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Abstract

This paper is the first to study liquidity costs based on actual observed bid-ask spreads (BAS) in commodity futures markets. Using electronically-traded corn futures contracts, we calculate the BAS directly faced by market participants, avoiding estimation problems encountered previously. Over the extended horizon that a contract is traded there exist a pronounced non-linear U-shaped maturity pattern, and a strong seasonality consistent with the term structure of implied volatilities. Statistical analysis in the nearby and next nearby periods, in which most trading activity occurs, indicates that the BAS is generally small (well below two ticks), despite the turbulent market in the 2008 to early 2010 sample period. As in open outcry markets, the BAS responds to daily volume and price volatility, particularly over the last 40 non-expiration month trading days. For the next nearby contracts, a significant declining trend exists in the BAS independent of daily volume and volatility. In both periods, USDA Grain Stock and Production-WASDE announcements significantly widen the BAS, as do short-term price trends. The index fund roll has little impact on the BAS, but contract specific effects are present reflecting a seasonal pattern where the BAS is lowest in December, and highest in September. Week-day effects are relatively weak in magnitude or non-existent.

***Keywords*:** bid-ask spread, corn futures, USDA reports, commodity index funds, price trends

Introduction

Liquidity costs in futures markets can be an important dimension of transaction costs for market participants. The most common gauge of liquidity costs is the bid-ask spread (BAS) which measures the wideness between the prevailing asking and buying prices.[1] Working (1967) first defined the BAS as compensation to liquidity providers for absorbing temporal imbalances between the short and long sides of the market—the cost of immediate order execution. The magnitude and variation of the BAS is of broad interest to a wide range of market participants. For an exchange, it is important to maintain liquidity costs at an affordable level in order to promote viable futures contract trading. Hedgers and speculators also need to know how liquidity costs vary through time and across different contracts in order to manage execution costs.

The study of the BAS in agricultural futures markets has been hampered by data limitations until recently. In the U.S., trading in futures contracts has been organized as an open outcry market, which means that the BAS is not directly observed. As a consequence researchers have had to develop procedures and proxies to infer the actual BAS faced by market participants (Roll, 1984; Thompson and Waller, 1987; Wang et al., 1997; Hasbrouck, 2004). Importantly, these methods are developed under strict assumptions about information flows and the trading

[1] Two other dimensions of liquidity cost are resilience and depth. For more detailed discussion, see Black (1971).

process, and transaction data are used to infer the BAS. Applications and comparisons of these procedures in a variety of markets often produces marked differences in the generated BAS measures (Gwilym and Thomas, 2002; Bryant and Haigh, 2004; Frank and Garcia, 2011). The inconsistency in the BAS estimation is problematic to both researchers and market participants in their efforts to understand market behavior and identify hedging and trading strategies.

A shift in the U.S. agricultural futures trading activity from the open outcry market to an electronic trading platform has occurred in recent years. Starting in June 2006, the proportion of trading volume on the electronic platform at the Chicago Mercantile Exchange (CME) for major field crops, like corn, wheat and soybeans, increased sharply. By the end of 2007 more than 90 percent of trading volume in these futures markets was recorded on the electronic platform (Irwin and Sanders, 2011). In electronic trading, the BAS is directly observable when traders make their transactions. By reconstructing the limit order book from electronic trading records, we can accurately measure the actual BAS faced by traders. These data permit a precise and comprehensive assessment of the structure and behavior of liquidity costs unencumbered by the limitations of previous estimates. Further, it provides an opportunity to investigate behavior at more distant horizons that are often not examined because transactions data are insufficient to estimate BAS using traditional statistical procedures.

With the prevalence and importance of electronic markets, market participation has increased and the supply of liquidity has been expanded beyond just a few floor traders. In this context, one might anticipate that the faster trading technology would dramatically decrease liquidity costs, reducing the BAS to their minimum competitive levels. However, in a comparison of LIFFE coffee and cocoa futures markets, Bryant and Haigh (2004) find that the BAS actually increased with electronic trading because anonymous trading put liquidity providers at an informational disadvantage on any trade, creating risk and widening the BAS. Moreover, the recent growth in these markets has changed the composition of participants; commodity index traders have assumed a larger part of trading activity and much debate exists over their market impact. Specifically, large order flows associated with the rollover of index trader positions can cause temporal imbalances between liquidity supply and demand and widen the BAS. These unexpected findings and recent changes in the composition of traders provide added motivation for a re-examination of liquidity issues in agricultural futures markets.

Using the Best Bid Offer (BBO) dataset from the CME Group for 2008 through January 2010, we identify the structure and determinants of the BAS for electronically traded corn futures contracts. The 2008 to 2010 sample reflects a particularly turbulent time in the corn market. Expanding export demand, government policies to reduce U.S. dependence on foreign oil through the production of corn-based ethanol, tighter linkages to energy markets, and somewhat limited supply response led to high and volatile prices.[2] In addition, this period saw the dramatic increase in market participation fueled by greater access through electronic trading and the development of new financial instruments, such as exchange-traded funds

[2] For instance, corn futures price almost doubled to $7/bushel in 2008 and then fell below $4/bushel as economic activity declined with the financial crisis.

(ETFs). The large changes in price levels and market structure could have a significant impact on liquidity costs.

The BBO dataset contains the prevailing best bids and offers from the electronic Globex trading book for each active contract. The observed BAS is the difference of the matching sequence of bid and ask prices. Each trading day, about ten to twenty contracts are recorded with different levels of activity. The number of observations differs dramatically from day-to-day and across contracts. For a nearby contract, more than forty thousand quote records are typically recorded daily.

This dataset enables us to examine aspects of BAS behavior that have been of great interest to researchers and market participants. We begin by documenting the general patterns in the daily BAS, focusing on its magnitude and variation over an extended portion of the contract life. Also, we estimate the differences in the BAS for alternative contract maturities to identify differences in liquidity costs when placing hedges and calendar spreads at more distant horizons. We expect the BAS to be higher in the deferred contracts, but the magnitude and variation are unclear. Subsequently, we focus on the specific factors influencing the nearby and next nearby BAS behavior. Volume and volatility have been found to be important determinants of the BAS in outcry markets (Wang et al., 1997; Wang and Yau, 2000; Frank and Garcia, 2011). Here, we assess statistically the degree to which these factors affect the electronic BAS using a GMM-IV estimator.

