NCCC-134
APPLIED COMMODITY PRICE ANALYSIS, FORECASTING AND MARKET RISK MANAGEMENT

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Suggested citation format:

Neff, T. and O. Isengildina-Massa. 2018. "How Well Do Commodity ETFs Track Underlying Assets?" Proceedings of the NCCC-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management. Minneapolis, MN. [http://www.farmdoc.illinois.edu/nccc134].

How Well Do Commodity ETFs Track Underlying Assets?

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Paper presented at the NCCC-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management
Minneapolis, Minnesota, April 16-17, 2018

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How Well Do Commodity Based ETFs Track Underlying Assets?

Exchange Traded Funds are growing in popularity and volume, however academic literature related to their performance is limited. This study analyzes how well the CORN, WEAT, SOYB, USO, and UGA commodity ETFs track their respective futures assets during the period of January 2012 to October 2017. Results indicate that tracking error is small on average, however CORN shows average excess returns significantly smaller than zero. The CORN, WEAT, USO, and UGA ETFs are found to move less aggressively than the respective asset baskets they track. While errors were small on average, large tracking errors were present across ETFs. The size of errors was affected by large price moves, as well as seasonality on a monthly and yearly level. USDA reports impacted the size of errors for CORN, WEAT and SOYB while EIA reports had no impact on error size. The mispricing analysis concluded that CORN and SOYB trade at a discount to Net Asset Value on average while WEAT trades at a premium.

Key words: Exchange Traded Funds, Tracking Performance, Mispricing, CORN, WEAT, SOYB, USO, UGA

Introduction

Exchange Traded Funds started trading in the United States in 1993 with the launch of the S&P 500 Trust ETF ("SPDR") by State Street Global Investors and have become some of the most popular investment vehicles over the last 25 years. Initially created to provide institutional investors the ability to execute sophisticated trading strategies, ETFs now provide financial advisors, portfolio managers, and individual investors investment options to satisfy a variety of money management strategies. The ETF market has evolved over time in terms of the number of ETFs offered, the types of ETFs being offered, and the amount of assets being invested in Funds. According to Global X Funds using Bloomberg and Morningstar data, U.S. ETF assets under management increased from under $500 billion to over $2.5 trillion from 2003 to 2016. Over time, Funds have become more sophisticated and specialized. In 2002, the first bond ETF was introduced while in 2004 the first commodity ETF was formed as a non-1940 Act legal structure. By 2008, the first actively managed ETF was created, opening the door for greater market offerings. Today investors can trade passive and active ETFs that track indexes, bonds, commodities, and other alternative assets with returns that are leveraged or unleveraged.

An Exchange Traded Fund in its most basic form is an asset basket tracking security that can be traded on an exchange. An ETF can track a basket of assets, and index, or a commodity like corn or gasoline. The Funds hold the assets and create shares where investors can invest in the Fund instead of having to invest in the underlying assets to get exposure to various markets. Many investors find ETFs advantageous as they can choose their desired level of exposure, can typically take lower exposure to the underlying assets than with traditional investment vehicles, may have lower management costs than mutual funds, and generally have higher liquidity than mutual funds.

Commodity ETFs are a subcategory in the Exchange Traded Fund marketplace that have benchmarks related to agricultural products, energies, metals, and other commodities. As of August 2017, commodity ETFs make up 2% of total market share with 122 Funds having $63.41

billion assets under management, according to Global X Funds using Morningstar data. Commodity ETFs provide investors with flexibility and convenience that were not available in the traditional investment tools. One of the main benefits of ETFs is the ability to gain exposure to certain assets, like commodities, which have traditionally been too expensive or unfeasible for some investors. Owning shares of a commodity ETF with futures market asset baskets allows investors to gain commodity exposure without being subjected to potentially expensive margin accounts that are marked-to-market daily[2].

ETF trading allows an investor to choose their desired level of shares of the Funds' assets to hold which may be well below the quantity that one futures contract represents. For example, one corn futures contract is equivalent to trading 5,000 bushels of corn while one CORN ETF share represents a percentage of total corn futures assets held by the Fund. As seen in Table 1, the value of one ETF share for the Funds in this study is considerably less than the value of one futures contract which gives investors a greater opportunity to gain exposure to commodity markets. Another benefit of ETFs is their liquidity compared to mutual funds, as noted above. ETFs are tradeable throughout the trading day like stocks, while closed end mutual funds are only convertible at the end of the trading day. Finally, lower costs of trading and small expense ratios have attracted investors to gain exposure to markets through ETFs. These benefits have helped the ETFs in this study grow their volume by an average of 134% from 2013 to 2016.

While Exchange Traded Funds offer some advantageous benefits to investors, it is important to consider the risks associated with trading ETFs as well. The first and most obvious risk is flat price risk to investors as they are not protected from price fluctuations or market volatility. Additionally, many ETFs, including the ones in this study, have no bank guarantee and are not FDIC insured. Another risk associated with ETFs is the potential mispricing between the Net Asset Value (NAV) and market price. Mispricing occurs when ETF shares are traded at a premium or discount to their respective NAV. Along with mispricing, tracking error is a concern for Exchange Traded Funds. If the Fund is not replicating the asset basket it is tracking, returns may differ from that of holding the underlying assets. The existence of a primary and secondary market exposes Funds to mispricing and tracking error risk. In theory, arbitrage opportunities should keep both measures from becoming large but this is not always the case. Finally, there is the risk that certain ETFs may be less liquid than others. Increased illiquidity causes the bid-ask spread to widen which leads to higher trading costs and diminishes the price discovery mechanism in the market.

Unfortunately, academic literature provides little guidance on the extent of tracking errors and mispricing issues in commodity ETFs. Most of the previous literature analyzes stock index ETFs with only a few studies evaluating commodity ETFs. Therefore, the objective of this study is to examine the ability of selected agricultural and energy commodity ETFs in tracking the movements of their respective futures based asset baskets. Specifically, the study will focus on the performance of CORN, SOYB, and WEAT in the agricultural sector and on USO and UGA among energy ETFs over the period of January 2012 through October 2017. CORN, SOYB, and WEAT track a weighted basket of corn, soybean, and wheat futures, respectively, listed on the

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[2] Marking-to-market occurs when the exchange settles gains and losses from the trading day by debiting money from losing accounts and crediting it to winning accounts.

Chicago Mercantile Exchange (CME). USO and UGA track the movements of front month WTI crude oil and RBOB gasoline futures listed on the New York Mercantile Exchange (NYMEX). While these funds commenced operations between 2006 and 2009, a "buffer zone" was established to account for any issues that may have occurred with the emergence of new Funds. Tracking ability for this study is defined as the ability of the ETF to replicate the returns of the respective asset basket held by the Fund. Specifically, we will look at the mean absolute difference in tracking error, the standard deviation of return differences, an OLS regression to measure tracking error, bias, and systematic risk, and an OLS regression to examine how various factors impact the size of tracking errors. Additionally, this study will conduct a mispricing analysis as an alternative measure of tracking ability.

Analyzing the tracking ability of ETFs is an important issue as any deviations in tracking could have adverse impacts on portfolio returns. The findings of this study will provide much needed evidence on the tracking ability of commodity ETFs that is currently not available in the academic literature. Our investigation of factors that affect tracking performance will provide guidance for potential improvements and arbitrage opportunities. Thus, this study will be particularly useful for institutional investors, portfolio managers, and individual investors/traders trying to gain exposure to commodity markets and looking for ways to improve decision making in regards to trading this relatively new asset class.

Previous studies

With commodity ETFs being relatively new, literature related to their tracking performance is sparse. Sousa (2014) analyzed the tracking ability of 27 metal Exchange Traded Funds. The author found that most of the ETFs in the study had negative alphas, a measure of excess return which the ETF can earn above or below its benchmark, but they were not statistically different from zero. The study also showed strong correlations and low deviations between the ETFs and their respective benchmarks. Additionally, Sousa found most ETFs in the study were traded at a premium to their Net Asset Value. Dorfleitner, Gerl, & Gerer (2018) were the first to examine the pricing efficiency and potential determinants of price deviations for Exchange Traded Commodities (ETCs) traded on the German Market. Their study analyzed 237 ETCs during the period from 2006 to 2012 using premium/discount analysis, quadratic and linear pricing methods, and regression models. The authors found that, on average, ETCs experience price deviations in daily trading. Dorfleitner, Gerl, & Gerer also noted that ETCs were more likely to trade at a premium to their net asset values than at a discount.

The literature related to tracking performance of equity ETFs is much larger and provides a baseline for analysis involving commodity ETFs. Deville (2006) provided an overview of the history of ETFs in both the North American and European markets, discussed creation and redemption mechanisms, and other performance related metrics. The paper looked at the pricing efficiency of ETFs compared to closed-end funds, the performance of ETFs vs index mutual funds, and the impact ETFs have had on market quality. While analyzing S&P 500 index funds, Frino & Gallagher (2001) noted that index managers may have had difficulties attempting to replicate the returns of a targeted benchmark due to tracking error in index fund performance. The authors examined the magnitude and variation of tracking errors of S&P 500 index mutual funds over time. The findings were compared to the performance of active mutual funds where it was determined that S&P 500 index funds, on average, outperformed actively managed funds. Additionally, they concluded that S&P 500 index funds were impacted by seasonality in tracking error. Rompotis (2006) took an empirical look at 30 American index tracking ETFs, finding significant return differences between ETFs and underlying indices. These differences, however, were small and not much greater than zero. The author found that ETFs in the study tended to trade at a premium to their NAV. Gallagher & Segara (2006) evaluated the performance and trading characteristics of ETFs on the Australian market. The authors found that long term investors would be able to achieve investment returns similar to index returns even though there was considerable variability in tracking error for the ETFs over time. Milonas & Rompotis (2006) studied a sample of 36 Swiss ETFs, finding that they underperform relative to their underlying indexes. The magnitude of tracking errors for the ETFs in this study averaged 1.02%. Shin & Soydemir (2010) estimated tracking errors from 26 Exchange Traded Funds, finding tracking errors that were significantly different from zero. The authors determined that risk adjusted returns were inferior to benchmark returns, concluding that passive investment strategy does not outperform market returns.

