Performance of the Producer Accumulator in Corn and Soybean Commodity Markets

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PERFORMANCE OF THE PRODUCER ACCUMULATOR IN CORN AND
SOYBEAN COMMODITY MARKETS

BY

CHAD TE SLAA

A thesis submitted in partial fulfillment of the requirements for the

Master of Science

Major in Economics

South Dakota State University

2017
PERFORMANCE OF THE PRODUCER ACCUMULATOR IN CORN AND
SOYBEAN COMMODITY MARKETS

CHAD TE SLAA

This thesis is approved as a creditable and independent investigation by a candidate
for the Master of Science in Economics degree and is acceptable for meeting the thesis
requirements for this degree. Acceptance of this does not imply that the conclusions
reached by the candidate are necessarily the conclusions of the major department.

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ABSTRACT

PERFORMANCE OF THE PRODUCER ACCUMULATOR IN CORN AND SOYBEAN COMMODITY MARKETS

CHAD TE SLAA

2017

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.
CHAPTER 1: INTRODUCTION

1.1 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 by firms such as Archer Daniels Midland (ADM), and Cargill. Producer accumulator contracts are dominantly concentrated in the Midwestern states of Iowa, Nebraska, and Illinois. The dual intent of commodity purchasing firms and 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 Chicago Board of Trade (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 provide an alternative grain marketing product and to increase the amount of grain sales originated from large scale corn and soybean operations (Johnson, 2006).
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 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).

Originating a producer accumulator contract with a producer helps the commodity buying firm to reduce supply risk by sourcing grain. In addition to sourcing grain, originating a producer accumulator contract with producers allows commodity buying firms to become more cost effective. The primary reduction in costs materializes through lower costs associated with logistics. Logistical costs are deflated by the grain buying firm’s ability to originate large volumes of predated sales for future delivery at a third-party location. Commonly, commodity buying firms target large scale operations with logistical advantages to store and transport grain directly to feedlots, processors, and terminals. Focusing on large-scale producers allows commodity purchasing firms to cut out a substantial share of handling and transportation costs. After the producer and
commodity buying firm outline the specifics of the producer accumulator contract, the
grain buying firm hedges the accumulator contract through INTL FCStone Trading. By
hedging the producer accumulator contract through INTL FCStone Trading, the
commodity purchasing firm reduces its firm-specific risk by passing on the price risk
(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).

1.2 Technical Definition

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 $H_d$. While the accumulation strike
price $X$ offers a premium to the commodity futures price upon contract initiation $F_0$, this
may not hold since the accumulation strike price $X$ stays at the same constant level during
the contract’s lifetime $t$. On the observation day $t_i$ if the futures weekly closing price $F_i$ is strictly greater than the accumulation strike price $X$, the producer sells twice the weekly fixing quantity $2q$. If on the observation day $t_i$ the futures weekly closing price $F_i$ is less than or equal to the accumulation strike price $X$ and the futures price for all CBOT futures contract trading hours $F_\tau$ is strictly greater than the knock-out barrier $H_d$, then the producer sells the weekly fixing quantity $q$. If at any CBOT trading hours $\tau$ the underlying futures price for all CBOT trading hours $F_\tau$ breaches the knock-out barrier $H_d$, knock-out prompts conclusion of the contract permanently, fixing no sales the current week, but keeping preceding weekly sales $q_i$ effective. Figure 1 visually represents, for ease of understanding, an example of producer accumulator contract price-time path among the accumulation strike price and the knock-out barrier.

Figure 1. Producer Accumulator Contract Price-Time Path

![Figure 1. Producer Accumulator Contract Price-Time Path](image)

1.3 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 consumer 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 (Cheng, 2010).

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.

1.4 Research Objectives

This empirical research focuses on the risk reduction and performance of the producer accumulator contract applied to corn and soybean commodity markets. We
examine the producer’s perspective focusing on the common producer accumulator contract offered to Midwestern farmers by cooperatives and commodity purchasing firms.

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.

CHAPTER 2: LITERATURE REVIEW

The literature review consists of three parts: agricultural marketing strategy performance in corn and soybean markets, barrier option pricing theory, and accumulator contract literature and pricing theory. The agricultural marketing strategy performance in corn and soybean markets section reviews research on pre-harvest, post-harvest, and new generation grain marketing strategies. Producer accumulator contracts are classified as a new generation grain marketing strategy and can be incorporated as either a pre-harvest or post-harvest risk management strategy. Accumulator contracts are composed of barrier options giving the product its exotic traits. Thus, in this section we examine the types of barrier options, along with the advantages and limitations of popular barrier option pricing models. In the accumulator literature and pricing theory section, we investigate general
accumulator characteristics and research to guide our producer accumulator theoretical model and the simulation of synthetic producer accumulator contracts.

2.1 Agricultural Marketing Strategy Performance in Corn and Soybeans

Traditional grain marketing consists of cash sales at harvest (naïve method), pre-harvest risk management using hedging or options, post-harvest risk management via on-farm storage, or assistance of a professional grain marketing service. As derivatives strategies for commodities advance, more risk management strategies become available to producers. More recently, the grain marketing industry introduced producers to a new form of marketing through new generation contracts like the producer accumulator. Using simulation and backtesting, many authors have shed light on the realistic returns, opportunity cost, and risk reducing ability of traditional and new generation grain marketing strategies. In this section, we review pre-harvest and post-harvest strategies, their performance, and the methods used to quantify strategy performance. Our objective is to identify alternative agricultural marketing strategy portfolios for comparison to the producer accumulator, along with methodology to quantify performance of all back-tested portfolios.

Wisner, Blue, and Baldwin (1998) investigated net returns of 10 pre-harvest marketing strategies using a combination of options and hedging in corn and soybeans. They focused on the producer’s perspective, testing the possibility of receiving positive net returns without drastically increasing return variability. A $t$-test was used to test for statistical difference between each pre-harvest strategy and the naïve method of selling at harvest. Two model farms, one in Iowa and the other in Ohio, were used to simulate the net returns of pre-harvest marketing strategies. In soybeans, the Ohio farm had five out of
ten strategies with higher net returns than the naïve benchmark, while the Iowa farm had four out of ten. The synthetic put had the greatest net return following a normal or short crop. In corn, the Ohio and Iowa farm each had two out of ten strategies outperform the naïve method. The Mixed Hedge/Put pre-harvest marketing strategy had the highest net return. In both corn and soybeans, the best performing strategy had net returns greater than the naïve benchmark. They accept the hypothesis of higher returns without increased variability using pre-harvest marketing strategies with hedging and options in corn and soybeans during 1985-1996 (Wisner, Blue, and Baldwin, 1998).

Bektemirova (2014) analyzed basis trading and basis trading with pre-spreading for corn and soybeans at varying cost of carry levels from the seller’s perspective. To measure the statistical significance of mean net returns, paired t-tests are used. Results are based on daily average cash bid price data from North Central Illinois. Cumulative mean net returns for harvest time basis trading and pre-harvest pre-spreading strategies at 150% the cost of carry level had comparable results with post-harvest storage in corn. In soybeans, cumulative net returns from basis trading and pre-spreading have declining returns beyond a 40-day storage period. Pre-spreading for short periods under 60 days or unhedged storing soybeans for extended periods over 110 days are found to have the highest returns. Unhedged corn storage had positive net returns 60% of the 60-175-day storage period, while unhedged soybean storage had positive net returns 67% of the 60-185-day storage period. In both commodities, cumulative net returns to storage were increasing at the end of the storage timeframe (Bektemirova, 2014).

Like other pre-harvest and post-harvest risk management strategies, new generation contracts intend to address the producer’s affliction with poor marketing performance.
Most new generation grain marketing contracts consist of option strategies, preset pricing rules or discretionary marketing decisions made by a grain marketing service (Hagedorn et al., 2003). Pricing bushels on a weekly basis over a defined period, the producer accumulator is akin to the new generation grain marketing contracts with automated pricing. Automated pricing contracts average sales over a specified pricing period by following predefined set rules.

Hagedorn et al. (2003) reviewed the unique characteristics of new generation grain marketing contracts and provide performance scenarios in varying market conditions. Their study focused on grain marketing strategies based on contracts that incorporate automated pricing, managed hedging, and a combination of the former. To induce an unbiased comparison between new generation contract types, the study frames contrasting price benchmarks. A pre-harvest price benchmark encompasses a twelve-month pre-harvest forward bid average. To measure post-harvest price, a twelve-month post-harvest cash price less carrying charge average is benchmarked. And, a twenty-four-month average price is benchmarked to establish a long run average of pre-harvest and post-harvest price (Hagedorn et al., 2003).

To simulate opposing market conditions, each new generation contract was simulated by Hagedorn et al. (2003) during three annual technical trends: up, flat, and down. 1995 represents the uptrend crop year, 1998 characterizes a downtrend crop year, and 2000 symbolizes the neutral trend crop year. Example final prices received by producers during uptrend, neutral trend, and downtrend years were identified for eight automated pricing contracts, one managed hedging contract, and two combination contracts offered to central Illinois producers by Cargill, Consolidated Grain and Barge
During the uptrend year, the Consolidated Grain and Barge (CGB) Equalizer “Post Harvest” automated pricing contract realized the highest final price at $3.78/bu. The Cargill AgHorizions ProPricing A+ Ultra combination contract achieved the best final price of $2.56/bu. during the downtrend year. For the neutral trend year, a combination contract, the Cargill AgHorizions ProPricing A+ produced the highest final price at $2.17/bu. (Hagedorn et al., 2003).

Wisner, Blue, and Baldwin (1998), Bektemirova (2014), and Hagedorn et al. (2003) show that positive net returns for certain pre-harvest, post-harvest, and new generation grain marketing strategies can occur. Our research will add to the current literature on agricultural strategy performance in corn and soybean commodity markets by providing risk and return performance of the producer accumulator and alternative agricultural marketing strategies through back-testing. Alternative agricultural marketing strategies back-tested will satisfy pre-harvest and post-harvest scenarios in corn and soybean markets to provide contextual performance comparison. Like Hagedorn et al. (2003), we incorporate a technical trend variable testing producer accumulator performance for producer accumulator contracts beginning following an uptrend, neutral trend, and downtrend. Results will provide further information and recommendations to producers on expected risk and return for agricultural marketing strategies incorporating futures and option contracts. The producer accumulator contract is established by combining barrier options. In the next section, barrier option pricing theory is reviewed.

2.2 Barrier Option Pricing Theory

Accumulator contracts are a portfolio consisting of barrier options. In this section, we review different types of barrier options and the methodology to value them. Varying
barrier option types are studied to identify the specific barrier option type that makes up the producer accumulator contract. After the specific type of barrier options that form the producer accumulator are identified, we need to value them to arrive at a zero-cost producer accumulator portfolio. To identify the best and most realistic method to value the underlying barrier options in the producer accumulator portfolio, we review popular barrier option pricing methodology identifying the advantages and limitations of each model.

