RESILIENCE OF GRAIN STORAGE MARKETS

TO UPHEAVAL IN FUTURES MARKETS

By

EMMA HAYHURST

Bachelor of Science in Agricultural Economics

Oklahoma State University

Stillwater, Oklahoma

2020

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
May, 2022

RESILIENCE OF GRAIN STORAGE MARKETS

TO UPHEAVAL IN FUTURES MARKETS

Thesis Approved:

Dr. B Wade Brorsen

Thesis Adviser

Dr. John Michael Riley

Dr. Phil Kenkel

Name: EMMA HAYHURST

Date of Degree: MAY, 2022

Title of Study: RESILIENCE OF GRAIN STORAGE MARKETS TO UPHEAVAL IN FUTURES MARKETS

Major Field: AGRICULTURAL ECONOMICS

Abstract: There has been an increase in the volume of long-only index funds in commodity markets as well as a time period where cash and futures markets did not converge. What is the economic impact of these events on storage markets? To answer this question the supply of storage is estimated before, during and after the rapid growth and the lack of convergence. An econometric model is used to estimate the supply of storage. Descriptive statistics are used to determine storage returns on Kansas City hard red winter wheat (KC HRWW), soybeans and corn across time periods. Empirical results suggest that markets were able to adapt to the influx of index fund trading as well as the concomitant lack of convergence. There is no strong relationship between the index funds investment and storage markets. Overall, the research indicates the resilience of storage markets to structural change.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figure Page

CHAPTER I

INTRODUCTION

Over the past two decades there have been large episodes of non-convergence in commodities markets. During much of the time period from 2005-2010, the Kansas City hard red winter wheat (KC HRWW), corn and soybeans futures markets experienced non-convergence. Non-convergence occurs when futures contracts are settled much higher or lower than the corresponding market's cash price (CME Group). Futures contracts nearing the expiration date are expected to be close to or equal to the cash price, as arbitrage is expected to cause the law of one price to hold (Adjemian et al., 2013). As Irwin et al., 2015 argues this divergence was created by a divergence in the price of deliverable warehouse receipts and the price of grain.

In a non-converging market, the hedger is still protected from price risk as long as the futures and cash prices move in the same direction. Cash market gains and losses can still be offset by futures market gains and losses. In this case, cash and futures prices do not converge to each other, but they converge with a predictable basis. On the other hand, if the basis at expiration exhibits random fluctuations, then a hedger is not insulated from price risk.

Non-convergence can lower hedging effectiveness by making basis unpredictable, thereby threatening the basic functioning of a futures markets contract, since its hedgers lose interest in trading (Irwin et al., 2011; Peck and Williams, 1991; Working, 1953; Working, 1970). Furthermore, unhedged agricultural merchandisers and producers face considerable price risks and welfare losses that jeopardize food production, marketing, and the food supply chain (Adjemian et al., 2013). Even though the KC HRWW, corn and soybeans markets experienced long periods of non-convergence, the volume of futures trading remained high.

According to the Commodity Futures Trading Commission (CFTC 2008), the total of various commodity index-related instruments purchased by institutional investors increased from an estimated $15 billion in 2003 to at least $200 billion in mid-2008. Over the past few decades, the financial industry has developed new products that institutions and individuals can use to invest in commodity markets through long-only index funds, over the counter (OTC) swap agreements, exchange traded funds and other structured products. These financial products have the same end goal – to provide investors with buy-side exposure to returns from an individual index of commodity prices. While it is uncertain how to best measure the large increase in investors in the commodity markets, it is safe to say that at least $100 billion of new investment moved into commodity futures between 2004 and 2008 (Irwin 2010). Domanski and Heath (2007) gave this influx the name of "financialization" of the commodity futures markets. Between 1970 and 2015, annual returns on the Bloomberg Commodity Index had a very low correlation with U.S. equities, as represented by the S&P 500 Index, and a correlation close to zero with global bonds, as represented by the Barclays Global Aggregate Index. However, they were positively correlated with the U.S. Consumer Price Index (PIMCO, 2017). These correlations suggests that commodities investments could help reduce the risk of financial investors.

What is the economic impact of such rapid growth of commodity index investment and large episodes of non-convergence? This research will show what the markets were before, during and after the rapid growth. The primary objective of this research is to determine the effect of lack of convergence on the supply of storage.

One hypothesis is that investments by long-only index funds have increased returns to storage. Kaldor (1939) proposed a theory that provides a link between the term structure of futures prices and the stocks of commodities stored. This link is also known as "cost of carry arbitrage," which entails that in order to encourage storage, futures prices and expected cash prices of commodities should rise over time to pay off inventory holders for the costs associated with storage. Previous research indicates that the growth of index funds had little causal effect on non-convergence (Gilbert 2009, 2010; Einloth, 2009; Tang and Xiong, 2010; Irwin, Sanders, and Merrin, 2009). Did the effect of index funds increase the returns to storage which then caused the non-convergence in the first place? When the markets are unstable are producers more likely to store their grain and wait for a higher expected profit? These are the questions this research will attempt to answer.

CHAPTER II

CONCEPTUAL FRAMEWORK

The increase in investment demand for commodities has sparked interest in old questions, such as the debate on whether commodity futures prices embed a risk premium, and conjectures by Keynes (1923) with his theory of normal backwardation. Keynes' theory states that futures markets speculators assume the price risk and receive a risk premium in return. The market entry of long-only index funds should lower risk premiums, so farmers can hedge at lower costs (Prehn et al. 2015). Intuitively, this provides incentives for storing commodities. However, empirical evidence over the last decade disputes this intuition. Most risk premiums are now positive (Main et al., 2013). This empirically supports Keynes theory of normal backwardation.

This Theory of Storage, (Kaldor (1939), Working (1949), and Brennan (1958)) can be stated in terms of the basis, the difference between the contemporaneous spot price in period *t*, S_t, and the futures price (as of date *t*) for delivery at date T, $F_{t,T}$. The theory views the (negative of) the basis as consisting of the cost-of-carry: interest foregone to borrow to buy the commodity, $S_t r_t$,(where r_t is the interest charge on a dollar from t to T), plus the physical storage costs $w(T-t)$, minus a convenience yield, c_t, which is an implied return on inventories and c_t:

(1)

$$F_{t,T} - S_t = S_t r_t + w(T-t) - c_t$$

where $F_{t,T}$ is the futures price and S_t is the spot price (cash price). The futures price minus the spot price equals basis. The basis is equal to $S_t r_t$, the opportunity cost, plus the marginal storage cost minus the convenience yield all from time T to t. The basis can also be a way to measure convergence because convergence happens when the cash price and futures price come together at the delivery date. Under the theory of storage, inventories are held only if the expected returns are positive; thus S_t and $F_{t,T}$ are both functions of the level of inventory. Therefore, the quantity stored depends on the expected basis and expected profit. A lack of convergence could distort this formula, due to the expected profit being inaccurate, and projecting it to be higher. Therefore, a shift in the demand for storage could occur and more grain would be stored. The expected profit maximization for a storage provider, assuming that the producer is hedging, can be expressed as

(2)

$$\max_Q E(\pi) = \big(E(F_{t+h} - F_t) - E(S_{t+h} - S_t)\big)Q - C(Q)$$

$$Q \leq Capacity$$

where $E(\pi)$ is the expected profit, Q is the quantity stored, F_{t+h} is the distant futures price, F_t is the nearby futures price, S_t is the cash price, $S_{t+1}$is the distant cash price and *C(Q)* is a cost function that includes storage fees, insurance, pest management and other costs associated with the storing of the grain. The amount of grain that can be stored is constrained by the capacity, where capacity equals the amount of storage available, for example grain elevators. Brennan (1958) describes that the amount of a commodity held in storage is determined by the equality of marginal cost of storage and the temporal price spread. The supply of storage is forthcoming from those firms holding titles to stocks stored from one period to another. In a competitive market a firm seeking to maximize net revenue will hold the amount of stocks such that the net marginal cost of storage per unit equals the expected change in price per unit of time.

There has been much discussion in the commodity futures literature on whether the scale of financialization was large enough to reduce the historical risk premiums of commodity futures markets. The traditional Keynesian theory of normal backwardation predicts that long speculators in commodity futures earn a risk premium from short hedgers in the form of an embedded downward bias in futures prices before maturity (Irwin et al., 2018). Theoretical models developed by Acharya et al. (2013), Etula (2013), Brunetti and Reiffen (2014), Hamilton and Wu (2015), and Basak and Pavlova (2016) demonstrate how buying pressure from commodity investors can exert downward pressure on risk premiums, or equivalently, upward pressure on commodity futures prices before expiration. The market entry of long-only index funds should lower risk premiums, so farmers can hedge at lower costs, which could create a risk premium on the buyer side (Prehn et al. 2015). Increased returns to storage increases demand for storage capacity. The shift in demand for storage leads to the following hypotheses: that markets were able to adapt to the influx of index fund trading as well as the concomitant lack of convergence.

Huellen (2017) offers insight on how the magnitude of nonconvergence augments the commodity storage model with a price-pressure component:

(3)

$$E(S_{t+h}) = F_{t,t+h} + \rho_t + E(Basis_{t+h})$$

where $E(S_{t+h})$ is the expected future cash price, $F_{t,t+h}$is the futures price at time *t* and contract maturity of $t + h$, ρ_t is a risk premium, and $E(Basis_{t+h})$ is the expected basis at time $t + h$. Nonconvergence makes it difficult for firms to forecast basis. If they are unable to predict the nonconvergence then their expected returns to storage will be inaccurate.