Petajisto (2017) provided evidence that prices of ETFs can deviate significantly from their Net Asset Values (NAVs) even though authorized participants can arbitrage through the creation or redemption of shares. The research showed deviations of up to 200 basis points (bps), with the largest deviations coming from funds holding international or illiquid securities. Chen (2015) demonstrated that prices of Exchange Traded Funds were impacted by investor sentiment in the stock market. Quantitative evidence was provided showing that tracking errors in commodity ETFs differed when the stock market was bullish vs. bearish and the aggregate tracking error was sensitive to market sentiment measures. Chen ultimately concluded that investor sentiment affected the valuation of assets across markets as arbitrage markets were specialized and participants could not act across the different markets (stocks vs. commodities). Our study will apply the approaches developed in these previous studies to examine the tracking performance of commodity ETFs.

Data and Descriptive Statistics

Since the goal of this study is to analyze the ability of the ETF to track the returns of the asset basket, data requirements include ETF prices, basket compositions and asset prices. Daily market prices for the CORN, SOYB, WEAT, USO, and UGA Exchange Traded Funds were downloaded from the Bloomberg Terminal. Prices are quoted in dollars per share and reflect the settlement price in the market for a given day. ETF price data was collected daily for the time period of the study, January 2012 through October 2017. Descriptive statistics for ETF prices can be found in Table 2. Non-stationary time series have statistical properties that are not constant over time like mean and variance (Dickey & Fuller, 1979). Non-constant statistical properties can lead to inaccurate forecasts or show relationships between variables that may truly not exist. Tables 2 and 3 shows the results of the Augmented Dickey-Fuller Test for a Unit Root with associated t-statistics and p-values for each variable. As shown in the Tables 2 and 3, the null hypothesis of unit root is not rejected in all cases, which means the ETF and asset basket prices for each Fund are non-stationary and should not be used for statistical analysis without transformation. To correct for non-stationarity in ETF prices, daily returns were calculated as following:

$$1)\quad R_{ETF,t} = \ln\left(\frac{P_{ETF}}{P_{ETF,t-1}}\right) x\ 100$$

Table 2 shows the descriptive statistics and stationarity tests for ETF returns indicating that return series are stationary.

Specific information on the basket of Fund holdings were obtained from the Funds that sponsor the ETFs (Teucrium Trading LLC and USCF Investments). One of the challenges with commodity ETFs is that since they hold futures contracts that periodically reach expiration, they need to roll their holdings into next to maturity contracts on a regular basis. Roll dates were obtained from Teucrium Trading LLC for CORN, SOYB, and WEAT and from USCF Investments for USO and UGA. For example, the CORN Fund always holds the second, third, and December following the third to expire, corn futures contracts traded on the CME at 35%, 30%, and 35% weightings respectively. When the second to expire contract becomes the "front-month" contract, the Fund has to roll their holdings from the now front-month contract into another month as outlined by the prospectus. While this study uses data from January 2012 through October 2017, the USO ETF changed its asset basket holding criteria in mid-2013 to only hold NYMEX crude oil futures. Because of this change in holding structure, the USO ETF will be evaluated from July 2013 to October 2017.

Futures prices for the Chicago Mercantile Exchange (CME) contracts for corn, soybean, wheat, and New York Mercantile Exchange (NYMEX) contracts for WTI crude oil and gasoline futures that comprise ETF baskets were collected from Quandl to construct the price of the basket the ETF is tracking. The basket price is the weighted average of the settle prices for each contract held by the ETF on a specific day based on the contracts and the weights specified in the Funds prospectus. It is important to note that the roll date periods were excluded from the analysis as it is impossible to determine the exact weights of each contract during the roll period. On average, roll dates accounted for about 4.88% of daily observations as shown in Table 3. Prices are non-stationary, so we calculate returns similar to before:

$$2)\quad R_{Asset\ Basket,t} = \ln\left(\frac{P_{Asset\ Basket}}{P_{Asset\ Basket,t-1}}\right) x\ 100$$

where R_t is the daily return of the respective measure at the end of the trading day t, P_t is the price at the end of trading day t, and P_{t-1} is the settle price at the end of trading day t-1 (the previous trading day). Note that we assume that rolling is completed by settle on the last day of the roll period.

The Net Asset Value (NAV) represents the market value of assets held by the Fund, less liabilities, divided by the number of shares outstanding of the Fund and thus describes the value of the basket of assets tracked by the ETF. The NAV is also quoted in dollars per share. The Net Asset Value of the five ETFs were also downloaded from the Bloomberg Terminal over the same time frame. An equality of means test was conducted between the ETF NAVs and ETF prices which determined that there is no significant difference in the means of the ETF price vs NAV for the Funds included in this study. The results determine that it is suitable to use the ETF price to analyze returns in tracking error. Price was chosen over NAV as this is the actual value investors are buying/selling the ETF for on the market. Since they have the choice to invest in the ETF or asset basket to gain exposure to the same market, the actual ETF prices and basket prices will be compared in this study.

Daily ETF and asset basket prices as well as NAVs are shown in Figure 1. Tracking error analysis will focus on differences between asset basket and ETF returns. This avoids potential problems associated with non-stationarity of price series and focuses on the actual trading prices and tracking ability. Alternatively, mispricing analysis will examine the differences between ETF prices and NAVs. Roll dates were not a factor for mispricing analysis as the ETF price and the NAV values are available for every trading day, which allows evaluation of sensitivity of tracking error results to omitting roll day data.

This study employs a variety of methods to analyze potential tracking errors that may have adverse impacts on portfolio returns. In its simplest form, error can be described as the difference between the daily ETF return (1) and the daily asset basket return (2). Tracking error, denoted R_d, is found using the following equation:

3) $$R_d = R_{ETF,t} - R_{Asset,t}$$

Table 5 provides descriptive statistics related to the tracking errors between the ETFs and their respective futures market asset baskets. Agricultural and energy graphs depicting daily tracking errors can be found in Figures 2 & 3.

Daily tracking error for the agricultural Funds in this study, on average, are small. The CORN ETF has the smallest average tracking error at -0.018% while SOYB and WEAT both have negative average tracking errors at -0.021% and -0.024% respectively. Conducting a t-test, average error for the CORN ETF was found to be statistically different from zero at a 5% level while SOYB and WEAT errors were not determined to be significantly different from zero on average. The SOYB ETF had the largest range of tracking errors of the agricultural Funds at 16.92%. Additionally, the SOYB ETF had the largest positive and negative daily tracking error of the agricultural Funds during the time period of this study at 8.97% and -7.95%. The CORN ETF had the lowest range of tracking errors at 3.5%, while the range of WEAT tracking errors was 8.43%. As depicted in Figure 2, daily tracking errors, in general, for the agricultural Funds tended to become smaller over time. This observation is clearly evident in the SOYB and WEAT graphs.

Daily tracking errors for the energy Funds in this study also tend to be small on average with errors smaller than those of the agricultural Funds. The USO ETF has the smallest average error of the energy Funds at 0.002% while UGA average error was -0.007%. Using a t-test, mean tracking error for the energy Funds was not found to be statistically different from zero. While USO had the smallest error on average for the energy Funds, the ETF had the largest range of tracking errors for the energy Funds at 8.76%. The tracking error range for UGA was found to be slightly smaller at 7.62%. Unlike the agricultural Funds, the energy Funds in this study tended to have tracking errors increase over time, as shown in Figure 3.

As stated above, tracking errors for the Funds tended to be small on average, with only CORN errors being statistically different from zero. What is concerning and will be investigated further is the presence of large daily tracking errors for the Funds. SOYB had the largest negative daily tracking error between the ETF and asset basket at -7.95%, USO at -6.01%, UGA at -4.44%, WEAT at -4.25%, and CORN at -1.20%. SOYB had the largest positive tracking error at 8.97%, WEAT at 4.18%, UGA at 3.18%, USO at 2.75%, and CORN at 2.03%. Further analysis will be conducted later in this paper to better determine the cause of large daily tracking error over time.

Several previous studies (Frino and Gallagher, 2001; Sousa, 2014; Rompotis, 2006; Dorfleitner, Gerl, and Gerer, 2018; Gallagher and Segara, 2006; Shin and Soydemir, 2010) look at the absolute difference in returns as well as standard deviation of return differences between the ETFs and their respective asset baskets. The mean absolute difference in returns can be described using the following equation:

4) $$Mean\ Absolute\ Difference = \frac{\sum_{t=1}^{N}|R_d|}{N}$$

where R_d is tracking error as defined in equation 3, and *N* is the size of the sample.

Another method frequently used by the industry looks at the standard deviation of return differences. This method measures the variability of the tracking error between the ETF and its respective asset basket as seen below:

5) $$Std\ Dev\ of\ Return\ Differences = \sqrt{\frac{1}{N-1}\sum_{t=1}^{N}(R_d - \overline{R_d})^2}$$

where R_d is the tracking error between the ETF and respective benchmark ($R_d = R_{ETF,t} - R_{Asset,t}$) and $\overline{R_d}$ is the average of the tracking error, R_d , over "*N*" periods.