Additionally, we consider how the release of public information, short-term price trends, seasonality, and day-of-the-week effects influence the BAS. A distinctive feature of corn and other agricultural futures is the systematic release of public information. The U.S. Department of Agriculture (USDA) produces regular crop reports and supply-demand estimates. Research has demonstrated that these releases have significant impact on market price and volatility (Fortenbery and Sumner, 1993; Garcia et al., 1997; Isengildina-Massa et al., 2008). We investigate whether the release of this new public information systematically affects the BAS. In addition, commodity prices often exhibit short-term trends. In the face of these price movements, liquidity traders may hold their positions longer to take advantage of these perceived patterns (Working, 1967). Also, trend-following technical trading may create demand for liquidity (Szakmary et al., 2010). In such a situation, BAS will widen as more liquidity is demanded and less supplied. Finally, we assess the existence of seasonality and fixed day-of-the-week effects in the BAS; the last effect has been shown to exist in other markets.

Literature Review

Research on open outcry markets has identified several factors that influence the BAS. The two fundamental factors are price volatility and volume. Volatility creates risk for liquidity providers' order inventories. When price is volatile, the value of acquired order positions for a liquidity provider is more vulnerable than when price is stable. To manage the added risk, liquidity providers will submit less aggressive bid and ask prices which can widen the BAS. In this context, inventory risk theory predicts that the BAS is positively correlated with an asset risk (Garman, 1976; Stoll, 1978; Amihud and Mendelson, 1980; Ho and Stoll, 1983). The underlying rationale for the effect of trading volume on BAS is a reduction of trading costs. Volume represents a scale effect for liquidity providers. With added volume in the market, it is easier and faster for liquidity providers to open and close positions. In effect, it drives down the time and financing cost of capital, and reduces exposure to the potential risk of holding positions. Based on futures contracts traded at the CME, Wang et al. (1997), Wang and Yau (2000) and Frank and Garcia (2011) find volume is negatively related to the BAS while price volatility is positively related. Moreover, driven by the underlying information process, evidence suggests that these two variables are endogeneously determined with the BAS.

Another factor that can affect the futures BAS is time to maturity. When a contract is either far from maturity or in the maturity month, there is less volume. Between these two periods, volume is higher and the BAS is lower, thus a U-shape emerges. Bryant and Haigh (2004) find BAS is U-shaped in cocoa and coffee futures. Brorsen (1989) and Frank and Garcia (2011), whose analyses do not include maturity month observations, find a trend variable is insignificant after controlling for volume in nearby contracts. This is consistent with the notion that volume is an important driver of the BAS. Another view of the time to maturity effect emerges from Copeland and Galai (1983) who suggest that posting a limit order offers a free trade option to the rest of the market. For instance, a limit order on the bid is a put option for others to sell at that bid price. In this context the BAS is the value of a short strangle on the bid and ask prices. The value of the strangle is affected by price volatility and the option's time to maturity—the anticipated time to the next transaction at the posted price. For a futures contract distant from maturity, transaction frequency is low and the time value of the option is high. As the time to maturity decreases, trading frequency increases, the time value of the option declines, and the BAS declines. This dimension of maturity effect is expected to be independent of the volume traded.

Commodity index funds play an increasingly important role in commodity futures trading. Driven by risk diversification, the last decade has seen considerable growth in commodity index investments to $174 billion in 2009 (Stoll and Whaley, 2010). These funds establish passively long positions, and roll their positions by selling the nearby and buying the next nearby contract on the fifth to ninth business day in the calendar month before the nearby contract expires. In the corn futures market, for example, index traders tend to roll from the March to May contract on the fifth to ninth trading day of February. If insufficient liquidity exists on the days index funds roll their positions, the BAS could temporarily widen. In the market microstructure literature, this illiquidity problem is said to arise from the asynchronous arrival of orders which amounts to a temporary mismatch between the supply and demand for liquidity (Garman, 1976; Grossman and Miller, 1988). In agricultural markets the effect of the roll may differ in the nearby and next nearby contracts because trading in agricultural futures is driven by merchandisers' hedging needs which primarily involve short selling. During the roll period, as index funds build long positions in the next nearby contract, short hedgers establishing their hedge positions may help absorb the added long pressure on liquidity providers. In contrast, as index funds sell the nearby contract to close their expiring positions, liquidity providers absorb short pressure without the assistance of the hedger. In this environment, the BAS in the next nearby contract may tighten while it may widen in the nearby contract. Empirical evidence of the commodity index effect on the BAS in agricultural markets is limited. Shah and Brorsen (2011) perform a *t*-test on the mean BAS between rolling and other periods for Kansas City Board of Trade (KCBT) wheat futures and report no significant difference, but the analysis is restricted to the nearby contract only. Frank and Garcia (2011) find higher volume per transaction during the roll period which contributes to a BAS increase, without directly testing the relationship.

The effect of USDA information releases on the BAS has not been systematically examined in agricultural futures markets. Research in agricultural futures markets suggests that the release of USDA reports affects price and increases volatility (Fortenbery and Sumner, 1993; Garcia et al., 1997; Isengildina-Massa et al., 2008). This increase in volatility may lead to increases in the BAS on the day of the release. On key USDA report announcement days added risk and uncertainty may exist about the direction and magnitude of price adjustments. In this risky context, liquidity providers may be reticent to provide their services leading to a wider BAS.

A largely neglected determinant of the BAS is the price trend. Working (1967) observed that liquidity providers recognize price trends, and often use a ‘cut losses and let profits run’ strategy in their trading. When on the right side of a price trend, they hold the position to accumulate profits. When on the wrong side, they offset the position immediately to stop losses. An implication of this strategy is a decrease in liquidity services during price trends. Additionally, an important portion of the volume in futures markets is driven by technical trading strategies which are often based on underlying trends in the price data (Park and Irwin, 2007; Park and Irwin, 2010). A common trend-following strategy is to bet that past price momentum will continue in the future and to even increase the trading positions in the presence of perceived trends (Szakmary et al., 2010). In the presence of trends, the combination of the ‘cut losses and let profits run’ strategy of liquidity traders (which reduces liquidity) and the trend-following strategy of technical traders (which increases the demand for liquidity), results in a wider BAS. No evidence on a trending price effect on the BAS exists in agricultural futures markets. Using data from the New York Stock Exchange, Chordia et al. (2001) find significant asymmetric lagged price trend effects on the current BAS and the BAS weakly declines in up markets and strongly widens in down markets, suggesting that traders were less willing to provide liquidity in declining markets.

Structure of the BAS Data

Information used in the analysis is the CME group Top-of-Book (BBO) Data on electronic traded corn futures for the period January 14, 2008 to January 29, 2010. The corn contract is the most actively traded agricultural commodity at the CME. It has five maturities a year: March, May, July, September and December. BBO data contain the top bid, bid size, top ask, ask size, and transaction prices and volume accompanied by a time-stamp. For each best ask price and number of orders available to trade, there is corresponding best bid price and available orders. When a transaction takes place, both the price and quantity are recorded. Once a bid or ask price better than the current quote is generated, or quantity in either bid or ask side changes, a new pair of records is generated to replace the previous one.