Barrier options were first traded in over-the-counter markets in 1967. They later became exchange traded in 1991. Barrier option exercise style can be American or European. American options allow the option holder to exercise the option prior to expiration, while European options only allow the option holder to exercise the option at expiration. Common asset underlying for barrier options include: equities, indexes, currency, interest rates, and commodities. Barrier options are a path dependent financial derivative with similar features as a standard vanilla call or put option. However, instead of the payoff being solely dependent on the strike price as with standard vanilla options, barrier option payoffs are dependent on the strike and barrier price.

Barrier options come in one of two forms: in-option or out-option. In-options carry a knock-in trait and begin as an inactive option. They become active when the underlying asset’s price touches the knock-in barrier price level. If the barrier price level remains untouched, the knock-in option remains inactive, expiring worthless at expiration. Out-barriers carry a knock-out trait and begin as an active option. They remain active, unless the underlying asset’s price touches the knock-out barrier price level. If the barrier price level is touched, the out-option becomes inactive, expiring worthless at expiration (Derman and Kani, 1996).
Out-options and in-options have either an up barrier or down barrier. The up barrier stipulates that the barrier price level is greater than the current asset’s spot price. If the underlying asset’s price crosses the barrier price level, it will be from below. The down barrier specifies a barrier price level that is initially spatially located below the underlying asset’s spot price. If the underlying asset’s price crosses the barrier price level, it will be from above. Up, down, knock-out, and knock-in properties integrate to produce eight independent barrier options: up-and-in call, up-and-out call, down-and-in call, down-and-out call, up-and-in put, up-and-out put, down-and-in put, and down-and-out put. Table 1 outlines all common barrier options by option, type, and barrier location (Derman and Kani, 1996).

### Table 1. Types of Barrier Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Type</th>
<th>Barrier Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Call</td>
<td>Up-and-Out</td>
<td>Above Spot</td>
</tr>
<tr>
<td></td>
<td>Up-and-In</td>
<td>Above Spot</td>
</tr>
<tr>
<td></td>
<td>Down-and-Out</td>
<td>Below Spot</td>
</tr>
<tr>
<td></td>
<td>Down-and-In</td>
<td>Below Spot</td>
</tr>
<tr>
<td>Put</td>
<td>Up-and-Out</td>
<td>Above Spot</td>
</tr>
<tr>
<td></td>
<td>Up-and-In</td>
<td>Above Spot</td>
</tr>
<tr>
<td></td>
<td>Down-and-Out</td>
<td>Below Spot</td>
</tr>
<tr>
<td></td>
<td>Down-and-In</td>
<td>Below Spot</td>
</tr>
</tbody>
</table>

The producer accumulator maintains a knock-out barrier below the underlying’s spot price and is therefore built out of a portfolio combining down-and-out barrier options. Containing a knock-out barrier above the underlying’s spot price, the consumer accumulator is created from a portfolio combining up-and-out barrier options. Barrier options are used to create producer and consumer accumulator contracts because barrier options offer a handful of possible advantages over standard vanilla options. Payoffs for
barrier options may match the holder’s belief about future market direction, therefore, eliminating payment for scenarios the holder doesn’t believe are probable. If the holder only wants exposure or protection over a certain range of risk possibilities, barrier options may match hedging needs more closely than standard vanilla options. Most importantly, premiums are commonly lower than standard vanilla options due to the barrier stipulation limiting coverage to fewer payoff scenarios (Derman and Kani, 1996).

As a portfolio of down-and-out barrier options, the producer accumulator is a path-dependent derivative with its price contingent on the underlying’s price-time path over the derivative’s lifetime. Because barrier options are a path-dependent derivative, valuing them is a complex process. Due to the difficulty of pricing barrier options, multiple option pricing frameworks have been applied to the valuation of barrier options. Another crucial factor is how the barrier is monitored. Barrier options may contain either a continuous or discretely monitored barrier. Two dominant valuation methods stand out: analytic valuation for European-style barrier options with continuous monitoring and numerical valuation for European and American barrier options with discrete monitoring. A closed form solution can be found through an analytical framework such as the Black-Scholes option pricing model. Alternatively, numerical frameworks like the lattice models of binomial and trinomial trees will not generate a closed form solution.

Black and Scholes (1973) proposed a seminal formula to theoretically price standard vanilla European-style options in continuous time. The Black-Scholes model assumes that all assets follow geometric Brownian motion with constant drift and volatility, the rate of return on the risk-free asset is constant, and assets don’t pay dividends. The model assumes the market provides no arbitrage opportunity, no restriction on borrowing
and lending money at the at the risk-free interest rate, no restriction on buying or selling any amount of the asset, and zero transaction fees or costs. Beyond standard vanilla options, European barrier options can be valued under closed form through the Black-Scholes framework (Black and Scholes, 1973).

Merton (1973) was the first academic to develop pricing methodology for barrier options by extending the Black-Scholes model. Merton established pricing methodology for the European down-and-out call option by valuing the standard vanilla European call subject to boundary conditions. Through this, Merton arrived at a closed form solution for the down-and-out call option with a continuously monitored fixed barrier (Merton, 1973). Rubinstein and Reiner (1991) expanded the barrier option valuation framework beyond the down-and-out barrier call by defining payoffs and pricing formulas for eight standard barrier options. Under their valuation technique, barrier options are valued using the risk-neutral valuation approach by calculating the asset price risk-neutral densities when the barrier is crossed from above and below. The barrier option’s price is obtained by discounting the barrier option payoffs over the densities (Rubinstein and Reiner, 1991).

The Black-Scholes model provides the advantage of quick closed form option price generation for standard vanilla options. Nevertheless, it suffers from multiple limitations. Inability to price American-style options and underlying model assumptions limit the usefulness of the model. Constant asset price observation, fixed interest rate, and constant volatility are assumed for the duration of the option contract under the Black-Scholes model. These criteria do not realistically fit the market. Constant asset price observation is difficult and can lead to arbitrage as markets maintain dissimilar trading hours across the world. Constant volatility is violated in practice as a volatility smile is standard, where at-
the-money options have a lower implied volatility than further out-of-the-money options. With these limitations, the Black-Scholes model becomes impractical for accurately pricing barrier options for our producer accumulator portfolio (Black and Scholes, 1973).

Cox, Ross, and Rubenstein (1979) established the CRR binomial option pricing model to value American and European options in discrete time. As with other lattice models, closed form solutions are not generated. The binomial model values options using a three-step process. Initially, a price tree is established by working forward, branching price up and down by a fixed interval at each time step from valuation to expiration. Final node payoffs or the intrinsic values are calculated at expiration or the end of the price tree. Working backwards through the price tree, discounting option payoffs from expiration to valuation, assigns the option its spot price. Assumptions of the binomial model include: binomial distribution of returns, constant interest rate for the option’s life, investors may borrow as much capital as they want at the risk-free rate, no transaction costs or taxes, no margin requirements, no arbitrage, short selling is permitted, the investor is risk neutral, and volatility is constant (Cox, Ross, and Rubinstein, 1979).

Boyle and Lau (1994) investigated CRR binomial model pricing of barrier options when the barrier is close to the horizontal layer of lattice nodes. Increasing time steps when the barrier resonates between two vertical lattice nodes creates bias by slowly shifting the horizontal layer of nodes toward the barrier, eventually pushing the node layer across the barrier. Valuation bias is corrected by adjusting the number of time steps where the horizontal layer of nodes is close to the barrier, yet slightly beyond it. By adjusting the number of time steps, convergence to the Black-Scholes calculated continuous time price is improved. With this adaption, knock-in and knock-out probability is more accurate for
the down-and-in call and down-and-out call (Boyle and Lau, 1994). Derman, Bardhan, Ergener and Kani (1995) evaluated slow convergence under the binomial option pricing method. They establish an enhanced method improving option pricing precision by minimizing specification error. Correcting nodes at the effective and modified barrier price levels using an algorithm allows for converge to the specified barrier price level, improving valuation estimates (Derman, Kani, Ergener, and Bardhan, 1995).

Binomial models are known to provide accurate option pricing results for standard European and American vanilla options. The ability of the binomial model to value options with early exercise, American-style options, is a crucial advantage of the binomial model over the Black-Scholes model. However, the binomial model does not take into consideration the observed volatility smile of traded options. Valuing barrier options or exotic derivatives with the binomial model may lead to slow convergence. Slow convergence arises as binomial trees involve many time steps for accurate barrier option pricing results. When pricing barrier options, binomial models tend to generate errors near the barrier due to inaccurate calculations of variance and local means (Ritchken, 1995).

Boyle (1986) extended the binomial option pricing model to produce the trinomial tree method for valuing European and American options in discrete time (Boyle, 1986). Like binomial trees, trinomial trees branch up and down from each prior node at each timestep. However, in addition to the up-and-down paths, trinomial trees contain a middle path. Because of the three paths, asset price can move up to a higher price, stay constant moving horizontally at the prior node price, or move down to a lower price. Option value is derived from the same three-step process as binomial trees, beginning with the calculation of asset prices on the tree from valuation to expiration, then finding the intrinsic
values at the final nodes, and then working backwards from option expiration to valuation. Assumptions of the trinomial tree model consist of no arbitrage, the investor is risk neutral, the interest rate and volatility are constant for the option’s duration, investors may borrow as much as they want at the risk-free interest rate with no margin requirements, there are no taxes or transaction fees, and short selling is permitted.

Ritchken (1995) investigated barrier option pricing under the binomial lattice and a corrected trinomial lattice. He provides a method to identify the stretch parameter by calculating the number of down moves before reaching the layer of nodes above the barrier. Incorporation of the stretch parameter creates a trinomial tree where the nodes hit the barrier exactly providing rapid convergence for down-and-out options using fewer time steps than the binomial model (Ritchken, 1995). Cheuk and Vorst (1996) extended the trinomial tree model to incorporate a time-dependent shift parameter for the valuation of barrier options. Optimal node positioning for continuously observed barriers occurs when the horizontal layer of nodes is equivalent to the horizontal barrier. Ideal node positioning for a discretely observed barrier requires the horizontal barrier to be equidistant between two vertical nodes. Notably, large pricing errors occur when discrete barrier options are valued using a continuous framework (Cheuk and Vorst, 1996).

