side or consumer's perspective for accumulators in equity, currency, and commodity markets. However, the existing research fails to explore the sell side of an accumulator or the producer's perspective. Moreover, while the literature has discussed the makeup and properties of accumulator contracts using theoretical pricing models, there has not been research validating alternative theoretical option pricing models to estimate actual accumulator contract specifications that are offered in the marketplace. Furthermore, the current literature is void of recommendations to execute and measure the performance of the producer accumulator in commodity markets.

We fill this void by providing empirical tests that determine the effectiveness of the producer accumulator as a risk management tool for producers of a commodity to hedge production in corn and soybeans. By quantifying profitability and risk reduction, we inform agricultural producers of

the effectiveness of the producer accumulator as a risk management tool. Further, we provide methods to quantify accumulator performance in other markets. Because of the scarcity of public research on accumulators, and its exotic nature, grain merchandisers, commodity purchasing firms, and producers may not fully understand the accumulator contract performance under changing market conditions. We contribute to the agricultural marketing risk management literature by providing clarity of zero-cost producer accumulator performance with delayed settlement in corn and soybean commodity markets to improve optimal use and execution of accumulator contracts.

*Research Objectives*

The specific objectives include:

1. Identify a theoretical price model that best fits the observed offerings of the producer accumulator using observed accumulation strike and knock-out barrier price data.

2. Quantify profitability and risk reduction for the producer accumulator.

3. Compare the risk reduction and profitability of the producer accumulator portfolio to alternative agricultural strategy portfolios.

4. Provide recommendations to producers for optimal use of the producer accumulator using back-testing in corn and soybean commodity markets.

## Methodology

*Zero-cost Producer Accumulator Model and Payoffs*

Zero-cost producer accumulator contracts are structured by combining three barrier options into a portfolio. Table 1 outlines all common barrier options by option, type, and barrier location (Derman & Kani, 1996). Specifically, the portfolio consists of one long down-and-out put option on a forward contract and two short down-and-out call options on a forward contract. All three barrier options maintain the same accumulation strike price, knock-out barrier price, settlement day, discrete barrier monitoring, and expiration day. Consequently, to obtain accumulation strike prices for the synthetic producer accumulator contracts, we theoretically price the portfolio of all three down-and-out options and find where the three options provide offsetting amounts of premiums received and premiums paid. The strike price, barrier price, barrier monitoring, and settlement date that satisfies the offsetting condition we define as the zero-cost accumulator that could theoretically be offered without assuming risk. In practice, producers integrating a producer accumulator contract into their marketing strategy deliver physical corn or soybeans sold after contract expiry. Because of this, we price our down-and-out barrier options assuming delayed settlement. In over-the-counter markets, barrier options are generally assumed to maintain a discretely monitored knock-out barrier. In addition, producer accumulator contracts knock-out if the knock-out barrier is crossed during CBOT market trading hours. Since underlying price is not monitored on a continuous basis, we assume a discretely monitored barrier.

We adapt the framework of Lam et al. (2009) to construct the synthetic producer accumulator portfolio and quantify the spatial payoffs. The value of the zero-cost producer accumulator with delayed settlement and discrete barrier monitoring is determined from a portfolio of two short down-and-out call options on a forward contract and one long down-and-out put option on a forward contract as defined in Equation 1,

(1) $V^{Delay} = \sum_{i=1}^{n}\{P_{do}^{F}(X, H_d, t_i, T_i) - 2 \cdot C_{do}^{F}(X, H_d, t_i, T_i)$

where $V^{Delay}$ is the value of the zero-cost producer accumulator portfolio under delayed settlement, $P_{do}^{F}(X, H_d, t_i, T_i)$ is the down-and-out put price on a forward contract, $C_{do}^{F}(X, H_d, t_i, T_i)$ is the down-and-out call price on a forward contract, $X$ is the accumulation strike price, $H_d$ is the discretely monitored knock-out barrier price, $T_i$ is the forward contract maturity date, and $t_i$ is the observation date.

Producer accumulator contracts require that during the contract's lifetime $t$, the producer sells a weekly fixed quantity $q$ of the underlying futures commodity $F$ at the accumulation strike price $X$ on the defined weekly observation day $t_i$, delivered on the settlement date $T_i$, contingent on the knock-out barrier $H_d$. Observation days cannot be the same day $t_1 < t_2 < \cdots < t_n$ , but delayed settlement days may be the same day $T_1 \leq T_2 \leq \cdots \leq T_n$. Producer accumulator contracts generally support a zero-cost structure, demanding no initial premium payment by the contract holder to establish the contract. To formalize our producer accumulator payoffs under delayed settlement and discrete barrier monitoring, we adapt the spatial payoff methodology of Lam et al. (2009). Spatial payoffs for the producer accumulator under delayed settlement and discrete barrier monitoring are defined as,

(2) $0 \qquad if\ \ max_{0 \leq \tau \leq ti}\, F_\tau \ \leq\ H_d$
(3) $X - F_{Ti} \qquad if\ \ max_{0 \leq \tau \leq ti}\, F_\tau \ >\ H_d,\ F_{ti} \ \leq\ X$
(4) $2(X - F_{Ti}) \qquad if\ \ max_{0 \leq \tau \leq ti}\, F_\tau \ >\ H_d,\ F_{ti} \ >\ X$

where $F_{ti}$ is the futures contract price on the observation day, $F_\tau$ is the futures contract price for all CBOT futures contract trading hours, $F_{Ti}$ is the futures contract price on the settlement day, $X$ is the accumulation strike price, $H_d$ is the knock-out barrier price with discrete monitoring, $ti$ is the observation day, $\tau$ is all trading hours, and $T_i$ is the maturity date of the forward contract.

The first payoff is zero. It follows that if the underlying futures contract price for all CBOT futures contract trading hours $F_\tau$ breaches the knock-out barrier price $H_d$, knock-out prompts conclusion of the contract permanently, fixing no current weekly sales, yet former weekly sales $q_i$ remain. The second payoff is the difference between the accumulation strike price $X$ and the futures contract price on the settlement day $F_{Ti}$. It follows that if the underlying futures contract price for all CBOT futures contract trading hours $F_\tau$ is strictly greater than the knock-out barrier price $H_d$ and the futures weekly closing price on the observation day $F_{ti}$ is less than or equal to the accumulation strike price $X$, then the producer sells the weekly fixing quantity $q$. The third payoff is two times the difference between the accumulation strike price $X$ and the futures contract price on the settlement day $F_{Ti}$. It follows that if the underlying futures contract price for all CBOT

futures contract trading hours $F_\tau$ is strictly greater than the knock-out barrier price $H_d$ and the futures weekly closing price on the observation day $F_{ti}$ is strictly greater than the accumulation strike price $X$, then the producer sells twice the weekly fixing quantity $2q$.

*Synthetic Producer Accumulator Contracts*

To determine our theoretical pricing method to model actual producer accumulator contracts offered in practice, we collected a limited set of producer accumulator contract indication data from 9/6/2016-2/28/2017 offered by INTL FCStone. To expand our set of accumulator contracts for performance back-testing, we constructed synthetic producer accumulator contracts and price them using option pricing models and linear regression models that best fit the specifications that were used by INTL FCStone. In total, we constructed 5,150 synthetic producer accumulator contracts referencing the monthly corn futures contracts of March (H), July (N), and December (Z) as underlying from 1/18/2008-2/23/2017. To simulate the producer accumulator in the soybean market, we constructed 5,166 synthetic producer accumulator contracts ranging from 1/18/2008-2/23/2017 referencing the soybean futures contract months of March (H), July (N), and November (X) as underlying.

Producer accumulator contract terms include: futures price, accumulation strike price, knock-out barrier price, and contract end date that is aligned with the referenced futures contract month. Violation of the accumulation strike price or knock-out barrier price is contingent on the price-time path of the referenced futures contract. Synthetic producer accumulator contracts follow the bushel pricing and payoff criteria outlined in the zero-cost accumulation strike models section. We use a multiple linear regression to determine a knock-out barrier price for our synthetic contracts. Determination of the knock-out barrier price for our synthetic contracts is discussed further in the knock-out barrier estimation section. Based on the contract's terms, zero-cost accumulation strike price for each synthetic contract is estimated by the three-alternative barrier option pricing models discussed in the zero-cost producer accumulation strike models section. To estimate the strike prices and find the zero-cost contract we used MATLAB's Financial package. The end date we used for all synthetic producer accumulator contracts was the expiration date of the underlying futures contract.

Our synthetic producer accumulator contracts range in duration from 60-20 weeks. Synthetic contracts are executed every week between 60 and 20 weeks allowing us to capture the performance of contracts with different durations. Coinciding with duration, each contract start date or execution date occurs on a weekly basis between 60-20 weeks from the expiration of the referenced futures contract. Regardless of duration and start date, each synthetic contract is designed to sell 5,000 bushels over the contract's life. Because of the producer accumulator's double accumulation and knock-out characteristics, potential bushels accumulated can range from 0-10,000 bushels despite the contract origination offering of 5,000 bushels. There is no guarantee level of the bushels accumulated by the producer accumulator contract. In a situation where contract knock-out occurs prior to pricing the contracted 5,000 bushels, or no double up occurs freeing up bushels that remain unpriced to cover up a potential double up scenario, are priced at the underlying futures price at the end of the contract period. Table 2 and Table 3 provide examples of corn and soybean producer accumulator contracts that were back-tested.

*Knock-Out Barrier Estimation*

To determine the knock-out barrier price of our synthetic producer accumulator contracts, we use the observed set of accumulator contracts offered by INTL FCStone and a multiple linear regression to estimate a model to predict barrier placement. Because the knock-out barrier price is a function of the underlying futures price and time to expiration, the futures price of the referenced futures contract and the number of trading days until contract expiration were used as independent variables. To estimate the coefficients for the independent variables in the knock-out barrier price equation, we use 176 INTL FCStone producer accumulator contract observations in corn and 195 INTL FCStone producer accumulator contract observations in soybeans. Observation data consisting of the knock-out barrier price, futures price, and the number of trading days until contract expiration is based off the referenced futures contracts CH7, CN7, CZ7, CH8 for corn and SH7, SN7, SX7, SH8 for soybeans during 9/6/2016-2/28/2017.

Regressing the INTL FCStone observed value for futures price and number of trading days until contract expiration on the observed INTL FCStone knock-out barrier prices, we identify the model parameters for the knock-out barrier price equation. To calculate the knock-out barrier price value for each synthetic producer accumulator contract, we identify the knock-out barrier price equation as seen in Equation 5 as,

(5) $y_i = \beta_i x_i + \beta_j x_j + e_i$

where $y_i$ is the knock-out barrier price value for the synthetic producer accumulator contract, $\beta_i$ is the futures price beta coefficient from the multiple linear regression defined by the observed data, $x_i$ is the futures price of the referenced futures contract month, $\beta_j$ is the number of trading days until contract expiration beta coefficient from the multiple linear regression defined by the observed data, $x_j$ is the number of trading days until contract expiration, and $e_i$ is the residual.

*Zero-Cost Accumulation Strike Models*

Once we established our contract valuation date, expiration date, underlying futures contract, and knock-out barrier price, we used the theoretical framework of the Cox-Ross-Rubinstein (CRR) binomial tree model, Longstaff-Schwartz (LS) method, and the finite difference (FD) explicit approximation method to estimate accumulation strike prices for our synthetic producer accumulator contracts and to validate the best model to estimate accumulation strike prices given our observed contract specifications offered by INTL FCStone. Using the MATLAB Financial package, our synthetic accumulator contract accumulation strike prices were determined where there was zero-cost to the contracting party. Specifically, this occurs when the premium needed to purchase the in-the-money down-and-out put is offset by selling two out-of-the-money down-and-out calls. To validate the accuracy of each model's estimated accumulation strike prices, we compared each model's zero-cost accumulation strike price to the accumulation strike prices offered by INTL FCStone using the observed producer accumulator contract data. The option pricing formula that best fit the INTL FCStone data was selected to further price the synthetic producer accumulator contract portfolios to conduct performance back-testing.

*Cox-Ross-Rubinstein Binomial Tree Model*

Cox, Ross and Rubenstein (1979) proposed the binomial options pricing model (BOPM) to value American and European options in discrete time. The CRR binomial model assumes that there only two potential prices for the underlying asset $S$ at the end of each time interval $t + 1$, either an up price $S_u$ with probability $p$ or a down price $S_d$ with probability $1 - p$ (Cox et al., 1979).

The CRR binomial tree consists of nodes at each time interval between option valuation and expiration. Each node represents a potential future price of the underlying asset at a specific point in time. Options are valued through the numerical method in a three-step process for American options. The binomial price tree is established by working forward, calculating the underlying asset's price at each node from the valuation date to expiration date. Underlying price can either branch up or down by a fixed value at each node, which is calculated based on volatility $\sigma$ and time $t$, following the random walk theory. Node positions for the binomial tree are established by the equations,

(6) $S_u = Su$
(7) $S_d = Sd$
(8) $u = e^{\sigma\sqrt{\delta t}}$
(9) $d = e^{-\sigma\sqrt{\delta t}}$
(10) $p = \frac{e^{R\delta t} - d}{u - d}$

where $R$ is the risk-free rate of return and $\delta t$ is the time interval between $t$ and $t + 1$.

At the option's expiration, intrinsic values are calculated at each final node. For a call option, the option value at the final node is defined in Equation 11 as,

(11) $V_n = Max[(S_n - X), 0]$

and for a put option, the option value at the final node is defined in Equation 12 as,

(12) $V_n = Max[X - (S_n), 0]$

where $V_n$ is the value of the node at expiration, $S_n$ is the price of the underlying asset and $X$ is the option's strike price.

The option's theoretical value is calculated by backward induction or discounting the option's payoffs backward from expiration to the valuation date. Through backward induction, a value is consecutively calculated at each node in the tree by the following for an American-style call option that is expressed in Equation 13 as,

(13) $V_n = Max\left[(S_n - Xe^{-R\delta t}(pV_u + (1 - p)V_d)\right]$

and an American-style put option as shown in Equation 14 as,

(14) $V_n = Max\left[(X - S_n e^{-R\delta t}(pV_u + (1-p)V_d)\right]$

where $V_u$ is the value of the option from an upper node in the next time period $t+1$ and $V_d$ is the value of the option from the lower node in the next time period $t+1$.

Discounted payoff value and early exercise value or intrinsic value are calculated at each node between the expiration date and the valuation date. Due to the no arbitrage rule, the greater of the discounted payoff value or early exercise value is taken for the option's value at each node. European options have a similar process, although they only consider the discounted payoff value at each node and not the early exercise value. This difference in valuation process ensues since early exercise is a feature of American options, not European options (Cox et al., 1979).

*Longstaff-Schwartz Model*

The Longstaff-Schwartz (LS) model values options using simulation to define the optimal exercise strategy by comparing the intrinsic and conditional expectation values at each exercise point to approximate a discounted cash flow matrix. Simulation functions as a comparative alternate to the valuation methods of binomial trees and finite difference. Derivatives with an American exercise style and a path-dependent nature can benefit from valuation by simulation. Since American options allow their owner to exercise them at any time from valuation to expiration, there are countless exercise possibilities. At any point in time, the owner of an American option contrasts the payoff associated with immediate exercise and the payoff associated with delayed exercise or the expected payoff from continuation (Longstaff & Schwartz, 2001).

The ideal exercise strategy requires determining if the payoff is greater from either immediate exercise or delayed exercise via the value of the expected payoff from continuation. Immediate exercise value is derived from the intrinsic value of the option. Because the option holder can choose between the two exercise times, with the option's intrinsic value known, the decision relies on the approximation of the continuous value. The delayed exercise value is found by calculating the conditional expectation through Monte Carlo simulation by means of OLS regression (Longstaff & Schwartz, 2001).

Final expected payoffs from continuation are regressed on state variables to find the fitted value. The regression's fitted value provides an estimated conditional expectation value for each exercise time on each path. Optimal exercise strategy or stopping rule at each in-the-money path is estimated by simulating the conditional expectation at all exercise times and comparing it to the immediate exercise value, then choosing the higher of the two. This process is repeated reiteratively to define the option cash flow matrix. Discounting the values in the option cash flow matrix back for all paths allows for the American option to be valued at time zero (Longstaff & Schwartz, 2001).

The Longstaff-Schwartz methodology assumes a probability space $(\Omega, F, P)$ and a finite timeframe $[0, T]$. State space $\Omega$ is the possibility of outcomes between 0 and T where the sample path $\omega$

represents an individual outcome, $F$ is the sigma information set of filtration actions at time $T$ and $P$ denotes the probability measure on the factors of $F$. $C(\omega, s\,; t, T)$ is the path of the option's cash flows with the stipulation that the option is only exercised later than $t$ and the option owner adopts the optimal stopping strategy at every point in time later than $t$. The holder of the American option considers the optimal stopping policy and can only exercise on restricted dates $0 < t_1 \leq t_2 \leq t_3 \ldots < t_K = T$. If the option owner immediately exercises the option when the immediate exercise value is equivalent or larger than the continuation value, option value is maximized. Considering the no-arbitrage environment, the value of continuation is required to be equivalent to the risk-neutral expectation of discounted future cash flows $C(\omega, s\,; t_k, T)$. The continuation value $F(\omega; t_k)$ is defined in Equation 15 as,

$$(15)\ F(\omega; t_k) = E_Q[\textstyle\sum_{j=k+1}^{K} \exp(-\int_{t_k}^{t_j} R(\omega, s)ds)\ C\big(\omega, t_j\,; t_k, T\big)\ l\ F_{t_k}]$$

where $R(\omega, t)$ is the risk-free discount rate and $(F_{t_k})$ is the information set at time $t_k$. At each possible exercise date, the algorithm uses ordinary least squares regression to estimate the conditional expectation value. Comparing the conditional expectation value to the immediate exercise value, optimal exercise occurs when the immediate value is greater than or equal to the conditional expectation value. From the valuation date to the final exercise date, the procedure is repeated at each exercise time (Longstaff & Schwartz, 2001).