Figure 1 provides an illustration of the top of book quotation prices in the first minute of the daytime trading session on January 29, 2010. In that minute, there are 882 pairs of quote records and 304 transactions. Transactions prices are interspersed among the quoted best ask and best bid prices. The BAS is the difference between the matching bid and ask prices at each pair of quotes, and the daily average BAS is the mean of all BASs that appear for the entire trading session. We focus the analysis on the daytime market since it is the most active with numerous professional traders involved. We also focus on daily average data for consistency and comparison with the previous research. Consequently, the analysis is based on 516 daily average observations.

Empirical Regularities of the BAS

In this section we document several empirical regularities in the daily BAS and volume, including time to maturity, term structure, and behavior on days of commodity index rolls and USDA announcement days.

To begin, we trace the evolution of the BAS through the contract life for the five contracts maturing in 2009, which possessed the largest number of trading days in the sample. Figure 2 (a), (b) and (c) plot the daily BASs and trading volumes per contract starting in January 2008 until maturity. The BAS exhibits a U-shaped pattern, consistent with previous literature. In the earlier stages, trading activity is minimal and is accompanied by a large and volatile BAS. For instance, in the least traded 2009 September contract, BAS reached a high of 54 cents/bushel, with 118 contracts traded on that day. The BAS steadily declines as maturity approaches with a sharp upturn in the expiration month when volume slumps. Closer examination of the figures also reveals a pattern of increased trading activity in the nearby contract. For instance, the March 2009 contract exhibits increased trading about two to three months prior to the beginning of its expiration month. Exceptions to this pattern are the December contract which exhibits an increase in trading activity as much as five months prior to its expiration month, and the September contract which exhibits an increase for only two months prior to its expiration month. These exceptions reflect the fact that December is the first new crop contract and is actively used for hedging, while the September contract combines old and new crop information and has less trading interest (Smith, 2005).

The maturity patterns imply a term structure of liquidity costs, with distant contracts having lower volumes and higher BASs. To examine the potential implications of the term structure on producer decisions, we plot the liquidity costs that correspond to a producer making a hedging decision in April 2008 and 2009 (Peterson and Tomek, 2007). In Figure 3 (a) and (b) we graph the BAS term structure for each trading day in April to illustrate the cost structure of placing hedges at distant horizons. For the current year contracts, liquidity costs are rather stable and show little dispersion. For more distant contracts, the BAS is higher in both level and variability. At these more distant horizons, a seasonal pattern emerges with the BAS for December being the lowest and least dispersed, followed by an increasing and widening BAS from March through September. At about a two-year horizon, the May and September contracts are rarely, if ever, traded which is reflected by large and highly dispersed BASs or the absence of a recorded BAS. These patterns are similar in shape with two other known seasonal patterns in the corn futures market: the term structure of implied volatility (Egelkraut et al., 2007) and variability in prices (Peterson and Tomek, 2007), strongly suggesting that the BASs are affected by the expected seasonal volatility.

Compared to the entire life of a contract, trading activity in a contract occurs most actively in the last 90 trading days prior to maturity. To examine this period in more detail, we plot the average daily BAS for the nine contracts during their last 90 trading days (Figure 4(a) and 4(b)).[3] In terms of magnitude, prior to the expiration month the BAS generally remains small and well below two ticks or 0.5 cents/bushel. Despite the general uniformity in the BAS across contracts, there is additional evidence that the September and May contracts are slightly higher. In terms of variation through time, all contracts follow a similar general pattern. From day 90 to about day 50, BAS declines gradually but systematically, reaching a level slightly above one tick. It then remains stable before entering the maturity month. In the maturity month, it rises sharply as trading activity fades, especially in the last week when traders offset their positions to avoid delivery.

To examine the short-term dynamics of the BAS more closely, we construct two BAS series, both of which exclude data from the expiration month. One series, *NB1BAS*, is the daily BAS in the nearby contract, while the other series, *NB2BAS*, is the daily BAS in the next nearby contract. We change or roll the nearby and next nearby contracts to their next maturity contracts on the last trading day prior to the maturity month. Figure 5 plots these two series. The next nearby BAS series in most periods clearly lies above the nearby series, and is more variable. The exceptions occur in July—August 2008 and 2009 when the next nearby contract is based on the December contract which is generally the lowest and the nearby contract is based on the September contract which is generally the highest (as identified earlier). The average values for the two series are 0.314 and 0.376 cents/bushel (table 1). Despite the exceptions noted above, pair-wise t-tests show the differences are significant at the 5% level, confirming a significant term structure, and identifying the liquidity costs that could emerge when making short-term hedging in more distant contracts or when taking spread positions across contracts.

Previous BAS findings based on transaction prices for the corn market provide insight into these recent electronic estimates. Brorsen (1989) finds the average BASs over a number of contracts is 0.305 cents/bushel for floor-traded corn futures. More recently for a short sample, Martinez et al. (2011) find an average BAS of 0.255 cents/bushel for electronic trading, and 0.275 cents/bushel for floor-traded corn futures. Importantly, both studies were conducted during relatively stable periods which may explain the slightly higher BAS values identified here (i.e., 0.314 and 0.376 cents/bushel). Shah and Brorsen (2011) identify a similar pattern when comparing 2008 BAS estimates to historical estimates for the Kansas City wheat contract.

Commodity index funds roll their positions in the corn market five times a year in February, April, June, August and October. In Figure 6 we compare the BAS and volume in the roll and non-roll periods. As expected, in both series the average daily volume is higher on the roll days than on non-roll days. Interestingly, the BAS falls slightly during the roll in the next nearby series, but increases slightly in the nearby series. The differential behavior of the BAS on roll days provides some support for an asymmetric relationship which may be related to use of futures contracts as a hedging vehicle.

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[3] May 2008 contract only contains 85 days records prior to expiration.

To examine the effect of USDA information we consider the release dates of four reports: World Agricultural Supply and Demand Estimate report (WASDE), the Crop Production report (PD), Crop Progress report (PS), and the Grain Stocks report (GS). The PD report contains U.S. crop production information, including acreage, area harvested and yield. Corn production data are reported monthly from August to November, with final estimates provided in January. The WASDE report provides monthly the USDA forecasts of U.S. and world supply-use balances of major grains using PD data. The PS report provides, during the crop season, weekly information on planting, crop and harvest progress as well as the overall conditions of selected crops in major producing states. The GS, which is issued four times annually in January, March, June and September, contains stocks of all major grains including corn by states and U.S. level and by position (on-farm or off-farm).