For simple option valuation, trinomial trees involve greater computational time than binomial trees for similar valuation accuracy. Trinomial trees are ideal for pricing exotic options due to more end nodes generating accurate and stable valuation of option payoffs. Trinomial trees efficiently value barrier options and have an advantage over binomial trees due to a more rapid convergence as time steps increase (Cheuk and Vorst, 1996). As with binomial trees, the constant volatility assumption of trinomial trees does
not often fit the observed implied volatilities of market traded options (Derman et al., 1996). When a volatility smile is observed, implied trees are a better fit.

Implied tree models value options similarly to constant volatility tree models; however, implied tree models assume non-constant implied volatility. Considering equivalent time to maturity and referenced asset price, implied volatility differs for options at each strike price. This occurrence is known as volatility smile or volatility skew. With differing implied volatilities at various strike prices, a smile shape is formed coining the term volatility smile. Corn and soybean options exhibit a volatility smile or term structure where implied volatility is greater for out-of-the-money options than at-the-money options. Guo and Su (2004) show that September corn futures options at varying strike prices exhibit a volatility smile (Guo and Su, 2004). R.J. O’Brien and Associates Inc. (2000) found that in commodity option markets, the implied volatility of out-of-the-money options is almost always higher than the implied volatility of at-the-money and in-the-money options (R.J. O’Brien and Associates Inc., 2000).

The implied binomial tree model was first introduced in 1994 with contributions from Dupire (1994), Derman and Kani (1994), and Rubinstein (1994) (Haug, 2007). Implied binomial trees are used to value complex American and European options in discrete time. The implied methodology prices options exhibiting a volatility smile by allowing local volatility to be a function of time and asset price. Binomial trees assume constant volatility forming a rigid lattice, while implied binomial trees incorporate local volatility and liquid option prices to create a flexible lattice. A flexible lattice allows differing local volatility from node to node. Using interpolation of market option prices, the location and probability of touching each node is calculated for all strikes and
expirations in the price tree. The implied binomial tree model requires that there are no preferences or arbitrage, the risk neutrality assumption holds, and the model properly reproduces the volatility smile observed in the marketplace (Derman and Kani, 1994).

Derman and Kani (1994) believed pricing barrier options using the implied framework will be beneficial where the probability of hitting the knock-out barrier is sensitive to the structure of the volatility smile. Because four parameters are involved, options values are generated efficiently and quickly. With the ability to adjust to uneven volatilities across several option strikes and expirations, implied binomial trees are known to generate superior dependability and elasticity than other option pricing models. The most accurate values for complex options are attainable when market option prices are liquid and transition probabilities remain positive (Derman and Kani, 1994). This methodology works proficiently for many situations, but it runs into issues when modifications are required, market option prices suffer from illiquidity, and negative transition probabilities occur. Most importantly, a well-structured lattice is unattainable when market option prices are inconsistent (Derman et al., 1996).

The implied trinomial tree (ITT) methodology is frequently applied to the valuation of complex options, particularly in option markets that demonstrate a persistent volatility smile. Implied trinomial trees are the implied volatility extension of the constant volatility trinomial tree. Constant volatility trinomial trees create a regular mesh; implied trinomial trees produce an irregular mesh. Because implied trinomial trees fit the observed market volatility smile, they are akin to implied binomial trees. However, implied binomial trees contain four parameters, while implied trinomial trees include five parameters. For accurate option valuation the implied trinomial tree model requires: transition probabilities to be
between zero and one to prevent arbitrage, fulfillment of the risk neutrality assumption, and appropriately replication of the volatility smile (Derman et al., 1996).

Having an extra parameter permits implied trinomial trees to duplicate a greater domain of volatility structures than implied binomial trees. Duplication of additional volatility structures allows for greater flexibility and consistency in fitting volatilities across option strikes and expirations (Haug, 2007). Users choose the state space or price at each node in the tree. This advantage allows implied trinomial trees to create a better fit to the volatility smile when market prices are inconsistent or violate the arbitrage assumption. On the downside, an additional parameter largely means greater computational time (Derman et al., 1996).

2.3 Accumulator Contract Literature and Pricing Theory

In this section of the literature review, we analyze accumulator contracts in multiple asset classes. Our objective is to gain an understanding of the pricing methodology and mechanics underlying the producer accumulator contract. There is limited producer accumulator pricing methodology and literature in commodities or any other asset class. We have access to some INTL FCStone contract information. Therefore, we rely on producer accumulator contract information to model a producer accumulator portfolio maintaining pricing and contract characteristics that are consistent with the INTL FCStone producer accumulator contract offered in corn and soybean commodity markets. However, consumer accumulator research and information is more abundant, so we also focus on research, theoretical pricing framework, and simulation results affiliated with the consumer accumulator contract.
Accumulator contracts come in two forms: producer accumulator and consumer accumulator. Producer accumulators allow for decumulation of the underlying asset; consumer accumulators allow for accumulation of the underlying asset. The producer accumulator requires the contract holder to sell a specified quantity of the referenced asset at a higher price than the referenced asset’s price at contract origination with the constraint of the accumulation strike price spatially located above the asset’s price at origination and a knock-out barrier price spatially located below the asset’s price at origination. Alternatively, the consumer accumulator requires the contract holder to buy a specified quantity of the referenced asset at a lower price than the referenced asset’s price at contract origination with the stipulation of the knock-out barrier price spatially located above the asset’s price at origination and an accumulation strike price spatially located below the asset’s price at origination. INTL FCStone Trading Company introduced accumulator contracts to commodity markets in the United States, allowing grain producers and consumers access to a new grain marketing tool. Grain producers, such as row crop farmers of corn and soybeans, sell their new or old crop production via the producer accumulator contract. Grain consumers, such as livestock firms, grain processors, and ethanol plants, accumulate grain through the consumer accumulator contract.

Consumer accumulators follow that during the contract’s lifetime \( t \), the consumer buys a fixed quantity \( q \) of the underlying stock \( S \) at the accumulation strike price \( X \) on the defined observation day \( t_i \), delivered on the settlement date \( T_i \), contingent on the continuous knock-out barrier \( H_c \). Standard consumer accumulator contracts maintain a zero-cost structure, requiring investors to pay no up-front premium to establish the
contract. Lam, Yu, and Xin (2009) provide payoffs for the zero-cost accumulator with delayed settlement and continuous knock-out barrier monitoring defined as,

\[
\begin{align*}
(1) & \quad 0 & \quad \text{if } \max_{0 \leq \tau \leq t_t} S_{\tau} \geq H_c \\
(2) & \quad S_{Ti} - X & \quad \text{if } \max_{0 \leq \tau \leq t_t} S_{\tau} < H_c, S_{t_t} \geq X \\
(3) & \quad 2(S_{Ti} - X) & \quad \text{if } \max_{0 \leq \tau \leq t_t} S_{\tau} < H_c, S_{t_t} < X
\end{align*}
\]

where \( S_{t_t} \) is the stock price on the observation day, \( S_{Ti} \) is the stock price on the settlement day, \( S_{\tau} \) is the continuous stock price, \( X \) is the accumulation strike price, \( H_c \) is the knock-out barrier price with continuous monitoring, \( t_t \) is the observation day, \( \tau \) is the continuously observed price for all time, and \( T_i \) is the maturity date of the forward contract (Lam et al., 2009).

The first payoff is zero. It follows that if at any trading hours \( \tau \) the underlying stock price for all trading hours \( S_{\tau} \) is greater than or equal to the continuous knock-out barrier price \( H_c \), knock out prompts conclusion of the contract permanently, fixing no sales on the current observation day \( t_t \), but leaving former fixed sales \( q_t \) effective. The second payoff is the difference between the stock price on the settlement day \( S_{Ti} \) and the accumulation strike price \( X \). It follows that the stock price for all trading hours \( S_{\tau} \) is strictly less than the continuous knock-out barrier price \( H_c \) and on the observation day \( t_t \) the stock’s closing price \( S_{t_t} \) is greater than or equal to the accumulation strike price \( X \), then the consumer buys the fixing quantity \( q \). The third payoff is two times the difference between the stock price on the settlement day \( S_{Ti} \) and the accumulation strike price \( X \). It follows that the stock price for all trading hours \( S_{\tau} \) is strictly less than the continuous knock-out barrier price \( H_c \) and on the observation day \( t_t \) the stock’s closing price \( S_{t_t} \) is strictly less than the accumulation strike price \( X \), then the consumer buys twice the fixing quantity \( 2q \) (Lam et al., 2009).
Combining one long up-and-out call on a forward contract and two short up-and-out puts on a forward contract creates the portfolio known as the zero-cost accumulator contract with delayed settlement. Lam et al. (2009) provide the portfolio definition for the zero-cost accumulator with delayed settlement and continuous knock-out barrier monitoring as defined in Equation 4,

\( V_{\text{Delay}}^{\text{Delay}} = \sum_{i=1}^{n} \{ C_{uo}^F(X, H_C, t_i, T_i) - 2 \cdot P_{uo}^F(X, H_C, t_i, T_i) \} \)

where \( V_{\text{Delay}}^{\text{Delay}} \) is the value of the zero-cost accumulator contract portfolio under delayed settlement, \( P_{uo}^F(X, H_C, t_i, T_i) \) is the up-and-out put price on a forward contract, \( C_{uo}^F(X, H_C, t_i, T_i) \) is the up-and-out call price on a forward contract, \( X \) is the accumulation strike price, \( H_C \) is the knock-out barrier price with continuous monitoring, \( t_i \) is the observation day, and \( T_i \) is the maturity date of the forward contract (Lam et al., 2009).

Across the globe, accumulator contracts are offered in unique over-the-counter formats in multiple asset classes. An example of the equity consumer accumulator is the KODA ELI (Knock-out Discount Accumulative Equity Linked Instrument) offered by the global investment company Macquarie (Lam et al., 2009). Accumulators in equities conventionally consist of a year of one long daily up-and-out call option and a year of two short daily up-and-out put options with the same accumulation strike price and knock-out barrier price. Cheng (2010) modeled an equity accumulator similar to a product issued by Rabobank (Cheng, 2010). Wystup (2007) discussed European incorporation of accumulator contracts in foreign currency markets for corporate investment (Wystup, 2007). Credit Suisse’s FX accumulator and Caylon’s accumulated forward boost contract are two such examples of the accumulator contract in European currency markets (Lam et

Consumer accumulators generally fix 0x the quantity above the knock-out barrier, fix 1x the quantity below the knock-out barrier price and above the accumulation strike price, and fix 2x the quantity below the accumulation strike price. Hence, the consumer accumulator maintains a gearing ratio of 0x, 1x, and 2x. However, less mainstream accumulators may sustain a gearing ratio different than the normal 0x, 1x, and 2x structure. In unique cases, the fixing quantity of 1x remains the same as normal between the barriers, but below the accumulation strike price, the gearing ratio $g_x$ may be greater or less than the common 2x structure (Lam et al., 2009). Based on the INTL FCStone producer accumulator indications, the producer accumulator bears the standard gearing ratio. It fixes 2x the quantity above the accumulation strike, 1x the quantity below the accumulation strike price and above the knock-out barrier price, and 0x the quantity below the knock-out barrier price.