Table 5 shows the mean absolute difference in tracking error and the standard deviation of tracking error between the ETFs in this study and their respective asset baskets on a daily basis. The CORN ETF had the smallest mean absolute difference at 0.183% while the USO ETF had the highest at 0.380%. In general, the agricultural Funds tended to have smaller mean absolute differences between the returns of the ETFs and asset baskets compared to the energy Funds in this study. A lower MD is desired as this indicates, on average, the Fund has lower errors in tracking between the returns of the ETF and respective asset basket. The CORN ETF also had the smallest standard deviation of return differences at 0.163% while SOYB had the highest at 0.492%. The size of the standard deviation of return differences was similar across the agricultural and energy Funds in this study.

Methodology

The methodology for this study will follow the previous literature on tracking error as it has been applied to a diverse set of ETFs, ETCs, and ETPs outside of the agricultural and energy sectors by examining the bias and systematic risk to which an ETF is exposed. This study will expand upon previous work by focusing specifically on agricultural and energy ETFs as well as by examining factors that affect the magnitude of tracking errors. Additionally, a mispricing analysis will be conducted as an alternate measure of error performance to better understand the tendency of ETFs to trade at a premium/discount to their NAVs.

Mincer & Zarnowitz (1969) outline expectations of bias and efficiency in their paper titled "The Evaluation of Economic Forecasts". Following this framework, tracking error as discussed in previous finance literature can be quantified using an Ordinary Least Squares (OLS) regression where bias and systematic risk are measured. A linear regression will be used to measure the relationship between the returns of the ETF and the returns of its respective asset basket. Since we are trying to explain the ETF returns, this will be our dependent variable. Returns of the asset basket will be the independent variable as they are being used to explain the changes in ETF returns. The form of the OLS regression is as follows:

6) $$R_{ETF,t} = \alpha + \beta R_{Asset,t} + \varepsilon_t$$

where $R_{ETF,t}$ and $R_{Asset,t}$ are the daily returns to the ETF and underlying asset basket, α is the intercept, β measures the relationship between the ETF return and the underlying asset basket return, and ε_t is the error term.

Alpha (α) is a measure of excess return which the ETF can earn above or below its asset basket holdings (bias). A negative alpha indicates that the ETF is returning less than the asset basket holdings while a positive alpha shows that the ETF is returning more than the asset basket holdings. If the ETF is tracking the asset basket well, alpha (α) should not be biased or significantly different from zero. Beta (β) is a measure of systematic risk to which the ETF is exposed and is measured against unity (β=1). If beta is smaller than unity, the ETF moves less aggressively in comparison to the underlying assets held by the Fund. If beta is larger than unity, the ETF moves more aggressively in comparison to the underlying asset basket. A beta coefficient of one designates perfect unity between the returns of the ETF and the returns of the assets. A t-test with associated p-values will be used to test the validity of the null hypothesis for alpha equal zero while a Wald Test will be used to test if beta is statistically different from one. A 95% confidence interval will be used, thus indicating that a p-value lower than 0.05 will reject the null hypothesis.

Frino and Gallagher (2001) note that tracking error using this method can be quantified as the standard error of the residuals of a returns regression. While the standard errors estimate of tracking error should be similar to the standard deviation of return differences (equation 4), a beta (β) coefficient not equal to one will cause the regression residuals to differ according to Pope and Yadav (1994).

This study will test for the impacts of various items on the magnitude of ETF tracking error. Following the work of Frino & Gallagher (2001) who analyze seasonality in tracking error of S&P 500 index mutual funds, this study will evaluate the potential seasonality in ETF tracking error as it relates to the selected agricultural and energy ETFs on a monthly and yearly basis. Additionally, this study will test the impacts of large price moves, various industry reports (WASDE, USDA Grain Stocks, EIA Short Term Energy Outlook, etc.), and the day before/after roll period for the impact they have on the size of tracking error. The findings of Isengildina-

Massa, Karali, Irwin, Cao, Adjemian, and Johansson (2016) regarding increased market volatility on USDA report days prompted this study to examine the impact various reports have on tracking error magnitude. The error size the day before and after the roll period will be analyzed since the roll period is excluded from this analysis. This is being done to examine whether the Funds are potentially incurring tracking issues right before/after they roll into new holdings. The error magnitude study will be accomplished by running an OLS regression with absolute error as the dependent variable, absolute ETF return as an independent variable, and the inclusion of the dummy variables to test for various impacts on the magnitude of errors. The following equation will be used to determine if large price moves, seasonality, industry reports, or the day before/after the roll period account for significant changes in the magnitude of tracking error.

7) $$|e_t| = \beta_0 + \beta_1|R_{ETF,t}| + \beta_2 S_{Feb} + \beta_3 S_{Mar} + \beta_4 S_{Apr} + \beta_5 S_{May} + \beta_6 S_{June} + \beta_7 S_{July} + \beta_8 S_{Aug} + \beta_9 S_{Sept} + \beta_{10} S_{Oct} + \beta_{11} S_{Nov} + \beta_{12} S_{Dec} + \beta_{13} Y_{2012} + \beta_{14} Y_{2013} + \beta_{15} Y_{2014} + \beta_{16} Y_{2015} + \beta_{17} Y_{2017} + \beta_{18} DB + \beta_{19} DA + \beta_{20} I_1 + .. + \beta_{21} I_n + \varepsilon_t$$

where $|e_t|$ is the absolute daily error between the ETF return and asset basket return, $|R_{ETF,t}|$ is the absolute daily return of the ETF, *S* is a dummy variable for the various months (February – December), *Y* is a dummy variable representing various years (2012, 2013, 2014, 2015, 2017), *DB* is a dummy variable for the day before the roll period starts, *DA* is a dummy variable for the day after the roll period, and *I* is a dummy variable representing various industry reports. Monthly dummy variables will be evaluated relative to the size of errors in January and yearly dummy variables will be evaluated relative to the size of errors in 2016. The rest of the dummy variables will be evaluated relative to the magnitude of errors on all other days.

Dummy variables were used to determine the size of error impact of the following industry reports for each sector:

<u>Agriculture</u>

- USDA World Agricultural Supply & Demand Estimates (WASDE)
- USDA WASDE+Crop Production (when released on same day)
- USDA Grain Stocks
- USDA Prospective Plantings Report
- USDA June Acreage Report
- USDA Cattle on Feed Report
- USDA Hogs & Pigs Report

<u>Energy</u>

- EIA Short Term Energy Outlook Report
- EIA Drilling Productivity Report
- EIA Monthly Petroleum Supply/ Production Report
- EIA Annual Energy Outlook

The coefficient for the absolute daily ETF return variable (β_1) should not be statistically different from zero if large price moves have no significant impact on the magnitude of tracking errors. The coefficients of the dummy variables (β_2 to β_n) should be close to zero if tracking error magnitude is not statistically different between the dummy variable and its respective comparison. The p-value of the coefficient estimate will be used to determine if the coefficient is statistically different from zero.

As mentioned previously, one of the risks of trading ETFs is the potential for mispricing between the ETF market price and the Fund's Net Asset Value or "intrinsic value". Mispricing can occur as ETFs are traded on a stock market while the underlying assets in this study are traded on commodity markets. The difference in exchanges subjects each investment vehicle to different pressures and supply/demand factors. The various influencing factors can cause ETFs to trade at a premium/discount to their respective Fund NAV. This measure differs from tracking error as mispricing looks at the deviations between the ETF price and NAV while tracking error analyzes daily return differences between the ETF and respective asset basket.

Following previous studies, the NAVs are used to analyze mispricing between the ETF and the Net Asset Value, using the following equation:

8) $$ETF\ Premuim/Discount\ to\ NAV = \ln\left(\frac{P_{ETF,t}}{NAV_t}\right)\ x\ 100$$

where $P_{ETF,t}$ is the settle price of the ETF on day t and NAV_t designates the Net Asset Value of the same ETF on day t.

Results

The results of the OLS regression in equation (6) are shown in Table 6. The returns of the CORN ETF have the smallest tracking error relative to the returns of its respective asset basket at 0.243% while the WEAT ETF has the highest error at 0.584%. The SOYB ETF had tracking error close to WEAT at 0.571%. Tracking error for the energy Funds was in the middle at 0.441% and 0.545% for UGA and USO respectively.

Alpha is a measure of excess return which the ETF can earn above or below its asset basket holdings (bias). Table 6 shows that the excess returns of the CORN ETF are biased as the p-value indicates that alpha is statistically different from zero at a 1% level. CORN has a negative alpha which suggests that this ETF has negative excess returns, on average, when the asset basket has a daily return of zero. A negative alpha indicates that the ETF returns will be less positive than positive asset basket returns and more negative than negative asset basket returns. Alpha for the returns of the SOYB, USO, and UGA ETFs are not statistically different from zero which indicates that these ETFs are not biased. An unbiased alpha demonstrates that the ETFs are tracking their respective asset baskets well.

The beta coefficient in Table 6 is a measure of systematic risk to which the ETF is exposed and is measured against unity (beta =1). Since the p-value from the regression is indicating statistical significance relative to a value of zero, a Wald test was conducted to determine if beta is statistically different from 1. The results show that the beta coefficients for the CORN, WEAT, USO, and UGA ETFs are significantly different from 1. The energy ETFs in this study have beta coefficients further from unity than the agricultural ETFs. Beta smaller than unity indicates the returns of these ETFs move less aggressively in comparison to their respective asset basket returns. The beta coefficient for SOYB is not statistically different from unity which implies that this Fund moves with the same aggression as the underlying assets it tracks. A beta coefficient equal to one is desired as this implies perfect unity between the returns of the ETF and the returns of the asset basket held by the Fund.

The R-squared statistic for the CORN, USO, and USO ETFs from the returns regression were large at 0.965, 0.932, and 0.942 respectively. Being a goodness of fit measure, the large R-squared statistics for these three ETFs indicate that a large percentage of ETF return variation is being explained by the asset basket return. Since the ETFs in this study are designed to track a set of underlying assets, an R-squared statistic close to one is desired. We would expect the ETFs with higher R-squared values to have lower errors in tracking as more ETF return variation is being explained by the asset basket. The WEAT and SOYB ETFs were found to have R-squared statistics of 0.856 and 0.785 respectively from the returns regression. The lower value designates that the returns of the underlying assets for these funds are not the only thing explaining the variability in ETF return and implies that these Funds may be subject to larger errors in tracking.