The Chicago Board of Trade (CBOT) and Kansas City Board of Trade (KCBOT) made changes to grain futures contract specifications to combat the 2005-2010 non-convergence problems. Changes included: limiting number of warehouse receipts and shipping certificates that a trader could hold, expanding delivery locations, and changing storage rates (Irwin, 2018). Irwin argues that the most fundamental change was the implementation of a variable storage rate (VSR) rule for CBOT wheat beginning with the September 2010. The Chicago Mercantile Exchange (CME) did not introduce VSR to corn and soybeans markets but chose to increase their fixed storage fees in 2008 and later in 2020 (Goswami et al., 2021). The objective of implementing VSR was to improve convergence, and that is ultimately what it did.

CHAPTER III

DATA

Data used for this research came from multiple sources. Futures prices for corn and soybeans were compiled by the Livestock Marketing Information Center (LMIC) and stem from reported prices of CBOT/CMEGroup futures contract settlement prices. Futures prices for #1 KC HRWW come from Barchart. Cash prices for all three commodities were compiled LMIC based on USDA reports with both #2 Yellow Corn and KC HRWW using Kansas City prices and #1 Yellow Soybeans using Central Illinois prices. All commodity prices are weekly averages which are averaged annually. The ending stocks for each commodity comes from the World Agricultural Supply and Demand Estimates (WASDE) report.

The annual ending stock quantities used for KC HRWW is May 1st, and corn and soybeans is July 1st. The commodities annual ending stocks with their respective months are shown in Figure 16. The annual interest rate used is the market yield on U.S. Treasury securities at 10-year constant maturity, which comes from the Federal Reserve Economic Data (FRED). Index funds data were obtained through the Commodity Futures Trading Commission (CFTC), using an annual average of the total Commodity Index Trades (CIT) long positions minus the CIT short positions. Non-convergence was measured using the basis of the 4 weeks prior to each contract's expiration date, which is the 15th of that month. The contract months for KC HRWW are March, May, July, September, and December. The contract months for corn are March, May, July, September, and

December. The contract months for soybeans are January, March May, July, August, September, and November. All data were from 2000 to 2020 and were averaged annually.

Potential limitations of the index funds data include the placement of a trader in a particular classification based upon their predominant business activity may involve some exercise of judgment on the part of the Commission staff. Some traders being classified in the "swap dealers" category engage in some commercial activities in the physical commodity or have counterparties that do so. Likewise, some traders classified in the "producer/merchant/processor/user" category engage in some swaps activity. Moreover, it has always been true that the staff classifies traders not their trading activity. Staff will generally know, for example, that a trader is a "producer/merchant/processor/user", but it cannot know with certainty that all of that trader's activity is hedging (CFTC).

CHAPTER IV

PROCEDURE

Econometric and statistical models are used to test the main hypotheses of this research and to address the study's objectives. The main objective is accomplished by estimating a regression model of the supply of storage to evaluate the supply of storage before, during and after the rapid growth and the lack of convergence.

This research is focused on commodities that were stored for a whole crop year. For example, wheat can be harvested as soon as late May in some regions, which is why the ending stock numbers used come from the May 1st WASDE report. The expected futures market profit will come from the contract months July and the following March. The main objective determines the effect of growth of index funds and lack of convergence on storage costs of KC HRWW, soybeans, and corn. Dummy variables are used to represent the three different time periods: before, during, and after the large increase of index funds and large episodes of nonconvergence. The first time period was 2000 – 2005, 2006 – 2012 was the second and 2013 – 2020 was the third. One regression model is created for the supply of storage. The equation for the supply of storage is

(4)

$$ES_t = \beta_0 + \beta_1 OppCost_t + \beta_2 Returns_t + \delta_1 T_1 + \delta_2 T_2 + \epsilon_t$$

where ES_t is the quantity of ending stocks of the commodity at time *t*, $OppCost_t$ is the cash price of the commodity multiplied by the annual interest rate at time *t*, which measures opportunity cost of storing the commodity, $Returns_t$, is the expected returns on storage of the commodity using the futures price, at time *t*, T_1 is a dummy variable used to express the time period from 2000 to 2005, T_2 is a dummy variable used to express the time period from 2006 to 2012, T_3 is a dummy variable used to express the time period from 2013 to 2020, and ϵ_t is the random error term such that $\epsilon_t \sim N(0, \sigma_s^2)$. The null and alternative hypothesis are as stated:

$$H_0: \delta_1 = \delta_2 = 0$$

$$H_a: \text{At least one } \delta_i \neq 0 \text{ (for } i = 1,2).$$

An estimate of the elasticity of demand is calculated at the variables means.

A second supply of storage equation used dummy interactions to represent the time periods multiplied with the returns on storage:

(5)

$$ES_t = \beta_0 + \beta_1 OppCost_t + \beta_2 Returns_t + \delta_1 T_{1t} Returns_t + \delta_2 T_{2t} Returns_t + \epsilon_t$$

where the only difference between Equation 4 and Equation 5 is the interaction term between the returns on storage and the dummy variables. The expected sign for the interactions term, δ_2, is to be negative. An interaction term was used to determine if the results differ from only using intercept dummy variables to represent the 3 different time periods.

A third supply of storage equation used an annual average of basis as a measurement of nonconvergence:

(6)

$$ES_t = \beta_0 + \beta_1 OppCost_t + \beta_2 Returns_t + \beta_3 NonConvergence_t + \epsilon_t$$

where $NonConvergence$ was used to replace the dummy variables to estimate an equation for the supply of storage. The nonconvergence variable is calculated by using an annual average of the commodities basis (Cash price – nearby futures price) for each commodity by using the 4 weeks basis leading up to the contract expiration date near the end of each crop year. For KC HRWW the contract date used was May, and for corn and soybeans July. The prices for KC HRWW and corn come from Kansas City and prices used for soybeans comes from Central Illinois.

The second objective uses descriptive statistics to look at each commodities returns on storage over the past two decades. The commodities returns on storage are calculated by the following equation:

(7)

$$F_{t,T+h} - F_{t,T}$$

where $F_{t,T+h}$ is the futures price at time t with a contract maturity of $t + h$, and $F_{t,T}$ is the futures price at time t with contract maturity of T. For example, since KC HRWW can be harvested as early as late May, the returns on storage will be calculated by subtracting the futures contract price in July with a maturity of March in the following year from the futures contract price of July with a maturity of July in the current year. The number used comes from a point in time near the 15^{th} of July.

The third objective, determining the effect of nonconvergence, is determined by using descriptive statistics as well. Basis is the difference between the local cash price of a commodity and the price of a specific futures contract month at any given point in time:

(8)

$$Basis_t = S_t - F_t$$

where S_t is the local cash price at time t and F_t is the futures price at time t. Basis can be either positive or negative. Because basis reflects local market conditions, it's directly influenced by several factors including transportation costs, local supply and demand conditions such as weather, and storage costs (CBOT 2003).

An efficient market is one that accurately incorporates all known information in the determining price (Fama 1991). A buy and hold strategy was created from the data to test for market efficiency. This is where someone buys a futures contract and holds it until it almost expires, then selling it to buy the next expiration. The weekly futures contract prices were transformed to natural logs and then were subtracted from each other, weekly, rolling to the next month after each contract's expiration date. For example, the March contract prices were used until the 8th of March and then it rolled to the May contract prices until the 8th of May and then rolled to July and so on. A true efficient market would show zero profits from a buy and hold strategy. The null and alternative hypothesis would be:

$$H_0: \gamma = 0$$

$$H_a: \gamma \neq 0$$

The equation used to test the buy and hold strategy is:

(9)

$$\ln\left(F_{t+h,T}\right) - \ln(F_{t,T})$$

where F_t, T is the futures price at time t with contract maturity of T, and $F_{t+1,T}$ is the futures price at time $t+h$ with the contract maturity of T. A t-test to test for significance for each time period in each commodities future markets.

To determine if the amount of long-only index funds had any effect on the returns to storage, the following regression equation was used:

(10)

$$R_t = \beta_0 + \beta_1 IF_t + \beta_2 ES_t + \epsilon_t$$

where R_t is returns on storage at time t, IF_t is the quantity of long-only index funds, ES_t is the quantity of ending stocks, and ϵ_t is the random error term such that $\epsilon_t \sim N(0, \sigma_s^2)$. The quantity of index funds was determined by an annual average of the net long-only open contracts by subtracting the short open contracts from the long open contracts.

CHAPTER V

RESULTS

Table 1 reports the estimated results from Equation 4, the supply of storage using dummy variables to represent the different time periods. The opportunity cost, $S_t R_t$, and ending stocks have a negative correlation because when it costs more to store, producers will store less. This relationship between the opportunity cost and ending stocks is the same across all three commodities. However, the return on storage has a positive relationship with ending stocks, which means that as returns are positive and increasing, more grain will be stored. This relationship between ending stocks and the return on storage is also the same for all three commodities. The intercept dummy variables T1 and T2 both have p-values that are not significant for all three commodities, implying a failure to reject the null hypothesis that there is no relationship between the time periods and ending stocks. During period 2, the lack of convergence resulted in returns to storage being overstated if producers had naive expectations. Thus, if producers were able to forecast the lack of convergence, the expected sign for time period 2 would be negative. While two of the three commodities have coefficients with the expected sign, none of them are significantly different from zero. The elasticity of supply for each commodity is listed in Table 2.

Most of the commodity's supply elasticities are less than one, excluding soybeans opportunity cost supply elasticity that is greater than 2. When the elasticity is less than one, the supply of the good is inelastic, which means that the good has low responsiveness to price changes.