Figure 7 compares the nearby and next nearby BAS on USDA announcement and non-announcement days. The release time for GS, PD and WASDE reports are 8:30 AM, and the information should go directly into market on that trading day. The PS report is released on Mondays at 4:00 PM after the market has closed, and the BAS reported in the figure corresponds to the following trading day. In both series, the GS, PD, and WASDE reports generally have a higher BAS compared to the non-announcement days, with the Grain Stock release exerting the most influence. In contrast, the BAS for the PS reports on the following trading day does not seem to be appreciably different than on non-announcement days. Presumably its information is incorporated quickly in the overnight trading or in the early moments on the next trading day.

In short, the empirical patterns in BAS support the existence of non-linear U-shaped maturity effect, a term structure across maturities, and identify contract differences related to seasonality in volatility and in hedging patterns. During the most actively traded nearby and next nearby contracts the BAS is well below two ticks. USDA releases appear to influence the BAS with the largest effects emerging from the Grain Stock report. Commodity index rolls seem to reduce BAS marginally in distant futures contracts. To assess these relationships along with the determinants of BAS, we employ a regression analysis to investigate the daily BAS behavior.

Regression Specification

In the regression model, we analyze the relationship between the BAS and volume, volatility, time to maturity, and the other dimensions identified previously using the nearby (*NB1BAS*) and next nearby (*NB2BAS*) series. The daily average BAS model is specified as:

(1) $$BAS_{i,t} = f(volume_{i,t}, volatility_{i,t}, maturity_t, trend1_{i,t-5,t-1}, trend2_{i,t-5:t-1}, RL_t, PD\_WASDE_t, GS_t, K_t, N_t, U_t, Z_t, Tue_t, Wed_t, Thu_t, Fri_t)$$

where *i* =1 and 2 stands for the *NB1BAS* and *NB2BAS* series, *Volume* is the daily trading volume, *Volatility* is calculated as the daily standard deviation from the midpoint of reported bid ask quotes on electronic platform for the corresponding contract, and *Maturity* is a decreasing linear trend identifying the number of days left to the switch to the next contract. To measure the price trends, we sum the close-open price differences on the previous five trading days. To allow for increasing and decreasing trends, two variables are defined following Chordia et al. (2001). The variable *trend1* is the summed price changes if positive or zero, otherwise zero; and *trend2* is the summed price change if negative, otherwise zero.

Dummy variables are used to estimate the effects of the other factors identified. Since production reports are always on the same date as the WASDE reports, we create a single dummy variable *PD_WASDE* equal to 1 on the day of WASDE reports, otherwise zero.[4] *GS* is a dummy variable for grain stock reports. We do not include crop progress reports because the release is always late on Monday and as discussed our preliminary examination found little response. *RL* is a dummy variable for commodity index roll periods. It equals to 1 for the fifth to ninth trading day of February, April, June, August and October. *K*, *N*, *U* and *Z* are four dummy variables for May, July, September and December contracts with the March contract effect in the intercept term. We also include weekday dummies *Tue, Wed, Thu* and *Fri* following Frank and Garcia (2011).

Volume and price volatility have been found to be the most important determinants of BAS in commodity futures (Brorsen, 1989; Bryant and Haigh, 2004; Frank and Garcia, 2011). Based on our graphical analysis and work by Bryant and Haigh (2004) we also include time to maturity. We first estimate the regression using these three factors, and then we add the other variables to assess their effects.

Several econometric problems may exist in estimation. Volume and volatility are likely to be simultaneously determined with the BAS. Serial correlation and heteroskedasticity may also exist in time series regression with daily observations. To test and correct for the bias, we use the General Method of Moments - Instrumental Variables (GMM-IV) method recommended by Baum et al. (2007) and used by Frank and Garcia (2011).

We can write the regression model specified in (1) in matrix form as

(2) $$y = X\beta + u$$

where β is the coefficient vector, X is the vector of right hand side variables, and u is the error term. First we estimate the OLS and instrumental variable regressions. Instruments for volume and volatility are lagged volume and first difference of volatility following Thompson et al. (1993) and Frank and Garcia (2011). Define data matrix Z which is same as X, but replace the endogeneous variables by their instruments. The 2SLS estimator is given by

(3) $$\hat{\beta}_{2SLS} = (X'P_z X)^{-1} X'P_z y$$

and $P_z = Z(Z'Z)^{-1}Z'$ is the projection matrix. The error covariance matrix is

(4) $$\Omega = E(uu'|X).$$

In 2SLS regression, we test for heteroskedasticity using the Pagan-Hall (1983) test, and autocorrelation using the Cumby-Huizinga (1992) modified Breusch-Godfrey test. If the residuals are not *iid*, the 2SLS estimator is not efficient, though still consistent. In presence of

[4] On October 2008, NASS reissued its crop production report on 28th of the same month. WASDE also has its reports reissued. So there are two releases for that month.

heteroskedasticity, we use two-step feasible GMM estimation to generate the most efficient estimator, which is

(5) $$\hat{\beta}_{GMM} = (X'Z\hat{S}^{-1}Z'X)^{-1}X'Z\hat{S}^{-1}Z'y$$

$\hat{S} = \frac{1}{T}\sum_1^T \hat{u}_t^2 Z'_t Z_t$ is the Huber-White robust variance estimator calculated from the first step regression. Further if error terms exhibit autocorrelation, $\hat{S}$ is modified by Newey-West (1994) automatic bandwidth correction procedure.

(6) $$\hat{S} = \hat{\Gamma}_0 + \sum_{j=1}^{q} \kappa(\hat{\Gamma}_j + \hat{\Gamma}'_j)$$

$\hat{\Gamma}_0 = \frac{1}{T}\sum_1^T \hat{u}_t^2 Z'_t Z_t$, and $\hat{\Gamma}_j = \frac{1}{T}\sum_{t=1}^{t-j} Z'_t \hat{u}_t \hat{u}_{t-j} Z_{t-j}$ is sample autocovariance matrix for lag j, with Bartlett kernel function $\kappa = (1 - j/q)$ if $j<q$, and 0 otherwise. To test endogeneity of volume and volatility respectively, we apply the modified Durbin-Wu-Hausman test based on GMM distance test (Baum et al., 2007). If variable endogeneity cannot be rejected, we also test for instruments weakness by Stock-Yogo (2005) statistics with the null of weak instruments.