*Finite Difference Explicit Approximation Model*

The finite difference method uses discrete difference equations to approximate the continuous differential equations that reveal how the options price changes across time. It can adapt to valuing a wide variety of options, including exotic American derivatives such as barrier options. Black and Scholes (1973) established the analytical solution for the valuation of European put and call options. When an analytical solution is not a plausible method, the finite difference method can be implemented to estimate solutions for option values that are accurate measures across tiny discrete time changes. Option price at time $t$ is linked to three different prices at time $t + \Delta t$ in the explicit version of the finite difference method (Hull & White, 1990).

Pricing options with the finite difference method requires a grid of potential future prices of the underlying asset. A price grid is established by taking the time between the valuation date and expiration and dividing it into $T$ equivalent time periods and dividing the underlying asset's price range into $N$ equivalent intervals. This creates a grid with $N + 1$ price intervals and $T + 1$ time periods. Notably, the price grid chosen should have the underlying asset's initial price at the middle of the $N$ equivalent price intervals (Hull & White, 1990).

Boundary conditions are defined for the anticipated price range of the unknown value $f(t, S)$. Identification of boundary conditions is important as they establish minimum and maximum values for $S$, along with outlining the expected payoff of the option at expiration. Boundary conditions are used to calculate the payoff at each boundary point on the grid. With the option's value at the boundary conditions calculated, values for the interior points on the grid can be calculated through backward induction at all grid locations (Hull & White, 1990).

The differential equation is satisfied by a riskless portfolio that consists of an asset whose value is represented by $S$ and an option whose value is represented by $f(t, S)$. The partial differential equation contains partial derivatives with respect to time $t$ and the underlying asset's value $S$.

The explicit finite difference method uses the Black-Scholes-Merton partial differential equation and is assumed to follow geometric Brownian motion. The Black-Scholes-Merton partial differential equation is defined as Equation 16,

(16) $\frac{\partial f}{\partial t} + R\frac{\partial f}{\partial S}S + \frac{1}{2}\frac{\partial^2 f}{\partial S^2}\sigma^2 S^2 = Rf$

where $R$ is the risk-free interest rate, $\sigma$ is volatility, and $f$ is the value of the option derivative.

For explicit finite difference approximation, the Black-Scholes-Merton partial differential equation is discretized by the backward approximation method through forward difference to find $\frac{\partial f}{\partial t}$. We get Equation 17 defined as,

(17) $\frac{\partial f}{\partial t} = \frac{f_{j+1,i} - f_{j,i}}{\delta t}$

where $f_{j,i}$ is the node price of the derivative on the grid at the price level $i$ and $j$ denotes the grid time step.

Delta $\frac{\partial f}{\partial S}$ is estimated by central differences as seen in Equation 18 as,

(18) $\frac{\partial f}{\partial S} = \frac{f_{j+1,i+1} - f_{j+1,i-1}}{2\delta S}$

Gamma $\frac{\partial^2 f}{\partial S^2}$ is estimated by central differences shown in Equation 19 as,

(19) $\frac{\partial^2 f}{\partial S^2} = \frac{f_{j+1,i+1} + f_{j+1,i-1} - 2f_{j+1,i}}{\delta S^2}$

All three approximations are substituted into the Black-Scholes-Merton partial differential equation to define Equation 20 as,

(20) $\frac{f_{j+1,i} - f_{j,i}}{\delta t} + r\frac{f_{j+1,i+1} - f_{j+1,i-1}}{2\delta S}S + \frac{1}{2}\frac{f_{j+1,i+1} + f_{j+1,i-1} - 2f_{j+1,i}}{\delta S^2}\sigma^2 S^2 = Rf_{j,i}$

which simplifies to Equation 21 as,

(21) $f_{j,i} = \frac{1}{1+R\delta t}(p_u f_{j+1,i+1} + p_m f_{j+1,i} + p_d f_{j+1,i-1})$

Explicit finite difference parameters are defined as,

(22) $p_u = \frac{1}{2}(\sigma^2 i^2 + Ri)\delta t$
(23) $p_m = 1 - (\sigma^2 i^2)\delta t$
(24) $p_d = \frac{1}{2}(\sigma^2 i^2 - Ri)\delta t$

Backward induction uses the options payoff at expiration to calculate the prior grid node values back to the valuation date to obtain the option's price at valuation (Haug, 2007).

*Zero-Cost Accumulation Strike Model Validation Methods*

To identify the best valuation model for pricing the zero-cost accumulation strike prices for our synthetic producer accumulator contracts, we focus on the accumulation strike price prediction accuracy and residual minimization ability of each barrier option pricing model. Contrasting the valuation capability of the Cox-Ross-Rubinstein binomial model, Longstaff-Schwartz method, and finite difference method, we employ three efficiency tests. Measuring prediction accuracy, we test the fit of each models predicted zero-cost accumulation strike price to the observed zero-cost accumulation strike price values from INTL FCStone. A root-mean-square error (RMSE) test and a mean absolute error (MAE) test quantify the residual minimization proficiency of each framework.

Testing the accuracy of the predicted zero-cost accumulation strike prices generated under each model, we run a simple linear regression to evaluate how well the predicted zero-cost accumulation strike price values fit the observed zero-cost accumulation strike price values. The simple linear regression equation is shown in Equation 25,

(25) $y_i = \beta \hat{x}_i + e_i$

where $y_i$ is the INTL FCStone observed zero-cost accumulation strike price, $\beta$ is the correlation coefficient, $\hat{x}_i$ is the predicted zero-cost accumulation strike price from the barrier option pricing model, and $e_i$ is the residual.

Root-mean-square error (RMSE) or root-mean-square deviation (RMSD) is implemented to measure the difference between observed values and values predicted by a model. By measuring the difference between observed and predicted values, the residuals identified represent the sample standard deviation. Taking the square root of the average squared errors gives a higher weighting to large errors and a lower weighting to small errors, thus testing error consistency. Comparing the root-mean-square values among models quantifies prediction accuracy. The model with the lowest root-mean-square error unit value has the best prediction accuracy since the predicted values fit the data efficiently, while the model with the highest root-mean-square error unit value has the worst predication accuracy as the predicted values don't fit the data proficiently. Root-mean-square error is calculated using Equation 26,

(26) $RMSE = \sqrt{\frac{\sum_{i=1}^{n}(\hat{y}_i - y_i)^2}{n}}$

where $\hat{y}_i$ is the predicted zero-cost accumulation strike price by the barrier option pricing model, $y$ is the observed INTL FCStone zero-cost accumulation strike price, and $n$ is the number of observations.

Mean absolute error (MAE) is applied to quantify the average absolute difference between the values predicted by a model and the observed data. By measuring the absolute difference between observed values and predicted values, residuals are calculated. Contrasting the mean absolute error values of apposing models indicates each model's prediction efficiency. The model with the lowest mean absolute error value maintains the greatest forecasting ability as the predicted values fit the observed data efficiently; the model achieving the highest mean absolute error value has the poorest predication proficiency since the predicted values cannot fit the data accurately. Mean absolute error is calculated by Equation 27,

(27) $MAE = \frac{1}{n}\sum_{i=1}^{n}|\hat{y}_i - y_i|$

where $\hat{y}_i$ is the predicted zero-cost accumulation strike price by the barrier option pricing model, $y$ is the observed INTL FCStone zero-cost accumulation strike price, and $n$ is the number of observations.

*Agriculture Strategy Portfolios*

Performance back-testing of the producer accumulator portfolio with other agricultural marketing strategy portfolios provides relative benchmarks to producer accumulator contract performance from a risk management and returns perspective. To gauge producer accumulator performance relative to other strategies, we compare eight agricultural marketing strategy portfolios. Risk management strategies chosen for comparison include: long futures, protective put, covered call, long strangle, short strangle, long straddle, short straddle, and collar.

Based on the nature of the eight strategies, we classify each strategy portfolio as a hedging portfolio strategy, long option portfolio strategy, or short option portfolio strategy. Table 4 lists the agricultural marketing strategy portfolios simulated. We categorize the long futures portfolio, collar portfolio, and producer accumulator portfolio as hedging strategies because they lock in a fixed price or a fixed price range for marketed bushels. The long futures portfolio consistently sells bushels on a weekly basis at a fixed price mirroring the weekly hedged price. Risk management through the collar strategy portfolio maintains downside price protection, adding a price floor, by limiting upside profit potential to establish a fixed price range. While the long futures portfolio purely integrates long futures contracts, the collar portfolio strategy consists of selling an out-of-the-money call and buying an out-of-the-money put. Premiums from these options offset one another and establish a price range. The producer accumulator portfolio prices bushels on a weekly basis at the fixed accumulation strike price. Pricing bushels at the accumulation strike price provides a premium to the underlying futures price at origination and hedges bushels if the underlying futures price remains above the knock-out barrier price.

Short option strategies generally benefit the seller when underlying price volatility stays low and price remains range bound over the strategy's duration. Often, these strategies consist of selling options either out-of-the money or at-the-money. The covered call portfolio, short strangle portfolio, and short straddle portfolio sell options, therefore, profiting when price volatility remains stagnant and underlying price remains in a range. Using the covered call strategy, selling an out-of-the money call for risk reduction, gives the producer downside protection by receiving premium for capping upside profit potential. Short strangle strategies, sell an out-of-the-money call and put, and short straddle strategies, sell an at-the-money call and put, paying the option seller premium to cover the risk associated with undesirable volatile market moves.

Long option strategies typically profit when underlying price volatility drastically changes during the strategy's life. Generally, strategies consisting of buying options at-the-money or out-of-the-money fall into this category. The protective put portfolio, long strangle portfolio, and long straddle portfolio purchase options; thus, profiting when underlying price moves out of the normal price range due to uncommonly high volatility. By buying an out-of-the-money put and paying a premium on each bushel, the protective put strategy is a natural way for the producer to establish a price floor for their production. Long strangle strategies buy an out-of-the-money call and put, while long straddle strategies buy an at-the-money call and put. Under both strategies, option buyers pay premium to the seller for risk coverage associated with unwanted volatile price changes.

All portfolio strategies contain long two futures contracts to simulate a naturally long market position of 10,000 bushels. Producers incorporating the producer accumulator contract into their risk management strategy will have corn or soybeans in the bin or in the field where the physical bushel price is correlated with long futures price risk. Each portfolio has no more than two futures contracts and two options. All simulated portfolios will be based off the same referenced monthly futures contracts for futures price, start date, end date, and maintain the same duration. Therefore, all portfolios provide a consistent comparison to hedge or enhance returns to a portfolio consisting of 10,000 bushels of corn or soybeans with expectations of exiting the long position at different durations between 20-60 weeks.

We quantify profitability and risk measures allowing the comparison of realized performance and risk reduction of each portfolio strategy. For all portfolio strategies, we calculate each synthetic portfolio contract's average price, average daily return, average daily log return, average daily portfolio standard deviation, average daily log portfolio standard deviation, and average daily portfolio Sharpe ratio. A higher daily portfolio standard deviation represents a higher variability of expected daily returns from the portfolio. A lower daily portfolio standard deviation signifies a lower variability in expected daily returns from the portfolio. The equation for daily portfolio standard deviation is defined as,

$$(28)\ \sigma_p = \sqrt{w_1^2\sigma_1^2 + w_2^2\sigma_2^2 + 2w_1w_2\rho_{1,2}\sigma_1\sigma_2}$$

where $\sigma_p$ is the daily portfolio standard deviation, $w_1$ is the proportion of the portfolio invested in asset one, $w_2$ is the proportion of the portfolio invested in asset two, $\sigma_1$ is the daily standard

deviation of returns for asset one, $\sigma_2$ is the daily standard deviation of returns for asset two, and $\rho_{1,2}$ is the correlation coefficient between the returns of asset one and asset two. Sharpe ratio is a measure for calculating risk-adjusted return on an asset or portfolio based on the return exceeding the risk-free rate of return per unit of risk. The Sharpe ratio shows the added return of holding a risky asset over a risk-free asset subject to the risky asset's volatility. A higher Sharpe ratio signifies greater return per unit of risk for the risky asset than the return on the risk-free asset. A lower Sharpe ratio denotes a lower return per unit of risk on the risky asset than the risk-free asset. The equation for the daily portfolio Sharpe ratio is shown by Equation 29 as,

$$(29)\ S_p = \frac{\bar{r}_p - r_f}{\sigma_p}$$

where $S_p$ is the daily portfolio Sharpe ratio, $\bar{r}_p$ is the expected daily log return, $r_p$ is the daily risk-free rate of return on a 1-year U.S. Treasury Bill, and $\sigma_p$ is the daily log portfolio standard deviation. In addition to profitability and risk metrics, specific to the producer accumulator portfolio, we quantify total bushel accumulation for each synthetic producer accumulator contract.

## Data

### *Futures and Interest Rate Prices*

To examine the performance of the producer accumulator contract, we price synthetic producer accumulator portfolio contracts and do back-testing using secondary corn and soybean futures contract data, producer accumulator contract corn and soybean indication data, and interest rate data. The price and volatility data was obtained from Bloomberg. The price series and volatility data used was daily last price, daily low price, and daily 100% at-the-money implied volatility for the corn futures contract months of March (H), July (N), and December (Z) from 1/18/2008-4/7/2017, and for the soybean futures contract months of March (H), July (N), and November (X) from 1/18/2008-4/10/2017. We used annual 1-year U.S. Treasury bill data from the beginning of the year, including annual rate and date, ranging from 1/1/2008-1/2/2017 to provide a benchmark risk-free rate of return.

### *Producer Accumulator Indications*

Actual producer accumulator contract offerings from INTL FCStone were obtained for a limited period. Producer accumulator contract indication data of valuation date, daily futures price, contract month, daily start date, daily end date, accumulator contract duration, accumulation strike price, and knock-out barrier price for the corn contract months of March (H), July (N), December (Z) were from 9/6/2016-2/28/2017 and for the soybean contract months of March (H), July (N), November (N) were from 9/6/2016-2/28/2017.

## Results and Discussion

In the knock-out barrier estimation results section, we review the results of the knock-out barrier price equation by applying a simple linear regression measuring how efficiently our predicted

knock-out barrier price values fit the observed INTL FCStone knock-out barrier price values. To designate the best option pricing model to value the zero-cost accumulation strike prices for our synthetic producer accumulator contracts, we compare the resulting fitness of predicted zero-cost accumulation strike prices, and minimization of root-mean-square error and mean absolute error under each barrier option pricing model. After back-testing the synthetic producer accumulator portfolios, along with the other eight agricultural marketing strategy portfolios, we analyze profitability and the risk reduction associated with each strategy portfolio. Average portfolio price, portfolio risk reduction, and Sharpe ratio are focused on to determine overall portfolio strategy performance. Specific to producer accumulator portfolios, we quantify bushel accumulation in the concluding segment. Further, we evaluate the performance of producer accumulator portfolios and long futures portfolios executed during non-growing season months, growing season months, and following the technical trends: uptrend, neutral trend, and downtrend.

*Knock-Out Barrier Estimation Results*

The intent of regressing the predicted knock-out barrier price values on the observed INTL FCStone knock-out barrier price values is to validate, in both commodities, the accuracy of our forecasted knock-out barrier values computed by the knock-out barrier price equation. Values predicted by the knock-out barrier price equation are based on the referenced futures price and the number of days until contract expiration. If the knock-out barrier price equation forecasts values that provide sufficient fit to the INTL FCStone observed data, it provides confidence that a regression model predicts suitable knock-out barrier prices for our synthetic producer accumulator contracts.

In the corn market, the predicted knock-out barrier values from the price equation closely approximate the observed INTL FCStone knock-out barrier price values. These results are shown visually in Figure 2 and statistically in Table 5. With a beta of .9900, an r-square of .9998, and a standard error of .0011, the predicted values fit the observed values efficiently. Similarly, in soybeans, the knock-out barrier price equation demonstrates accurate forecasting results as the predicted knock-out barrier price values fit the observed INTL FCStone data proficiently. These results are revealed graphically in Figure 3 and numerically in Table 6. Producing a beta of 1.0050, an r-square of .9999, and a standard error of .0008, the predicted values for soybeans robustly explain the observed data values. Knock-out barrier prices estimated in soybeans fit the observed data slightly better than in corn.

Overall, the prediction ability of the knock-out barrier price equation is efficient in both commodities. Accordingly, we feel confident valuing the knock-out barrier price for the synthetic producer accumulator contracts with the knock-out barrier price equation shown as Equation 5.