Table 3 reports the estimated results from Equation 5, the second supply of storage equation using slope dummy variables. Using slope dummy variables rather than only using regular dummy variables provides similar results. The relationships between the returns on storage and the opportunity cost are the same with the annual ending stocks as they were in Table 2. The signs for the interaction terms are almost the same with the intercept dummy variables, excluding time period 2 for soybeans, which now shows a negative relationship with the annual ending stocks, which is what was expected to counter the naive returns on storage expectations.

Table 4 presents the estimates of Equation 5, the third supply of storage equation using opportunity cost, the returns from storage and a measurement of non-convergence. The dummy variables are replaced with a measurement of basis to determine if the relationship between supply of storage and basis is positive or negative. Basis, the cash price minus the futures price at the 4 weeks leading up to each contract's expiration date, is used for a measure of non-convergence. Non-convergence was measured by using the basis of the 4 weeks prior to each contract's delivery date, which is normally the 15th day of that month. When trying to connect non-convergence to the amount of grain stored, Table 4 indicates that the measure of convergence is not statistically significant. The expected sign for the convergence variable is to be negative, to counter the naive expectation of higher returns on storage than the actual returns. The expected basis is a determining factor in the estimated future cash price, so when the future cash price is overestimated nonconvergence occurs. Because if your basis expectation is naive and you assume it will converge when it doesn't, then your expected returns will be higher than the actual returns, leading to producers to store more than the optimal level.

Figures 1, 2 and 3 present the returns on storage for their respective commodities from years 2000 to 2020. The black lines represent the three different time periods. During the second time period, from 2006 to 2012, all three commodities experienced larger positive and negative returns when compared to time periods 1 and 3. The second time period does represent the years when nonconvergence was at its highest, but it was also during a time when commodity prices were at an all-time high. The large profits and losses could be due to the lack of effective estimation of the future cash price, leading to biased expectations which created nonconvergence. In time period 3 the returns became less intense than in the time period 2.

Figures 4, 5 and 6 represent the basis for soybeans, corn, and KC HRWW respectively, as basis equals the cash price – the nearby futures price. The black lines represent the three different time periods. All three graphs show large time periods of nonconvergence, specifically during time period 2, but in the other time periods as well.

A second set of graphs (Figures 7, 8 and 9) depict the commodity basis near the delivery date, rather than across the whole year. Each line represents a contract month. The basis for each month was calculated by the average of the 4 weeks leading up to the 15th of each month. For example, the basis for the March 2000 corn contract was the average basis of the weeks of February 17, February 24, March 2, and March 9. The contract months for each commodity are listed in Table 5. The delivery date for each contract is normally the 15th day of the contract month but can vary.

Table 6 reports the estimates of Equation 6, determining the effect of quantity of index funds on the expected returns on storage by using the futures price calendar spread ($F_{t+1} - F_t$). The index funds had little to no effect on the expected returns from storage. Each commodity has a positive relationship between the expected returns and the investment of index funds.

Figures 10, 11 and 12 show the quantity of Long-Only index funds in each commodities market. Please note that each chart shows data from years 2006 – 2020, this is due to the data prior to 2006 not being available from the CFTC. It can be assumed that there is an upward trend from 2000 – 2006. However, the trend line in soybeans and corn show a downward or straight trend, while KC HRWW has an upward trend. Long-only index funds became popular around this time, due to speculators thinking they would make a profit on grain futures markets. While theory was developed to explain how index funds trading could disrupt storage markets, empirical results find no strong relationship to investment in index funds. In fact, the growth has been slower and much more erratic than the popular press has led people to believe.

Figures 13, 14 and 15 are graphs to represent the buy and hold returns for each commodity for the years 2000 to 2020. Figure 13 shows the buy and hold returns average weekly for KC HRWW from 2000 to 2020. The 20-year average of the rolling buy and hold returns is natural log of (-0.00005). Figure 14 shows the buy and hold returns for Kansas City corn from the years 2000 to 2020. The 20-year average is the natural log of (0.0009). Figure 15 presents the buy and hold returns for soybeans from the years 2000 to 2020. The 20-year average is natural log of (0.0009). The t-test used to test the null hypothesis for each commodity in the three different time periods showed that each t-value was less than the critical value, resulting in failing to reject the null hypothesis.

Table 7 presents the averages for each commodity's buy and hold returns during the three different time periods, to test for market efficiency. All three commodities in all three time periods had almost zero buy and hold returns, which means that the data used come from an efficient market. It should be noted that both corn and soybeans had a higher natural log in time period 2, 2006 – 2012, which is the same time period that had the most nonconvergence.

CHAPTER VI

CONCLUSION

The goal of this research was the determine the economic impact of the large episodes of nonconvergence and the large increase in index funds in the commodities futures markets. Statistical models and descriptive statistics were used to test the main hypothesis of this research. Theory was developed to link the lack of convergence to creating biased expectations of the future cash price and expected returns. Ultimately, the empirical results suggest that markets were able to adapt to the influx of index fund trading as well as the concomitant lack of convergence. The supply of storage has shifted out over time as costs have gone up. There is no strong relationship to investment in index funds. Overall, this research does conclude that there is a negative relationship between opportunity cost and ending stocks, as well as a positive relationship between the returns on storage and ending stocks. In terms of policy implications, there is strong support for what exchanges have done by implementing the VSR in KC HRWW and raising storage rates in corn and soybeans. In this case, policy makers should be applauded for their decision to do nothing.

REFERENCES

Adjemian, M. K., P. Garcia, S. Irwin, and A. Smith. 2003. Non-convergence in Domestic Commodity Futures Markets: Causes, Consequences, and Remedies. Economic Research Service, Aug. 2013, https://www.ers.usda.gov/webdocs/publications/43777/39376_eib115.pdf?v=41492.

Brennan, Michael. 1958. The Supply of Storage. American Economic Review. 48: 50-72.

Commodity Futures Trading Commission (CFTC). 2008. "Report and Recommendations of the Subcommittee on Convergence in Agricultural Commodity Markets to the Agricultural Advisory Committee of the Commodity Futures Trading Commission on Convergence in Wheat with Implications for Other Commodity Markets." 1-12.

Domanski, D., A. Heath. Financial Investors and Commodity Markets. 2007 BIS Quarterly Review.

Etienne, X. L., S. H. Irwin and, P. Garcia. 2015. Price Explosiveness, Speculation, and Grain Futures Prices. American Journal of Agricultural Economics. 97 (1): 65-87.

Gardiner, W.H. and Dixit, P.M., 1987. Price elasticity of export demand: concepts and estimates. ERS Foreign Agric. Econ. Rep. 228, U.S. Department of Agriculture, Washington, DC.

Goswasmi, A., M. K. Adjemian and B. Karali. 2021. The Impact of Futures Contract Storage Rate Policy on Convergence Expectations in Domestic Commodity Markets. NCCC-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management.

Hamilton, J.D., and J.C. Wu. 2015. Effects of Index-Fund Investing on Commodity Futures Prices. International Economic Review. 56 (1): 187—205.

Irwin, S. H., P. Garcia, D. L. Good and, E. L. Kunda. 2008. Recent Convergence Performance of CBOT Corn, Soybean, and Wheat Futures Contracts. Choices 23 (2): 16-21.

Irwin, S. H., D. R. Sanders and, R. P. Merrin. 2009. Devil or Angel? The Role of Speculation in the Recent Commodity Price Boom (and Bust). Journal of Agricultural and Applied Economics. 41. 10.1017/S1074070800002856.

Irwin, S. H., P. Garcia, D. L. Good, and E. L. Kunda. Spreads and Non-convergence in Chicago Board of Trade in Corn, Soybean, and Wheat Futures: Are Index Funds to Blame? Applied Economic Perspectives and Policy 33: 116-142.

Irwin, S.H., and D.R. Sanders. 2011. “Index Funds, Financialization, and Commodity Futures Markets.” Applied Economic Perspectives and Policy 33 (1): 1 - 31.

Kaldor, N. 1939. Speculation and Economic Stability. The Review of Economic Studies. 7 (1). 1-27.

Keynes, J. M. (1923): Aspects of Commodity Markets, Manchester Guardian Commercial. European Reconstruction Series. Section 13. 784-7.

Main, S., S.H. Irwin, D.R. Sanders, and A. Smith. 2013. How could we have been so wrong? The puzzle of disappointing returns to commodity index investments. Proceeding of the NCCC-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management, St. Louis, MO.

Peck, A.E., and J.C. Williams. 1991. Deliveries on Chicago Board of Trade Wheat, Corn, and Soybean Futures Contract, 1964/65-1988/89. Food Research Institute, Stanford University. 22 (2). 8. 129 - 136

Prehn, S., T. Glauben, S. H. Irwin, J. P. Loy, I. Pies, and M. G. Will. 2015. “The impact of long-only index funds on price discovery and market performance in agricultural futures markets.” Discussion Paper No. 147.

Tang, K., and W. Xiong. 2012. Index Investment and the Financialization of Commodities. Financial Analysts Journal. 68 (6). 54-74.

Working, Holbrook. 1949. The Theory of Price of Storage. American Economic Review. 39 (6) (December):1254-62.

Working, Holbrook. 1948. Theory of Inverse Carrying Charge in Futures Markets. Journal of Farm Economics. 30 (1): 1-28.