Regression Results

Table 1 provides summary statistics for the continuous variables used in the analysis. As anticipated, average daily volume in the nearby series (which corresponds to the nearby contracts) is larger than the volume in next nearby series (contracts). The BAS in the next nearby exceeds the BAS in the nearby contract and exhibits more variability. Somewhat unexpectedly, the volatility (i.e., the standard deviation of the midpoint of quoted bid and ask prices) in prices in the next nearby contract only marginally exceeds the volatility in the nearby contract. Prior to estimation, the two BAS series, and their volumes and volatility series were tested for non-stationarity using the augmented Dickey-Fuller test. As shown in Table 2, all series reject the null hypothesis of non-stationarity at the 1% level.

Tables 3 and 4 provide the OLS and the GMM-IV regression results for the two BAS series. For the GMM-IV model, p-values for the test results are reported in the lower part of the tables. Since significant heteroskedasticity and autocorrelation are present, we employ GMM estimation with Newey-West corrections. Tests indicate that volume and volatility are endogeneously determined with the BAS, except for volume in the next nearby BAS series when all the variables are included. For the endogeneous variables, all the instruments are strongly significant to identify the instrumented variables. Adjusted coefficients of determination show the models fit reasonably well. For the two right-hand side endogenous variables, the signs are consistent with expectations across the models, but are lower in magnitude and statistical significance in the GMM-IV framework.

In the models which contain only volume, volatility, and time to maturity, all parameters are significant for both BAS series, except for the maturity variable in the nearby analysis. The BAS decreases with volume due to a scale effect, and increases with volatility due to risks of providing liquidity service. These findings are consistent with Wang et al. (1997), Wang and Yau (2000) and Frank and Garcia (2011) who performed their analysis using data from open outcry markets. As expected from the graphical analysis, the time to maturity effect is significantly decreasing in the next nearby period (i.e., the further from maturity the wider the BAS) but equals zero for the nearby BAS. These results help explain why Brorsen (1989) and Frank and Garcia (2011) fail to find pronounced linear maturity patterns in their analyses of nearby series; the prominent maturity effect is non-linear in nature, but only tends to emerge at more distant horizons.

When we include other variables, volume and volatility remain significant in nearby series but not in the next nearby series. In the nearby series, their parameter values decline only slightly, but in the next nearby series they shrink dramatically, declining by more than 60 percent. For the nearby series, a one percent increase in the volume traded reduces the BAS by 0.18 percent, and a one percent increase in the volatility (i.e., standard deviation) leads to 0.06 percent increase in the BAS. In monetary terms, an increase of one standard deviation in daily volume (i.e., 28.58 thousand contracts) reduces the BAS by only 0.0286 cents/bushel, or $1.43 per contract. A one cent/bushel increase in the standard deviation in prices leads to a 0.0074 cent/bushel increase in BAS or $0.37 in the contract value. These numbers are quite small and support the notation that the corn market is highly liquid.

The time to maturity effect is zero in the nearby series, but becomes larger in the distant to maturity period. Clearly, when the contract is more distant from expiration, the BAS is influenced more by a maturity effect which reflects the general market activity in the contract rather than specific daily risk and scale considerations. On average, the BAS drops daily by 0.0014 cents/bushel in the next nearby period. Summing the daily changes for the next nearby period (50 days) leads to a total effect of 0.07 cents/bushel or $3.50 per contract reduction in total. The appearance of the steady decline in the BAS in the next nearby period independent of the actual volume traded and price volatility may best be understood in the context of Copeland and Galai's (1983) option framework. The BAS can be viewed as the short strangle whose value is affected by volatility and the time to maturity—the anticipated time to the next transaction at the posted price. For a contract distant from maturity, transaction frequency is low which increases the time value of the strangle. As traders migrate into the contract, trading frequency increases (as does the volume traded), the time value declines, and the BAS declines.

It should also be clear that the explanatory ability of volume and volatility in the second series is linked closely to the additional factors included, but much less so in the nearby series. This finding suggests that higher volume was attracted to the market by the other factors including fixed-effect days and price trends which changed the BAS. These results expand the findings of previous literature which suggests that volume and volatility are uniformly significant determinants of the BAS (Ding, 1999; Wang et al., 1997; Wang and Yau, 2000; Frank and Garcia, 2011).

The significance and magnitude of the effects of the other factors varied substantially. Short-term price trends significantly affect the BAS in both the nearby and next nearby series. Since the variable *trend2* is a negative number reflecting downward trends, the general effect of trends in either direction is to increase the BAS. A test of the equality of absolute value of the trend coefficients for the next nearby series indicates little difference ($p = 0.53$) between the parameters. A similar test for nearby series suggests some difference ($p = 0.06$), with larger response occurring with the positive trends. The average magnitude of the responses in both BAS series to a one cent/bushel change in the price trend is about a 0.0007 cent/bushel change or 3.5 cents per contract. These findings provide evidence that positions taken by trend-following technical traders and by liquidity providers to take advantage of short-term price trends result in a higher BAS.

USDA announcements significantly affect the BAS in both series, with the Grain Stock (GS) reports having the biggest impact. On the day the report is released the BAS increases by 0.042 and 0.06 cents/bushel, or $2.10 and $3 per contract, in the nearby and next nearby contracts. On average, this amounts to a fifteen percent increase in BAS on the release day. During the 2008 and 2009 period, changes in market demand and supply resulted in low stock-to-use ratios. In this situation, the market was extremely sensitive to inventory information and liquidity costs increased in response. The relatively large magnitudes, after accounting for price volatility and trading volume, suggest added uncertainty in the market may exist over the trajectory of price adjustments which widened the BAS. Production and WASDE reports (PD_WASDE) have smaller effects, about one fourth the size of the GS report, which consistently lead to a widening of the BAS. On days of WASDE reports, the BAS increases by 0.01 and 0.017 cents/bushel respectively in the nearby and next nearby series, or $0.5 and $0.85 per contract.

The roll of commodity index positions fails to have a significant effect on the BAS, as the roll date dummy variable is insignificant in both series. This finding implies that index trading volume does not impose liquidity pressure on trading activity. Higher volume in the rolling period appears to have attracted enough liquidity provision for both the opening and closing of index positions. The result supports Shah and Brorsen's (2011) finding that commodity positions rolls do not raise BAS in the nearby period, and extend the finding to the next nearby period even when trading volume is smaller.

The findings on the existence of a seasonal term structure and fixed effects for the day of the week are somewhat mixed. In the nearby series, the BAS for the December and March contracts is the lowest; it then increases through the May and July contracts to the September contract. However, the significance of the coefficients is quite marginal, except for September which differs at the 10% level. For the next nearby series, the BAS in December is clearly the lowest with the same seasonal pattern as in the nearby series. The existence of lower BAS in December is consistent with the notion that this contract is used heavily for hedging and Working's (1967) discussion that hedging attracts speculative liquidity service. Trading December contracts at a distant horizon is on average $2.91/contract less expensive than other contracts, adding to its attractiveness as a hedging tool. Weekday effects are weak. The Tuesday, Thursday and Friday BASs are slightly higher than Monday for the nearby series, but are insignificant for the next nearby series. Little differences in magnitude of the BAS emerge among weekdays.