*Zero-Cost Accumulation Strike Model Results*

To maximize zero-cost accumulation strike price accuracy for our synthetic producer accumulator contracts, we analyze the fit of the Cox-Ross-Rubinstein (CRR) binomial tree model, Longstaff-Schwartz (LS) method, and finite difference (FD) explicit approximation method to estimate strike prices given equivalent accumulator specifications. By running a simple linear regression, we

analyze the fit and bias of each model's predicted zero-cost accumulation strike prices against the INTL FCStone observed accumulation strike prices. We also compare each model's root-mean-square error and mean absolute error with predicting the observed INTL FCStone strikes.

Regressing the predicted zero-cost accumulation strike prices from each methodology on the observed INTL FCStone accumulation strike prices in corn indicates that the predicted values for all models fit the observed values well. Results are shown graphically over the comparison period in Figure 4 and numerically in Table 7. All models and model averages produced a beta coefficient near one indicating minimal bias. A high r-square also indicates that the predicted values explain much of the variability in the observed strike values and a low standard error implies low standard deviation. The CRR model has a beta of .9950, and is tied with multiple models for the highest r-square and lowest standard error. The FD-CRR model estimates the least biased beta at .9984, and ties with many other models for the greatest r-square and lowest standard error. Performing the worst of all models in approximating the zero-cost accumulation strike price in corn was the LS model with a beta of .9805, an r-square which is tied with all other models, and the highest standard error at .0010.

When regressing predicted zero-cost accumulation strike prices for each model on the observed INTL FCStone accumulation strike prices, all models predicted strike prices fitting the observed data well in soybeans. Table 8 reports the comparison results and Figure 5 illustrates the strike prices over the period of comparison. The CRR model predicted accumulation strike prices had the second highest beta at .9982, equivalent r-square of .9999, and a tied lowest standard error of .0006. At .9894 for beta, an equal r-square of .9999, and the highest tied standard error of .0007, the LS model had the worst fit of all models in soybeans. Alternatively, the FD-CRR model estimated the most efficient zero-cost accumulation strikes with a beta at 1.0002, a comparable r-square of .9999, and the tied lowest standard error of .0006.

Root-mean-square error (RMSE) evaluates model prediction accuracy by comparing observed data and model predicted values. Table 9 displays results of the root-mean-square error (RMSE) test showing the CRR model ranking third behind the FD-CRR model average and the FD model for the lowest degree of model error in corn. In soybeans, the CRR model produces the third lowest RMSE after the FD-CRR model average and FD model. The LS model produces the highest and worst RMSE values in corn and soybeans, confirming higher comparable model error. RMSE for the CRR model is low in both commodity markets; thus, the CRR model confirms that it sufficiently values the zero-cost accumulation strike price with minimal error.

Mean absolute error (MAE) measures the difference between observed values and model predicted values by calculating average absolute error. Table 10 presents the mean absolute error (MAE) test results. The CRR model realizes the third lowest MAE. The FD-CRR model average has the lowest MAE and the FD model has the second lowest MAE in corn. In soybeans, the CRR model ties with the FD-CRR model average for the lowest MAE value. The LS model had the highest MAE in corn and soybeans affirming comparatively higher prediction error than the other models evaluated. In both corn and soybeans, the CRR model efficiently minimizes MAE. These results give us assurance in the ability of the CRR model to accurately estimate the zero-cost accumulation strike for the synthetic producer accumulator contracts we create.

The regression model estimates, root-square-mean error (RMSE) test, and mean absolute error (MAE) test confirm that all models efficiently approximate the zero-cost accumulation strike price. After reviewing the results of all methodologies, we elect the Cox-Ross-Rubinstein (CRR) binomial tree model to value the zero-cost accumulation strike prices using Equation 1 for the synthetic producer accumulator contracts that we use for performance back-testing.

*Average Price Analysis*

The producer accumulator's average price for corn was slightly less than the long futures portfolio between 2008-2017. The producer accumulator portfolio had an average price of $4.78/bu. The accumulator average price per bushel ranked it with the sixth highest average price out of all nine simulated portfolios. The producer accumulator underperformed the long futures portfolio by $.05/bu. Short option strategies expectantly did well under low volatility range-bound markets, these include: the short strangle and short straddle. In addition to the short option strategies, the covered call had the best portfolio average bushel price over the aggregated period. Performing the worst were portfolios with long options strategies, only profiting during high volatility and price breakout that occurred less frequently than range bound markets. Table 11 reports the average aggregate price of each portfolio strategy in corn and soybeans for the aggregate period of 2008-2017.

During the aggregate period, the soybean producer accumulator portfolio achieved the fifth highest average price out of the nine strategy portfolios. Outperforming the long futures portfolio from 2008-2017, the producer accumulator achieved an average price of $11.43/bu versus the average price of the long futures portfolio at $11.42/bu. Long option portfolio strategies including: the long strangle, long straddle, and protective put realized the lowest average prices in soybeans. Alternatively, the short option strategies consisting of portfolios selling options had the highest average price per bushel over the aggregate timeframe.

Figure 6 in corn and Figure 7 in soybeans present a time-series graph of average annual price for each portfolio strategy from 2008-2017. The average annual price each year of the producer accumulator portfolio and long futures portfolio were similar in both commodities. Table 12 displays average aggregate price by portfolio valuation month for producer accumulator strategy portfolios and long futures strategy portfolios from 2008-2017.

The producer accumulator portfolio, in corn, achieves an average price above $4.80/bu for contracts beginning between August and March with some months outperforming the long futures portfolio. Lower average price for producer accumulator contracts occur for contracts originated between April and July. They underperform the long futures portfolio each month. Producer accumulator portfolios beginning during the growing season underperform the long futures portfolio, but they outperform the long futures portfolio during the non-growing season. In soybeans, the producer accumulator generates an average price above $11.50/bu for contracts executed between July and December beating the long futures portfolio each valuation month. Contracts valued between January and June maintain lower average prices for producer accumulator portfolios underperforming the long futures portfolio each month. Producer

accumulator portfolios in soybeans perform consistently with the long futures portfolio during the growing and non-growing season.

Table 13 presents average price for producer accumulator portfolios and long futures portfolios categorized by trend type and trend length in days for corn and soybeans from 2008-2017. We review the average price performance of producer accumulator contracts beginning following an uptrend, neutral trend, and downtrend of 25, 50, and 100 days. The producer accumulator in corn and soybeans had the highest average price following an uptrend. Long futures portfolios enacted after an uptrend outperformed producer accumulator portfolios originated after an uptrend in corn. Long futures portfolios beginning following an uptrend performed equivalently to producer accumulator portfolios valued following an uptrend in soybeans. In corn, the producer accumulator outperformed the long futures portfolio for contracts that began after the 50 and 100-day neutral trend, underperforming in all other scenarios. In soybeans, the producer accumulator portfolio outperformed the long futures portfolio for contracts originated or enacted after the 25 and 50-day uptrend, 50 and 100-day neutral trend, and 25 and 50-day downtrend. Producer accumulator contracts beginning after the neutral trend had the lowest average price out of all three trends in both commodities. Yet, producer accumulator portfolios executed after a neutral trend had a higher average price than long futures portfolios beginning following a neutral trend.

Figure 8 and 9 show the price ratio, December expiration in corn and November expiration in soybeans, by comparing the average portfolio price of the producer accumulator portfolio to the long futures portfolio. Each ratio is divided into quadrants by year, month, week of the month, and day of the week, where each quadrant symbolizes the price ratio of a producer accumulator portfolio compared to a long futures portfolio executed on that date. Average daily portfolio price ratio around 1.2 is indicated by a deep green hue and represents that the producer accumulator had a greater average price of approximately 20% to that of the long futures only portfolio. The price of the producer accumulator portfolio is determined by the bushels accumulated times the accumulation strike price and the remaining unpriced bushels are sold at the referenced futures price on the producer accumulator contract's expiration date. A price ratio around 1 is shown in white indicating an equivalent price to the average long futures price, and the red color implies an accumulator price less than the long futures average price.

*Portfolio Risk Analysis*

In the corn market, the producer accumulator ranked fourth in portfolio risk over the period ranging from 2008-2017. The accumulator had an average daily portfolio standard deviation of $681.90. Alternatively, the long futures portfolio had an average daily portfolio standard deviation of $836.69, representing the third highest portfolio risk. The producer accumulator portfolio achieved a lower average daily standard deviation than the long futures portfolio from 2008-2017 on an annual and aggregate basis. Reviewing the performance of the long option portfolio strategies, the long straddle and strangle had the greatest average daily portfolio risk, while the protective put portfolio significantly reduced risk ranking it with the third lowest risk. The long strangle and straddle attained higher average daily standard deviation than the long futures portfolio; hence, these strategies accomplished no risk reduction, rather they attempted to enhance return by increasing risk. Throughout this period, the risk management strategies including the collar,

covered call, and protective put had the lowest average daily sigma values at $523.88, $522.54, and $577.89, respectively. Short option strategy portfolios, except for the covered call, minimally reduce risk. Table 14 reveals aggregate average portfolio risk for each portfolio strategy in corn and soybeans for the aggregate period of 2008-2017.

From 2008-2017, the producer accumulator in soybeans had an average daily standard deviation of $1,189.14. This performance ranks the producer accumulator portfolio with the third lowest sigma value out of all nine portfolios. Divergent from corn, the accumulator reduced standard deviation more than the protective put in soybeans. This result is likely due to the higher positive soybean price volatility creating a greater accumulation of bushels that were priced, thus reducing risk. Like the producer accumulator portfolio in corn, the producer accumulator in soybeans had greater risk reduction than the long futures portfolio. The long futures average daily portfolio standard deviation was $1,571.26. On an aggregate and annual basis, the producer accumulator produced a lower average daily portfolio standard deviation than the long futures portfolio. The most risk reducing strategy was the covered call portfolio that had an average daily portfolio sigma of $999.35. Ranging from 2008-2017, the short strangle and straddle minimally reduced risk, while the long strangle and straddle increased risk compared to the long portfolio strategy in soybeans.

Figure 10 for corn and Figure 11 for soybeans illustrate time-series graphs of strategy portfolio risk measured in average daily portfolio standard deviation from 2008-2017. Table 15 displays average daily portfolio risk by the valuation month for producer accumulator strategy portfolios and long futures strategy portfolios during 2008-2017. In corn and soybeans, all valuation months show comparably lower portfolio risk for the producer accumulator portfolio than the long futures portfolio. Producer accumulator portfolios in corn with valuation months between March and September had average daily portfolio standard deviation above $675, while contracts beginning between October and February had average daily portfolio risk below $675. In soybeans, producer accumulator portfolios executed or valued between March and September had an average daily portfolio standard deviation above $1,150; contracts executed between October and February attained an average daily portfolio standard deviation less than $1,150. As expected, portfolio risk for the producer accumulator portfolio and long futures portfolio is higher during the growing season than during the non-growing season in both commodities.

Table 16 illustrates average daily portfolio standard deviation for producer accumulator portfolios and long futures portfolios broken down by trend type and trend length in days for corn and soybeans from 2008-2017. We analyze risk reduction by measuring average daily portfolio standard deviation of producer accumulator contracts that began succeeding an uptrend, neutral trend, and downtrend consisting of 25, 50, and 100 days. Following all trends, producer accumulator portfolios achieved lower average daily portfolio standard deviation than the equivalent long futures portfolio in both corn and soybeans. Producer accumulator contracts following a neutral trend had the lowest average daily portfolio standard deviation in corn and soybeans. Contracts executed after the 25-day neutral trend had the lowest average daily portfolio standard deviation for both long futures and producer accumulator portfolios in corn. Contracts beginning after the 50-day neutral trend had the lowest average daily portfolio standard deviation in soybeans. In both commodities, producer accumulator contracts following an uptrend maintain the highest average daily portfolio standard deviation. Corn and soybean producer accumulator

contracts and long futures portfolios valued following the 100-day uptrend had the highest average daily portfolio standard deviation out of all trends and trend lengths.

Figure 12 in corn with December expiration and Figure 13 in soybeans with November expiration show the sigma ratio represented as producer accumulator portfolio risk to long futures portfolio risk. Broken down by year, month, week of the month, and day of the week, each square symbolizes the sigma ratio of the producer accumulator portfolio compared to the long futures portfolio executed on the date embodied by that square. The deep green color specifies a sigma ratio around 1. In this case, the producer accumulator portfolio has an equivalent average daily portfolio standard deviation to the long futures portfolio. Bushels are sold at the referenced futures price upon producer accumulator contract expiration if the producer accumulator knock-out occurs prior to selling all contracted bushels. Therefore, early knock-out scenarios minimally manage risk causing a sigma ratio close to 1 as most bushels are sold at the long futures price at contract expiration. Boxes colored gold to deep red show instances where the producer accumulator portfolio decreases and significantly decreases average daily portfolio standard deviation compared to the long futures portfolio.

*Sharpe Ratio Analysis*

In corn, the producer accumulator portfolio exhibited the best risk adjusted performance by outperforming all other portfolios. The producer accumulator portfolio achieved an average daily portfolio Sharpe ratio of .081 over the 2008-2017 period. Moreover, on an average annual basis, the producer accumulator had the best portfolio Sharpe ratio each year during 2009-2017. In 2008, the short strangle and short straddle had an incrementally better Sharpe ratio edging out the producer accumulator portfolio. Out of all nine strategies, only four strategy portfolios maintained a positive average daily portfolio Sharpe ratio from 2008-2017. Portfolios with a positive Sharpe ratio on an average aggregate basis include: the producer accumulator portfolio, the short straddle portfolio, the short strangle portfolio, and the covered call portfolio. Obtaining a -.013 average daily portfolio Sharpe ratio, the long futures portfolio had the fourth worst Sharpe ratio out of all portfolios. All long option portfolios averaged negative Sharpe ratios; the protective put portfolio had the worst risk adjusted return at a -.044 Sharpe ratio. Table 17 displays each portfolio's average daily portfolio Sharpe ratio during 2008-2017 in corn and soybeans.

Ranking first on an aggregate and annual average basis from 2008-2017, the soybean producer accumulator portfolio upheld an aggregate average daily portfolio Sharpe ratio of .178. The long futures portfolio underperformed the producer accumulator portfolio with an average daily portfolio Sharpe ratio of .005 over the period. Portfolios performed better in the soybean market than in the corn market with only three out of the nine portfolios producing a negative average daily portfolio Sharpe ratio. Short option strategy portfolios like the covered call portfolio, the short strangle portfolio, and the short straddle portfolio had some of the highest average daily portfolio Sharpe ratios. In contrast to the corn market, the protective put portfolio in soybeans was not the worst performer. Instead, the long strangle portfolio ranked last signifying poor risk-adjusted return. The collar portfolio turned from a negative Sharpe ratio in corn to a positive average daily portfolio Sharpe ratio in soybeans. All long option strategy portfolios maintained a negative average daily portfolio Sharpe ratio from 2008-2017.

Figure 14 for corn and Figure 15 for soybeans present each strategy portfolio's average daily portfolio Sharpe ratio in a time-series graph on an average annual basis from 2008-2017. Table 18 presents average daily portfolio Sharpe ratio by valuation month for producer accumulator strategy portfolios and long futures strategy portfolios during 2008-2017. In both corn and soybeans, the producer accumulator portfolio had a higher average daily Sharpe ratio than the long futures portfolio for all valuation months, the growing season period, and non-growing season period. The producer accumulator in corn had average daily portfolio Sharpe ratio above .1 for contract portfolios beginning between September and February and Sharpe ratios under .1 for contracts executed between March and August. The producer accumulator in soybeans had higher average daily portfolio Sharpe ratios above .16 for contracts executed or enacted between September and March and average daily portfolio Sharpe ratios under .16 for contracts beginning between April and August. Producer accumulator Sharpe ratios were higher during the non-growing season than the growing season for corn and soybeans conveying superior risk adjusted return for producer accumulators executed during non-growing season valuation months.

Table 19 exhibits average daily portfolio Sharpe ratios for producer accumulator and long futures portfolios categorized by trend type and trend length in days for contracts in corn and soybeans from 2008-2017. We investigate risk adjusted return by quantifying average daily portfolio Sharpe ratio for producer accumulator contracts executed after an uptrend, neutral trend, and downtrend. Each trend is split into trend lengths of 25, 50, and 100 days. Producer accumulator portfolios, valued following all trends and trend lengths, had a higher average daily portfolio Sharpe ratio than the corresponding long futures portfolio in corn and soybeans. Producer accumulator contracts beginning after a neutral trend had the highest average daily portfolio Sharpe ratios in corn and soybeans. The long futures portfolio realized the highest average daily portfolio Sharpe ratios for contracts beginning following a downtrend in corn and soybeans. In corn, producer accumulator contracts executed after a 25-day neutral trend had the highest average daily portfolio Sharpe ratio, while contracts that began after a 50-day uptrend generated the lowest average daily portfolio Sharpe ratio. In soybeans, producer accumulator portfolios beginning following a 25-day neutral trend achieved the best average daily portfolio Sharpe ratio; contracts executed after a 100-day uptrend had the worst average daily portfolio Sharpe ratio. In both commodities, producer accumulator contracts and long futures portfolios realized the lowest average daily portfolio Sharpe ratio following an uptrend.