APPENDICES

Table 1. Regression Estimates for Ending Stocks (mil. bu) versus Supply Shifters and Time Dummy Variables

Commodity	Variable	β		t	Pr > |t|
KCHRW	Intercept	499	***	5.85	<.0001
	Opportunity cost[a] ($/bu)	-1281	***	-2.92	0.01
	Return on storage[b] ($/bu)	281	***	3.00	0.11
	T1 2000 - 2005	-40		-0.87	0.40
	T2 2006 - 2012	-92		-1.68	0.11
Corn					
	Intercept	1755	***	5.62	<.0001
	Opportunity cost[a] ($/bu)	-6600	**	-2.54	0.02
	Return on storage[b] ($/bu)	2828	***	4.07	0.001
	T1 2000 - 2005	-136		-0.75	0.46
	T2 2006 - 2012	-88		-0.34	0.74
Soybeans					
	Intercept	836	***	6.02	<.0001
	Opportunity cost[a] ($/bu)	-2369	**	-3.87	0.001
	Return on storage[b] ($/bu)	1697	***	4.39	0.001
	T1 2000 - 2005	-88		-1.08	0.296
	T2 2006 - 2012	55		0.49	0.629

Notes: Observations = 21, Dependent Variable: Ending Stocks, *p<0.1, ** p<0.05, ***p<0.01
Ending stocks used for KCHRW, Corn and Soybeans is May 1, July 1 July 1, respectively

[a]: Opportunity cost is the local cash price times the annual interest rate at a certain point in time ($/bu)

[b]: Return on Storage is the difference in two future contract months to represent the beginning of the crop year and the end of the crop year (ex: KC HRW March 2018 Futures Contract Price - KC HRW July 2017 Futures Contract Price)

Table 2. Supply Price Elasticities for KC HRWW, Corn, and Soybeans

Commodity/Variable	KC HRW	Corn	Soybeans
Opportunity Cost	-0.701	-0.450	-2.041
Returns on Storage	0.685	0.409	0.441

Table 3. Regression Estimates for Ending Stocks (mil. bu) versus Supply Shifters and Time Slope Dummy Variables

Commodity	Variable	β		t	Pr > |t|
KCHRW	Intercept	402	***	4.47	<.0001
	Opportunity cost[a] ($/bu)	-1271	***	-3.98	0.0011
	Return on storage[b] ($/bu)	591	***	3.87	0.0014
	T1 x Return on storage	-65		-0.43	0.6759
	T2 x Return on storage	-308	**	-2.40	0.0287
Corn					
	Intercept	1565	***	4.01	0.001
	Opportunity cost[a] ($/bu)	-5755	**	-2.14	0.0481
	Return on storage[b] ($/bu)	3309	***	3.35	0.004
	T1 x Return on storage	-484		-0.63	0.5404
	T2 x Return on storage	-768		-0.75	0.4637
Soybeans					
	Intercept	682	***	4.70	0.0002
	Opportunity cost[a] ($/bu)	-1819	***	-3.28	0.0047
	Return on storage[b] ($/bu)	1881	***	3.48	0.0031
	T1 x Return on storage	-235		-0.35	0.7315
	T2 x Return on storage	-851		-0.98	0.3424

Notes: Observations = 21, Dependent Variable: Ending Stocks, *p<0.1, ** p<0.05, ***p<0.01
Ending stocks used for KCHRW, Corn and Soybeans is May 1, July 1 July 1, respectively
[a]: Opportunity cost is the local cash price times the annual interest rate at a certain point in time ($/bu)
[b]: Return on Storage is the difference in two future contract months to represent the beginning of the crop year and the end of the crop year (ex: KC HRW March 2018 Futures Contract Price - KC HRW July 2017 Futures Contract Price)

Table 4. Estimates of the Supply of Storage with Non-convergence

Commodity	Variable	β		t	Pr > |t|
KCHRW	Intercept	518	***	7.85	0.001
	Opportunity cost ($/bu)	-1463	***	-4.26	0.001
	Return on storage[a] ($/bu)	295	**	2.79	0.012
	Basis[b] ($/bu)	-35		-0.93	0.368
Corn					
	Intercept	1669	***	4.82	0.000
	Opportunity cost ($/bu)	-7754	***	-3.39	0.004
	Return on storage[a] ($/bu)	2978	***	3.62	0.002
	Basis[b] ($/bu)	37		0.46	0.649
Soybeans					
	Intercept	738	***	6.23	<.0001
	Oppportunity cost ($/bu)	-1924	***	-4.18	0.001
	Return on storage[a] ($/bu)	1425	***	3.50	0.003
	Basis[b] ($/bu)	-286		-1.49	0.156

Notes: Oberservations = 21, Dependent Variable: Ending Stocks, *p<0.1, ** p<0.05, ***p<0.01
Ending stocks used for KCHRW, Corn and Soybeans is May 1, July 1 July 1, respectively

[a]: Return on Storage is the difference in two future contract months to represent the beginning of the crop year and the end of the crop year (ex: KC HRW March 2018 Futures Contract Price - KC HRW July 2017 Futures Contract Price)

b: Basis is calculated by the annual average of the basis of the 4 weeks prior to each contract's expiration date (KC HRWW May, Corn and Soybeans July)
where basis = cash price - futures price

Table 5. Commodity Contract Months

Contract Months		
Corn	KC HRWW	Soybeans
March	March	January
May	May	March
July	July	May
September	September	July
December	December	August
		September
		December

Table 6. Estimates of the Returns on Storage ($/bu) with the Effect of Index Funds Traded (thousand open contracts) in Commodity Markets

Commodity	Variable	β		t	Pr > |t|
KCHRW	Intercept	0.18		1.44	0.168
	Index Funds (K contracts)	1.41E-06		0.47	0.644
	Ending Stocks (mil. bu)	3.54E-04		1.06	0.303
Corn					
	Intercept	-0.05		-0.47	0.645
	Index Funds (K contracts)	0.09		0.88	0.390
	Ending Stocks (mil. bu)	1.40E-04	**	3.52	0.002
Soybeans					
	Intercept	0.04		0.77	0.454
	Index Funds (K contracts)	-2.56E-03		-0.29	0.774
	Ending Stocks (mil. bu)	1.68E-04	*	1.92	0.071

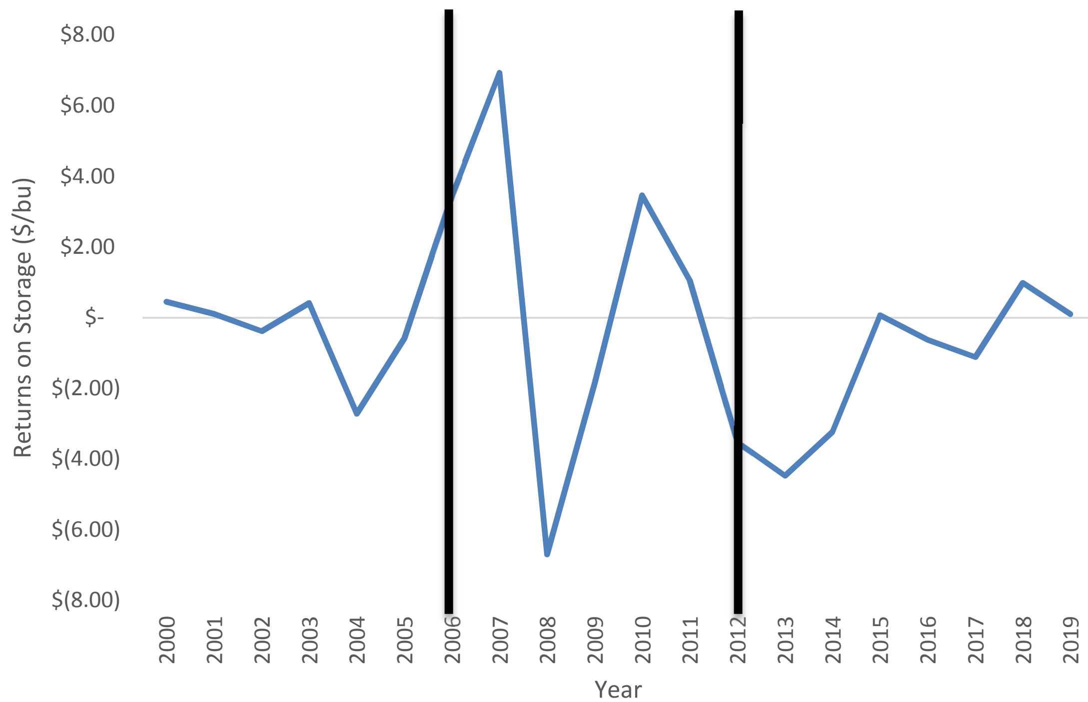
Notes: Oberservations = 21, Dependent Variable: Returns on storage,
 * significant at p<0.1, ** signifcant at p<0.05
Ending stocks used for KCHRW, Corn and Soybeans is May 1, July 1 July 1, respectively

Table 7. Natural Log Averages of Buy and Hold Returns in Different Time Periods

Year/Commodity	Corn	Soybeans	KC HRW
2000 - 2005	0.0002	0.0008	0.0001
2006 - 2012	0.0032	0.0022	-0.0001
2013 - 2020	-0.0005	-0.0003	-0.0001