Dependent on factors such as implied volatility, risk-free interest rate, maturity, and referenced asset price, consumer accumulator accumulation strike prices and knock-out barrier prices range in spatial distance from the underlying asset’s price at origination. Discount percentage specifies the spatial distance the accumulation strike price is placed below the underlying asset’s price at origination. A lower discount percentage means a lower rebate on the accumulation of the referenced asset, a higher discount percentage gives investors a larger rebate on the accrual of the underlying. Knock-out percentage indicates the spatial distance the knock-out barrier is located above the underlying asset’s price at origination. Higher knock-out percentage allows for greater price volatility without
the occurrence of knock-out; lower knock-out percentage permits less price volatility before knock-out transpires. Alterations of these two metrics significantly affects the profitability and risk associated with the consumer accumulator (Kwong, Fok, Kwong, and Fok, 2012).

Kwong et al. (2012) compared consumer accumulators with differing knock-out percentages (2-7%) and discount percentages (4-15%). Concluding findings show higher knock-out percentages combined with higher discount percentages yield the greatest cumulative profits. When a high knock-out percentage is united with a low discount percentage, significant cumulative loss occurs (Kwong et al., 2012). Example accumulator contracts in Cheng (2010) assigned a knock-out percentage of 110% and a discount percentage of 94.3% for the equity accumulator simulated. The FX accumulator with the suspension feature simulated, under the Heston framework, assumes a discounted strike at 87.5% and suspension barrier at 105%. Under the Black-Scholes model, a discounted accumulation strike at 95% and suspension feature of 114% is adopted for simulation. The consumer accumulator simulated in the commodity market assumes a knock-out feature at 106% and double commitment strike set at 95% (Cheng, 2010). Producer accumulator contracts, revealed by INTL FCStone indications, set accumulation strike prices ranging from 100.07% to 107.60% the referenced futures price in corn and 101.76% to 107.84% the referenced futures price in soybeans. Knock-out barrier price ranges from 85.38% to 94.67% the referenced futures price in corn and 90.74% to 105.57% the referenced futures price in soybeans.

Contingent on contract structure and asset class, accumulator asset settlement can be either immediate or delayed. For immediate settlement, the observation day and delivery
day are the same day, so assets are fixed and delivered to the investor on the observation day. Under delayed settlement, the observation and delivery day are not the same day. Quantity and price are determined on the observation date, but the investor takes future delivery via forward contracts on the referenced underlying asset. Fixed quantity is reconciled periodically for consumer accumulators, commonly weekly or monthly. Lam et al. (2009) stated that in practice, delayed settlement is more routine than immediate settlement (Lam et al., 2009). INTL FCStone producer accumulator contracts assume delayed settlement as corn and soybean bushels are delivered or reconciled at accumulator contract expiration.

Knock-out barrier options possess a continuously or discretely monitored barrier. Continuously and discretely monitored barriers differ based on price observation of the underlying asset. Discrete price observation takes place at a certain point in time; knock-out occurs if the knock-out barrier price is breached at the end of the observation day. Accumulators with continuous barriers maintain continuous price monitoring of the underlying asset at all market hours. Knock-out occurs if the underlying’s price crosses the knock-out barrier during any market trading hours (Lam et al., 2009). In the market, most barrier options contain a discretely monitored barrier. If the barrier is continuously monitored, illiquid markets may present arbitrage opportunity since markets around the world support inconsistent trading hours (Kou, 2003). Lam et al. (2009) developed theoretical models for discrete and continuous consumer accumulators. For the producer accumulator, the referenced futures price is monitored at all CBOT trading hours, not all market hours; therefore, INTL FCStone producer accumulator contracts contain a knock-out barrier that is monitored in discrete time.
Lam et al. (2009) investigated the zero-cost structure consumer accumulator designed for two barrier structures, continuous and discrete, to define risk traits, payoffs, and theoretical pricing models under immediate and delayed settlement. Applying the same pricing methodology of the continuous barrier accumulator to the discrete barrier accumulator results in significant valuation error. Consequently, for the discrete barrier accumulator, a modification of the continuous barrier by a correction term is used. The substitution of the corrected discrete barrier for the continuous barrier establishes an approximate valuation model to value the discrete barrier accumulator under immediate and delayed settlement. Each accumulator portfolio, under both barrier structures and settlement types, is established by combining daily up-and-out call and put options valued using the Black-Scholes model for the continuous barrier accumulator and Monte Carlo simulation for the discrete barrier accumulator. Developing a sample discrete accumulator for each settlement and testing it using Monte Carlo simulation indicates that the discrete barrier approximation is efficient and consistent with the continuous accumulator for each settlement type (Lam et al., 2009).

Lam et al. (2009) computed an asymmetrical profit and loss distribution with an extended left tail and short right tail for the consumer accumulator. The asymmetric profit and loss distribution conveys the potential of vast downside loss and limited upside profit. Findings quantitatively display higher risk for the buyer than the seller. High Vega and Delta values arise when the investor is losing compared to winning, exhibiting that losing investors have a superior susceptibility to volatility and directional price changes. Concluding findings convey that regardless of the market, accumulator contracts exhibit
strong asymmetrical risk; therefore, large profits are unlikely and high loss is probable (Lam et al., 2009).

Kwong et al. (2012) studied accumulator profit and loss probability through Monte Carlo simulation using HSBC data for 2006 and 2007. To judge the fairness of the accumulator, average and cumulative profit or loss and standard deviation are calculated. Findings show early knock-out to be the deterministic factor for positive or negative profit. In each case, when the contract knocked-out early, profit ended positive. When the accumulator continued through contract expiry, profit was continually negative. Market trend is found to severely affect accumulator profitability. Results confirm that the accumulator offers a reasonable investment for investors in a neutral or upward trend. Yet, when market trend is downward, accumulator contracts become substantially more dangerous. Naturally, heightened volatility leads to a higher probability of knock-out and purchase of double the daily fixing quantity of shares. Concluding results show that accumulator contracts are an unfair investment for buyers due to their limited upside profit potential and unlimited downside loss potential (Kwong et al., 2012).

Cheng (2010) reviewed pricing and simulation under the Black-Scholes and Heston frameworks for three structurally unique accumulators: suspension feature, knock-out feature, and double-commitment with knock-out feature. Accumulating GBP/USD, the FX-linked accumulator with suspension feature attains a positive simulated contract price and positively skewed payoffs. The equity accumulator with knock-out feature, accrues HSBC shares, has a negative contract price under simulation and Black-Scholes, but a positive simulated contract price under the Heston framework. Payoffs are unbalanced and skewed toward negative profit, average duration is 91 trading days, and knock-out
probability is 77%. Accumulating December corn, the consumer accumulator with knock-out and double commitment features has a negative simulated contract price and negatively skewed payoffs, average duration of 15 weeks, and a 70% knock-out probability. Concluding findings demonstrate that volatility is the most powerful parameter in accumulator pricing. When volatility is low, simulated accumulator prices are slightly positive; however, when volatility is high, simulated accumulator prices are heavily negative. The Heston model is found to produce inconsistent results with simulation and the Black-Scholes model illustrating that the Heston framework inefficiently prices accumulator contracts (Cheng, 2010).

Research by Lam et al. (2009), Kwong et al. (2012), and Cheng (2010) deemed the consumer accumulator to be an unfair and risky investment strategy due to simulation results confirming large negative asymmetric risk. Consumer and producer accumulators differ as consumer accumulators cap upside profit and leave unlimited downside risk, while producer accumulators leave unlimited upside profit and cap downside risk. Due to this difference in mechanics, our research plans to dispel the notion that the producer accumulator suffers from the same negative asymmetric risk as the consumer accumulator. With confirmation by our results, our objective is to verify that the producer accumulator is a favorable risk management tool for corn and soybean producers to employ. Our research adds to accumulator contract literature and pricing theory by identifying a theoretical pricing model and quantifying simulation performance of the producer accumulator in corn and soybean commodity markets.

CHAPTER 3: DATA AND METHODOLOGY

3.1 Data Description
To examine the performance of the producer accumulator contract, we priced 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.

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.

3.2 Zero-Cost Producer Accumulator Model and Payoffs

Zero-cost producer accumulator contracts are structured by combining three barrier options into a portfolio. 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 follow the assumptions of the binomial model as the synthetic producer accumulator contracts we back-test are constructed from barrier options priced using the binomial model. These assumptions include: no transaction costs, no taxes, no margin requirements, no arbitrage, the investor is risk neutral, binomial distribution of returns, constant interest rate for the option’s lifetime, investors may borrow as much capital as they need at the risk-free rate, short selling is permitted, and volatility is constant (Cox, Ross, and Rubinstein, 1979).

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 is defined in Equation 5,

\[
V^\text{Delay} = \sum_{i=1}^{n} (P^F_{do}(X, H_d, t_i, T_i) - 2 \cdot C^F_{do}(X, H_d, t_i, T_i))
\]

where \( V^\text{Delay} \) is the value of the zero-cost producer accumulator portfolio under delayed settlement, \( P^F_{do}(X, H_d, t_i, T_i) \) is the down-and-out put price on a forward contract, \( C^F_{do}(X, H_d, t_i, T_i) \) 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,

\[
(6) \quad 0 \quad \text{if } \max_{0 \leq t \leq T_i} F_t \leq H_d
\]

\[
(7) \quad X - F_{T_i} \quad \text{if } \max_{0 \leq t \leq T_i} F_t > H_d, \quad F_{t_i} \leq X
\]

\[
(8) \quad 2(X - F_{T_i}) \quad \text{if } \max_{0 \leq t \leq T_i} F_t > H_d, \quad F_{t_i} > X
\]
where $F_{ti}$ is the futures contract price on the observation day, $F_{t}$ is the futures contract price for all CBOT futures contract trading hours, $F_{Tt}$ 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 $T_t$ 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 $q_t$ remain. The second payoff is the difference between the accumulation strike price $X$ and the futures contract price on the settlement day $F_{Tt}$. 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 $F_{Tt}$. 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 $2q$.

3.3 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 accumulator 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 20 to 60 weeks. Synthetic contracts are executed every week between 20 and 60 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 20-60 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. An example of actual INTL FCStone contract terms is presented in A1 of the appendix.