The results of the size of errors regression to test for error magnitude differences in equation (7) can be found in Table 7. The results show the coefficients on the ETF absolute return variable are significantly different from zero for all commodity ETFs in the study at a 1% level. The positive coefficients indicate that days with large price moves, and thus larger returns, cause the size of errors to increase. SOYB ETF errors are impacted most heavily as a 1% larger price move causes tracking error to increase by 0.24% on average. Errors size for the CORN ETF is least impacted by large price moves in this study as a 1% larger price move would cause tracking error to increase by 0.031%. The impact on the energy Funds was found to be larger than corn but smaller than WEAT at 0.050% and 0.061% for USO and UGA. Checking the OLS assumptions, Variance Inflation Factors (VIFs) showed no indication of multicollinearity between variables in the regression for any ETF while the Breusch-Godfrey test for serial correlation indicated the presence of autocorrelation in all 5 regressions. Additionally, the Breusch-Pagan test for heteroscedasticity indicated the presence of heteroscedasticity in the size of the error terms.

Using dummy variables, this study was able to assess the impact various industry reports have on the size of ETF tracking error by comparing errors on report days to all other days. CORN tracking errors were found to be significantly larger than all other days during the Prospective Plantings report. Significant differences in the size of tracking error vs all other days were found on WASDE, WASDE+Crop Production[3], and USDA June Acreage report release days for the SOYB ETF and on WASDE+Crop Production report days for the WEAT ETF. SOYB tracking error on these respective report days was significantly smaller in magnitude relative to all other days. Conversely, the size of WEAT tracking error on WASDE+Crop Production report days was significantly larger relative to all other days. Dummy variables for Energy Information Association (EIA) reports did not show significant differences from zero. It can be concluded that the EIA reports tested tended to have no impact on the size of tracking error relative to all other days.

Implementing the approach of Frino & Gallagher (2001) who analyze seasonality in tracking error of S&P 500 index mutual funds, this study evaluated the impacts of seasonality on the size of ETF tracking error on a monthly and yearly basis. Seasonality occurs as commodity markets are subject to different pressures throughout the year which may cause prices to consistently react certain ways during those times. Comparing size of errors relative to January, it was found that all funds exhibited monthly seasonal tendencies. The CORN ETF had significantly larger errors in June (0.042%) while having significantly smaller error magnitude in October (-0.032%). Tracking error for WEAT was significantly larger in size in March (0.11%) and April (0.095%) while significantly smaller in August (-0.088%), October (-0.094%), and December (-0.10%) relative to errors in January. The SOYB ETF had error tendencies that were significantly larger in magnitude than that of January in the months of March (0.16%) and April (0.12%) while significantly smaller in August (-0.12%), October (-0.10%), and November (-0.10%). Across all of the agricultural Funds in this study, October tended to produce a significantly smaller magnitude of tracking errors when compared with those in January. Tracking error size for USO was found to be significantly smaller in March (-0.16%), May (-0.23%), June (-0.17%), July (-0.20%), August (-0.14%), September (-0.14%), and October (-0.24%) when compared to errors in January. For UGA, the magnitude of tracking error was significantly larger in February (0.073%) and December (0.087%), compared to errors in January, while being significantly smaller in March (-0.094%), April (-0.069%), May (-0.079%), and July (-0.086%). As a whole, the energy Funds in this study had a consistently smaller size of tracking error relative to January in the months of March, May, and July.

When analyzed on a yearly basis, seasonality in the size of tracking errors was found across all of the funds in the study when compared to that of 2016. The CORN ETF had significantly larger error size in 2014 and significantly smaller errors in 2015 and 2016 when compared with 2016 errors. WEAT and SOYB ETFs both had significantly larger error size in 2012, 2013, and 2014 when compared to 2016. The energy Funds exhibited the opposite tendency as USO had significantly smaller error magnitude in 2013, 2014, and 2017 and UGA in 2012, 2013, 2014, 2015 and 2017 when compared to 2016 errors. Overall, the size of errors relative to 2016 tended to be larger for agricultural ETFs and smaller for Energy ETFs.

[3] USDA releases of WASDE and Crop Production reports occur together during the months of August, September, October, November, December, and January for corn and soybeans. For wheat, these reports are released together during the months of May, June, July, August, and January.

Since roll dates are excluded from this analysis, this study wanted to examine if there were differences in error magnitude on the day before or after the roll periods for the Funds. This was done as a way to check whether the Funds were having any tracking issues in rolling from one set of holdings to the next or potentially if this roll was during a larger period then stated. Dummy variables for the day before and after the roll periods were generated to test whether tracking errors on these days were larger or smaller in size relative to all other days. The magnitude of tracking error results in Table 7 show that the size of tracking error for USO is statistically smaller on the day before the roll period starts vs all other days at a 5% level. A coefficient of -0.00144 indicates that errors on the day before the roll for USO are 0.144% smaller on average when compared to all other days. The other funds in the study did not exhibit errors that were different in magnitude the day before the roll period relative to all other days. CORN, WEAT, SOYB, USO, and UGA all had insignificant tracking errors the day after the roll period ended relative to all other days in the study. Tracking errors magnitudes for all funds the day after the roll are not found to be different when compared to all other days.

Additionally, a mispricing analysis was conducted to evaluate whether the ETF market price trades at a premium or discount to the Funds respective Net Asset Value as an alternative measure of error performance (Figure 1, ETF price vs. NAV). As noted earlier in the paper, the mispricing analysis was conducted using all days in the study, including the roll periods, to fully understand where the ETF trades in relation to its Net Asset Value. Including all days increased the sample size by an average of 92 days per ETF. Using equation (8), the mispricing results are illustrated in Table 8 and visual representations of mispricing can be found in Figure 4.

On average, the CORN and SOYB market prices trade at a discount to the Funds respective Net Asset Value. The WEAT ETF is the only Fund in this study that was found to trade at a premium to its NAV, on average. Conducting a t-test, it was concluded that the mean premium/discount value in Table 8 is statistically different from zero for CORN, SOYB, and WEAT. CORN and WEAT are significantly different at a 1% level while SOYB is significantly different at a 10% level. It is worth noting that each ETF can and has traded at both a premium and discount to its Net Asset Value as seen by the “Min” and “Max” descriptive statistics in Table 8. The SOYB ETF has the widest levels of the Funds in this study as it traded at both the largest premium and discount to its NAV. The CORN ETF traded at the smallest premium and discount deviation to NAV of the Funds in the study. Visual representations of the Funds market price relative to NAV can be seen in Figure 4 for the agricultural and energy ETFs. In general, the level of premium/discount to NAV for the agricultural Funds has gotten smaller over time while it has gotten larger for the energy Funds.

Overall the CORN ETF had the smallest premium/discount to NAV range of the agricultural Funds in this study. The CORN market price traded up to a 0.95% premium and -1.26% discount to the Funds NAV over the period of the study. SOYB had the largest range of all of Funds in this study, with price trading up to a 4.77% premium and -8.50% discount to the Funds NAV. The WEAT ETF traded up to a 4.52% premium and 2.04% discount to the Funds NAV. Over time the SOYB and WEAT ETFs have seen decreased levels in the price premium/discount to NAV as referenced in Figure 4.

The UGA ETF had the smallest premium/discount to NAV value, on average, of all the Funds in the study at -0.005% and this value is not statistically different from zero. The USO ETF traded up to a 3.96% premium and -2.05% discount to NAV while UGA traded up to a 3.59% premium and 1.28% discount to NAV. Over time, both Funds have seen increased levels in the price premium/discount to NAV as seen in Figure 4. This is opposite of the agricultural Funds in the study that have seen decreased level differences between their Net Asset Values and market prices.

Conclusions

Since the launch of the S&P 500 Trust ETF ("SPDR") by State Street Global Investors in 1993, Exchange Traded Funds have continued to grow in terms of investor interest and assets under management. This growth has encouraged the creation of Funds that give investors access to a variety of markets including stocks, bonds, commodities, and other alternatives. With the first commodity ETF being introduced in 2004, investors are now able to gain exposure to commodity markets that have previously been infeasible or too expensive as they do not have to hold the physical assets, trade futures, or be subject to margin calls. While this interest has prompted commodity ETFs to capture 2% of total market share in a short period of time, there is a lack of literature related to commodity ETF performance. The goal of this study was to analyze how well the selected agricultural and energy commodity Exchange Traded Funds track the movements of their respective futures market based asset baskets. In doing so, this study wanted to convey a better understanding of commodity ETF return performance and improve decision making for investors in regards to trading this relatively new asset class.

Overall, results demonstrate that tracking error between the returns of the ETFs and respective asset baskets are small on average. However, while return differences are small, a t-test indicates that daily tracking error between the ETFs and respective asset baskets is significantly negative for the CORN Fund. Since tracking error is designated as $R_d = R_{ETF,t} - R_{Asset,t}$, this finding shows that the daily returns for CORN are significantly smaller than the returns of the Funds asset basket holdings on average. This differs from Rompotis (2006) who finds small but significant return differences that are greater than zero for American index tracking ETFs. Additionally, the CORN ETF is returning a smaller positive value compared to the asset basket when asset basket returns are greater than zero and a larger negative value compared to the asset basket when asset basket returns are less than zero as concluded by a statistically negative alpha. Comparable to Sousa's (2014) findings for metals ETFs, the majority of the Funds in this study have insignificant alpha coefficients meaning they have performance consistent with their asset basket returns. CORN, WEAT, USO, and UGA returns are all found to move significantly less aggressively in comparison to the returns of their respective asset basket holdings as these ETFs had beta coefficients that were significantly less than unity (β=1). Similarly, Milanos & Rompotis (2006) find Swiss ETFs tend to underperform relative to underlying indices.