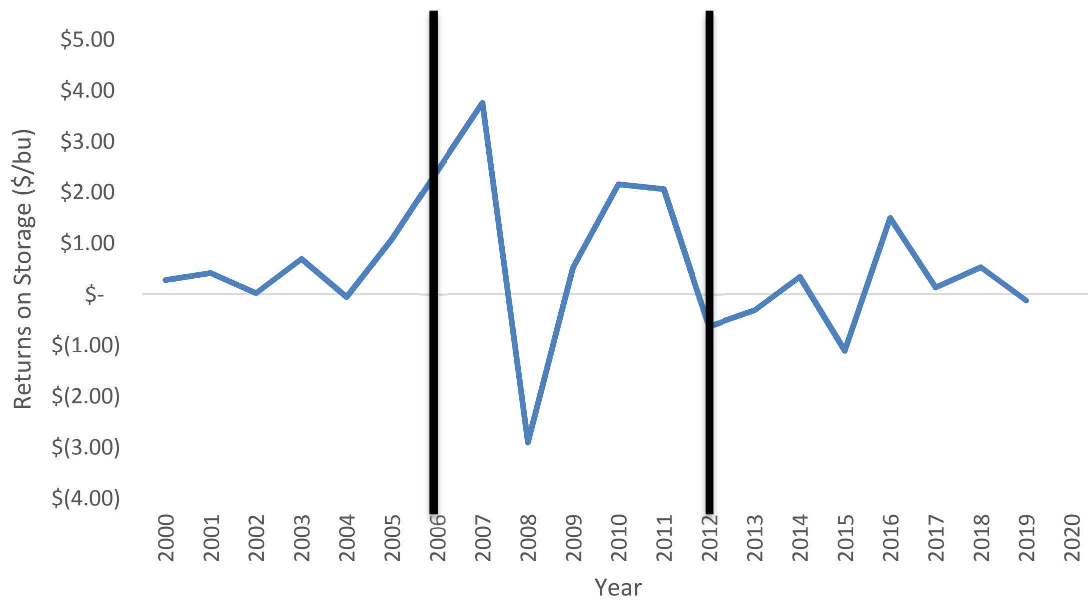
Note: Each commodity's buy and hold return in each time period had a test statistic value that was less than the critical value of t (1.984)

Figure 1. Soybeans Returns on Storage, 2000 – 2020



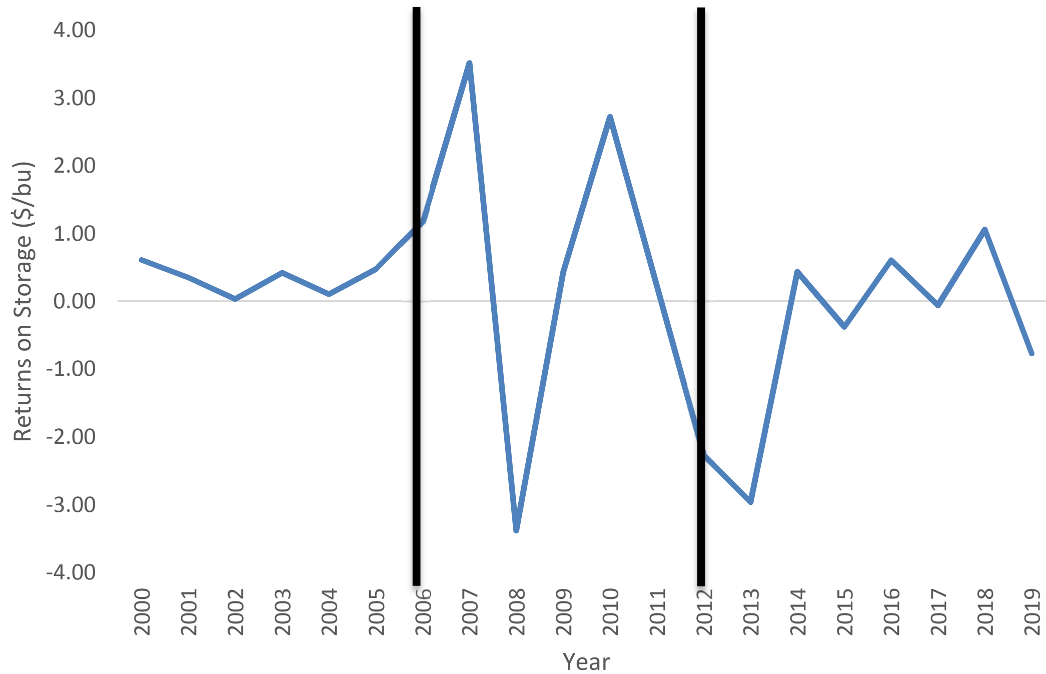
Note: Returns on storage for soybeans = $(F_{t,T+h} - F_{t,T})$ where F_{T+h} is the futures price at time t with a contract maturity of $t+h$, and $F_{t,T}$ is futures price at time t with a contract maturity of T.

Figure 2. KC HRWW Returns on Storage, Kansas City 2000 – 2020



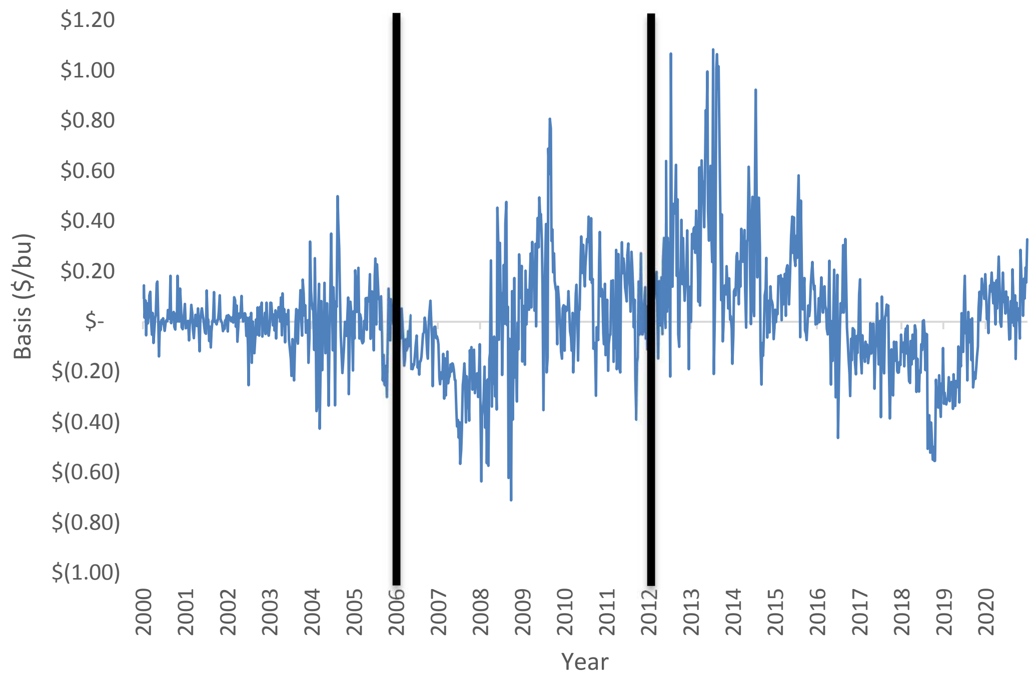
Note: Returns on storage for soybeans = $(F_{t,T+h} - F_{t,T})$ where F_{T+h} is the futures price at time t with a contract maturity of $t+h$, and $F_{t,T}$ is futures price at time t with a contract maturity of T.

Figure 3. Corn Returns on Storage, Kansas City 2000 – 2020



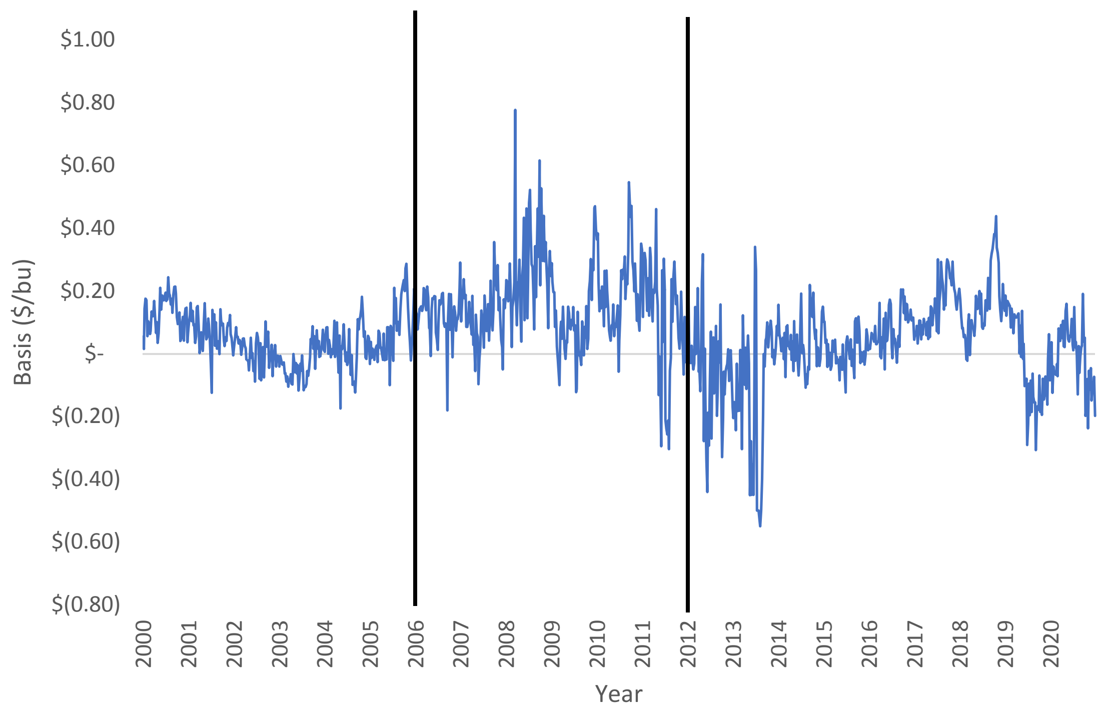
Note: Returns on storage for soybeans = $(F_{t,T+h} - F_{t,T})$ where F_{T+h} is the futures price at time t with a contract maturity of t+h, and $F_{t,T}$ is futures price at time t with a contract maturity of T.