<table>
<thead>
<tr>
<th>Table 2. Synthetic Producer Accumulator Contract Terms in Corn</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Issuer</strong></td>
</tr>
<tr>
<td><strong>Accumulator Type</strong></td>
</tr>
<tr>
<td><strong>Futures Contract</strong></td>
</tr>
<tr>
<td><strong>Futures Price</strong></td>
</tr>
<tr>
<td><strong>Start Date</strong></td>
</tr>
<tr>
<td><strong>End Date</strong></td>
</tr>
<tr>
<td><strong>Periods</strong></td>
</tr>
<tr>
<td><strong>Accumulation Strike</strong></td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Issuer</th>
<th>FCStone International</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accumulator Type</td>
<td>Producer Accumulator</td>
</tr>
<tr>
<td>Futures Contract</td>
<td>SX7</td>
</tr>
<tr>
<td>Futures Price</td>
<td>1008</td>
</tr>
<tr>
<td>Start Date</td>
<td>11/25/2016</td>
</tr>
<tr>
<td>End Date</td>
<td>11/24/2017</td>
</tr>
<tr>
<td>Periods</td>
<td>53 Weeks</td>
</tr>
<tr>
<td>Accumulation Strike</td>
<td>1087</td>
</tr>
<tr>
<td>Knock-Out Barrier</td>
<td>980</td>
</tr>
<tr>
<td>Guaranteed Level</td>
<td>N/A</td>
</tr>
</tbody>
</table>

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.

3.4 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. The intercept alpha value is zero in equation 9. Including an intercept value decreases the accuracy of 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 9 as,

\[ y_i = \beta_i x_i + \beta_j x_j + e_i \]

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.
Verifying the accuracy of our predicted knock-out barrier price values from the knock-out barrier price equation, we run a simple linear regression to review how precisely the predicted knock-out barrier price values fit the observed knock-out barrier price values. The simple linear regression equation is shown in Equation 10,

\[
y_i = \alpha + \beta \hat{x}_i + e_i
\]

where \(y_i\) is the INTL FCStone observed knock-out barrier price value, \(\alpha\) is the intercept value, \(\beta\) is the correlation coefficient, \(\hat{x}_i\) is the predicted knock-out barrier price value from the knock-out barrier price equation, and \(e_i\) is the residual.

3.5 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.

3.5.1 Cox-Ross-Rubinstein (CRR) 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,

\begin{align}
(11) \quad S_u &= S u \\
(12) \quad S_d &= S d \\
(13) \quad u &= e^{\sigma\sqrt{\delta t}} \\
(14) \quad d &= e^{-\sigma\sqrt{\delta t}} \\
(15) \quad p &= \frac{e^{R\delta t} - d}{u - d}
\end{align}

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 16 as,

\[ V_n = \max[(S_n - X), 0] \]

and for a put option, the option value at the final node is defined in Equation 17,

\[ V_n = \max[X - (S_n), 0] \]

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 18 as,

\[ V_n = \max[(S_n - X e^{-R \delta t} (p V_u + (1 - p) V_d)) \]

and an American-style put option as shown in Equation 19,

\[ V_n = \max[(X - S_n e^{-R \delta t} (p V_u + (1 - p) V_d))] \]

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).

3.5.2 Longstaff-Schwartz (LS) 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 and 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 and 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 and 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 20,

\[
(20) F(\omega; t_k) = E_Q \left[ \sum_{j=k+1}^{\infty} \exp \left( - \int_{t_k}^{t_j} R(\omega, s) \, ds \right) C(\omega, t_j; t_k, T) \right] F_{t_k}
\]

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 and Schwartz, 2001).

3.5.3 Finite Difference (FD) 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 and 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 and
White, 1990). The size of the grid in MATLAB is set at 400 price intervals and 100 time intervals.

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 and 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 21,

\[
(21) \frac{\partial f}{\partial t} + R \frac{\partial f}{\partial S} S + \frac{1}{2} \frac{\partial^2 f}{\partial S^2} \sigma^2 S^2 = R f
\]

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 22 defined as,

\[
(22) \frac{\partial f}{\partial t} = \frac{f_{j+1,i} - f_{j,i}}{\delta t}
\]

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 23 as,

\[
(23) \frac{\partial f}{\partial S} = \frac{f_{j+1,i+1} + f_{j+1,i-1} - 2f_{j+1,i}}{\delta S}
\]

Gamma $\frac{\partial^2 f}{\partial S^2}$ is estimated by central differences shown in Equation 24 as,

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

All three approximations are substituted into the Black-Scholes-Merton partial differential equation to define Equation 25,

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

which simplifies to Equation 26,

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

Explicit finite difference parameters are defined as,

\[
(27) p_u = \frac{1}{2} (\sigma^2 i^2 + Ri) \delta t
\]

\[
(28) p_m = 1 - (\sigma^2 i^2) \delta t
\]
\[ p_d = \frac{1}{2} (\sigma^2 i^2 - Ri) \delta t \]

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).

### 3.6 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 30 as,

\[ y_i = \alpha + \beta \hat{x}_i + e_i \]

where \( y_i \) is the INTL FCStone observed zero-cost accumulation strike price, \( \alpha \) is the intercept value, \( \beta \) 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 31,

\[
(31) \quad RMSE = \sqrt{\frac{\sum_{i=1}^{n}(\hat{y}_i - y_i)^2}{n}}
\]

where \(\hat{y}_i\) is the predicted zero-cost accumulation strike price by the barrier option pricing model, \(y_i\) 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 opposing 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 32,

\[ MAE = \frac{1}{n} \sum_{i=1}^{n} |\hat{y}_i - y_i| \]

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

3.7 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. For collar portfolios simulated, premiums don’t offset equivalently for all portfolios as the premium received for the out-of-the-money call and the premium paid for the out-of-the-money put depend on the accumulation strike and knock-out barrier established by our models. 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 by 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 duration. 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.

Table 4. Agricultural Marketing Strategy Portfolios

<table>
<thead>
<tr>
<th>Portfolio Strategy</th>
<th>Futures</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Producer Accumulator Hedging Portfolio</td>
<td>Long 2 Futures Contracts</td>
<td>Short 2 OTM Down-and-Out Barrier Calls (X = Accumulation Level, H = Barrier Level) Long 1 ITM Down-and-Out Barrier Put (X = Accumulation Level, H = Barrier Level)</td>
</tr>
<tr>
<td>Long Futures Hedging Portfolio</td>
<td>Long 2 Futures Contracts</td>
<td></td>
</tr>
<tr>
<td>Protective Put Long Option Portfolio</td>
<td>Long 2 Futures Contracts</td>
<td>Long 2 OTM Vanilla Puts (X = Barrier Level)</td>
</tr>
<tr>
<td>Covered Call Short Option Portfolio</td>
<td>Long 2 Futures Contracts</td>
<td>Short 2 OTM Vanilla Calls (X = Accumulation Level)</td>
</tr>
<tr>
<td>Long Strangle Long Option Portfolio</td>
<td>Long 2 Futures Contracts</td>
<td>Long 1 OTM Vanilla Call (X = Accumulation Level) Long 1 OTM Vanilla Put (X = Barrier Level)</td>
</tr>
<tr>
<td>Short Strangle Short Option Portfolio</td>
<td>Long 2 Futures Contracts</td>
<td>Short 1 OTM Vanilla Call (X = Accumulation Level) Short 1 OTM Vanilla Put (X = Barrier Level)</td>
</tr>
</tbody>
</table>
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,

\[
\sigma_p = \sqrt{w_1^2 \sigma_1^2 + w_2^2 \sigma_2^2 + 2w_1w_2 \rho_{1,2} \sigma_1 \sigma_2}
\]

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 34,

\[
S_p = \frac{\bar{r}_p - r_f}{\sigma_p}
\]

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.
We analyze the average price performance of producer accumulator contracts enacted following an uptrend, neutral trend, and downtrend of 25, 50, and 100 days. The 25-day, 50-day, and 100-day uptrends in corn are defined as having an average slope, or the ratio of price and time changes between two points, greater than fifty cents for the prior 25, 50, or 100 trading days. The 25-day, 50-day, and 100-day neutral trends in corn are characterized as an average slope between positive fifty and negative fifty cents for the previous 25, 50, or 100 trading days. The 25-day, 50-day, and 100-day downtrends in corn are defined as maintaining an average slope less than negative fifty cents for the former 25, 50, or 100 trading days. In soybeans, the 25-day, 50-day, and 100-day uptrends are categorized as maintaining an average slope greater than one hundred cents for the prior 25, 50, or 100 trading days. The 25-day, 50-day, and 100-day neutral trends in soybeans are quantified as having an average slope between positive one hundred and negative one hundred cents for the former 25, 50, or 100 trading days. The 25-day, 50-day, and 100-day downtrends in soybeans are defined as having an average slope less than negative one hundred cents for the previous 25, 50, or 100 trading days.

CHAPTER 4: RESEARCH ANALYSIS 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.

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

<table>
<thead>
<tr>
<th>Knock-Out Barrier Corn</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>19.0877**</td>
</tr>
<tr>
<td></td>
<td>(9.3251)</td>
</tr>
<tr>
<td>Predicted Knock-Out Barrier Strike</td>
<td>.9348***</td>
</tr>
<tr>
<td></td>
<td>(.0270)</td>
</tr>
<tr>
<td>R-square</td>
<td>.8734</td>
</tr>
<tr>
<td>F Test</td>
<td>1200.88</td>
</tr>
<tr>
<td>Observations</td>
<td>176</td>
</tr>
</tbody>
</table>

Coefficients are significant at 1%(***), 5%(**), 10%(*).

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 for the predicted knock-out barrier strike of .9348, an r-square of .8734, and a standard error for
the beta coefficient of .0270, the predicted values fit the observed values efficiently. Similarly, in soybeans, the knock-out barrier price equation demonstrates robust 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 predicted knock-out barrier strike beta of .9644, an r-square of .9311, and a standard error for the beta coefficient of .0189, the predicted values for soybeans robustly explain the observed values. Knock-out barrier prices estimated in soybeans fit the observed data slightly better than in corn. For knock-out barriers in corn and soybeans, a Breusch-Pagan and White test were incorporated to ensure homoscedasticity. The null hypothesis for homoscedasticity was accepted in the Breusch-Pagan and White test. Testing for autocorrelation, a Durbin-Watson test was implemented; the null for no autocorrelation was accepted.
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 9.
4.2 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.