While errors tended to be small on average, this study notes the occurrence of large errors in tracking between the returns of the ETFs and asset baskets. This study finds that the magnitude of errors in tracking are impacted by large price moves as well as monthly and yearly seasonality. CORN errors were found to be significantly larger on Prospective Planting report days vs all other days. Additionally, SOYB errors are found to be significantly smaller on the WASDE, WASDE+Crop Production and USDA June Acreage report days vs all other days and WEAT errors significantly larger on WASDE+Crop Production days vs. all other days. EIA reports included in this study did not impact the size of errors on release days for the energy ETFs compared to all other days in the study.

A mispricing analysis was conducted as an alternative approach to measuring error performance. The findings are consistent with those above as mispricing tended to be small on average but a large range of mispricing existed for each Fund. Large ranges of mispricing likely occur as ETFs and commodities are traded in different markets (stock market vs. commodity market) and these investment vehicles incur different pressures and supply/demand factors. Using a t-test, the mispricing of CORN, and WEAT was determined to be significantly different from zero at a 1% level while SOYB was significantly different at a 10% level. CORN and SOYB had negative coefficients, indicating that these ETFs traded at a significant discount to their Fund Net Asset Value on average. The coefficient on the WEAT ETF was positive which shows that this ETF trades at a significant premium to its NAV on average. These findings mostly differ with the majority of previous literature which concluded ETFs tended to trade at a premium to Fund NAV. An ETF trading at a premium to NAV implies that the market price is overvalued relative to the value of assets being held by the Fund while an ETF trading at a discount to NAV implies that the market price is undervalued relative to the value of assets being held by the Fund.

The findings of this study can be used by market participants to better understand the return performance and tracking ability of commodity ETFs. With academic literature related to commodity ETF performance being scarce, this study aims to improve decision making in regards to trading this relatively new asset class. The contents of this study are for educational purposes only. The risk of loss in trading is substantial and each investor and/or trader must consider their investment objective, level of experience, and risk appetite before making investment decisions.

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Table 1. Value of 1 ETF share vs. 1 Futures Contract

Commodity	Value of 1 ETF Share	Value of 1 Futures Contract	Futures Margin Requirement
Corn	$18.03	$19,438	$720/contract
Wheat	$6.42	$23,600	$1,250/contract
Soybeans	$18.84	$51,688	$1,850/contract
WTI Crude Oil	$12.51	$61,950	$2,300/contract
Gasoline	$31.09	$81,837	$2,800/contract

Source: Data from NYSE Arca and CME Group on 4/6/2018. Note: the value of ETFs and futures contracts will change daily.

Table 2. ETF Price Descriptive Statistics, 2012-2017

	CORN	WEAT	SOYB	USO	UGA
Mean	29.21	13.36	21.32	20.26	43.19
Std. Dev.	9.73	5.53	2.84	11.19	14.43
Skewness	0.630	0.508	0.321	0.587	-0.046
Kurtosis	2.15	2.00	1.92	1.60	1.29
Min	17.13	6.20	17.06	7.96	20.67
Max	52.67	25.35	28.85	39.36	65.71
Roll Days Excluded	80	59	41	207	70
Obs.	1468	1462	1462	1088	1467
Augmented Dickey-Fuller Test for Unit Root					
ETF PX	-0.9584 [0.770]	-1.0522 [0.736]	-1.4408 [0.563]	-1.3177 [0.623]	-0.8013 [0.818]
ETF % Return	-37.0636*** [0.000]	-38.2949*** [0.000]	-43.2275*** [0.000]	-31.5655*** [0.000]	-37.4201*** [0.000]

Source: Data from Bloomberg, Teucrium Trading LLC, and USCF Investments.
Note: Single, double, and triple asterisks (, **, ***) denote statistical significance at 10%, 5%, and 1% levels, respectively.*

Table 3. Asset Basket Price Descriptive Statistics, 2012-2017

	Corn	Wheat	Soybeans	WTI Crude Oil	RBOB Gasoline
Mean	4.62	5.99	11.17	64.02	2.18
Std. Dev.	1.11	1.26	1.86	24.51	0.680
Skewness	1.149	0.729	0.548	0.689	0.039
Kurtosis	3.08	2.60	2.16	1.80	1.41
Min	3.34	4.22	8.59	28.35	0.899
Max	7.74	9.21	16.32	110.53	3.40
Roll Days Excluded	80	59	41	207	70
Obs.	1468	1462	1462	1088	1467
Augmented Dickey-Fuller Test for Unit Root					
Asset Basket Price	-0.8314 [0.809]	-0.8713 [0.798]	-1.0223 [0.747]	0.1083 [0.966]	-1.1856 [0.683]
Asset % Return	-37.0105*** [0.000]	-36.0127*** [0.000]	-39.6109*** [0.000]	-33.6366*** [0.000]	-38.3680*** [0.000]

Source: Data from the Quandl CME database.
Note: Single, double, and triple asterisks (, **, ***) denote statistical significance at 10%, 5%, and 1% levels, respectively.*

Table 4. ETF and Asset Basket Percentage Return Descriptive Statistics

	CORN % Return	C % Asset Return	WEAT % Return	W % Asset Return	SOYB % Return	S % Asset Return	USO % Return	CL % Asset Return	UGA % Return	RB % Asset Return
Mean	-0.064%	-0.046%	-0.073%	-0.073%	-0.009%	-0.012%	-0.074%	-0.076%	-0.050%	-0.0430%
MD	0.183%		0.377%		0.290%		0.380%		0.322%	
Std. Dev.	0.013	0.013	0.015	0.015	0.012	0.011	0.021	0.02	0.018	0.019
Skewness	0.160	0.215	0.298	0.210	0.031	-0.142	0.112	0.181	0.030	0.059
Kurtosis	5.80	5.49	4.27	4.33	7.54	4.86	5.22	5.82	4.66	5.6
Min	-7.26%	-6.10%	-5.45%	-5.91%	-7.55%	-5.77%	-8.68%	-10.79%	-7.73%	-9.61%
Max	6.34%	6.59%	7.72%	6.85%	9.22%	4.59%	8.84%	10.15%	7.66%	10.24%
Obs.	1387	1387	1402	1402	1420	1420	880	880	1396	1396

Table 5: Daily Tracking Error Descriptive Statistics

	CORN Error	WEAT Error	SOYB Error	USO Error	UGA Error
Mean	-0.018%***	-0.024%	-0.021%	0.002%	-0.007%
Std. Dev.	0.00245	0.00585	0.00571	0.00585	0.00464
Skewness	0.265	-0.229	0.542	-0.836	-0.339
Kurtosis	7.67	12.52	78.12	18.46	12.32
Min	-1.20%	-4.25%	-7.95%	-6.01%	-4.44%
Max	2.03%	4.18%	8.97%	2.75%	3.18%
Obs.	1387	1402	1420	881	1396
MD and Standard Deviation of Return Differences					
MD	0.183%	0.377%	0.290%	0.380%	0.322%
Std Dev	0.163%	0.447%	0.492%	0.445%	0.334%

Note: Single, double, and triple asterisks (, **, ***) denote statistical significance at 10%, 5%, and 1% levels, respectively. MD is the mean absolute difference between the returns of the ETF and asset basket as calculated using equation 4. The standard deviation of return differences is calculated using equation 5.*

Table 6: Tracking Error Results as Defined by the Standard Error of the Residuals of a Returns Regression

ETF	Std. Error of Residuals	Alpha	Beta	R^2
CORN	0.243%	-0.000198*** [0.0024]	0.978*** [0.0000]	0.965
SOYB	0.571%	-0.00020 [0.1787]	0.992 [0.5553]	0.785
WEAT	0.584%	-0.00025 [0.1086]	0.980* [0.0633]	0.856
USO	0.545%	-0.00005 [0.7697]	0.904*** [0.0000]	0.932
UGA	0.441%	-0.00010 [0.3928]	0.924*** [0.0000]	0.942

Note: Single, double, and triple asterisks (, **, ***) denote statistical significance at 10%, 5%, and 1% levels, respectively.*