Figure 4. Soybean Basis, Central Illinois 2000 - 2020



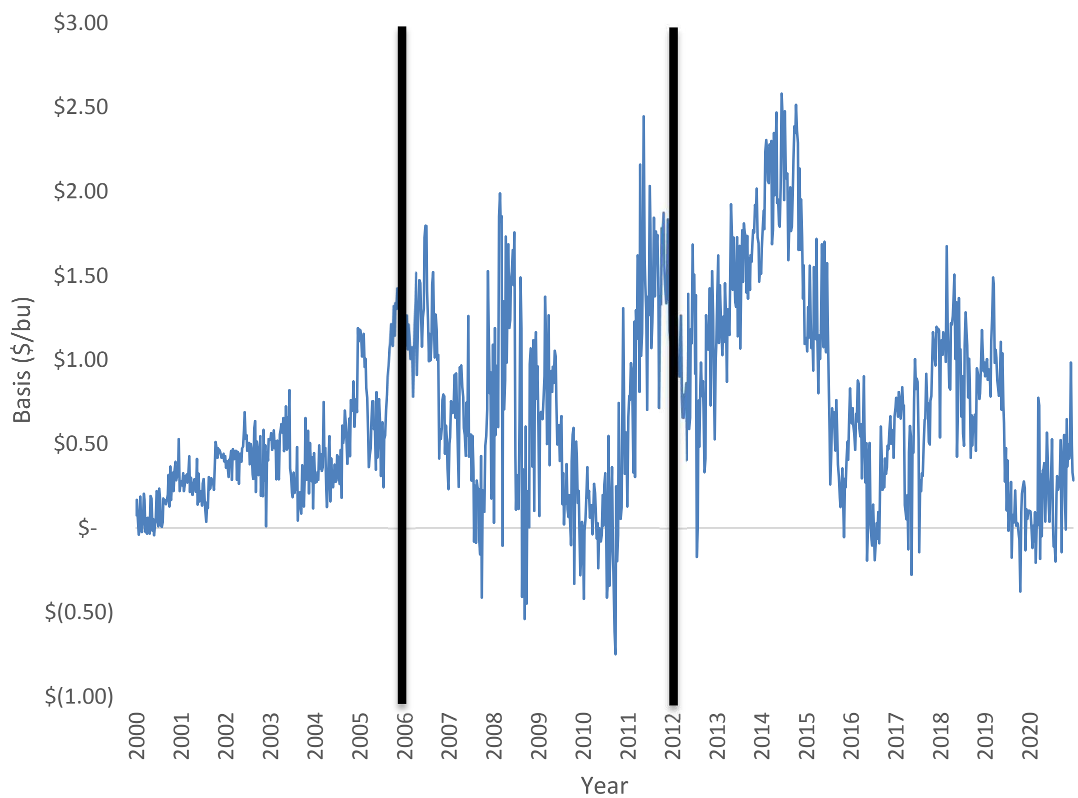
Note: Basis was calculated by subtracting the nearby futures price from the local cash price using weekly average data.

Figure 5. Corn Basis, Kansas City 2000 - 2020



Note: Basis was calculated by subtracting the nearby futures price from the local cash price using weekly average data.

Figure 6. KC HRWW Basis, Kansas City 2000 – 2020



Note: Basis was calculated by subtracting the nearby futures price from the local KC cash price using weekly averages.

Figure 7. # 2 Yellow Corn Basis Near Delivery Date, Kansas City 2000 - 2020

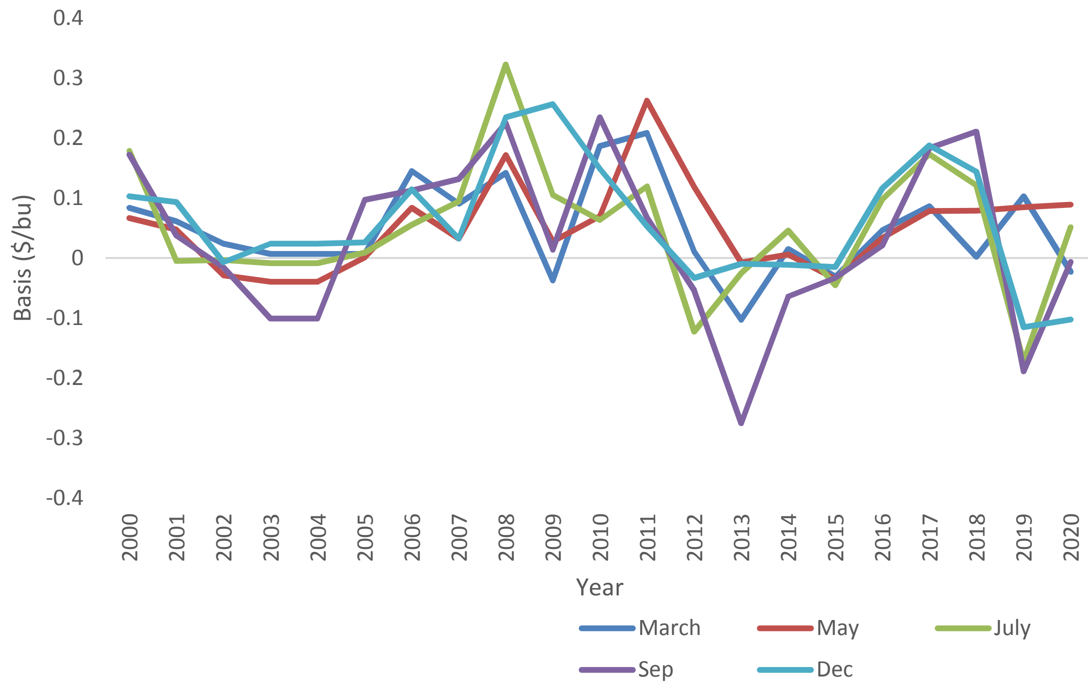


Figure 8. #1 KC HRWW Basis Near Delivery Date, Kansas City 2000 – 2020

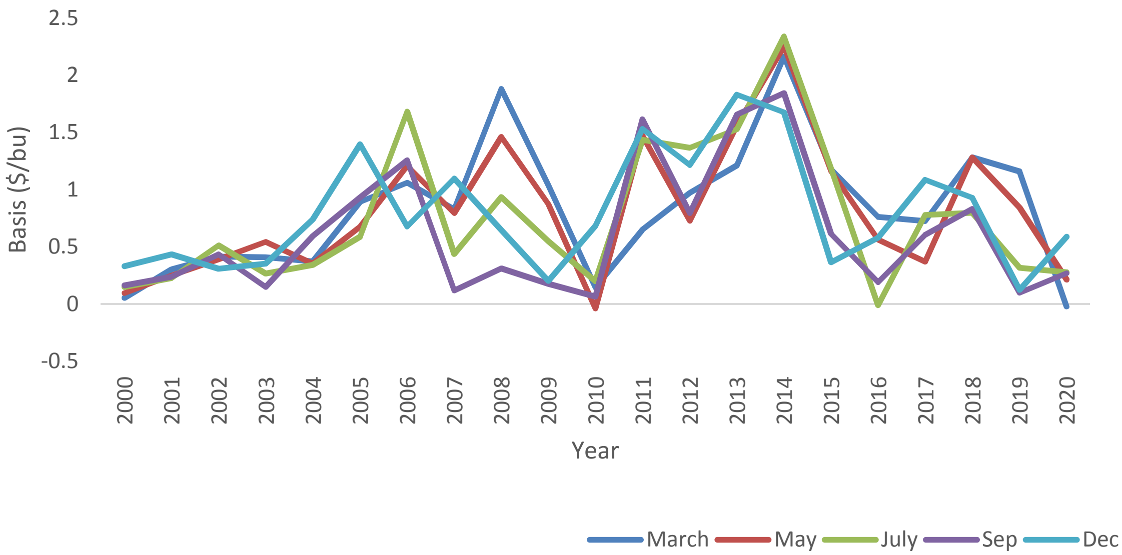


Figure 9. #1 Yellow Soybean Basis Near Delivery Date, Central Illinois 2000 – 2020