Figure 4. Zero-Cost Accumulation Strike in Corn – Observed vs Predicted
Table 7. Zero-Cost Accumulation Strike in Corn – Observed vs Predicted

<table>
<thead>
<tr>
<th>Model</th>
<th>CRR</th>
<th>LS</th>
<th>FD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-14.6550**</td>
<td>-18.3887</td>
<td>-13.7850**</td>
</tr>
<tr>
<td></td>
<td>(6.9364)</td>
<td>(7.3184)</td>
<td>(6.9740)</td>
</tr>
<tr>
<td>Predicted Zero-Cost</td>
<td>1.0319***</td>
<td>1.0261***</td>
<td>1.0367***</td>
</tr>
<tr>
<td>Accumulation Strike</td>
<td>(.0175)</td>
<td>(.0182)</td>
<td>(.0177)</td>
</tr>
<tr>
<td>R-square</td>
<td>.9524</td>
<td>.9482</td>
<td>.9517</td>
</tr>
<tr>
<td>F Test</td>
<td>3483.51</td>
<td>3186.63</td>
<td>3431.51</td>
</tr>
<tr>
<td>Observations</td>
<td>176</td>
<td>176</td>
<td>176</td>
</tr>
</tbody>
</table>

Coefficients are significant at 1%(***), 5%(**), 10%(*).

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 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 for the predicted zero-cost accumulation strike of 1.0319, it had the highest r-square, and lowest standard error for the predicted zero-cost accumulation strike. The FD model estimates a similar biased beta at 1.0367, it had the second highest r-square, and the second lowest standard error for the predicted zero-cost accumulation strike. Performing the worst of all models in approximating the zero-cost accumulation strike price in corn was the LS model with a beta of 1.0261, it had the lowest r-square value, and the highest standard error of all models for the predicted zero-cost accumulation strike at .0182. To check for heteroskedasticity, a Breusch-Pagan and White test were applied. Results of the Breusch-Pagan and White test accepted the null hypothesis for homoscedasticity. We incorporated
a Durbin-Watson test to test for autocorrelation. The null for no autocorrelation was accepted.

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

<table>
<thead>
<tr>
<th>Model</th>
<th>CRR</th>
<th>LS</th>
<th>FD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>14.1476</td>
<td>22.3021</td>
<td>12.7772</td>
</tr>
<tr>
<td></td>
<td>(20.6685)</td>
<td>(22.4074)</td>
<td>(20.5056)</td>
</tr>
<tr>
<td>Predicted Zero-Cost</td>
<td>.9848***</td>
<td>.9684***</td>
<td>.9900***</td>
</tr>
<tr>
<td>Accumulation Strike</td>
<td>(.0196)</td>
<td>(.0210)</td>
<td>(.0195)</td>
</tr>
<tr>
<td>R-square</td>
<td>.9287</td>
<td>.9160</td>
<td>.9299</td>
</tr>
<tr>
<td>F Test</td>
<td>2527.47</td>
<td>2116.77</td>
<td>2574.56</td>
</tr>
<tr>
<td>Observations</td>
<td>196</td>
<td>196</td>
<td>196</td>
</tr>
</tbody>
</table>

Coefficients are significant at 1%(***), 5%(**), 10%(*).
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 results of all three models and Figure 5 illustrates the strike prices over the period of comparison. The CRR model predicted zero-cost accumulation strike prices had a beta of .9848, an r-square of .9287, and a standard error for the predicted zero-cost accumulation strike beta at .0196. At .9684 for the predicted zero-cost accumulation strike beta, an r-square of .9160, and the highest standard error for the predicted zero-cost accumulation strike of .0210, the LS model had the worst fit of all models in soybeans. Alternatively, the FD model estimated a zero-cost accumulation strike beta at .9900, the highest r-square at .9299, and the lowest standard error of .0195. A Breusch-Pagan and White test were applied to check for homoscedasticity; for both tests the null hypothesis for homoscedasticity was accepted. A Durbin-Watson test was used to test for autocorrelation. We accept the null for no autocorrelation.

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 second behind the FD model for the lowest degree of model error in corn. In soybeans, the CRR model produces the second lowest RMSE after the 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.

Table 9. Model Root-Mean-Square Error (RMSE)
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 second lowest MAE. The FD model has the lowest MAE in corn. In soybeans, the CRR model has 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.

<table>
<thead>
<tr>
<th>Model</th>
<th>Corn</th>
<th>Soybean</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRR</td>
<td>3.94</td>
<td>7.34</td>
</tr>
<tr>
<td>LS</td>
<td>8.03</td>
<td>12.27</td>
</tr>
<tr>
<td>FD</td>
<td>3.81</td>
<td>7.72</td>
</tr>
</tbody>
</table>

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 5 for the synthetic producer accumulator contracts that we use for performance back-testing.
4.3 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.

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

<table>
<thead>
<tr>
<th>Portfolio Strategy</th>
<th>Corn</th>
<th>Soybeans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Producer Accumulator</td>
<td>$4.78</td>
<td>$11.43</td>
</tr>
<tr>
<td>Long Futures</td>
<td>$4.83</td>
<td>$11.42</td>
</tr>
<tr>
<td>Protective Put</td>
<td>$4.54</td>
<td>$10.95</td>
</tr>
<tr>
<td>Covered Call</td>
<td>$5.25</td>
<td>$12.32</td>
</tr>
<tr>
<td>Long Strangle</td>
<td>$4.52</td>
<td>$10.99</td>
</tr>
<tr>
<td>Short Strangle</td>
<td>$5.22</td>
<td>$12.37</td>
</tr>
<tr>
<td>Long Straddle</td>
<td>$3.95</td>
<td>$9.95</td>
</tr>
<tr>
<td>Short Straddle</td>
<td>$5.79</td>
<td>$13.41</td>
</tr>
<tr>
<td>Collar</td>
<td>$4.90</td>
<td>$11.64</td>
</tr>
</tbody>
</table>

*average price per bushel in USD

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. Portfolio Strategy Average Annual Price in Corn
Figure 7 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 12. Average Price by Month in Corn and Soybeans 2008-2017

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

*average price per bushel in USD

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 enacted 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.

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

<table>
<thead>
<tr>
<th>Trend</th>
<th>Trend Length</th>
<th>Corn – Producer Accumulator</th>
<th>Corn – Long Futures</th>
<th>Soybeans – Producer Accumulator</th>
<th>Soybeans – Long Futures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uptrend</td>
<td>25-day</td>
<td>$5.04</td>
<td>$5.10</td>
<td>$11.74</td>
<td>$11.72</td>
</tr>
<tr>
<td></td>
<td>50-day</td>
<td>$5.04</td>
<td>$5.10</td>
<td>$11.80</td>
<td>$11.76</td>
</tr>
<tr>
<td></td>
<td>100-day</td>
<td>$5.37</td>
<td>$5.46</td>
<td>$11.81</td>
<td>$11.86</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>$5.15</td>
<td>$5.22</td>
<td>$11.78</td>
<td>$11.78</td>
</tr>
<tr>
<td>Neutral Trend</td>
<td>25-day</td>
<td>$4.48</td>
<td>$4.49</td>
<td>$11.14</td>
<td>$11.18</td>
</tr>
<tr>
<td></td>
<td>50-day</td>
<td>$4.51</td>
<td>$4.49</td>
<td>$11.34</td>
<td>$11.25</td>
</tr>
<tr>
<td></td>
<td>100-day</td>
<td>$4.47</td>
<td>$4.42</td>
<td>$11.32</td>
<td>$11.28</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>$4.49</td>
<td>$4.47</td>
<td>$11.27</td>
<td>$11.24</td>
</tr>
<tr>
<td>Downtrend</td>
<td>25-day</td>
<td>$4.75</td>
<td>$4.83</td>
<td>$11.31</td>
<td>$11.28</td>
</tr>
<tr>
<td></td>
<td>50-day</td>
<td>$4.82</td>
<td>$4.92</td>
<td>$11.20</td>
<td>$11.27</td>
</tr>
<tr>
<td></td>
<td>100-day</td>
<td>$4.91</td>
<td>$5.08</td>
<td>$11.55</td>
<td>$11.47</td>
</tr>
</tbody>
</table>
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. A2 of the appendix presents the price ratio in corn and soybeans for the March and July contract expirations.
Figure 8. Price Ratio in Corn – December Expiration

Figure 9. Price Ratio in Soybeans – November Expiration

4.4 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, 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.

<table>
<thead>
<tr>
<th>Portfolio Strategy</th>
<th>Corn</th>
<th>Soybeans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Producer Accumulator</td>
<td>$681.90</td>
<td>$1189.14</td>
</tr>
<tr>
<td>Long Futures</td>
<td>$836.69</td>
<td>$1571.26</td>
</tr>
<tr>
<td>Protective Put</td>
<td>$577.89</td>
<td>$1201.49</td>
</tr>
<tr>
<td>Covered Call</td>
<td>$522.54</td>
<td>$881.92</td>
</tr>
<tr>
<td>Long Strangle</td>
<td>$880.85</td>
<td>$1760.88</td>
</tr>
<tr>
<td>Short Strangle</td>
<td>$818.15</td>
<td>$1414.80</td>
</tr>
<tr>
<td>Long Straddle</td>
<td>$892.72</td>
<td>$1657.49</td>
</tr>
<tr>
<td>Short Straddle</td>
<td>$782.34</td>
<td>$1482.98</td>
</tr>
<tr>
<td>Collar</td>
<td>$523.88</td>
<td>$999.35</td>
</tr>
</tbody>
</table>
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. Strategy Portfolio Average Annual Portfolio Risk in Corn

Figure 11. Strategy Portfolio Average Annual Portfolio Risk 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>
<thead>
<tr>
<th>Month</th>
<th>Corn – Producer Accumulator</th>
<th>Corn – Long Futures</th>
<th>Soybeans – Producer Accumulator</th>
<th>Soybeans – Long Futures</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>$630.36</td>
<td>$805.65</td>
<td>$1,062.58</td>
<td>$1,483.69</td>
</tr>
<tr>
<td>February</td>
<td>$663.21</td>
<td>$825.51</td>
<td>$1,077.51</td>
<td>$1,519.27</td>
</tr>
<tr>
<td>March</td>
<td>$710.02</td>
<td>$865.68</td>
<td>$1,150.56</td>
<td>$1,627.48</td>
</tr>
<tr>
<td>April</td>
<td>$723.27</td>
<td>$871.28</td>
<td>$1,225.77</td>
<td>$1,659.67</td>
</tr>
<tr>
<td>May</td>
<td>$743.95</td>
<td>$888.15</td>
<td>$1,275.16</td>
<td>$1,691.65</td>
</tr>
<tr>
<td>June</td>
<td>$748.49</td>
<td>$889.20</td>
<td>$1,379.96</td>
<td>$1,694.13</td>
</tr>
<tr>
<td>July</td>
<td>$688.56</td>
<td>$842.66</td>
<td>$1,350.77</td>
<td>$1,628.07</td>
</tr>
<tr>
<td>August</td>
<td>$696.42</td>
<td>$837.57</td>
<td>$1,301.36</td>
<td>$1,585.24</td>
</tr>
<tr>
<td>September</td>
<td>$681.04</td>
<td>$822.15</td>
<td>$1,237.51</td>
<td>$1,548.63</td>
</tr>
<tr>
<td>October</td>
<td>$643.94</td>
<td>$779.23</td>
<td>$1,112.96</td>
<td>$1,488.12</td>
</tr>
<tr>
<td>November</td>
<td>$635.82</td>
<td>$798.77</td>
<td>$1,063.91</td>
<td>$1,468.34</td>
</tr>
</tbody>
</table>
Table 16. Risk by Trend in Corn and Soybeans 2008-2017

<table>
<thead>
<tr>
<th>Trend</th>
<th>Trend Length</th>
<th>Corn – Producer Accumulator</th>
<th>Corn – Long Futures</th>
<th>Soybeans – Producer Accumulator</th>
<th>Soybeans – Long Futures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uptrend</td>
<td>25-day</td>
<td>$771.26</td>
<td>$936.08</td>
<td>$1,305.07</td>
<td>$1,658.45</td>
</tr>
</tbody>
</table>

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 beginning 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 valued 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 or valued 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. A3 of the appendix displays the sigma ratio in corn and soybeans for the March and July contract expirations.
Figure 12. Sigma Ratio in Corn – December Expiration

Figure 13. Sigma Ratio in Soybeans – November Expiration

4.5 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 2008-2016 period. Moreover, on an average annual basis, the producer accumulator had the best portfolio Sharpe ratio each year during 2009-2016. 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 2008-2016. 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 2008-2016 in corn and soybeans.