Table 7: Magnitude of Error Results

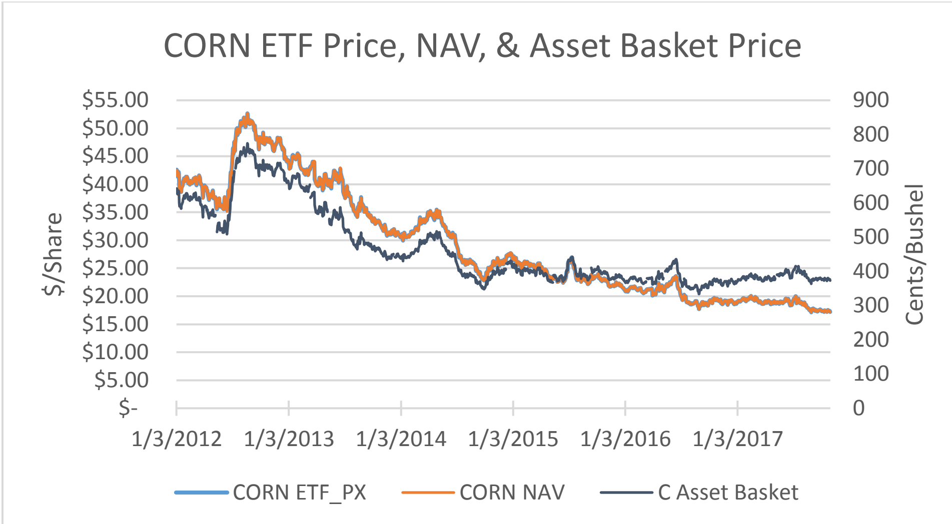
	CORN	WEAT	SOYB	USO	UGA
ETF Abs Return	0.031306*** [0.0000]	0.078943*** [0.0000]	0.241626*** [0.0000]	0.050017*** [0.0000]	0.060770*** [0.0000]
WASDE	-0.000330 [0.277]	-0.000508 [0.477]	-0.001365** [0.0458]		
WASDE + Crop Production	0.000102 [0.784]	0.002472*** [0.0055]	-0.001704* [0.0671]	-	-
Grain Stocks	0.000007 [0.989]	-0.001813 [0.151]	-0.000312 [0.820]	-	-
Prospective Plantings	0.001527* [0.0697]	0.000500 [0.809]	0.003304 [0.138]	-	-
Acreage Report	-0.000422 [0.611]	-0.000105 [0.960]	-0.004786** [0.0329]	-	-
Cattle on Feed	0.000084 [0.663]	-0.000139 [0.775]	0.000140 [0.787]	-	-
Hogs & Pigs	0.000040 [0.911]	-0.000412 [0.644]	0.000382 [0.688]	-	-
Short Term Energy Outlook	-	-	-	0.001726 [0.116]	-0.000087 [0.820]
Drilling Productivity Report	-	-	-	-0.000357 [0.688]	-0.000536 [0.262]
Monthly Petroleum Supply/ Production	-	-	-	0.000502 [0.388]	-0.000127 [0.740]
Annual Energy Outlook	-	-	-	-0.001624 [0.494]	0.000750 [0.556]
February	0.000093 [0.652]	0.000597 [0.251]	0.000654 [0.251]	0.000864 [0.235]	0.000727* [0.0787]
March	0.000200 [0.342]	0.001091** [0.0382]	0.001863*** [0.0010]	-0.001603** [0.0223]	-0.000938** [0.0199]
April	0.000255 [0.209]	0.000951 [0.0629]*	0.001243** [0.0260]	-0.000983 [0.169]	-0.000687* [0.0909]
May	-0.000015 [0.945]	0.000591 [0.262]	0.000855 [0.127]	-0.002283*** [0.0014]	-0.000793** [0.0495]
June	0.000420** [0.0410]	0.000766 [0.137]	0.000372 [0.508]	-0.001703** [0.0167]	-0.000543 [0.178]
July	0.000138 [0.512]	-0.000608 [0.245]	-0.000789 [0.159]	-0.002049*** [0.0028]	-0.000865** [0.0323]
August	-0.000081 [0.687]	-0.000884* [0.0775]	-0.001203** [0.0287]	-0.001411** [0.0360]	-0.000127 [0.750]
September	-0.000121 [0.568]	-0.000692 [0.191]	-0.000793 [0.161]	-0.001402** [0.0402]	-0.000160 [0.695]
October	-0.000332* [0.0957]	-0.000936* [0.0625]	-0.001029* [0.0612]	-0.002352*** [0.0005]	-0.000122 [0.760]
November	-0.000182 [0.395]	-0.000551 [0.309]	-0.001015* [0.0925]	-0.001101 [0.131]	-0.000041 [0.925]
December	-0.000315 [0.156]	-0.001003* [0.0697]	-0.000782 [0.181]	-0.000515 [0.473]	0.000866** [0.0414]
2012	0.000159 [0.275]	0.004719*** [0.0000]	0.002850*** [0.0000]	-	-0.001815*** [0.0000]
2013	0.000218 [0.131]	0.002289*** [0.0000]	0.001594*** [0.0000]	-0.002971*** [0.0000]	-0.002069*** [0.0000]
2014	0.000363** [0.0111]	0.001138*** [0.0015]	0.001122*** [0.0031]	-0.002421*** [0.0000]	-0.001605*** [0.0000]
2015	-0.000396*** [0.0056]	-0.000228 [0.527]	0.000068 [0.858]	-0.000550 [0.171]	-0.000567** [0.0449]
2017	-0.000387** [0.0110]	-0.000160 [0.675]	-0.000196 [0.626]	-0.002701*** [0.0000]	-0.001451*** [0.0000]
Day Before Roll	0.000245 [0.423]	0.000446 [0.557]	-0.000877 [0.291]	-0.001443** [0.0218]	0.000303 [0.427]
Day After Roll	0.000343 [0.2536]	0.000872 [0.248]	0.000047 [0.954]	0.000746 [0.238]	-0.000271 [0.478]

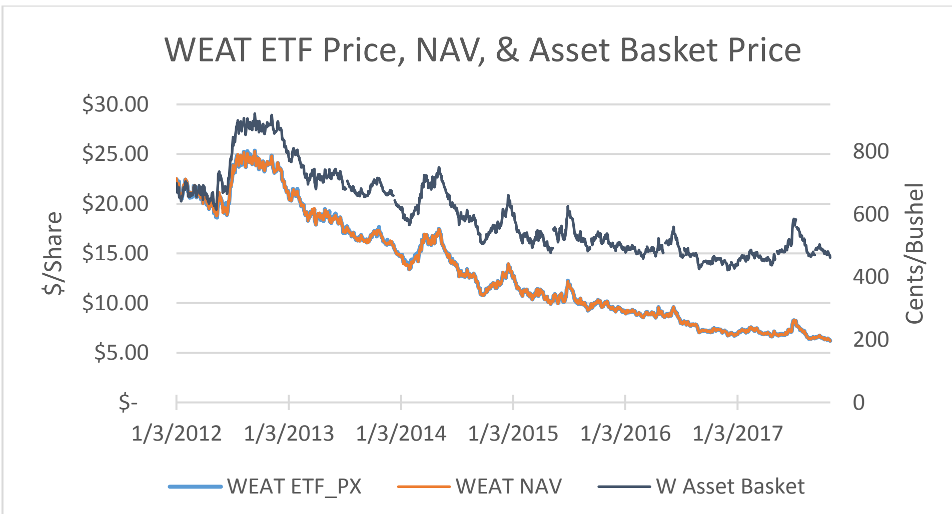
Note: Single, double, and triple asterisks (, **, ***) denote statistical significance at 10%, 5%, and 1% levels, respectively.*

Table 8. Premium/Discount Relative to Net Asset Value

	CORN	WEAT	SOYB	USO	UGA
Mean	-0.023%***	0.064%***	-0.037%*	-0.019%	-0.005%
Std. Dev.	0.002	0.005	0.008	0.004	0.003
Skewness	-0.144	1.092	-0.689	1.042	1.346
Kurtosis	5.34	13.42	14.67	14.93	14.84
Min	-1.26%	-2.04%	-8.50%	-2.05%	-1.28%
Max	0.95%	4.52%	4.77%	3.96%	3.59%
Obs.	1468	1462	1462	1088	1467

Note: Single, double, and triple asterisks (, **, ***) denote statistical significance at 10%, 5%, and 1% levels, respectively.*





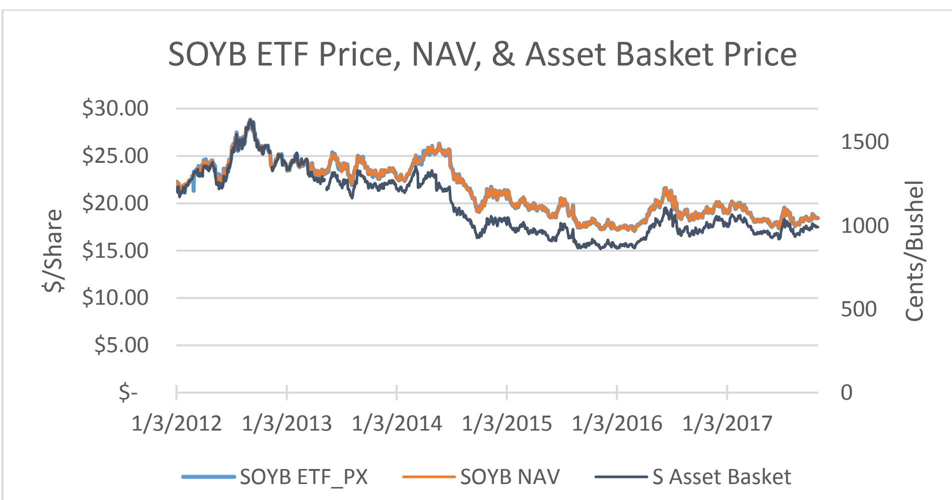
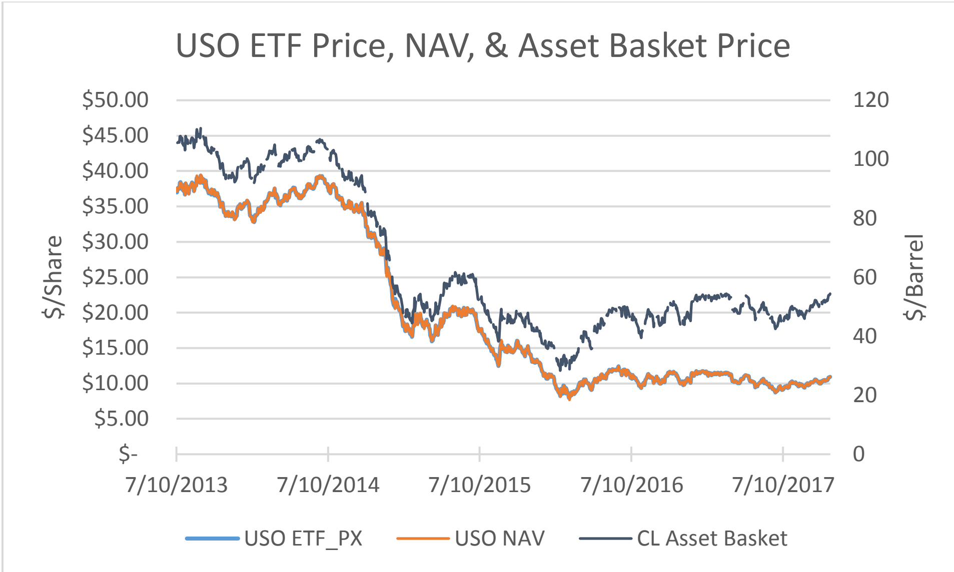