Figure 16 in corn with December expiration and Figure 17 in soybeans with November expiration display the average daily portfolio Sharpe ratio for all simulated producer accumulator portfolios. Split into tranches by year, month, week of the month, and day of the week, each tranche signifies the producer accumulator portfolio Sharpe ratio where the valuation date or start date of each simulated accumulator portfolio is represented by each tranche. Tranches with a deep green color indicate average daily portfolio Sharpe ratio around .4 or higher. White tranches represent accumulator portfolios with an average daily portfolio Sharpe ratio around 0, and the pink implies a producer accumulator portfolio average daily portfolio Sharpe ratio that is slightly negative.

*Bushels Accumulation Analysis*

Aggregate results from 2008-2017 in corn indicate an average bushel accumulation of 3,165 bushels for producer accumulator contracts contracted to accumulate 5,000 bushels. Out of 5,117 producer accumulator contracts simulated in corn, 3,920 contracts or 76.6% of all producer accumulator portfolios accumulated less than 5,000 bushels; 1,197 contracts or 23.4% of the total producer accumulator portfolios accumulated more than 5,000 bushels. On an annual basis from 2008-2017, 2010 and 2017 attained the highest number of average annual bushels accumulated. For 2010, 47.6% of contracts priced more than 5,000 total bushels with an annual average of 6,380 bushels priced. In 2017, an annual average of 5,362 bushels were priced with 97.8% of contracts pricing more than 5,000 bushels. The years of 2008 and 2013 had the lowest quantity of bushels accumulated at 1,240 and 1,752. In 2008, 95.3% of contracts sold less than 5,000 bushels. Comparable results occurred in 2013 with 93.5% of contracts selling under 5,000 bushels. Table 20 presents results from corn and soybean bushels accumulated from 2008-2017 on an average annual and average aggregate basis.

From 2008-2017, producer accumulator portfolio aggregate results in the soybeans show an average bushel accumulation of 4,752 bushels. Simulating 5,093 contracts in soybeans, 2,635 contracts, or 51.7% of the total simulated producer accumulator portfolios accumulated less than 5,000 bushels; 2,458 contracts or 48.3% of all simulated producer accumulator portfolios accumulated more than 5,000 bushels. Ranging from 2008-2017, 2010 and 2016 had the highest number of average annual bushels accumulated. In 2010, an annual average of 8,169 bushels were accumulated with 91.2% of contracts pricing more than 5,000 total bushels. During 2016, 78.8% of contracts priced more than 5,000 bushels with an annual average of 6,228 bushels accumulated. Accumulating the lowest quantity of bushels, 2008 and 2014 average bushels accumulated were 1,585 and 3,015. In 2008, 94.8% of contracts accumulated less than 5,000 bushels. Similarly, 78.1% of contracts in 2014 accumulated less than 5,000 bushels.

Figure 18 for corn and Figure 19 for soybeans illustrate the frequency of bushels accumulated from simulated producer accumulator contracts accumulating specific bushel ranges between 0-10,000 bushels. The frequency of bushels accumulated is skewed toward lower bushels in corn. Frequency in soybeans is more evenly distributed, but shows skew towards higher and lower bushel bins near 0 and 10,000. Table 21 displays the average bushels accumulated in corn and soybeans from 2008-2017 broken down by producer accumulator portfolio valuation month. Producer accumulator contracts accumulate a higher quantity of bushels when contracts were executed during the non-growing season, 9.3% more in corn and 21.3% more in soybeans, than when contracts begin during the growing season. In corn, producer accumulators executed between August and February accumulated more than 3,000 bushels; producer accumulators beginning between March and July accumulated less than 3,000 bushels. In soybeans, producer accumulators valued between October and March accumulated more than 5,000 bushels; producer accumulators executed or valued between April and September accumulated less than 5,000 bushels.

Table 22 displays average corn and soybean bushels accumulated by producer accumulator contracts categorized by trend type and length of trend in days from 2008-2017. In this table, we evaluate the quantity of bushels accumulated by producer accumulator contracts that began following an uptrend, neutral trend, and downtrend of 25, 50, and 100-days in length. To show the distribution of producer accumulator contracts for each trend type and trend length, we list the

number of producer accumulator contracts in corn and soybeans fitting the criteria of each trend type and trend length. In corn and soybeans, producer accumulator contract portfolios accumulated the highest number of bushels when they began after a downtrend. Specifically, the highest quantity of bushels was accumulated for producer accumulator portfolios beginning following a 100-day downtrend in corn and a 50-day downtrend in soybeans. Contracts in both commodities accumulated the lowest quantity of bushels when accumulator portfolios were executed after an uptrend. Producer accumulator portfolios executed after a 50-day uptrend in corn and a 100-day uptrend in soybeans had the lowest quantity of bushels accumulated.

Figure 20 signifies bushels accumulated for December expiration in corn and Figure 21 characterizes bushels accumulated for November expiration in soybeans. Figure 20 and 21 show the quantity of bushels accumulated from 0-10,000 for all simulated producer accumulator contracts. Organized into squares based on year, month, week of the month, and day of the week, each individual square represents the date a simulated producer accumulator portfolio was enacted. The color of each square is dependent on the total quantity of bushels accumulated by the producer accumulator enacted on the date the square represents. A deep green color signifies accumulation of bushels close to 10,000 bushels, the gold hue represents bushel accumulation around 5,000 bushels, and the bright red signifies accumulation of bushels close to or at zero bushels.

## Conclusions

### *Summary*

The producer accumulator portfolio performs similarly to the long futures portfolio with respect to average price. Our analysis shows the producer accumulator historically narrowly underperformed the long futures portfolio in corn, $4.78/bu versus $4.83/bu, and marginally outperformed the long futures portfolio in soybeans, $11.43/bu versus $11.42/bu. Producer accumulator contracts in corn beginning during the growing season underperformed the long futures portfolio, but outperformed long futures during the non-growing season. In soybeans, producer accumulator portfolios executed or valued during the growing season and non-growing season performed similarly to the long futures portfolio executed during the growing and non-growing season. In both corn and soybeans, producer accumulator portfolios achieved the highest average price when contracts were executed after an uptrend whether the uptrend ranged from 25 to 100-days. Producer accumulator contracts beginning after a 25 to 100-day neutral trend had the lowest average price in both commodities.

When risk is taken into consideration in addition to return, the producer accumulator in corn and soybeans outperformed all other strategy portfolios. Average daily portfolio Sharpe ratio on an annual and aggregate basis is greater than all strategy portfolios from 2009-2017 in corn and 2008-2017 in soybeans. The producer accumulator portfolio, in both commodities, had a higher average daily portfolio Sharpe ratio than the long futures portfolio for all valuation months, the growing season period, and the non-growing season period. In corn and soybeans, higher Sharpe ratios occurred for contracts executed or enacted during the non-growing season than during the growing season conveying superior risk adjusted return for producer accumulator contracts executed during non-growing season months. Producer accumulator contracts valued following all trend types and

trend lengths in corn and soybeans realized a higher average daily portfolio Sharpe ratio than the corresponding long futures portfolio. In both commodities, producer accumulator contracts beginning after a neutral trend attained the highest average daily portfolio Sharpe ratios; however, the long futures portfolio in corn and soybeans had the highest average daily portfolio Sharpe ratios for contracts beginning following a downtrend. Producer accumulator contracts and long futures portfolios in corn and soybeans had the lowest average daily portfolio Sharpe ratio when contracts began after an uptrend.

Producer accumulator portfolios, in both commodity markets, produced an average daily portfolio standard deviation that is much lower than the long futures average daily portfolio standard deviation. All valuation months present lower portfolio risk for the producer accumulator portfolio than the long futures portfolio. Long futures and producer accumulator portfolio risk is greater during the growing season than during the non-growing season in both commodities. Producer accumulator portfolios executed after an uptrend, neutral trend, and downtrend, ranging from 25 to 100-days in length, achieved a lower average daily portfolio standard deviation than the corresponding long futures portfolio. In corn and soybeans, producer accumulator contracts executed after a neutral trend realized the lowest average daily portfolio standard deviation, while producer accumulator contracts executed following an uptrend maintained the highest and worst average daily portfolio standard deviation. Producer accumulator contracts reduce risk compared to long futures based on the quantification of average daily portfolio standard deviation verifying the producer accumulator as an efficient way to manage risk.

In corn and soybeans, the producer accumulator is found to price less bushels than it originally contracts. During the 2008-2017 timeframe, accumulated bushels averaged 3,165 bushels in corn and 4,752 bushels in soybeans. Frequency of bushels accumulated is skewed toward lower bushel bins in corn, whereas the distribution is more consistent in soybeans, but producer accumulators accumulating soybeans show some skew toward higher and lower bushel bins. When contracts were executed during the non-growing season, producer accumulator contracts accumulated a higher quantity of bushels, 9.3% more in corn and 21.3% more in soybeans, than when contracts begin during the growing season. Producer accumulator contracts in corn and soybeans accumulated the highest number of bushels when the contract began bushel accumulation following a downtrend. In both commodities, accumulator portfolios accumulated the lowest quantity of bushels when the accumulator was executed after an uptrend.

*Producer Implications*

Based on our quantitative research, we deem the producer accumulator contract to be an efficient risk management strategy for producers to employ in corn and soybean commodity markets. Our research shows that accumulator average price received per bushel is similar to the average futures price during the contracted period, but risk is reduced by adopting a producer accumulator contract. Reduction of risk, while maintaining a similar average price to the futures price results in a higher Sharpe ratio indicating a more efficient portfolio according to Modern Portfolio Theory (Markowitz, 1952). Thus, producers would be rationally expected to adopt the producer accumulator contract into their grain marketing strategy.

Our research supports that producers may optimally execute producer accumulator contracts during non-growing season months between October and March rather than growing season months between April and September. Producer accumulator portfolios valued during non-growing season months produce a similar average price to the average price of the long futures portfolio and a higher average daily portfolio Sharpe ratio because of lower portfolio risk measured by standard deviation. Moreover, accumulators enacted during the non-growing season exhibited higher bushel accumulation than producer accumulators executed or valued during the growing season. Therefore, producers may achieve greater risk reduction by executing accumulator contracts during the non-growing season to enhance their risk adjusted return.

When incorporating technical trend into performance, producers receive a higher average price, higher risk adjusted return and lower risk, and greater bushel accumulation following different trend types. In corn and soybeans, our research illustrates that the best average price for producer accumulator contracts occurs for contracts beginning after an uptrend. The highest average daily portfolio Sharpe ratio and lowest average daily portfolio standard deviation is realized by contracts executed after a neutral trend. And, the highest bushel accumulated occurred for contract portfolios executed after a downtrend. Producers implementing the producer accumulator contract should consider their primary goal to decide which trend type to follow. Risk seeking producers seeking higher reward and correspondingly higher risk should consider executing or beginning their producer accumulator contract after an uptrend to receive the highest average price. Risk adverse producers seeking lower risk and thus lower reward should consider beginning their producer accumulator contract following a neutral trend to receive the highest risk adjusted return and lowest risk. If producers are risk neutral and seek the highest risk adjusted return, they should consider beginning their producer accumulator contract following a neutral trend.

Price-time path of the referenced futures price among the accumulation strike price and knock-out barrier affects the quantity of bushels accumulated. On average, bushel accumulation is less than the contracted 5,000 bushels in corn and close to the contracted bushel quantity in soybeans. With this finding, producers should consider a hedging account to defend their producer accumulator using vanilla options and futures contracts during unfavorable price movements to manage risk. Producer accumulator contracts do not reduce basis risk; therefore, producers should also consider incorporating a basis contract to reduce basis risk when adopting a producer accumulator contract.

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Table 1. Types of Barrier Options

| Option | Type | Barrier Location |
|---|---|---|
| Call | Up-and-Out | Above Spot |
| | Up-and-In | Above Spot |
| | Down-and-Out | Below Spot |
| | Down-and-In | Below Spot |
| Put | Up-and-Out | Above Spot |
| | Up-and-In | Above Spot |
| | Down-and-Out | Below Spot |
| | Down-and-In | Below Spot |

Table 2. Synthetic Producer Accumulator Contract Terms in Corn

| | |
|---|---|
| Issuer | FCStone International |
| Accumulator Type | Producer Accumulator |
| Futures Contract | CZ7 |
| Futures Price | 373 |
| Start Date | 9/16/2016 |
| End Date | 11/24/2017 |
| Periods | 63 Weeks |
| Accumulation Strike | 398 |
| Knock-Out Barrier | 335 |
| Guaranteed Level | N/A |
| Each week that the referenced futures contract price settles at or below the accumulation strike, 100% of the weekly quantity is priced at the accumulation strike. | |
| Each week that the referenced futures contract price settles above the accumulation strike, 200% of the weekly quantity is priced at the accumulation strike. | |
| If on any date between start date and end date, during the non-electronic or electronic daily session, the referenced futures contract ever trades or settles at or below the knock-out barrier, accumulation ceases. Any bushels already accumulated in prior weeks will continue to be priced at the accumulation strike. | |

Table 3. Synthetic Producer Accumulator Contract Terms in Soybeans

| | |
|---|---|
| Issuer | FCStone International |
| Accumulator Type | Producer Accumulator |
| Futures Contract | SX7 |
| Futures Price | 1008 |
| Start Date | 11/25/2016 |
| End Date | 11/24/2017 |

| | |
|---|---|
| Periods | 53 Weeks |
| Accumulation Strike | 1087 |
| Knock-Out Barrier | 980 |
| Guaranteed Level | N/A |
| Each week that the referenced futures contract price settles at or below the accumulation strike, 100% of the weekly quantity is priced at the accumulation strike. | |
| Each week that the referenced futures contract price settles above the accumulation strike, 200% of the weekly quantity is priced at the accumulation strike. | |
| If on any date between start date and end date, during the non-electronic or electronic daily session, the referenced futures contract ever trades or settles at or below the knock-out barrier, accumulation ceases. Any bushels already accumulated in prior weeks will continue to be priced at the accumulation strike. | |

Table 4. Agricultural Marketing Strategy Portfolios

| Portfolio Strategy | Portfolio Type | Futures | Options |
|---|---|---|---|
| Producer Accumulator | Hedging Portfolio | Long 2 Futures Contracts | Short 2 OTM Down-and-Out Barrier Calls (X = Accumulation Level, H = Barrier Level)<br>Long 1 ITM Down-and-Out Barrier Put (X = Accumulation Level, H = Barrier Level) |
| Long Futures | Hedging Portfolio | Long 2 Futures Contracts | |
| Protective Put | Long Option Portfolio | Long 2 Futures Contracts | Long 2 OTM Vanilla Puts (X = Barrier Level) |
| Covered Call | Short Option Portfolio | Long 2 Futures Contracts | Short 2 OTM Vanilla Calls (X = Accumulation Level) |
| Long Strangle | Long Option Portfolio | Long 2 Futures Contracts | Long 1 OTM Vanilla Call (X = Accumulation Level)<br>Long 1 OTM Vanilla Put (X = Barrier Level) |
| Short Strangle | Short Option Portfolio | Long 2 Futures Contracts | Short 1 OTM Vanilla Call (X = Accumulation Level)<br>Short 1 OTM Vanilla Put (X = Barrier Level) |
| Long Straddle | Long Option Portfolio | Long 2 Futures Contracts | Long 1 ATM Vanilla Call (X = Futures Price Level)<br>Long 1 ATM Vanilla Put (X = Futures Price Level) |

| | | | |
|---|---|---|---|
| Short Straddle | Short Option Portfolio | Long 2 Futures Contracts | Short 1 ATM Vanilla Call (X = Futures Price Level)<br>Short 1 ATM Vanilla Put (X = Futures Price Level) |
| Collar | Hedging Portfolio | Long 2 Futures Contracts | Short 1 OTM Vanilla Call (X = Accumulation Level)<br>Long 1 OTM Vanilla Put (X = Barrier Level) |

Table 5. Knock-Out Barrier in Corn – Observed vs Predicted

| Commodity | Beta | R-Square | Standard Error |
|---|---|---|---|
| Corn | .9900 | .9998 | .0011 |

Table 6. Knock-Out Barrier in Soybeans – Observed vs Predicted

| Commodity | Beta | R-Square | Standard Error |
|---|---|---|---|
| Soybeans | 1.0050 | .9999 | .0008 |

Table 7. Zero-Cost Accumulation Strike in Corn – Observed vs Predicted

| Model | Beta | R-Square | Standard Error |
|---|---|---|---|
| CRR | .9950 | .9998 | .0009 |
| LS | .9805 | .9998 | .0010 |
| FD | 1.0018 | .9998 | .0009 |
| CRR-LS Average | .9877 | .9998 | .0009 |
| LS-FD Average | .9910 | .9998 | .0009 |
| FD-CRR Average | .9984 | .9998 | .0009 |
| CRR-LS-FD Average | .9923 | .9998 | .0009 |