Conclusions

In this paper we investigate bid-ask spread (BAS) behavior in the electronically traded corn futures market, which now accounts for nearly 90 percent of the corn volume traded at the Chicago Mercantile Exchange (CME). The study uses the order book BAS which market participants directly face when trading, which overcomes estimation problems in past studies. Over the life of the contracts traded, a pronounced non-linear U-shaped maturity pattern exists in the BAS for all contracts. In the context of long- and short-term hedging, strong seasonality in the level of BAS and its variability are consistent with the term structure of implied volatility (Egelkraut, Garcia, and Sherrick, 2007) and seasonal volatility in spot prices (Peterson and Tomek, 2005). The BAS is lowest in the December contract which is actively used for hedging, and highest in September which appears to have less commercial interest because it reflects both old and new crops.

For the nearby and next nearby contracts, where most trading activity concentrates, the BAS is generally small, well below two ticks—0.50 cents per bushel. During the last forty trading days prior to the expiration month, the average BAS is slightly more than one tick, 0.314 cents/bushel, supporting the notion that the corn futures market is highly liquid. Compared to previous BAS estimates for the corn market derived using transaction data, we find the observed BAS to be slightly larger which is most likely attributable to the turbulent sample period. Daily volume and price volatility are important determinants of the BAS in the nearby period, which is consistent with previous findings in outcry market (Wang et al., 1997; Wang and Yau, 2000; Frank and Garcia, 2011). The magnitudes of the volume and volatility effects in the nearby series are small as one would expect in a liquid market. The elasticity estimates for a percentage increase in volume and volatility are -0.18 and 0.06 percent. For the next nearby contracts, a significant declining trend exists in the BAS, and daily volume and volatility lose statistical significance. This pattern in the next nearby contract may reflect insufficient market activity during the period as traders have not yet migrated into the contract to increase the frequency of transactions.

For both the nearby and the next nearby series, we find USDA Grain Stock reports widen the BAS by an average of 15% and production and WASDE reports widen it by 4% on release days. These findings are consistent with research showing that USDA releases provide information which alters prices and their volatility. During the sample, market changes resulted in low stock-to-use ratios which made the market very sensitive to inventory information and liquidity costs increased in response (Wright, 2011). The significance and rather large magnitude of the increase in the BAS may be reflective of higher uncertainty in the value of the contract as the market adjusts to new information. Short-term price trends also widen the BAS, which supports Working's observation (1967) that liquidity providers take advantage of price trends to gain profit, and the notion that trend-following technical traders increase the demand for liquidity. We fail to find any effect of the position roll by commodity index funds on the BAS, which supports the evidence provided by Shah and Brorsen (2011) developed in a less comprehensive framework. Finally, day of the week effects are weak in magnitude or non-existent.

It should be clear that the electronically traded corn futures market has provided a low transaction cost platform for traders even during a period of numerous and significant changes in the spot and futures market. Despite the general level of low liquidity costs, however, opportunities exist for market participants to reduce execution cost by controlling the timing of trade and choosing contract maturities. Modest differences between the nearby and next nearby contracts exist. More pronounced, seasonal and contract-specific differences also exist, with higher BASs positively related to expected volatility and in the September contract when less volume is traded. Lower levels of BAS occur in the December contract when hedging activity and speculative response are the highest. Relatively large increases in the BAS also can occur on USDA report release days, and market participants should be aware of the added liquidity costs. Finally, market participants interesting in taking advantage of perceived trending prices should be aware that the trends may restrict liquidity, result in higher transaction costs, and reduce the attractiveness of their trading strategies.

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Table 1. Summary Statistics

Variable	volume1	volume2	volatility1	volatility2	trend1(BAS1)	trend2(BAS1)	trend1(BAS2)	trend2(BAS2)	BAS1	BAS2
Mean	57.54	24.67	2.56	2.58	9.71	-10.12	10.24	-10.15	0.314	0.376
Std. Dev.	28.58	28.28	1.59	1.59	13.64	16.67	14.12	16.81	0.043	0.061
Min	1.63	1.56	0.00	0.00	0.00	-103.50	0.00	-103.25	0.258	0.264
Max	196.44	149.94	11.82	11.96	78.00	0.00	81.50	0.00	0.509	0.691
Obs	516	516	516	516	516	516	516	516	516	516

Note: Volume1 and volume2 are the average daily volumes in the nearby and next nearby series, in the unit of thousand contracts per day. Volatility1 and volatility2 are the daily standard deviations of the mid-quote of intraday bid and ask prices, in cents/bushel. Trend1 (trend2) is the sum of close-open price changes in the previous five trading days, if the sum is positive (negative) or zero, else zero, in cents/bushel. BAS1 and BAS2 are the daily average bid-ask spreads.

Table 2. ADF Test of Stationarity

	ADF statistics	p-value	Lag terms
BAS1	-6.23	0.00	5
BAS2	-6.97	0.00	5
Volume1	-11.20	0.00	5
Volume2	-6.22	0.00	5
Volatility1	-17.39	0.00	5
Volatility2	-17.33	0.00	5

Note: The ADF test is conducted with an intercept but no trend terms.

Table 3. Regression Results for the Nearby BAS Series

	OLS		GMM-IV			
	Estimate	t value	Estimate	t value	Estimate	t value
Intercept	0.3300***	90.0	0.3530***	72.52	0.3209***	42.50
volatility	0.0148***	16.8	0.0080***	4.61	0.0074***	5.90
volume	-0.0009***	-16.9	-0.0011***	-11.58	-0.0010***	-5.95
maturity	0.0000	1.36	0.0000	0.18	0.0000	-0.36
trend1					0.0009***	4.29
trend2					-0.0005***	-3.83
RL					-0.0046	-0.72
PD_WASDE					0.0101*	1.76
GS					0.0421**	2.47
K					0.0105	1.21
N					0.0216	1.55
U					0.0251*	1.66
Z					0.0075	1.26
Tue					0.0079***	2.61
Wed					0.0022	0.74
Thu					0.0074***	2.78
Fri					0.0066**	2.34
d.f.	511		511		498	
adj. R square	0.50		0.42		0.56	
Endogeneity test			volume	0.00	volume	0.00
			volatility	0.00	volatility	0.00
Heteroskedasticity				0.00		0.00
Autocorrelation				0.00		0.00
Weak identification				0.00		0.00

Note: The asterisks ***,**,* indicate significance at the 1%, 5% and 10% levels. p-values are reported for each test. Volatility is the daily standard deviation of intraday mid-point of bid and ask quote prices in cents/bushel. Volume is in thousand contracts. Maturity measures the number of days to the switch to the next contract**.** Trend1 and trend2 are positive and negative price trend effects in cents/bushel. RL is a dummy variable for days that index funds roll the positions. PD_WASDE and GS are dummy variables for USDA report release dates. K, N, U, Z are dummy variables for contracts (May, July, September, December). Tue, Wed, Thu and Fri are weekday dummy variables.