<table>
<thead>
<tr>
<th>Portfolio Strategy</th>
<th>Corn</th>
<th>Soybeans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Producer Accumulator</td>
<td>.081</td>
<td>.178</td>
</tr>
<tr>
<td>Long Futures</td>
<td>-.013</td>
<td>.005</td>
</tr>
<tr>
<td>Protective Put</td>
<td>-.044</td>
<td>-.017</td>
</tr>
<tr>
<td>Covered Call</td>
<td>.013</td>
<td>.041</td>
</tr>
<tr>
<td>Long Strangle</td>
<td>-.030</td>
<td>-.009</td>
</tr>
<tr>
<td>Short Strangle</td>
<td>.007</td>
<td>.026</td>
</tr>
<tr>
<td>Long Straddle</td>
<td>-.040</td>
<td>-.022</td>
</tr>
<tr>
<td>Short Straddle</td>
<td>.021</td>
<td>.040</td>
</tr>
<tr>
<td>Collar</td>
<td>-.014</td>
<td>.009</td>
</tr>
</tbody>
</table>

*average daily portfolio Sharpe ratio
Ranking first on an aggregate and annual average basis from 2008-2016, 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 2008-2016.
Figure 14. Strategy Portfolio Average Annual Sharpe Ratio in Corn

Figure 15. Strategy Portfolio Average Annual Sharpe Ratio in Soybeans
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 2008-2016. Table 18 presents average daily portfolio Sharpe ratio by valuation month for producer accumulator strategy portfolios and long futures strategy portfolios during 2008-2016. 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 ratios 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 originated between September and March and average daily portfolio Sharpe ratios under .16 for contracts that began 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 or enacted during non-growing season valuation months.

<table>
<thead>
<tr>
<th>Month</th>
<th>Corn – Producer Accumulator</th>
<th>Corn – Long Futures</th>
<th>Soybeans – Producer Accumulator</th>
<th>Soybeans – Long Futures</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>.126</td>
<td>-.014</td>
<td>.225</td>
<td>.003</td>
</tr>
<tr>
<td>February</td>
<td>.112</td>
<td>-.019</td>
<td>.226</td>
<td>-.007</td>
</tr>
<tr>
<td>March</td>
<td>.050</td>
<td>-.010</td>
<td>.171</td>
<td>.008</td>
</tr>
<tr>
<td>April</td>
<td>.044</td>
<td>-.014</td>
<td>.156</td>
<td>-.002</td>
</tr>
<tr>
<td>May</td>
<td>.047</td>
<td>-.016</td>
<td>.145</td>
<td>-.001</td>
</tr>
<tr>
<td>June</td>
<td>.038</td>
<td>-.019</td>
<td>.096</td>
<td>-.007</td>
</tr>
<tr>
<td>July</td>
<td>.058</td>
<td>-.014</td>
<td>.113</td>
<td>.000</td>
</tr>
<tr>
<td>August</td>
<td>.067</td>
<td>-.012</td>
<td>.142</td>
<td>.005</td>
</tr>
<tr>
<td>September</td>
<td>.106</td>
<td>-.008</td>
<td>.186</td>
<td>.009</td>
</tr>
</tbody>
</table>
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 2008-2016. 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, beginning 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 valued 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 valued 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.

<table>
<thead>
<tr>
<th></th>
<th>0.105</th>
<th>-0.009</th>
<th>0.220</th>
<th>0.018</th>
</tr>
</thead>
<tbody>
<tr>
<td>October</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>November</td>
<td>0.106</td>
<td>-0.010</td>
<td>0.217</td>
<td>0.018</td>
</tr>
<tr>
<td>December</td>
<td>0.126</td>
<td>-0.009</td>
<td>0.226</td>
<td>0.013</td>
</tr>
<tr>
<td>Growing Season (April-September)</td>
<td>0.060</td>
<td>-0.014</td>
<td>0.140</td>
<td>0.001</td>
</tr>
<tr>
<td>Non-Growing Season (October-March)</td>
<td>0.104</td>
<td>-0.012</td>
<td>0.214</td>
<td>0.009</td>
</tr>
</tbody>
</table>

*average daily portfolio Sharpe Ratio*
Table 19. Sharpe Ratio by Trend in Corn and Soybeans 2008-2016

<table>
<thead>
<tr>
<th>Trend</th>
<th>Trend Length</th>
<th>Corn – Producer Accumulator</th>
<th>Corn – Long Futures</th>
<th>Soybeans – Producer Accumulator</th>
<th>Soybeans – Long Futures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uptrend</td>
<td>25-day</td>
<td>.052</td>
<td>-.021</td>
<td>.142</td>
<td>-0.004</td>
</tr>
<tr>
<td></td>
<td>50-day</td>
<td>.032</td>
<td>-.024</td>
<td>.118</td>
<td>-0.007</td>
</tr>
<tr>
<td></td>
<td>100-day</td>
<td>.037</td>
<td>-.025</td>
<td>.081</td>
<td>-0.018</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>.040</td>
<td>-.023</td>
<td>.114</td>
<td>-0.010</td>
</tr>
<tr>
<td>Neutral Trend</td>
<td>25-day</td>
<td>.125</td>
<td>-.013</td>
<td>.214</td>
<td>.001</td>
</tr>
<tr>
<td></td>
<td>50-day</td>
<td>.122</td>
<td>-.011</td>
<td>.212</td>
<td>.001</td>
</tr>
<tr>
<td></td>
<td>100-day</td>
<td>.092</td>
<td>-.010</td>
<td>.205</td>
<td>.006</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>.113</td>
<td>-.011</td>
<td>.210</td>
<td>.003</td>
</tr>
<tr>
<td>Downtrend</td>
<td>25-day</td>
<td>.078</td>
<td>-.006</td>
<td>.192</td>
<td>.017</td>
</tr>
<tr>
<td></td>
<td>50-day</td>
<td>.087</td>
<td>-.005</td>
<td>.203</td>
<td>.022</td>
</tr>
<tr>
<td></td>
<td>100-day</td>
<td>.105</td>
<td>-.005</td>
<td>.203</td>
<td>.028</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>.090</td>
<td>-.005</td>
<td>.199</td>
<td>.022</td>
</tr>
</tbody>
</table>

*average daily portfolio Sharpe Ratio

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 conveying the producer accumulator to have a superior return per unit of volatility compared to the alternative risk-free portfolio of 1-year treasury bills. White tranches represent accumulator portfolios with an average daily portfolio Sharpe ratio around 0 showing the producer accumulator to have an equivalent return per unit of volatility to the alternative risk-free portfolio of 1-year treasury bills. The pink implies a producer accumulator portfolio average daily portfolio Sharpe ratio that is slightly negative displaying the producer accumulator to have worse return per unit of volatility than the
alternative risk-free portfolio of 1-year treasury bills. A4 of the appendix exhibits the average daily portfolio Sharpe ratio in corn and soybeans for the March and July contract expirations.

Figure 16. Producer Accumulator Sharpe Ratio in Corn – December Expiration
Figure 17. Producer Accumulator Sharpe Ratio in Soybeans – November Expiration

4.6 Bushel 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.

Table 20. Annual Bushels Accumulated in Corn and Soybeans

<table>
<thead>
<tr>
<th>Year</th>
<th>Corn</th>
<th>Soybean</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>1,240</td>
<td>1,585</td>
</tr>
<tr>
<td>2009</td>
<td>2,385</td>
<td>3,727</td>
</tr>
<tr>
<td>2010</td>
<td>6,380</td>
<td>8,169</td>
</tr>
<tr>
<td>2011</td>
<td>2,947</td>
<td>3,421</td>
</tr>
<tr>
<td>2012</td>
<td>4,335</td>
<td>5,830</td>
</tr>
<tr>
<td>2013</td>
<td>1,752</td>
<td>5,573</td>
</tr>
<tr>
<td>2014</td>
<td>2,615</td>
<td>3,015</td>
</tr>
<tr>
<td>2015</td>
<td>2,361</td>
<td>4,330</td>
</tr>
<tr>
<td>2016</td>
<td>3,507</td>
<td>6,228</td>
</tr>
<tr>
<td>2017</td>
<td>5,362</td>
<td>4,979</td>
</tr>
<tr>
<td>2008-2017</td>
<td>3,165</td>
<td>4,752</td>
</tr>
</tbody>
</table>

*average quantity of bushels accumulated*

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 originate or begin 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 valued between March and July accumulated less than 3,000 bushels. In soybeans, producer accumulators beginning between October and March accumulated more than 5,000 bushels; producer accumulators executed between April and September accumulated less than 5,000 bushels.