Table 8. Zero-Cost Accumulation Strike in Soybeans – Observed vs Predicted

| Model | Beta | R-Square | Standard Error |
|---|---|---|---|
| CRR | .9982 | .9999 | .0006 |
| LS | .9894 | .9999 | .0007 |
| FD | 1.0021 | .9999 | .0006 |
| CRR-LS Average | .9938 | .9999 | .0007 |
| LS-FD Average | .9957 | .9999 | .0007 |
| FD-CRR Average | 1.0002 | .9999 | .0006 |
| CRR-LS-FD Average | .9965 | .9999 | .0006 |

Table 9. Model Root-Mean-Square Error (RMSE)

| Model | Corn | Soybean |
|---|---|---|
| CRR | 5.30 | 9.54 |
| LS | 9.38 | 15.20 |
| FD | 4.99 | 9.53 |
| CRR-LS Average | 7.00 | 11.69 |
| LS-FD Average | 6.14 | 10.63 |
| FD-CRR Average | 4.96 | 9.09 |
| CRR-LS-FD Average | 5.81 | 10.81 |

Table 10. Model Mean Absolute Error (MAE)

| Model | Corn | Soybean |
|---|---|---|
| CRR | 3.94 | 7.34 |
| LS | 8.03 | 12.27 |
| FD | 3.81 | 7.72 |
| CRR-LS Average | 5.55 | 8.97 |
| LS-FD Average | 4.66 | 8.08 |
| FD-CRR Average | 3.71 | 7.34 |
| CRR-LS-FD Average | 4.36 | 7.74 |

Table 11. Portfolio Strategy Average Price in Corn and Soybeans 2008-2017

| Portfolio Strategy | Corn | Soybeans |
|---|---|---|
| Producer Accumulator | $4.78 | $11.43 |
| Long Futures | $4.83 | $11.42 |
| Protective Put | $4.54 | $10.95 |
| Covered Call | $5.25 | $12.32 |
| Long Strangle | $4.52 | $10.99 |
| Short Strangle | $5.22 | $12.37 |
| Long Straddle | $3.95 | $9.95 |
| Short Straddle | $5.79 | $13.41 |
| Collar | $4.90 | $11.64 |

**average price per bushel in USD*

Table 12. Average Price by Month in Corn and Soybeans 2008-2017

| Month | Corn – Producer Accumulator | Corn – Long Futures | Soybeans – Producer Accumulator | Soybeans – Long Futures |
|---|---|---|---|---|
| January | $4.87 | $4.79 | $11.41 | $11.44 |
| February | $4.89 | $4.80 | $11.26 | $11.44 |
| March | $4.83 | $4.86 | $11.13 | $11.40 |
| April | $4.69 | $4.82 | $11.35 | $11.42 |
| May | $4.69 | $4.89 | $11.33 | $11.55 |
| June | $4.57 | $4.87 | $11.32 | $11.49 |
| July | $4.69 | $4.84 | $11.55 | $11.44 |
| August | $4.83 | $4.91 | $11.67 | $11.49 |
| September | $4.82 | $4.82 | $11.51 | $11.30 |
| October | $4.87 | $4.80 | $11.51 | $11.31 |
| November | $4.87 | $4.80 | $11.61 | $11.42 |
| December | $4.83 | $4.76 | $11.50 | $11.39 |
| Growing Season (April-September) | $4.72 | $4.86 | $11.46 | $11.45 |
| Non-Growing Season (October-March) | $4.86 | $4.80 | $11.40 | $11.40 |

**average price per bushel in USD*

Table 13. Average Price by Trend in Corn and Soybeans 2008-2017

| Trend | Trend Length | Corn – Producer Accumulator | Corn – Long Futures | Soybeans – Producer Accumulator | Soybeans – Long Futures |
|---|---|---|---|---|---|
| Uptrend | 25-day | $5.04 | $5.10 | $11.74 | $11.72 |
| | 50-day | $5.04 | $5.10 | $11.80 | $11.76 |
| | 100-day | $5.37 | $5.46 | $11.81 | $11.86 |
| | Average | $5.15 | $5.22 | $11.78 | $11.78 |
| Neutral Trend | 25-day | $4.48 | $4.49 | $11.14 | $11.18 |
| | 50-day | $4.51 | $4.49 | $11.34 | $11.25 |
| | 100-day | $4.47 | $4.42 | $11.32 | $11.28 |
| | Average | $4.49 | $4.47 | $11.27 | $11.24 |
| Downtrend | 25-day | $4.75 | $4.83 | $11.31 | $11.28 |
| | 50-day | $4.82 | $4.92 | $11.20 | $11.27 |
| | 100-day | $4.91 | $5.08 | $11.55 | $11.47 |
| | Average | $4.83 | $4.94 | $11.35 | $11.34 |

**average price per bushel in USD*

Table 14. Portfolio Risk in Corn and Soybeans 2008-2017

| Portfolio Strategy | Corn | Soybeans |
|---|---|---|
| Producer Accumulator | $681.90 | $1189.14 |
| Long Futures | $836.69 | $1571.26 |
| Protective Put | $577.89 | $1201.49 |
| Covered Call | $522.54 | $881.92 |
| Long Strangle | $880.85 | $1760.88 |
| Short Strangle | $818.15 | $1414.80 |
| Long Straddle | $892.72 | $1657.49 |
| Short Straddle | $782.34 | $1482.98 |
| Collar | $523.88 | $999.35 |

**average daily portfolio standard deviation in USD*

Table 15. Risk by Month in Corn and Soybeans 2008-2017

| Month | Corn – Producer Accumulator | Corn – Long Futures | Soybeans – Producer Accumulator | Soybeans – Long Futures |
|---|---|---|---|---|
| January | $630.36 | $805.65 | $1,062.58 | $1,483.69 |
| February | $663.21 | $825.51 | $1,077.51 | $1,519.27 |
| March | $710.02 | $865.68 | $1,150.56 | $1,627.48 |
| April | $723.27 | $871.28 | $1,225.77 | $1,659.67 |
| May | $743.95 | $888.15 | $1,275.16 | $1,691.65 |
| June | $748.49 | $889.20 | $1,379.96 | $1,694.13 |
| July | $688.56 | $842.66 | $1,350.77 | $1,628.07 |
| August | $696.42 | $837.57 | $1,301.36 | $1,585.24 |
| September | $681.04 | $822.15 | $1,237.51 | $1,548.63 |
| October | $643.94 | $779.23 | $1,112.96 | $1,488.12 |
| November | $635.82 | $798.77 | $1,063.91 | $1,468.34 |
| December | $601.11 | $801.87 | $1,026.02 | $1,477.41 |
| Growing Season (April-September) | $713.62 | $858.50 | $1,295.09 | $1,634.57 |
| Non-Growing Season (October-March) | $647.41 | $812.79 | $1,082.26 | $1,510.72 |

**average daily portfolio standard deviation in USD*

Table 16. Risk by Trend in Corn and Soybeans 2008-2017

| Trend | Trend Length | Corn – Producer Accumulator | Corn – Long Futures | Soybeans – Producer Accumulator | Soybeans – Long Futures |
|---|---|---|---|---|---|
| Uptrend | 25-day | $771.26 | $936.08 | $1,305.07 | $1,658.45 |
| | 50-day | $788.01 | $940.01 | $1,374.28 | $1,690.31 |
| | 100-day | $835.72 | $993.90 | $1,560.40 | $1,828.20 |
| | Average | $803.49 | $956.66 | $1,413.25 | $1,725.65 |
| Neutral Trend | 25-day | $569.26 | $700.71 | $1,019.77 | $1,433.59 |
| | 50-day | $576.91 | $722.81 | $1,015.97 | $1,420.35 |
| | 100-day | $592.82 | $723.22 | $1,039.50 | $1,434.68 |
| | Average | $579.66 | $715.58 | $1,025.08 | $1,429.54 |
| Downtrend | 25-day | $678.46 | $836.64 | $1,170.21 | $1,560.66 |
| | 50-day | $684.66 | $844.11 | $1,164.62 | $1,590.44 |
| | 100-day | $696.54 | $883.08 | $1,188.43 | $1,631.54 |
| | Average | $686.55 | $854.61 | $1,174.42 | $1,594.21 |

**average daily portfolio standard deviation in USD*

Table 17. Portfolio Sharpe Ratio in Corn and Soybeans 2008-2017

| Portfolio Strategy | Corn | Soybeans |
|---|---|---|
| Producer Accumulator | .081 | .178 |
| Long Futures | -.013 | .005 |
| Protective Put | -.044 | -.017 |
| Covered Call | .013 | .041 |
| Long Strangle | -.030 | -.009 |
| Short Strangle | .007 | .026 |
| Long Straddle | -.040 | -.022 |
| Short Straddle | .021 | .040 |
| Collar | -.014 | .009 |

**average daily portfolio Sharpe ratio*

Table 18. Sharpe Ratio by Month in Corn and Soybeans 2008-2017

| Month | Corn – Producer Accumulator | Corn – Long Futures | Soybeans – Producer Accumulator | Soybeans – Long Futures |
|---|---|---|---|---|
| January | .126 | -.014 | .225 | .003 |
| February | .112 | -.019 | .226 | -.007 |
| March | .050 | -.010 | .171 | .008 |

| | | | | |
|---|---|---|---|---|
| April | .044 | -.014 | .156 | -.002 |
| May | .047 | -.016 | .145 | -.001 |
| June | .038 | -.019 | .096 | -.007 |
| July | .058 | -.014 | .113 | .000 |
| August | .067 | -.012 | .142 | .005 |
| September | .106 | -.008 | .186 | .009 |
| October | .105 | -.009 | .220 | .018 |
| November | .106 | -.010 | .217 | .018 |
| December | .126 | -.009 | .226 | .013 |
| Growing Season (April-September) | .060 | -.014 | .140 | .001 |
| Non-Growing Season (October-March) | .104 | -.012 | .214 | .009 |

**average daily portfolio Sharpe Ratio*

Table 19. Sharpe Ratio by Trend in Corn and Soybeans 2008-2017

| Trend | Trend Length | Corn – Producer Accumulator | Corn – Long Futures | Soybeans – Producer Accumulator | Soybeans – Long Futures |
|---|---|---|---|---|---|
| Uptrend | 25-day | .052 | -.021 | .142 | -.004 |
| | 50-day | .032 | -.024 | .118 | -.007 |
| | 100-day | .037 | -.025 | .081 | -.018 |
| | Average | .040 | -.023 | .114 | -.010 |
| Neutral Trend | 25-day | .125 | -.013 | .214 | .001 |
| | 50-day | .122 | -.011 | .212 | .001 |
| | 100-day | .092 | -.010 | .205 | .006 |
| | Average | .113 | -.011 | .210 | .003 |
| Downtrend | 25-day | .078 | -.006 | .192 | .017 |
| | 50-day | .087 | -.005 | .203 | .022 |
| | 100-day | .105 | -.005 | .203 | .028 |
| | Average | .090 | -.005 | .199 | .022 |

**average daily portfolio Sharpe Ratio*

Table 20. Annual Bushels Accumulated in Corn and Soybeans

| Year | Corn | Soybean |
|---|---|---|
| 2008 | 1,240 | 1,585 |
| 2009 | 2,385 | 3,727 |
| 2010 | 6,380 | 8,169 |

| | | |
|---|---|---|
| 2011 | 2,947 | 3,421 |
| 2012 | 4,335 | 5,830 |
| 2013 | 1,752 | 5,573 |
| 2014 | 2,615 | 3,015 |
| 2015 | 2,361 | 4,330 |
| 2016 | 3,507 | 6,228 |
| 2017 | 5,362 | 4,979 |
| 2008-2017 | 3,165 | 4,752 |

**average quantity of bushels accumulated*

Table 21. Bushels Accumulated by Month in Corn and Soybeans 2008-2017

| Month | Corn | % Change from Prior Month | Soybeans | % Change from Prior Month |
|---|---|---|---|---|
| January | 3,489 | -10.04% | 5,025 | -5.95% |
| February | 3,214 | -8.53% | 5,428 | 7.43% |
| March | 2,855 | -12.58% | 5,667 | 4.22% |
| April | 2,713 | -5.24% | 4,927 | -15.01% |
| May | 2,950 | 8.02% | 4,463 | -10.40% |
| June | 2,861 | -3.08% | 3,381 | -32.02% |
| July | 2,770 | -3.30% | 3,720 | 9.13% |
| August | 3,011 | 8.00% | 3,880 | 4.11% |
| September | 3,870 | 22.20% | 4,789 | 18.98% |
| October | 3,222 | -20.11% | 5,359 | 10.64% |
| November | 3,409 | 5.47% | 5,167 | -3.71% |
| December | 3,839 | 11.21% | 5,323 | 2.94% |
| Growing Season (April-September) | 3,029 | -10.20% | 4,193 | -27.06% |
| Non-Growing Season (October-March) | 3,338 | 9.25% | 5,328 | 21.30% |

**average quantity of bushels accumulated*

Table 22. Bushels Accumulated by Trend in Corn and Soybeans 2008-2017

| Trend | Trend Length | Corn – Producer Accumulator | Corn – # of Contracts in Trend | Soybeans – Producer Accumulator | Soybeans – # of Contracts in Trend |
|---|---|---|---|---|---|
| Uptrend | 25-day | 2,719 | 1,804 | 4,086 | 1,988 |
| | 50-day | 2,324 | 1,571 | 3,570 | 1,627 |

| | | | | | |
|---|---|---|---|---|---|
| | 100-day | 2,328 | 1,119 | 2,969 | 938 |
| | Average | 2,457 | 1,498 | 3,542 | 1,518 |
| Neutral Trend | 25-day | 3,497 | 1,404 | 5,305 | 1,338 |
| | 50-day | 3,406 | 1,758 | 5,135 | 1,898 |
| | 100-day | 3,018 | 2,572 | 5,106 | 3,116 |
| | Average | 3,307 | 1,911 | 5,182 | 2,117 |
| Downtrend | 25-day | 3,318 | 1,918 | 5,115 | 1,816 |
| | 50-day | 3,649 | 1,772 | 5,607 | 1,592 |
| | 100-day | 4,147 | 1,360 | 5,586 | 1,013 |
| | Average | 3,705 | 1,683 | 5,436 | 1,474 |