Figure 1: Daily ETF, NAV, and Asset Basket Prices



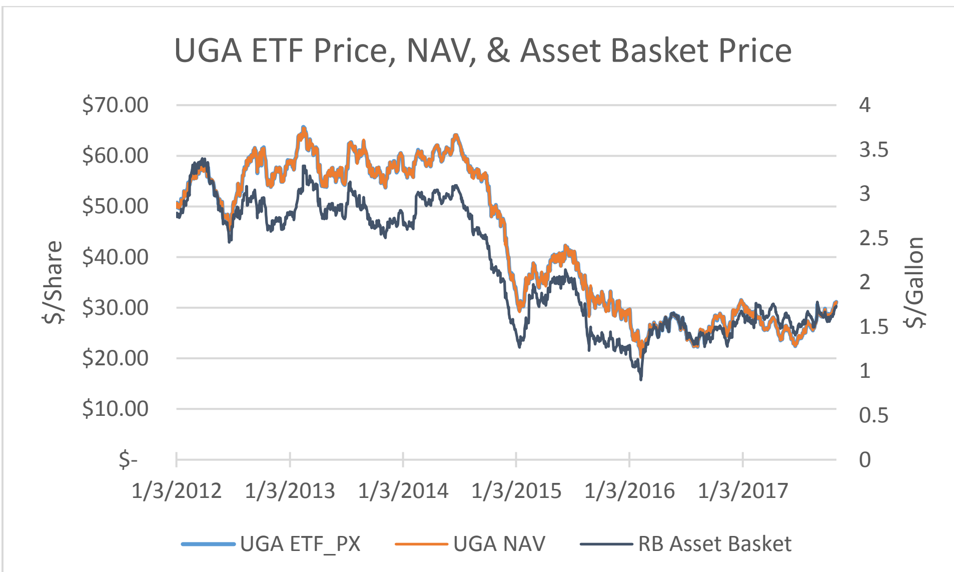


Figure 1 (Continued): Daily ETF, NAV, and Asset Basket Prices

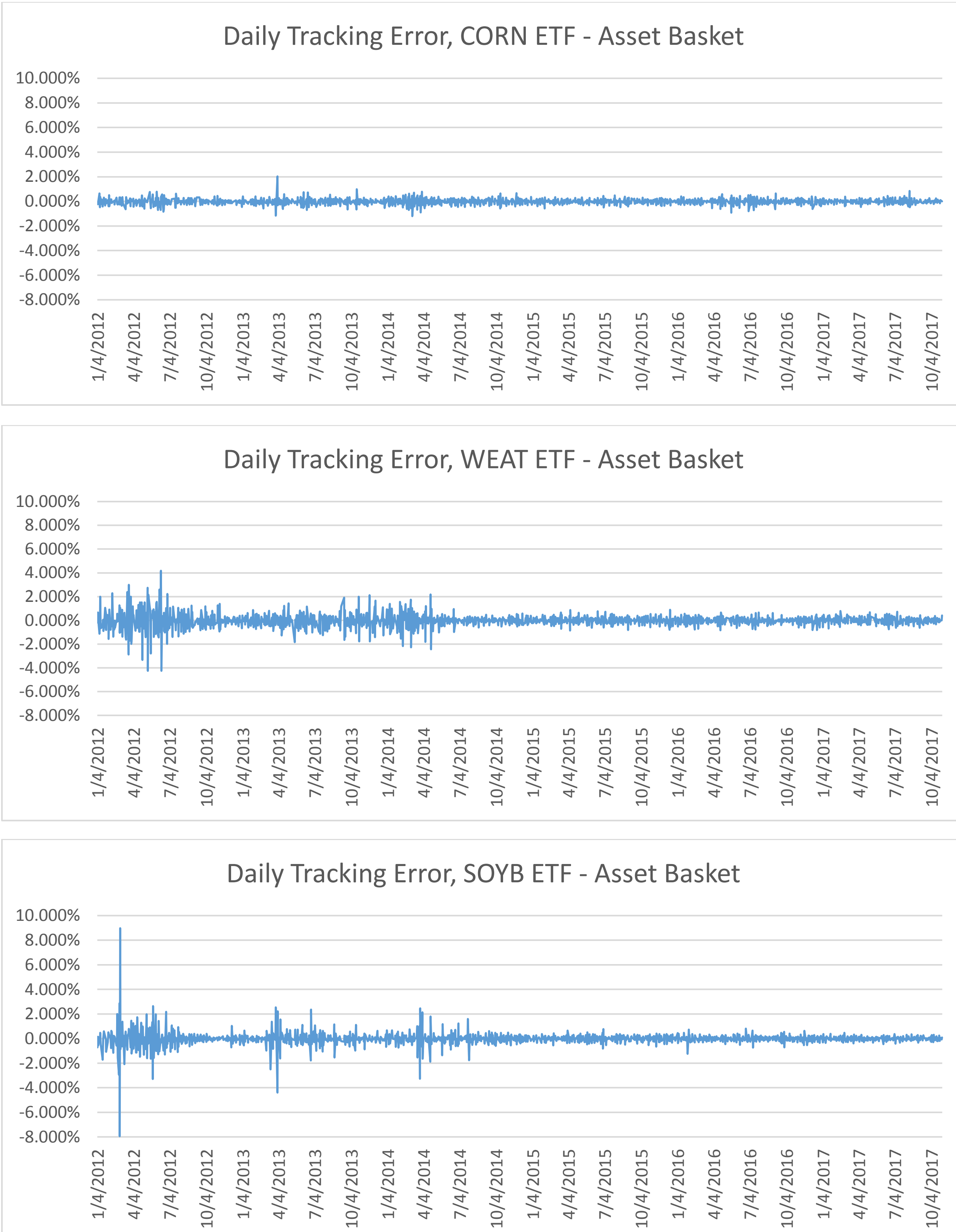
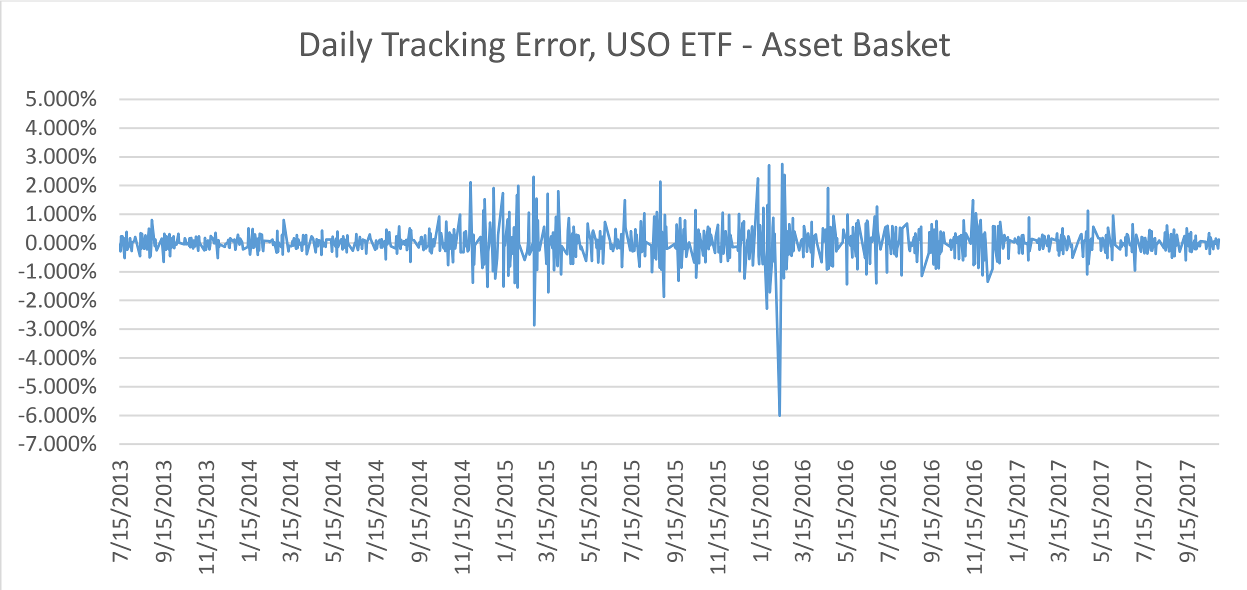