Table 4. Regression Results for the Next Nearby BAS Series

	OLS		GMM-IV regression			
	Estimate	t value	Estimate	t value	Estimate	t value
Intercept	0.3510***	76.15	0.3662***	29.62	0.3459***	28.88
volatility	0.0138***	11.70	0.0044***	3.00	0.0017	0.92
volume	0.0014***	-19.92	-0.0012***	-5.37	-0.0005	-1.16
maturity	0.0009***	7.52	0.0011***	3.48	0.0014***	3.85
trend1					0.0008***	3.71
trend2					-0.0007***	-3.74
RL					0.0020	0.28
PD_WASDE					0.0170*	1.73
GS					0.0603*	1.80
K					-0.0107	0.80
N					-0.0200	-1.41
U					0.0223	1.16
Z					-0.0582**	-2.19
Tue					-0.0002	0.06
Wed					-0.0011	-0.33
Thu					0.0028	0.87
Fri					0.0031	0.89
d.f.	511		511		498	
adj. R square	0.57		0.53		0.65	
Endogeneity test			volume	0.00	volume	0.44
			volatility	0.00	volatility	0.00
Heteroskedasticity				0.00		0.00
Autocorrelation				0.00		0.00
Weak identification				0.00		0.00

Note: The asterisks ***,**,* indicate significance at the 1%, 5% and 10% levels. p-values are reported for each test. Volatility is the daily standard deviation of intraday mid-point of bid and ask quote prices in cents/bushel. Volume is in thousand contracts. Maturity measures the number of days to the switch to the next contract**.** Trend1 and trend2 are positive and negative price trend effects in cents/bushel. RL is a dummy variable for days that index funds roll the positions. PD_WASDE and GS are dummy variables for USDA report release dates. K, N, U, Z are dummy variables for contracts (May, July, September, December). Tue, Wed, Thu and Fri are weekday dummy variables.

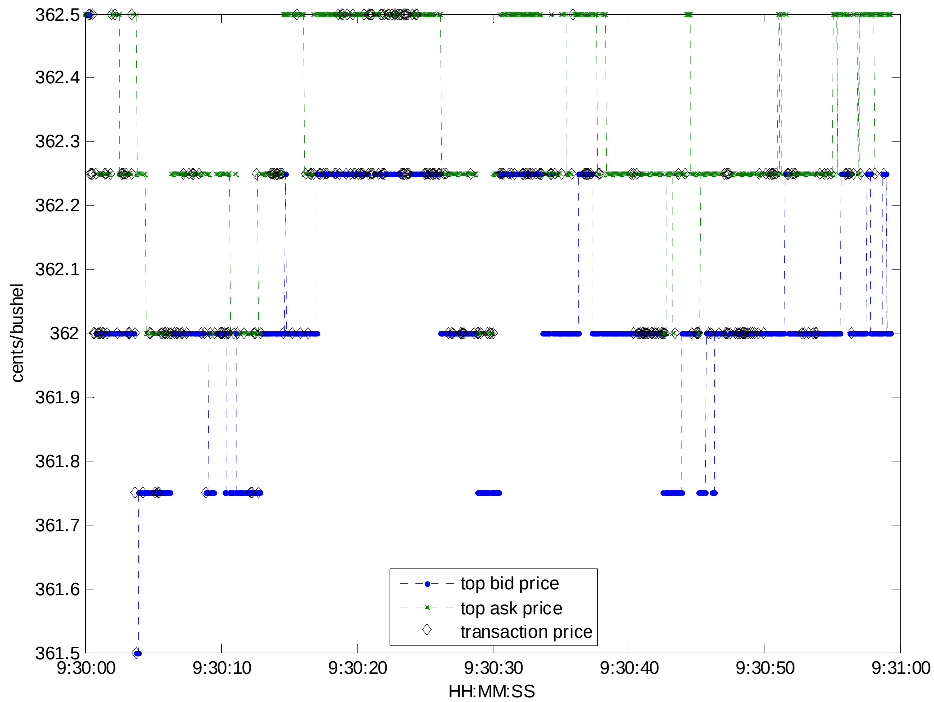


Figure 1. Quote and transaction prices for 2010 March contract on January 29, 2010 between 9:30:00-9:31:00