**average quantity of bushels accumulated*

Figure 1. Producer Accumulator Contract Price-Time Path

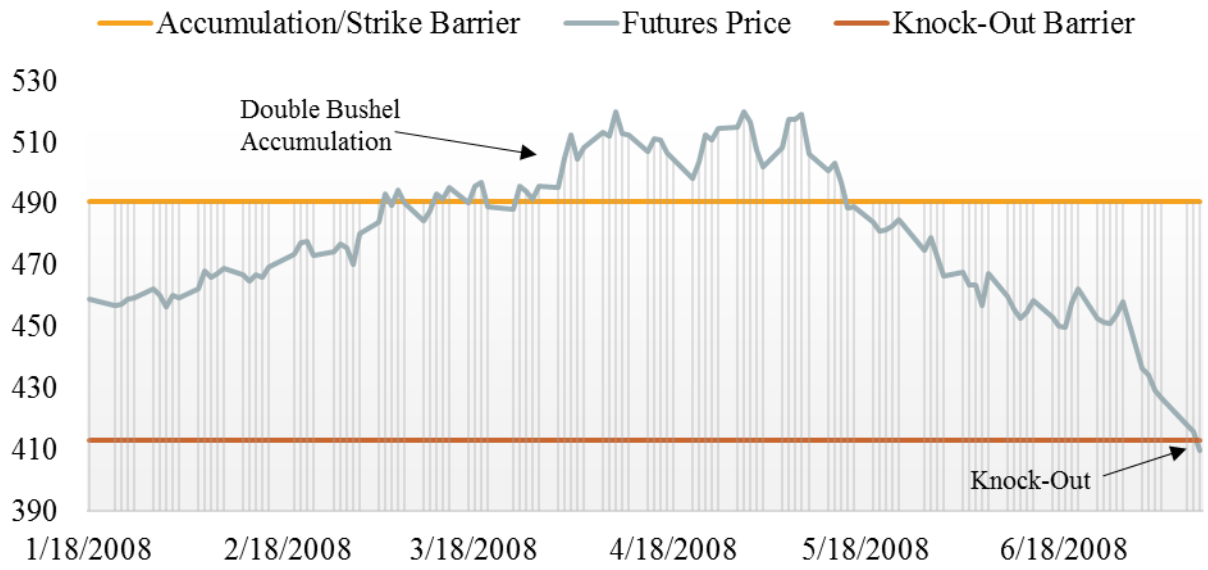

Figure 2. Knock-Out Barrier in Corn – Observed vs Predicted

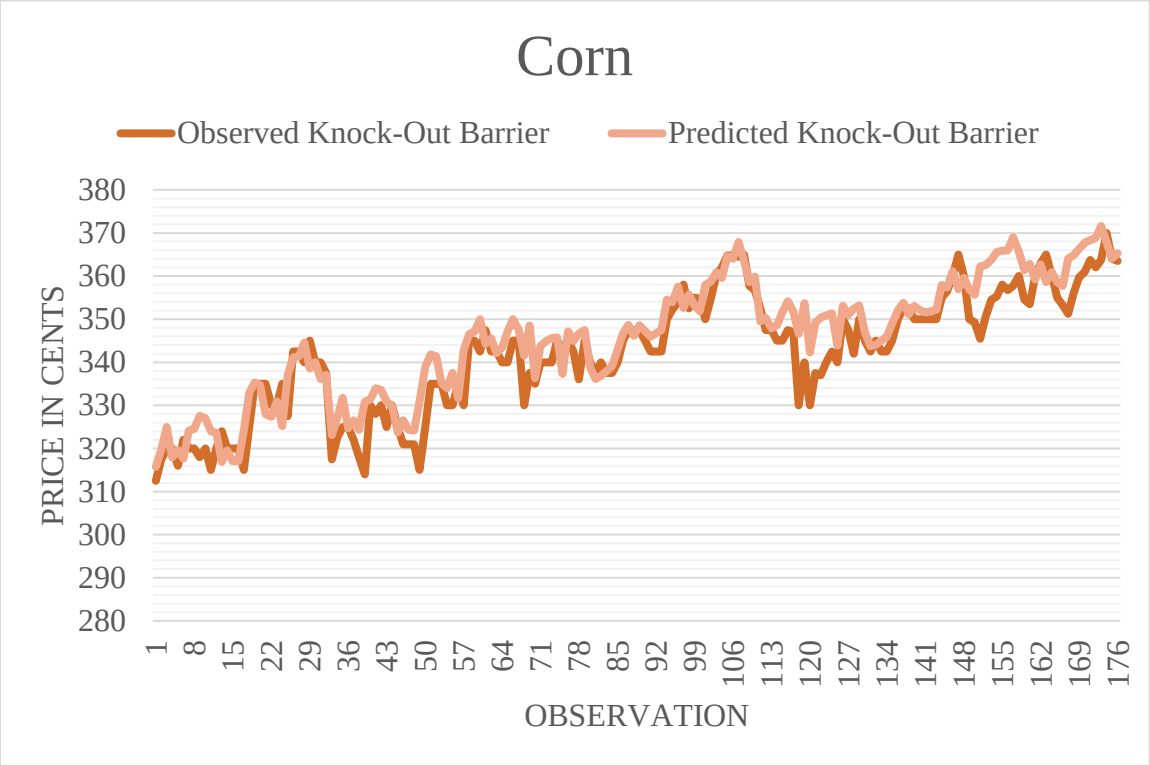


Figure 3. Knock-Out Barrier in Soybeans – Observed vs Predicted

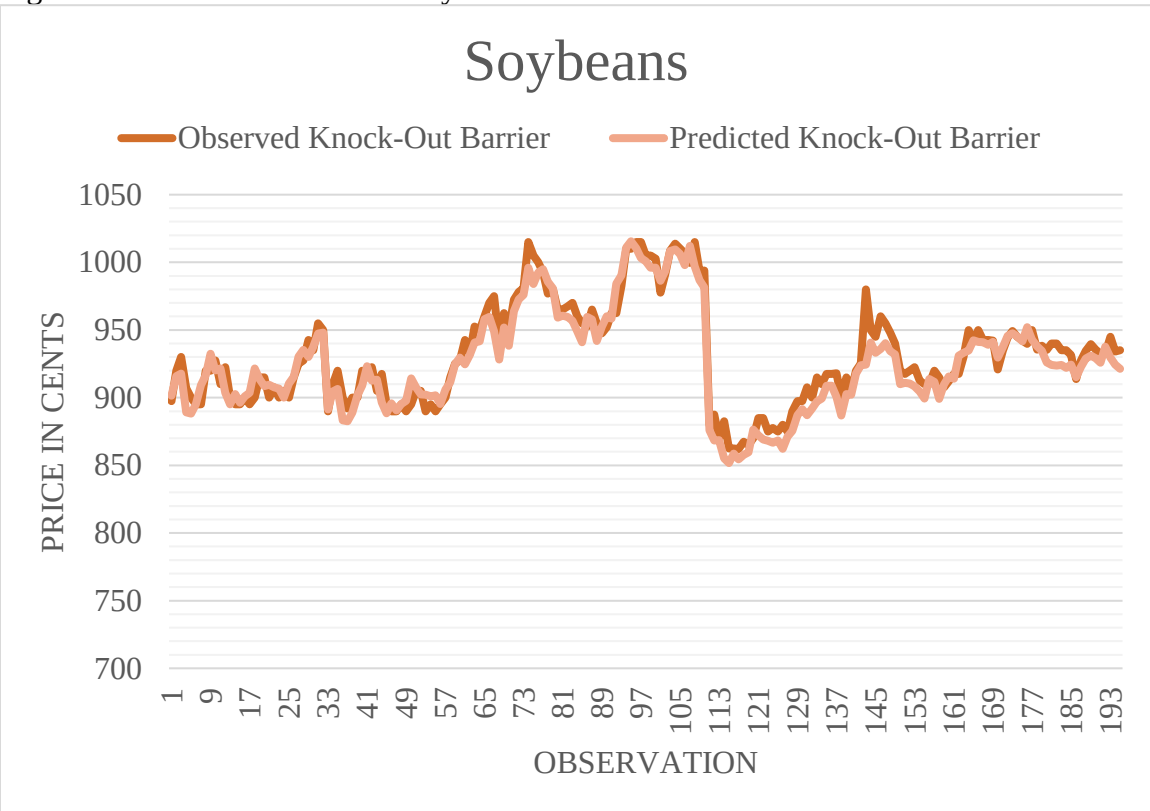

Figure 4. Zero-Cost Accumulation Strike in Corn – Observed vs Predicted

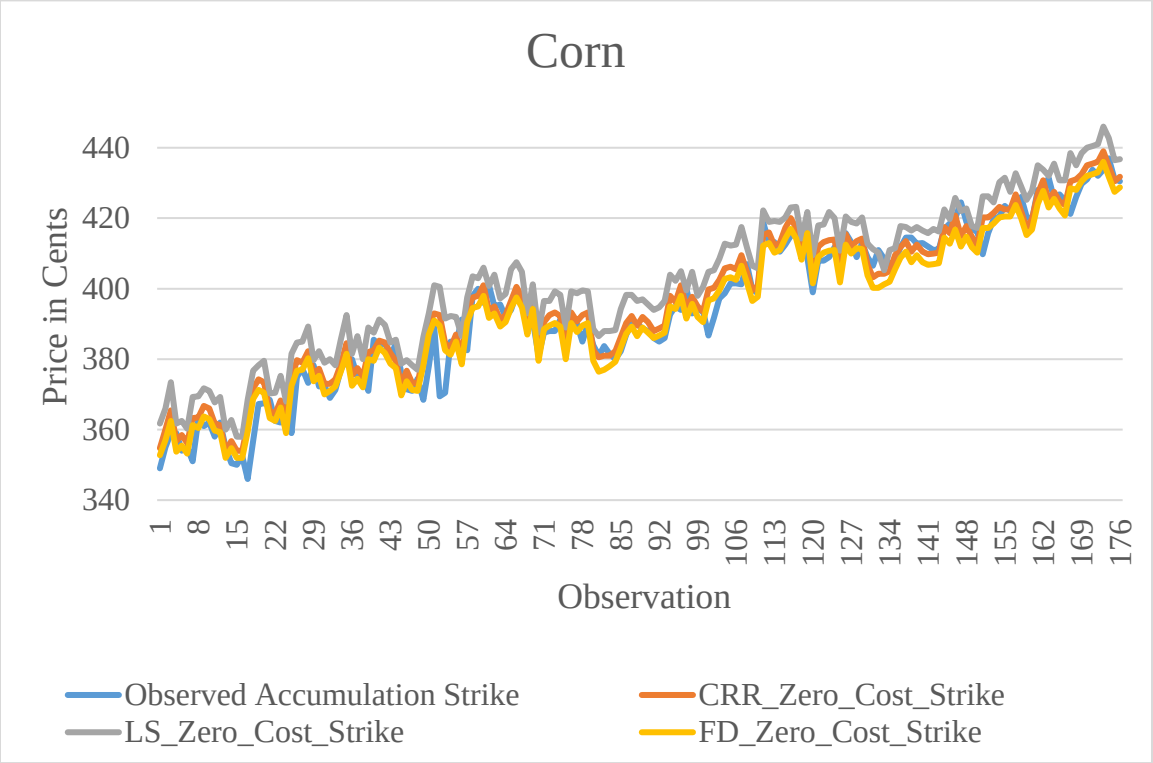


Figure 5. Zero-Cost Accumulation Strike in Soybeans – Observed vs Predicted

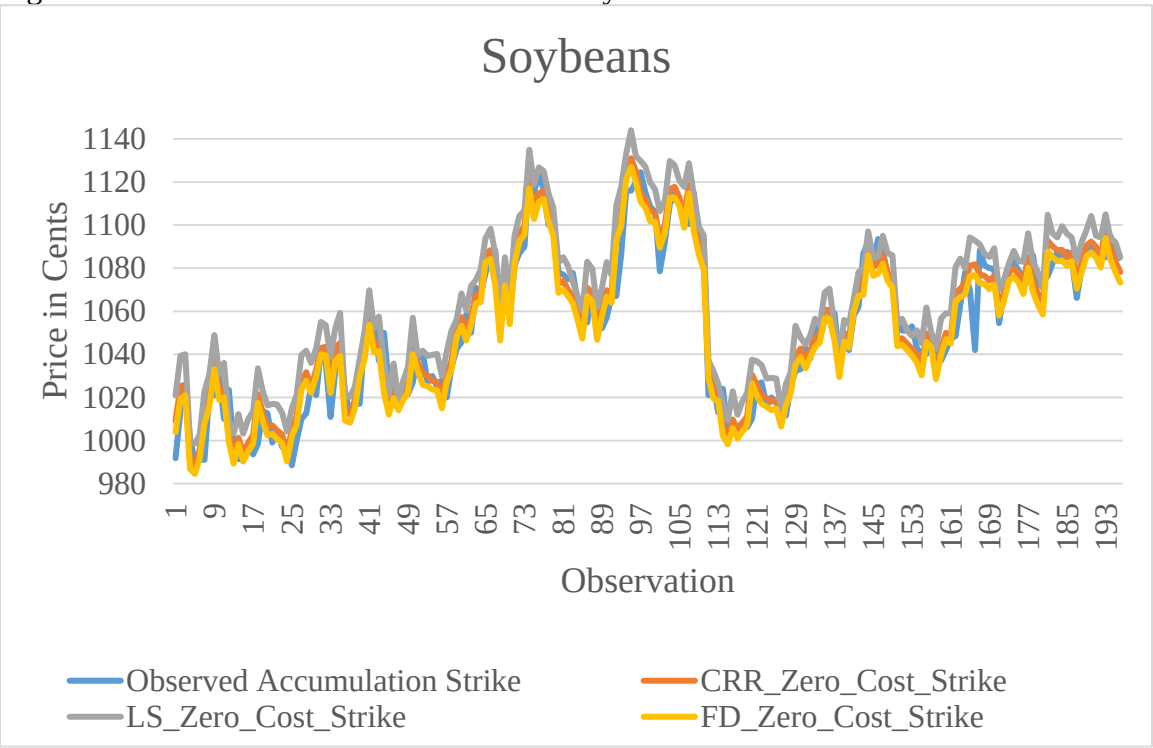

Figure 6. Portfolio Strategy Average Annual Price in Corn

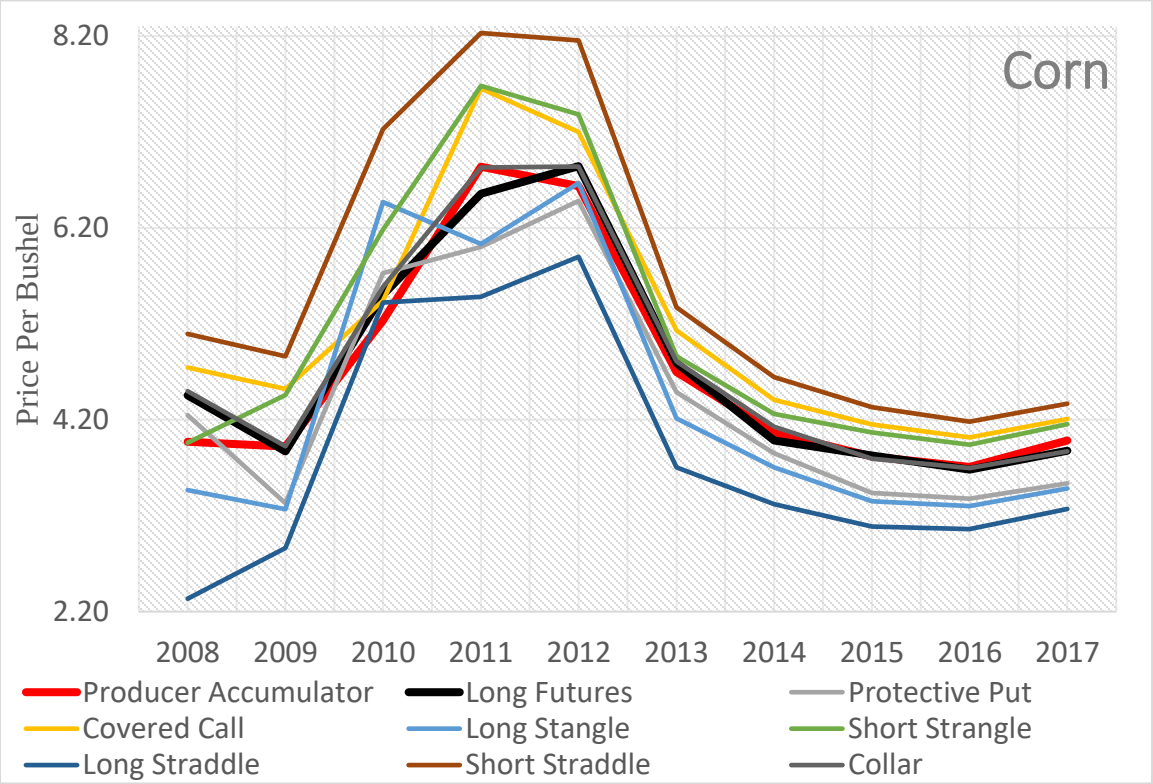


Figure 7. Portfolio Strategy Average Annual Price in Soybeans