Figure 2: Daily Agricultural Tracking Errors over Time, 2012-2017



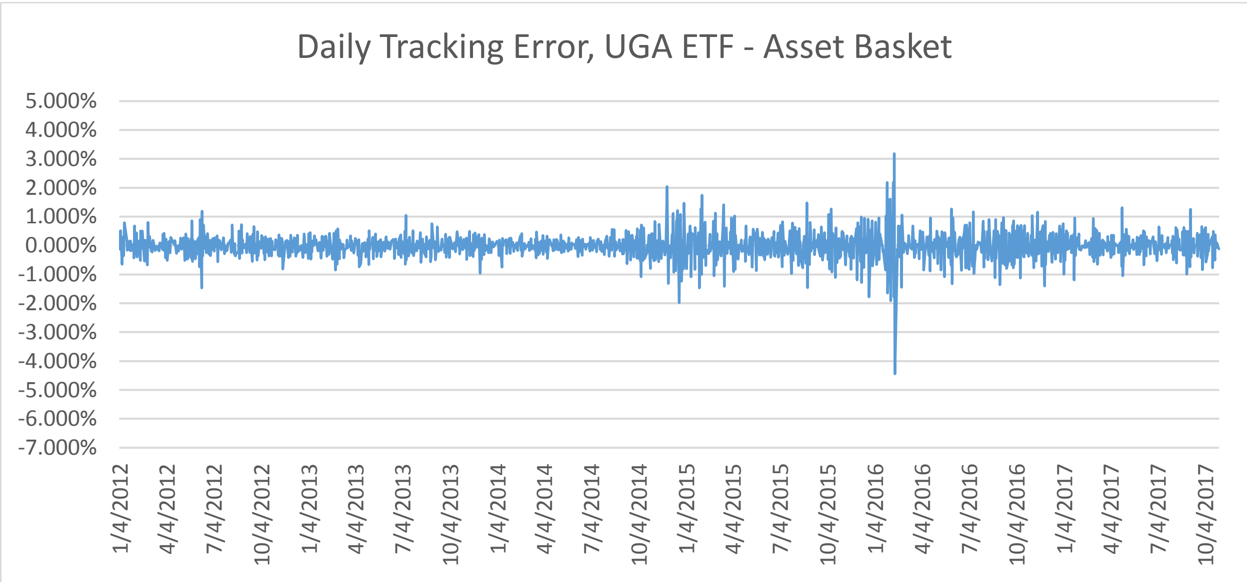


Figure 3: Daily Energy Tracking Errors over Time

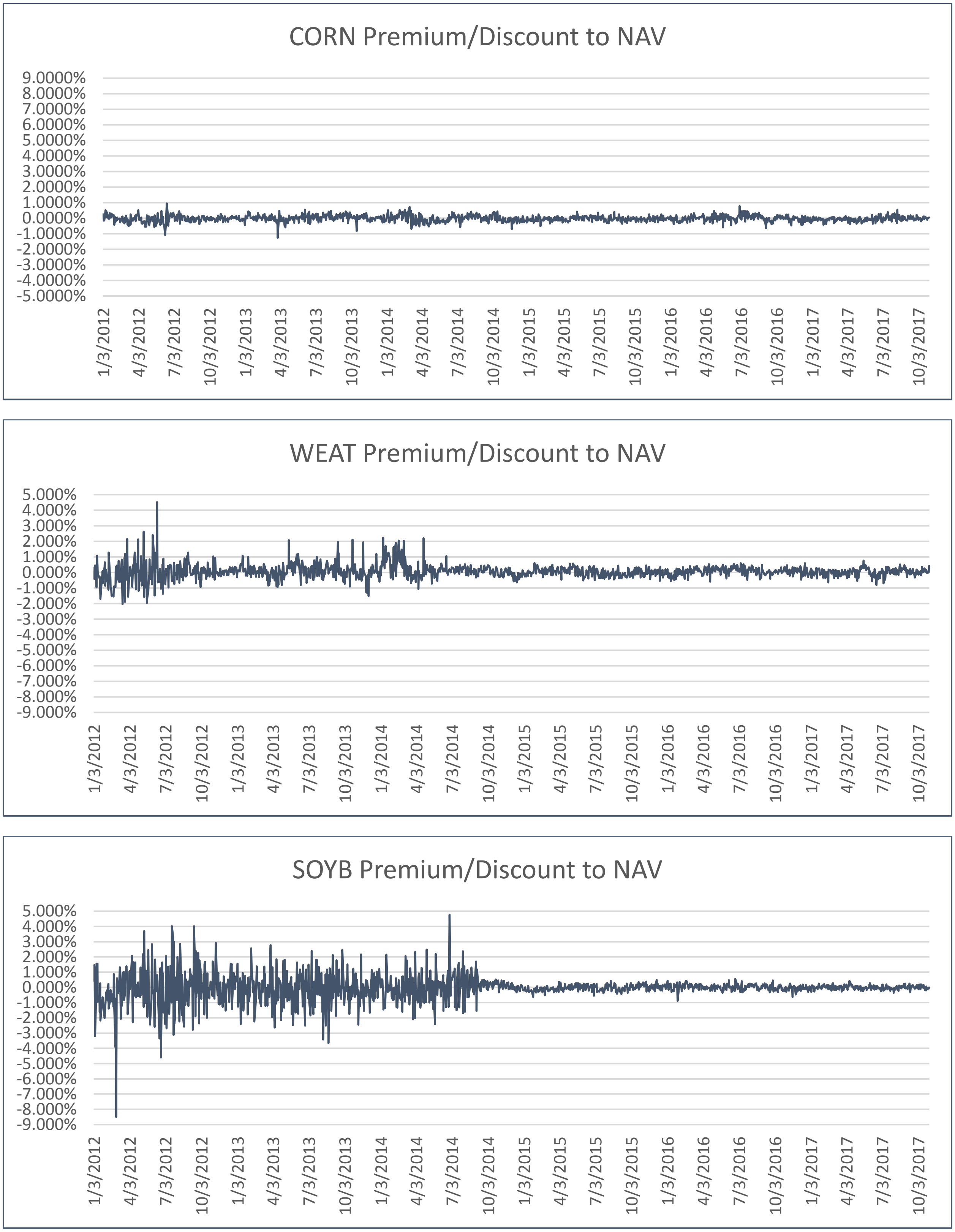
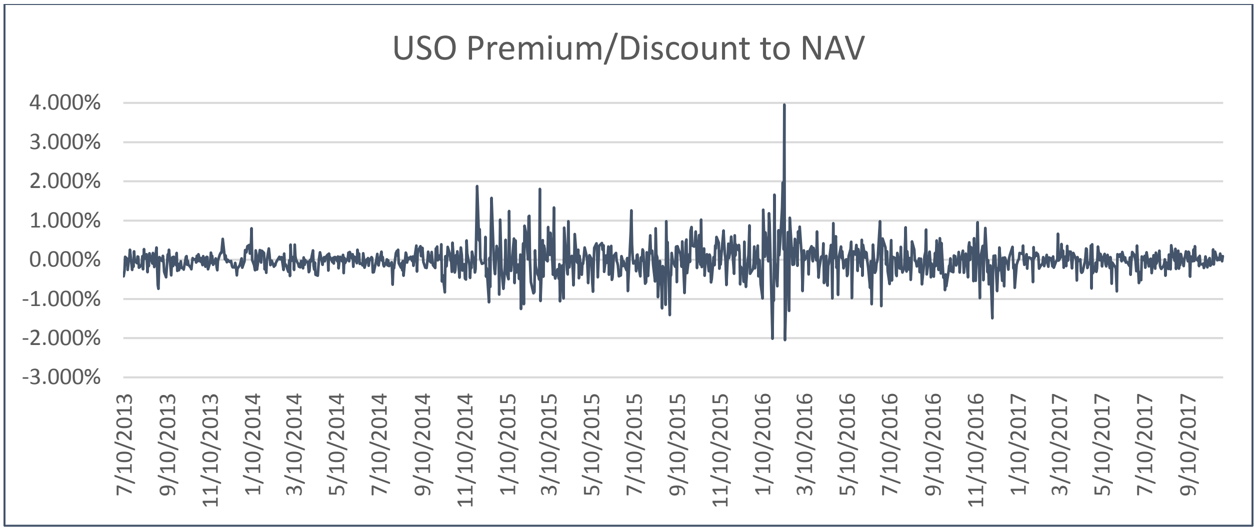


Figure 4: Agricultural ETFs Premium/Discount to Net Asset Value



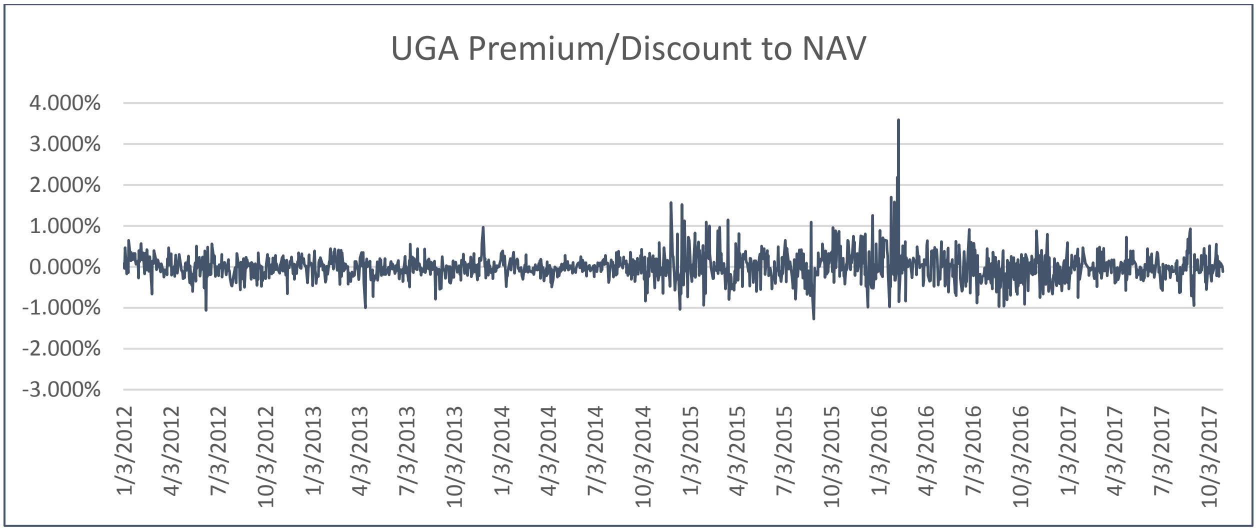


Figure 4 (Continued): Energy ETFs Premium/Discount to Net Asset Value