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

<table>
<thead>
<tr>
<th>Month</th>
<th>Corn</th>
<th>% Change from Prior Month</th>
<th>Soybeans</th>
<th>% Change from Prior Month</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>3,489</td>
<td>-10.04%</td>
<td>5,025</td>
<td>-5.95%</td>
</tr>
<tr>
<td>February</td>
<td>3,214</td>
<td>-8.53%</td>
<td>5,428</td>
<td>7.43%</td>
</tr>
<tr>
<td>March</td>
<td>2,855</td>
<td>-12.58%</td>
<td>5,667</td>
<td>4.22%</td>
</tr>
<tr>
<td>April</td>
<td>2,713</td>
<td>-5.24%</td>
<td>4,927</td>
<td>-15.01%</td>
</tr>
<tr>
<td>May</td>
<td>2,950</td>
<td>8.02%</td>
<td>4,463</td>
<td>-10.40%</td>
</tr>
<tr>
<td>June</td>
<td>2,861</td>
<td>-3.08%</td>
<td>3,381</td>
<td>-32.02%</td>
</tr>
<tr>
<td>July</td>
<td>2,770</td>
<td>-3.30%</td>
<td>3,720</td>
<td>9.13%</td>
</tr>
<tr>
<td>August</td>
<td>3,011</td>
<td>8.00%</td>
<td>3,880</td>
<td>4.11%</td>
</tr>
<tr>
<td>September</td>
<td>3,870</td>
<td>22.20%</td>
<td>4,789</td>
<td>18.98%</td>
</tr>
<tr>
<td>October</td>
<td>3,222</td>
<td>-20.11%</td>
<td>5,359</td>
<td>10.64%</td>
</tr>
<tr>
<td>November</td>
<td>3,409</td>
<td>5.47%</td>
<td>5,167</td>
<td>-3.71%</td>
</tr>
</tbody>
</table>
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 valued 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 or enacted after a 50-day uptrend in corn and a 100-day uptrend in soybeans had the lowest quantity of bushels accumulated.

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

<table>
<thead>
<tr>
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<th></th>
<th></th>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Uptrend</td>
<td>25-day</td>
<td>2,719</td>
<td>1,804</td>
<td>4,086</td>
<td>1,988</td>
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<tr>
<td></td>
<td>50-day</td>
<td>2,324</td>
<td>1,571</td>
<td>3,570</td>
<td>1,627</td>
</tr>
<tr>
<td>Trend</td>
<td>25-day</td>
<td>50-day</td>
<td>100-day</td>
<td>Average</td>
<td></td>
</tr>
<tr>
<td>--------------</td>
<td>--------</td>
<td>--------</td>
<td>---------</td>
<td>---------</td>
<td></td>
</tr>
<tr>
<td>Neutral</td>
<td>3,497</td>
<td>3,406</td>
<td>3,018</td>
<td>3,307</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>3,457</td>
<td>1,498</td>
<td>3,542</td>
<td>1,518</td>
<td></td>
</tr>
<tr>
<td>Downtrend</td>
<td>3,318</td>
<td>3,649</td>
<td>4,147</td>
<td>3,705</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>3,338</td>
<td>1,918</td>
<td>5,115</td>
<td>2,117</td>
<td></td>
</tr>
</tbody>
</table>

*average 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.
CHAPTER 5: CONCLUSION
5.1 Summary

The producer accumulator portfolio performed 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 originated during the growing season and non-growing season performed similarly to the long futures portfolio executed or valued 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 valued 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 originated 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 beginning following all trends 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 that began 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 valued 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 or enacted 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 originate 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.

5.2 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 valued 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 originated or valued 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 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 consider incorporating a basis contract to reduce basis risk when adopting a producer accumulator contract.

Research conducted by Lam et al. (2009), Kwong et al. (2012), and Cheng (2010) showed simulation results confirming large negative asymmetric risk for the accumulator. These papers concluded the accumulator to be a biased and risky investment strategy for investors purchasing assets through the accumulator. Our research on the producer accumulator in corn and soybean commodity markets differs from prior research on the consumer accumulator. We show the producer accumulator to offer overall risk reduction and superior risk adjusted return compared to the other strategy portfolios we back-test. Our research dismisses the belief that the producer accumulator suffers from the same negative asymmetric risk as the consumer accumulator. We verify that the producer accumulator is a favorable risk management tool for corn and soybean producers to employ.

5.3 Research Extension
Our producer accumulator contract research could be extended by simulating producer accumulator portfolios prior to 2008 to gain further insight and perspective of historical producer accumulator performance. It may be beneficial to extend research associated with downside risk by quantifying downside deviation via the Sortino ratio. Further research could be conducted by evaluating producer accumulator contract performance during technical trends varying in length other than the 25, 50, and 100-day trends tested in this research. The methodology outlined in our research could be extended to the producer accumulator with Euro double up and the producer accumulator with Euro double up and guaranteed quantity to investigate zero-cost structure, average price, average daily portfolio standard deviation, average daily portfolio Sharpe ratio, and bushel accumulation.
LITERATURE CITED


Cheng, P. (2010). *Accumulator or "i-kill-you-later": analytical pricing and sensitivity tests of occupation time derivatives*. The Chinese University of Hong Kong.


## A1. INTL FCStone Producer Accumulator Contract

Here are indicative levels on several popular structures. The information and data contained herein is not tradable and is for indication only purposes. For tradable levels and live quotes, please contact your broker.

<table>
<thead>
<tr>
<th>Accumulator Type</th>
<th>FUT</th>
<th>EX</th>
<th>Start Date</th>
<th>End Date</th>
<th>Periods</th>
<th>Accum</th>
<th>Barrier</th>
<th>CTDLVL</th>
<th>MMM</th>
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<tbody>
<tr>
<td>Producer Accumulator</td>
<td>373.5</td>
<td>CN7</td>
<td>1/6/2017</td>
<td>6/23/2017</td>
<td>25 weeks</td>
<td>390</td>
<td>347.5</td>
<td>NA</td>
<td>5.00</td>
</tr>
<tr>
<td>Producer Accumulator with Euro D.U.</td>
<td>373.5</td>
<td>CN7</td>
<td>1/6/2017</td>
<td>6/23/2017</td>
<td>25 weeks</td>
<td>390</td>
<td>347.5</td>
<td>NA</td>
<td>5.00</td>
</tr>
<tr>
<td>Prod Accum w/Euro D.U K.O and Guaranteed</td>
<td>387.5</td>
<td>CZ7</td>
<td>1/6/2017</td>
<td>11/24/2017</td>
<td>47 weeks</td>
<td>414.5</td>
<td>352.5</td>
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<tr>
<td>Producer Accumulator</td>
<td>387.5</td>
<td>CZ7</td>
<td>1/6/2017</td>
<td>11/24/2017</td>
<td>47 weeks</td>
<td>422.25</td>
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<tr>
<td>Producer Accumulator with Euro D.U</td>
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<td>CZ7</td>
<td>1/6/2017</td>
<td>11/24/2017</td>
<td>47 weeks</td>
<td>405.5</td>
<td>397.5</td>
<td>945.5</td>
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<tr>
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<td>396</td>
<td>CHB</td>
<td>1/6/2017</td>
<td>2/23/2018</td>
<td>50 weeks</td>
<td>427</td>
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<td>486</td>
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<td>5.75</td>
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<td>CHB</td>
<td>1/6/2017</td>
<td>2/23/2018</td>
<td>50 weeks</td>
<td>416</td>
<td>346</td>
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<tr>
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<td>1/6/2017</td>
<td>6/23/2017</td>
<td>25 weeks</td>
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<td>9.00</td>
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<tr>
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<td>25 weeks</td>
<td>1071</td>
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<td>10.00</td>
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<tr>
<td>Prod Accum w/Euro D.U K.O and Guaranteed</td>
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<td>SX7</td>
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<td>10/27/2017</td>
<td>43 weeks</td>
<td>1045</td>
<td>915</td>
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<td>10.00</td>
</tr>
<tr>
<td>Producer Accumulator</td>
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<td>SX7</td>
<td>1/6/2017</td>
<td>10/27/2017</td>
<td>43 weeks</td>
<td>1060</td>
<td>915</td>
<td>NA</td>
<td>11.00</td>
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<td>Producer Accumulator with Euro D.U</td>
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<td>SX7</td>
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<td>10/27/2017</td>
<td>43 weeks</td>
<td>1039.75</td>
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<td>S-HB</td>
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<td>12.50</td>
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<td>50 weeks</td>
<td>1033.5</td>
<td>895</td>
<td>911</td>
<td>7.25</td>
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</tbody>
</table>

**Producer Accumulator**

- Each week that the referenced futures contract settles at or below the Accumulation Level, 100% of the weekly quantity is priced at the Accumulation Level.
- Each week that the referenced futures contract settles above the Accumulation Level, 100% of the weekly quantity is priced at the Accumulation Level.
- If on any date between Trade Date and End Date (inclusive), during the non-electronic or electronic daily session, the referenced futures contract ever trades or settles at or below the Knock-Out Level, accumulation ceases. Any swaps already accumulated will continue to exist at the Accumulation Level.

**Producer Accumulator with Euro D.U**

- Each week that the referenced futures contract is above the Knock-Out Level, 100% of the weekly quantity is priced at the Accumulation Level.
- At expiration, if the referenced futures contract settles above the Accumulation Level and a barrier event has not occurred, an additional quantity equal to the original traded quantity is priced at the Accumulation Level.
- If on any date between Trade Date and End Date (inclusive), during the electronic or non-electronic regular Exchange daily session, the referenced futures contract or settles at or below the Knock-Out Level, accumulation ceases. Any swaps already accumulated will continue to exist at the Accumulation Level.

**Prod Accum w/Euro D.U K.O and Guaranteed Quantity**

- Each week 100% of the weekly quantity is priced at the Accumulation Level as long as a barrier event has not occurred.
- At expiration, if the referenced futures contract settles above the Accumulation Level and a barrier event has not occurred, an additional quantity equal to the original traded quantity is priced at the Accumulation Level.
- If on any date between Trade Date and End Date (inclusive), during the electronic or non-electronic regular Exchange daily session, the referenced futures contract or settles at or below the Knock-Out Level, accumulation ceases and the remaining quantity is priced at the Guaranteed Level.
A2. Price Ratio in Corn and Soybeans – March and July Expiration

Price Ratio in Corn – March Expiration

Price Ratio in Corn – July Expiration
Price Ratio in Soybeans – March Expiration

Price Ratio in Soybeans – July Expiration
A3. Sigma Ratio in Corn and Soybeans – March and July Expiration

**Sigma Ratio in Corn – March Expiration**

<table>
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<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Sep</th>
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</tbody>
</table>

**Sigma Ratio in Corn – July Expiration**

<table>
<thead>
<tr>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Sep</th>
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</table>
Sigma Ratio in Soybeans – March Expiration

Sigma Ratio in Soybeans – July Expiration
A4. Producer Accumulator Sharpe Ratio in Corn and Soybeans – March and July Expiration

Producer Accumulator Sharpe Ratio in Corn – March Expiration

Producer Accumulator Portfolio Ratio in Corn – July Expiration
A5. Bushels Accumulated in Corn and Soybeans – March and July Expiration

Bushels Accumulated in Corn – March Expiration

Bushels Accumulated in Corn – July Expiration
Bushels Accumulated in Soybeans – March Expiration

Bushels Accumulated in Soybeans – July Expiration