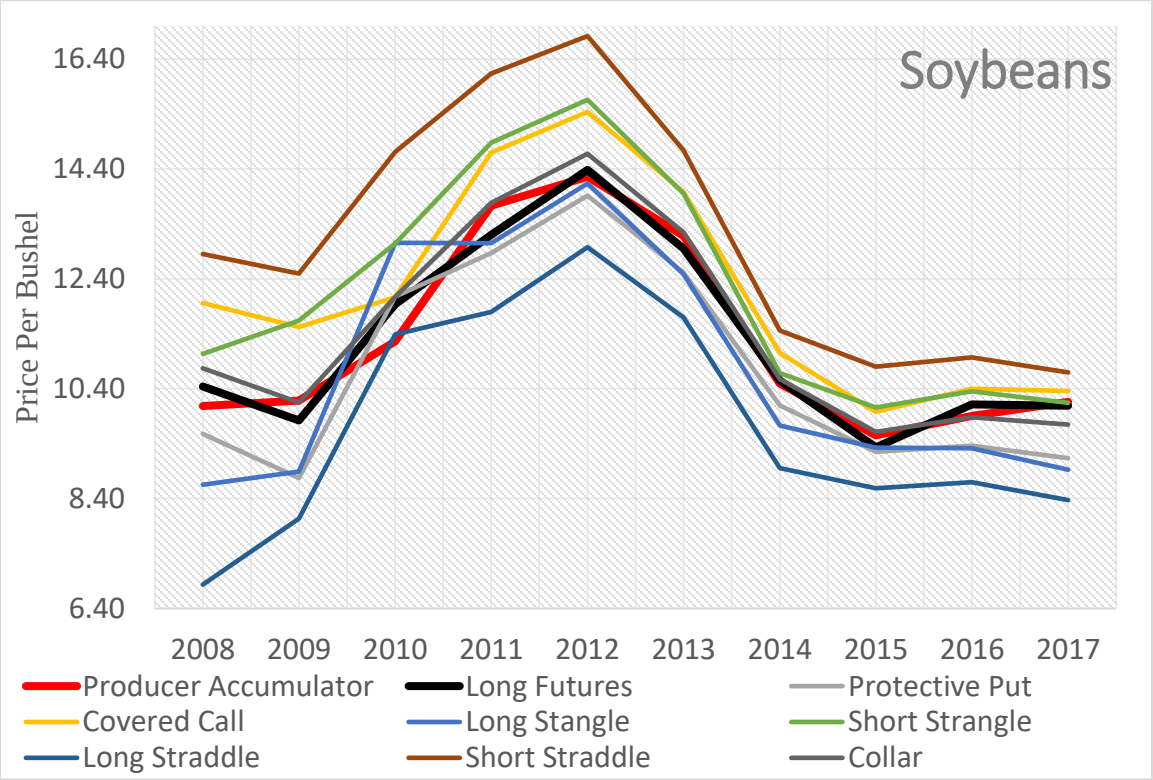

Figure 8. Price Ratio in Corn – December Expiration

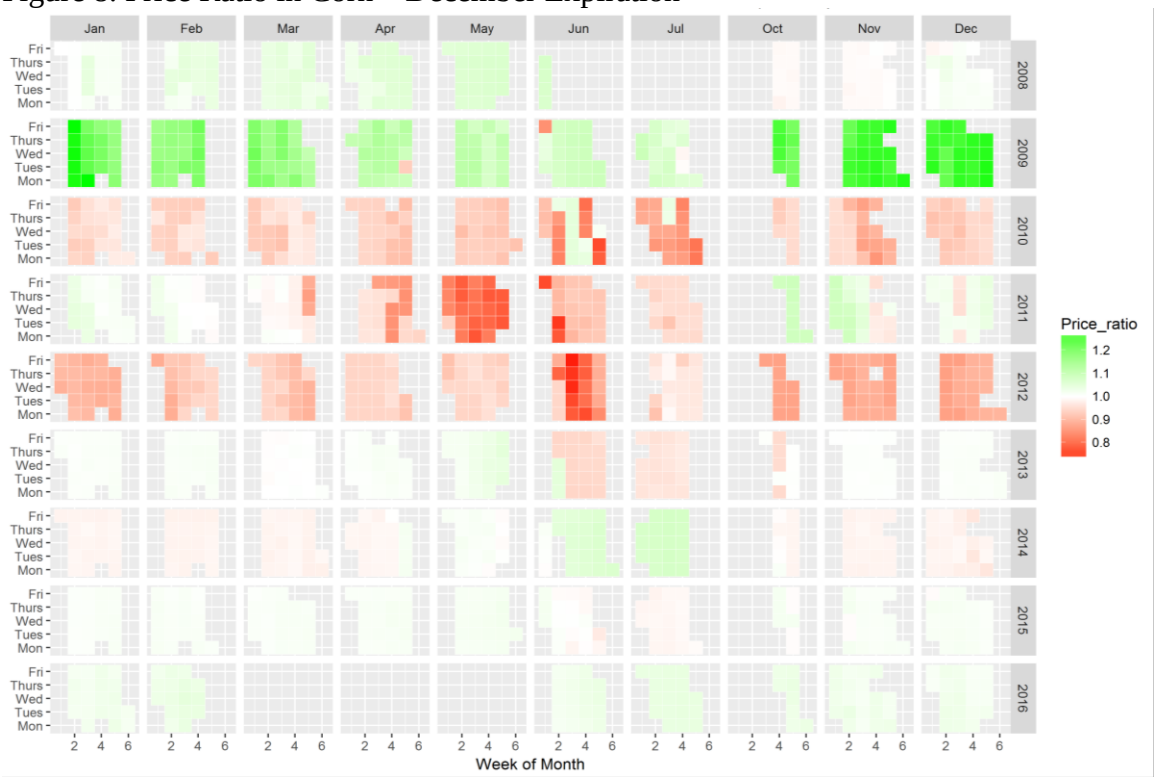


Figure 9. Price Ratio in Soybeans – November Expiration

Figure 10. Strategy Portfolio Average Annual Portfolio Risk in Corn

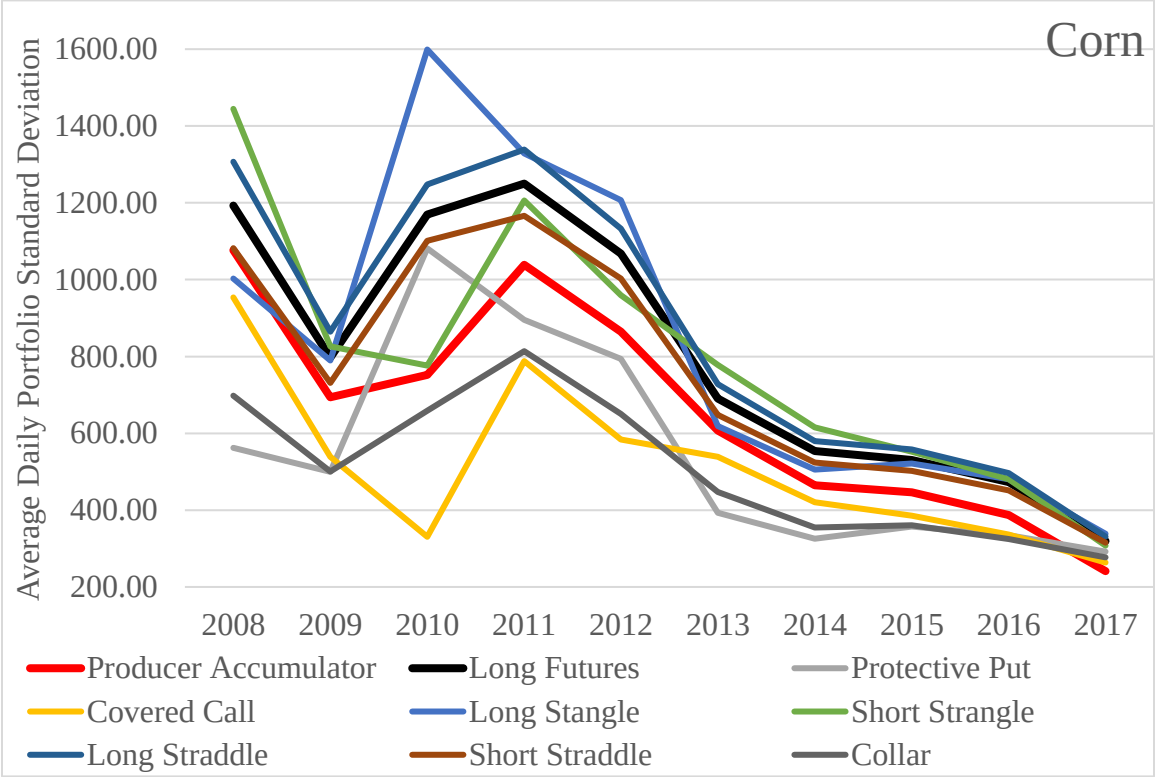


Figure 11. Strategy Portfolio Average Annual Portfolio Risk in Soybeans

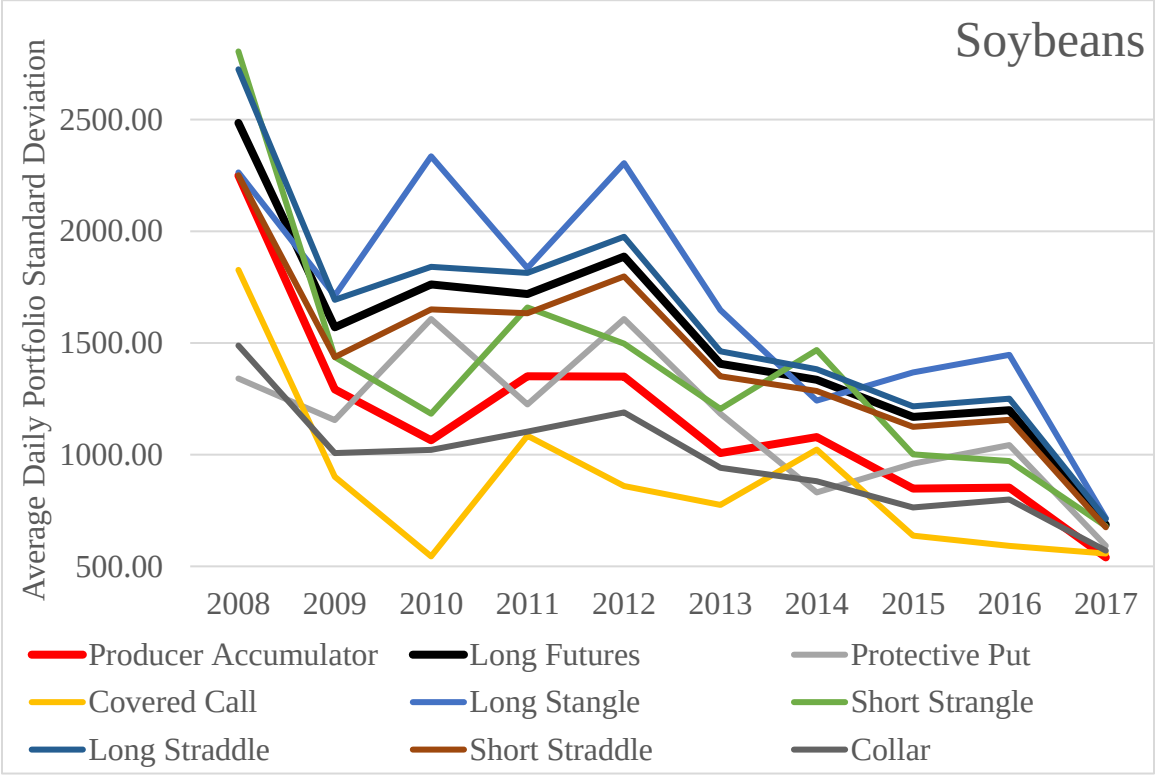

Figure 12. Sigma Ratio in Corn – December Expiration

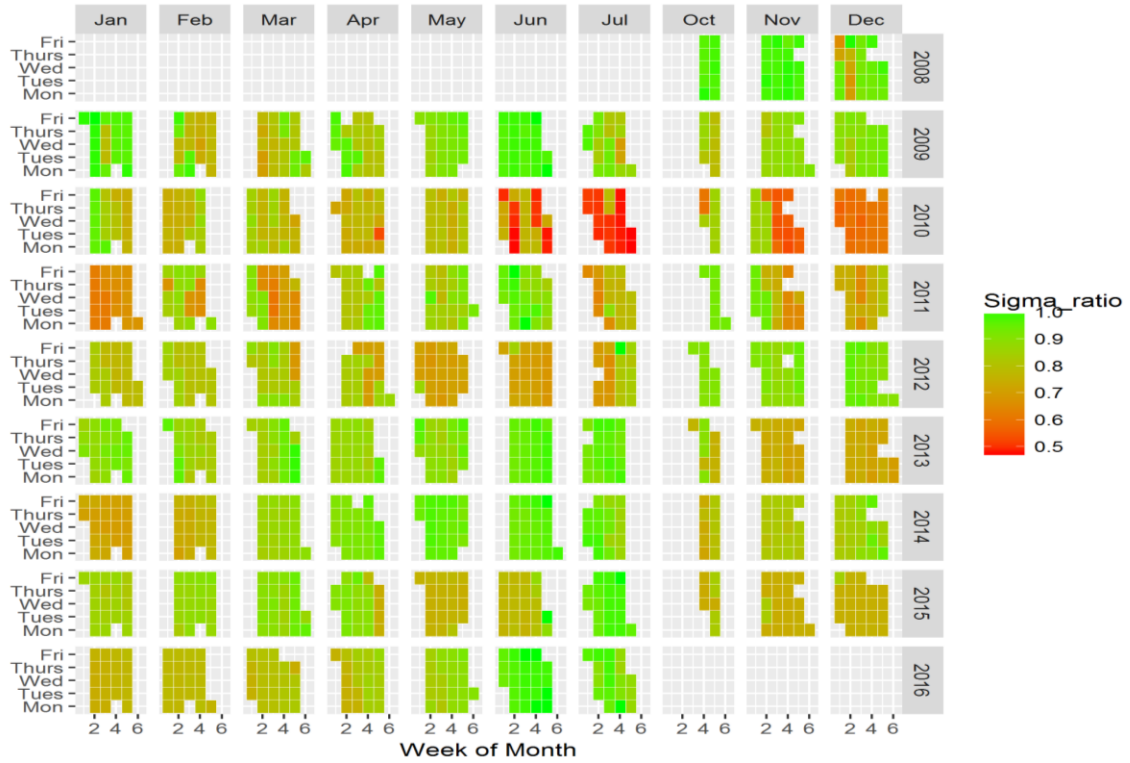


Figure 13. Sigma Ratio in Soybeans – November Expiration

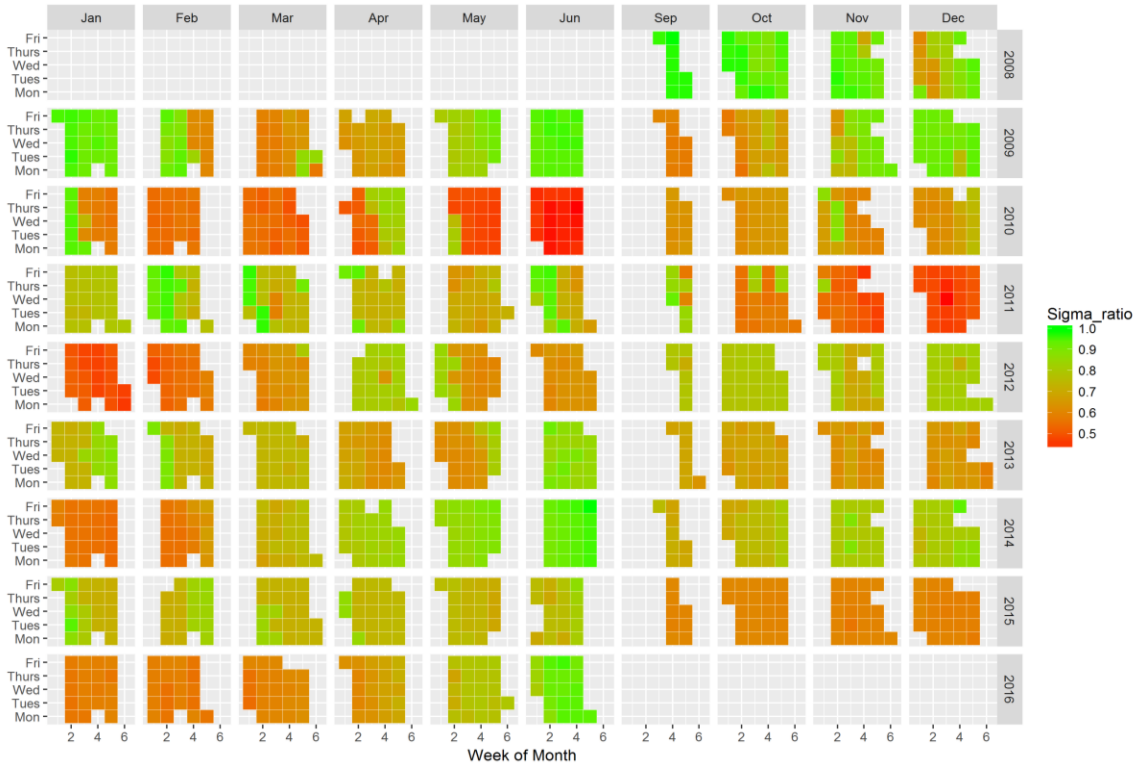

Figure 14. Strategy Portfolio Average Annual Sharpe Ratio in Corn

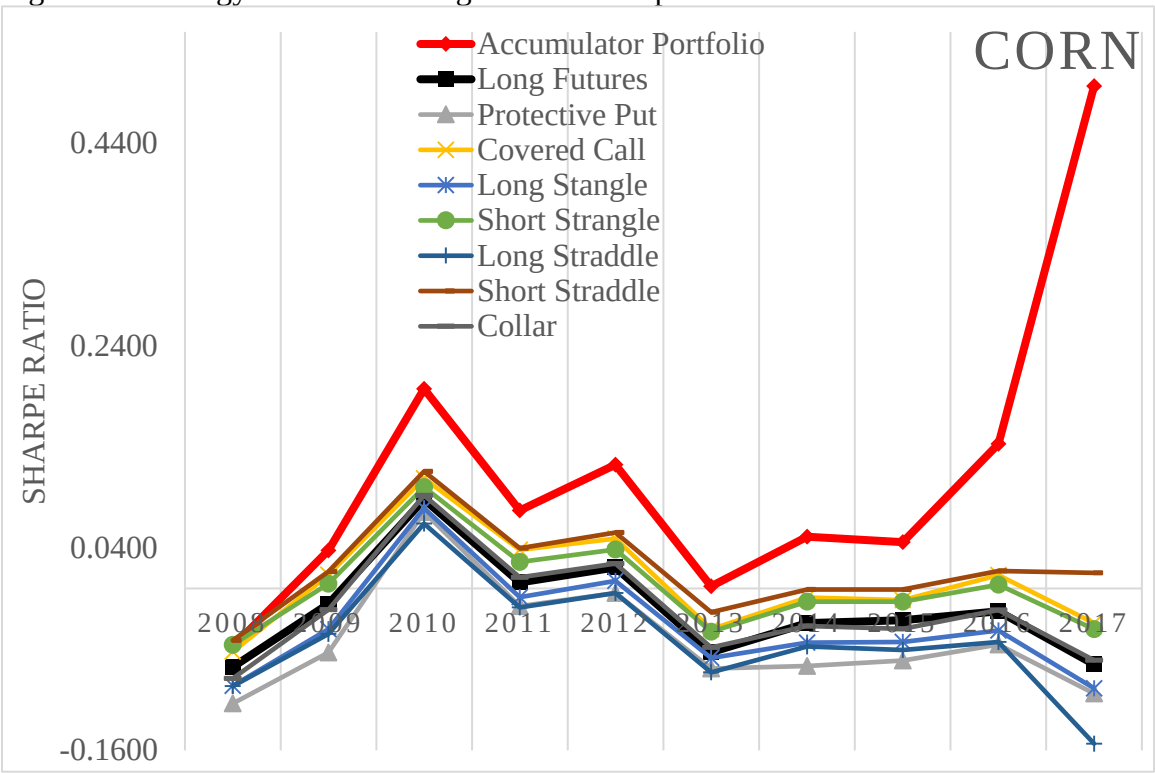