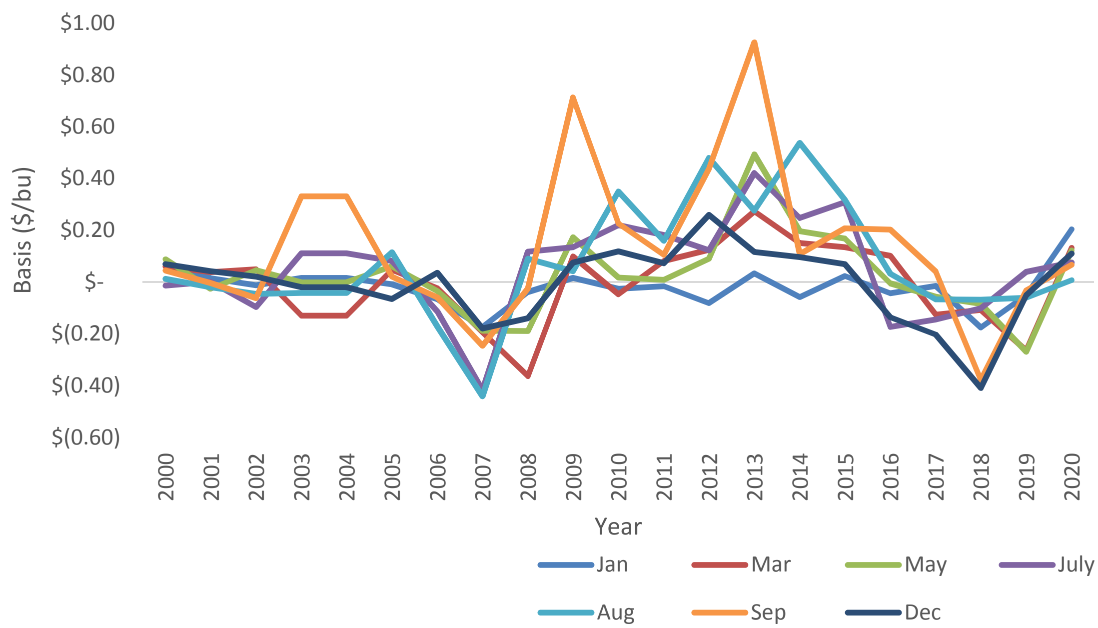
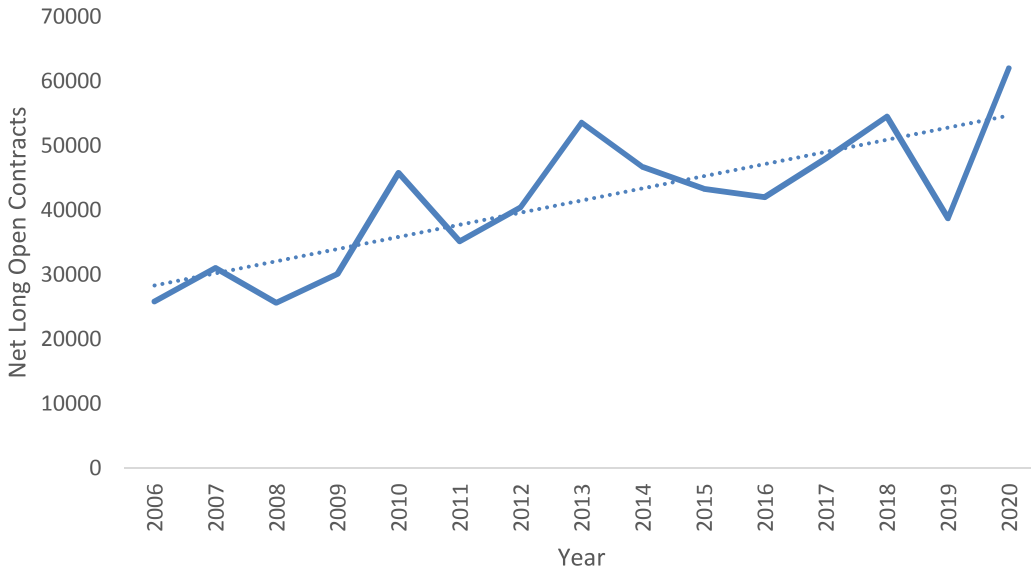
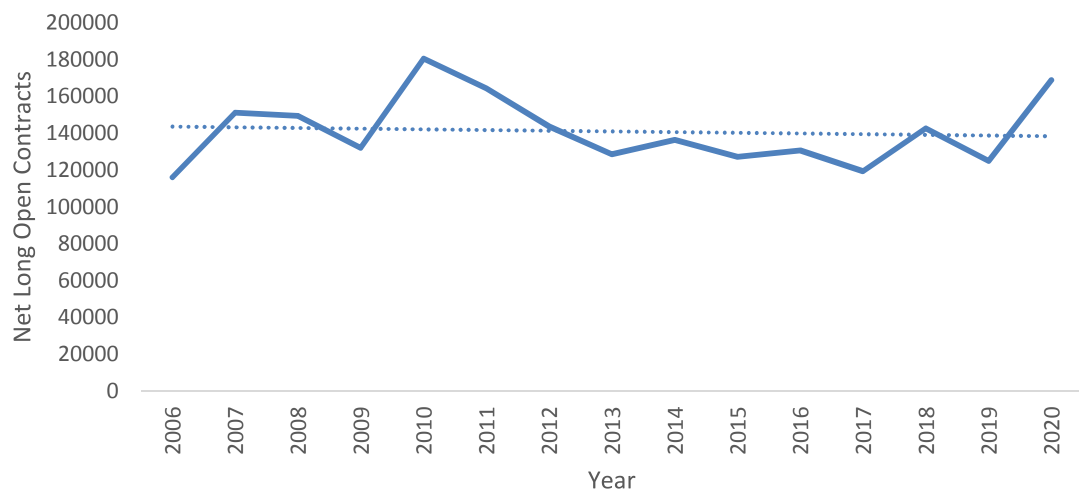


Figure 10. Long Only Index Funds KC HRWW, 2006 - 2020



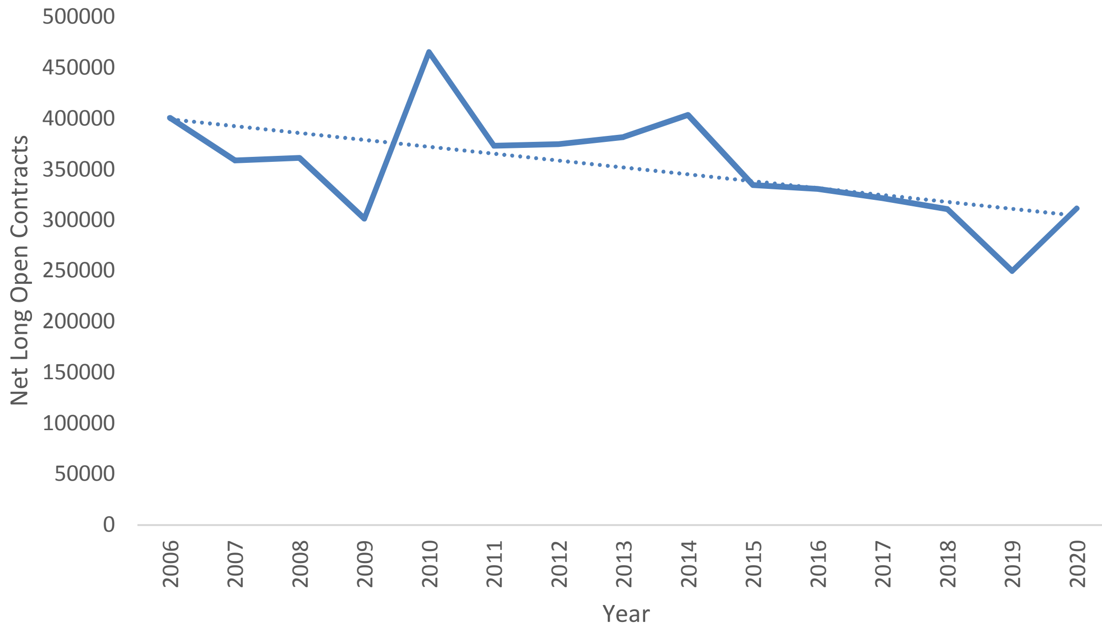
Note: The net long open contracts come from subtracting the amount of open short contracts from the open long contracts.

Figure 11. Long Only Index Funds in Soybeans Markets, 2006 - 2020



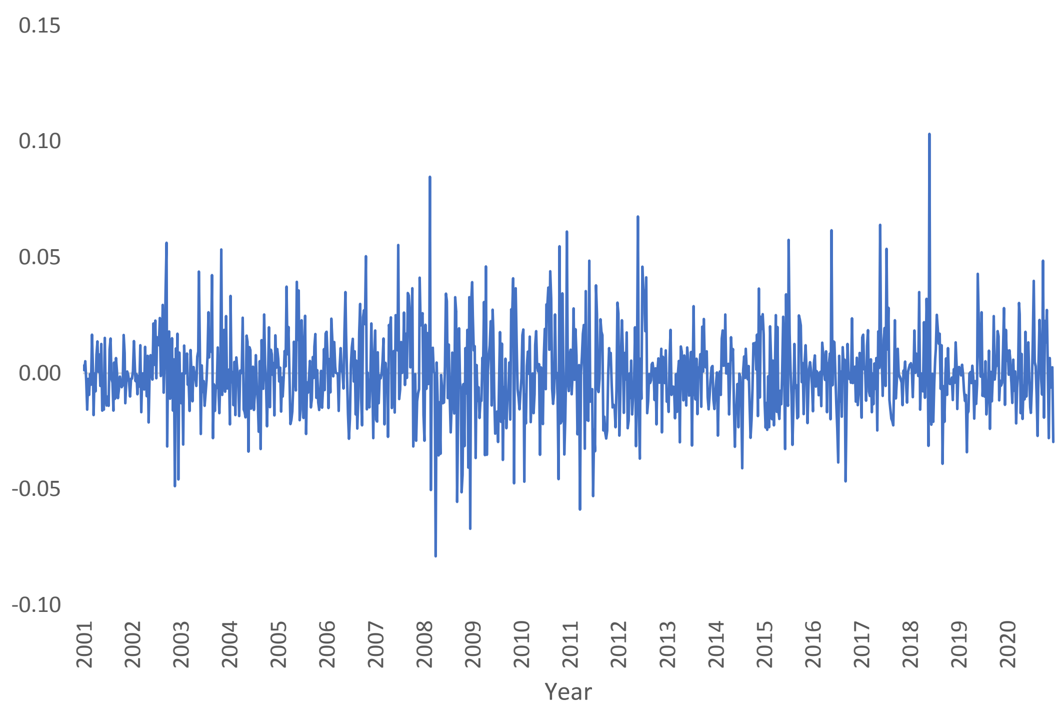
Note: The net long open contracts come from subtracting the amount of open short contracts from the open long contracts.