Figure 15. Strategy Portfolio Average Annual Sharpe Ratio in Soybeans

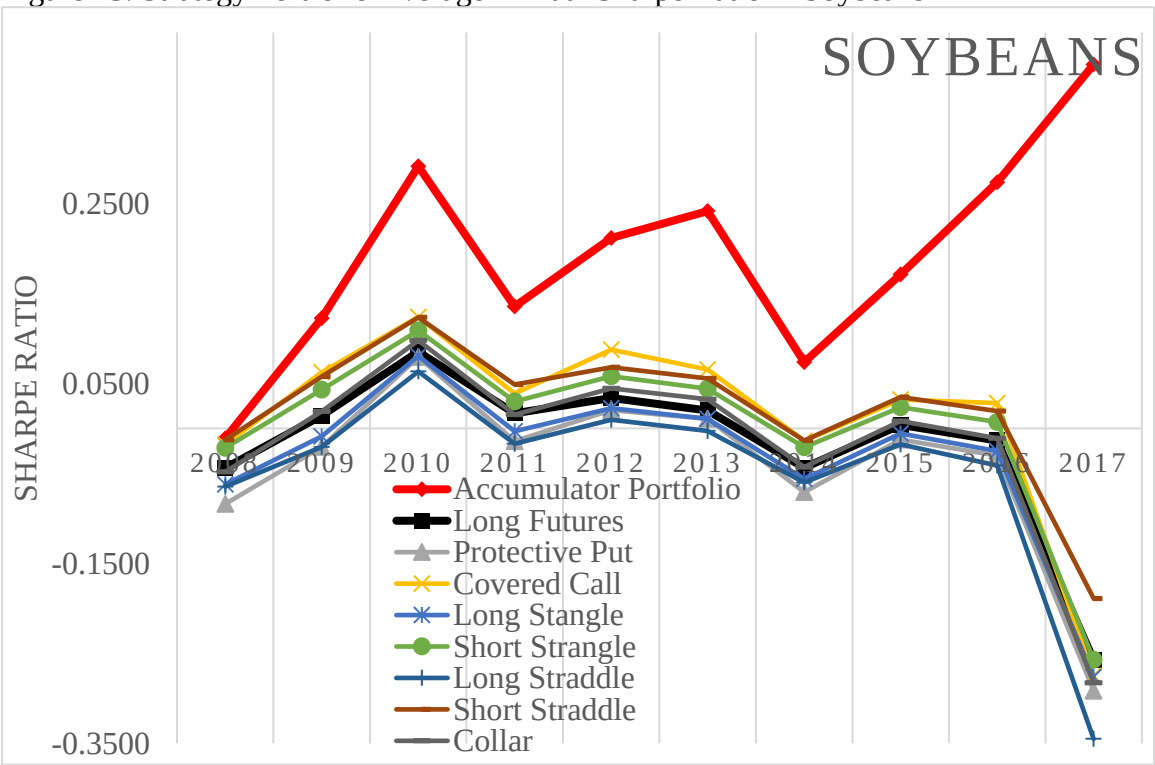

Figure 16. Producer Accumulator Sharpe Ratio in Corn – December Expiration

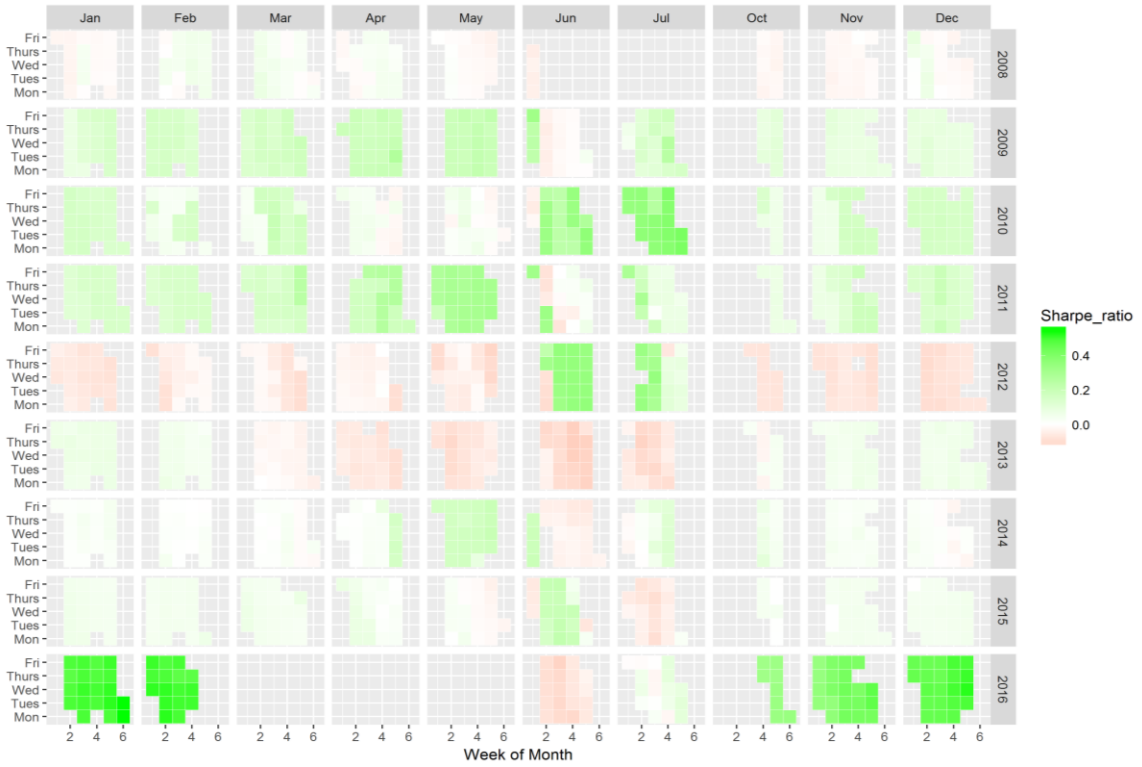


Figure 17. Producer Accumulator Sharpe Ratio in Soybeans – November Expiration

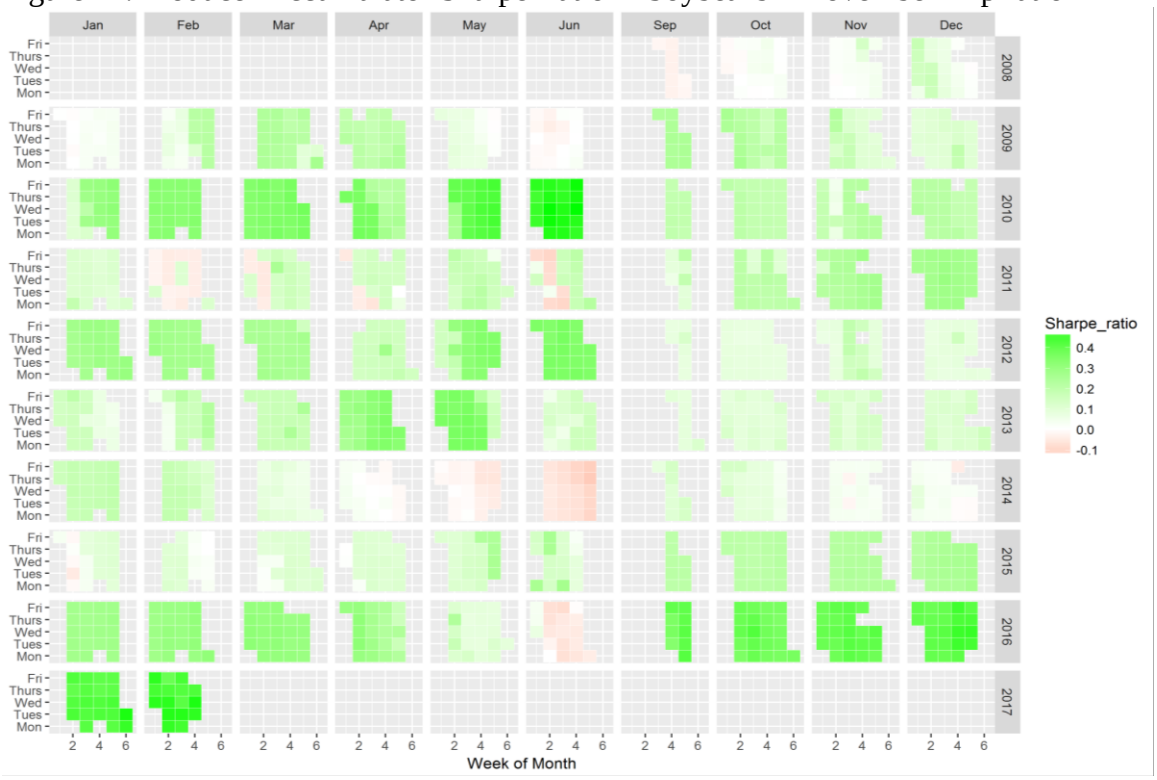

Figure 18. Bushels Accumulated Histogram in Corn 2008-2017

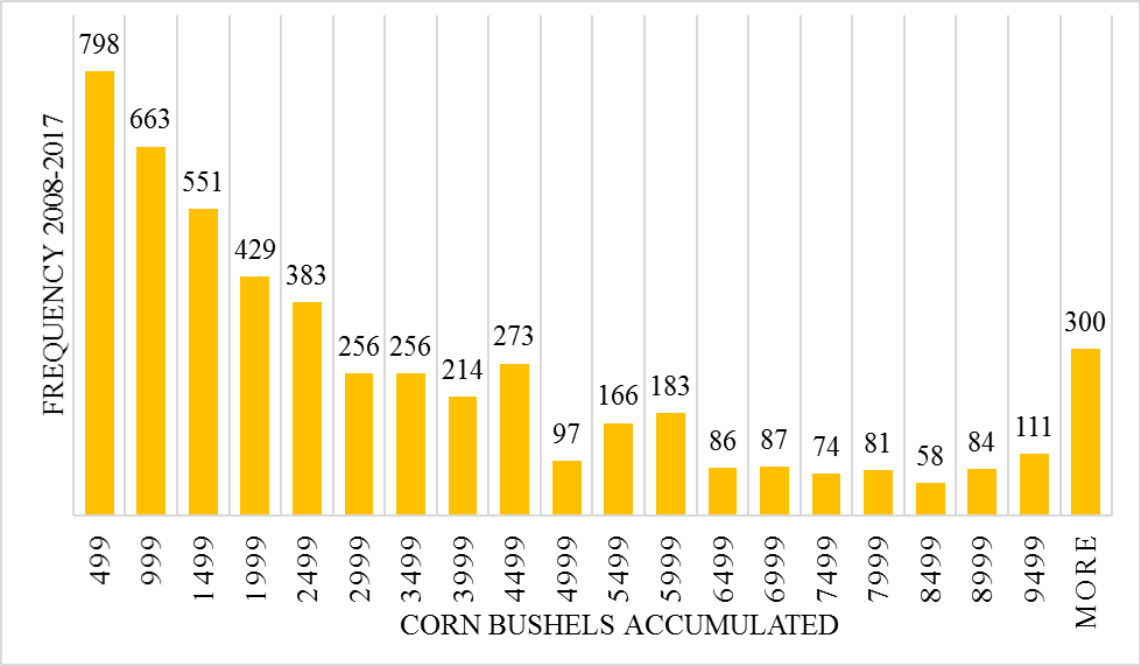


Figure 19. Bushels Accumulated Histogram in Soybeans 2008-2017

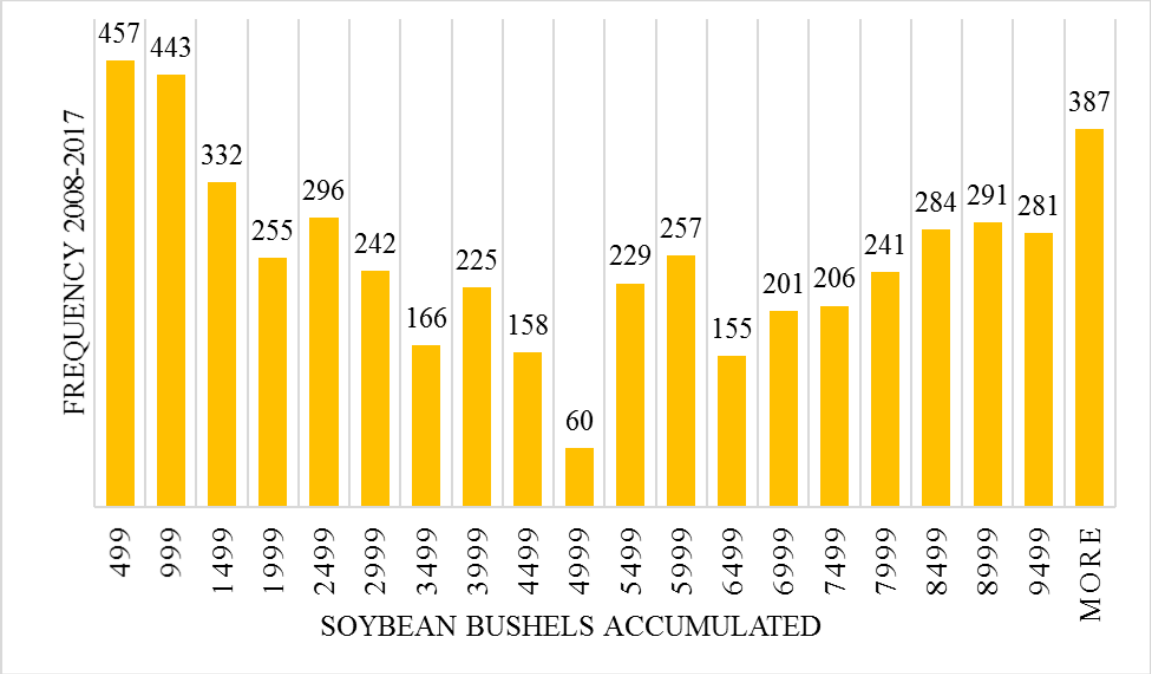

Figure 20. Bushels Accumulated in Corn – December Expiration

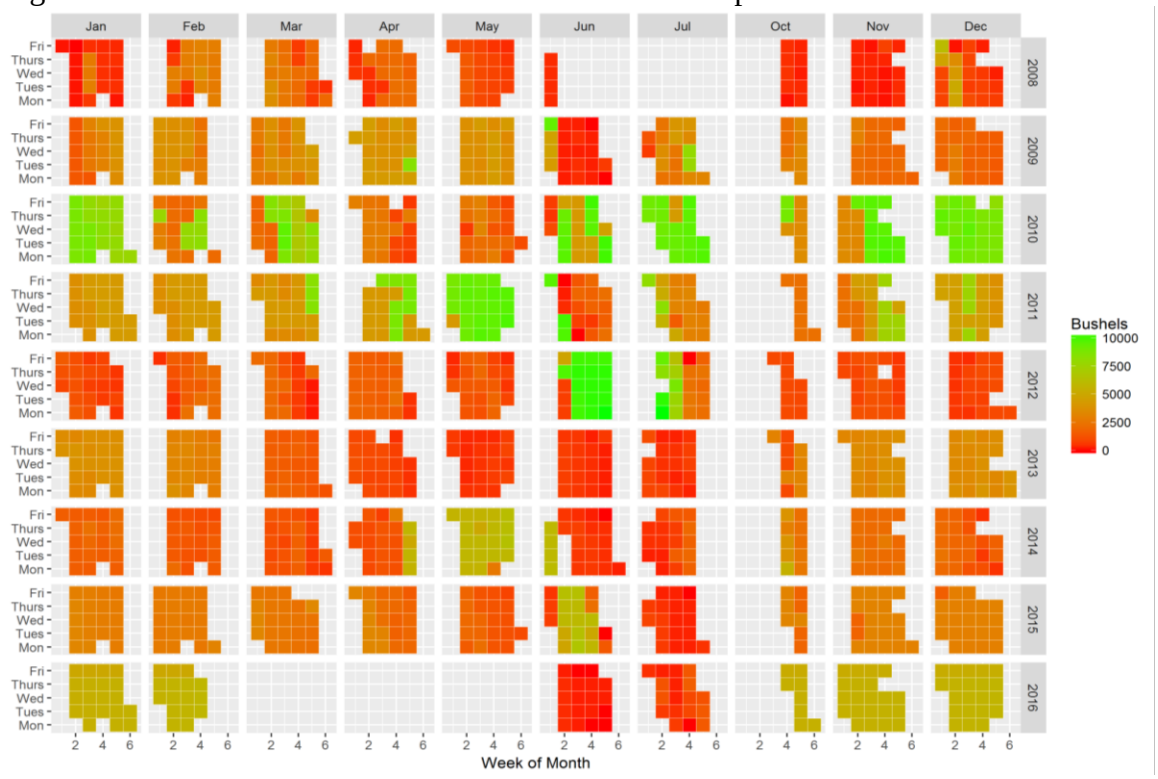


Figure 21. Bushels Accumulated in Soybeans – November Expiration