Figure 12. Long Only Index Funds in Corn, 2006 - 2020



Note: The net long open contracts come from subtracting the amount of open short contracts from the open long contracts.

Figure 13. KC HRWW Futures Buy and Hold Returns, Kansas City 2000 - 2020

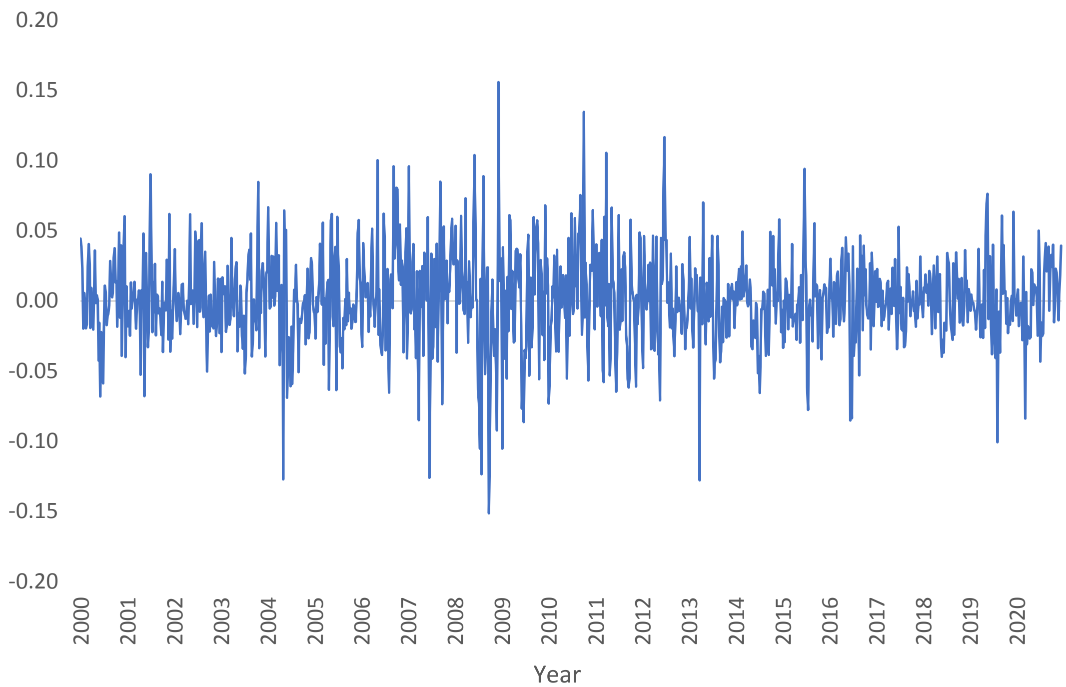


Note: The equation used for the buy and hold strategy is:

$$\ln\left(F_{t+h,T}\right) - \ln(F_{t,T})$$

where F_t, T is the futures price at time t with contract maturity of T, and $F_{t+1,T}$ is the futures price at time $t + h$ with the contract maturity of T.

Figure 14. Corn Buy and Hold Returns, Kansas City 2000 – 2020

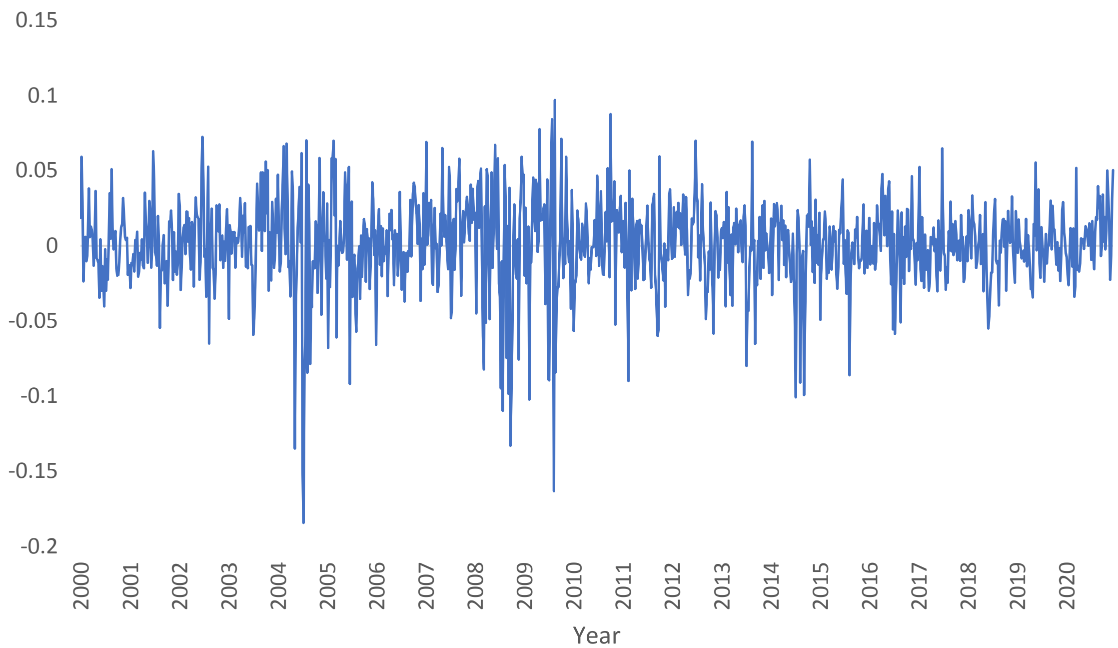


Note: The equation used for the buy and hold strategy is:

$$\ln\left(F_{t+h,T}\right) - \ln(F_{t,T})$$

where F_t, T is the futures price at time t with contract maturity of T, and $F_{t+1,T}$ is the futures price at time $t + h$ with the contract maturity of T.

Figure 15. Soybeans Buy and Hold Returns, Central Illinois 2000 – 2020

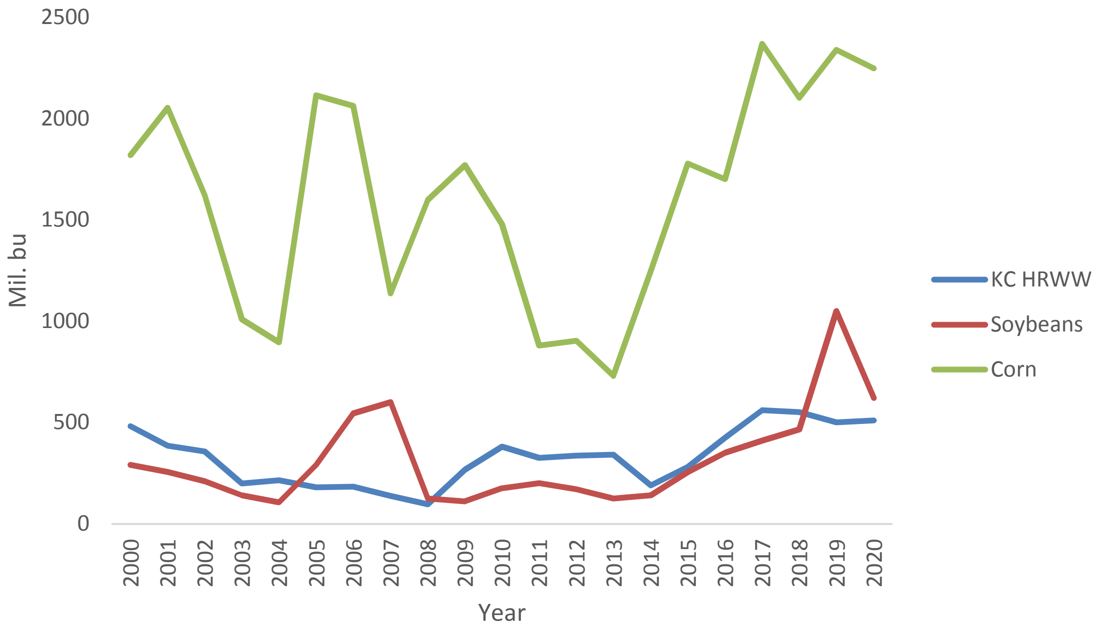


Note: The equation used for the buy and hold strategy is:

$$\ln\left(F_{t+h,T}\right) - \ln(F_{t,T})$$

where F_t, T is the futures price at time t with contract maturity of T, and $F_{t+1,T}$ is the futures price at time $t + h$ with the contract maturity of T.

Figure 16. US Commodities Annual Ending Stocks at End of Crop Year, 2000 - 2020



VITA

Emma Renee Hayhurst

Candidate for the Degree of

Master of Science

Thesis: RESILIENCE OF GRAIN STORAGE MARKETS TO UPHEAVAL IN FUTURES MARKETS

Major Field: Agricultural Economics

Biographical:

Education:

Completed the requirements for the Master of Science in Agricultural Economics at Oklahoma State University, Stillwater, Oklahoma in May, 2022.

Completed the requirements for the Bachelor of Science in Agricultural Economics at Oklahoma State University, Stillwater, Oklahoma in 2020.

Experience:

Graduate Research Assistant
Department of Agriculture Economics, Oklahoma State University, 2021 - 2020

Professional Memberships:

Southern Association of Agricultural Economics