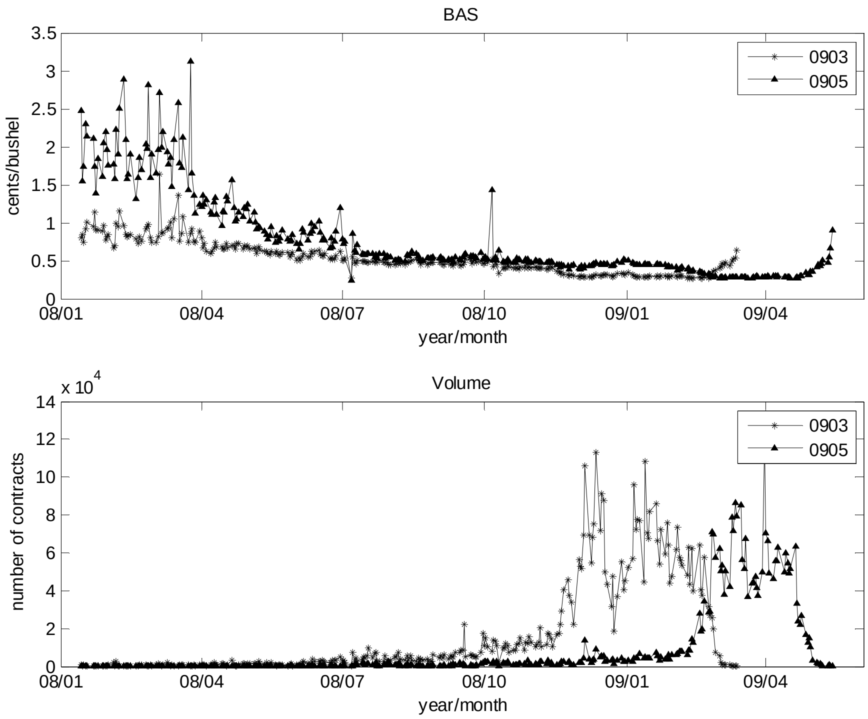


Figure 2 (a). BAS and Daily Volume for March and May 2009 Contracts

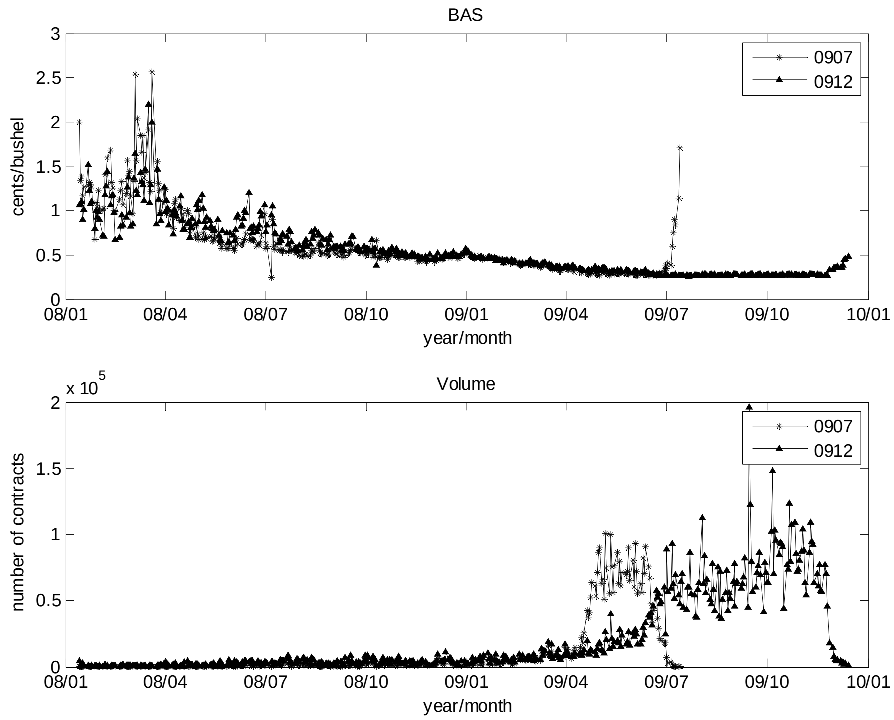


Figure 2 (b). BAS and Daily Volume for July and December 2009 Contracts

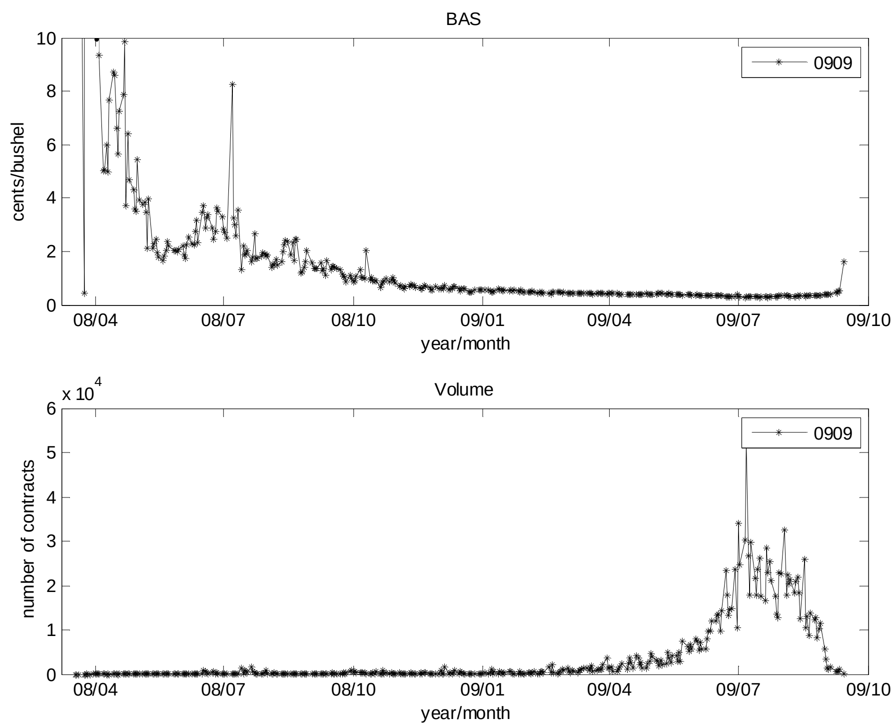


Figure 2 (c). BAS and Volume for September 2009 Contracts

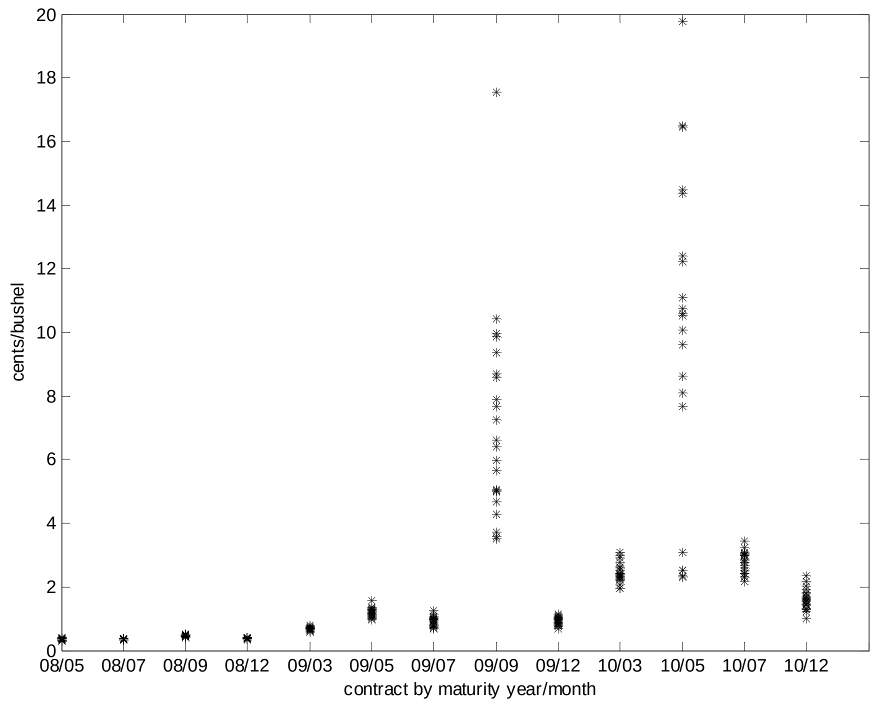


Figure 3 (a). BAS Term Structure in April 2008 (N = 22)

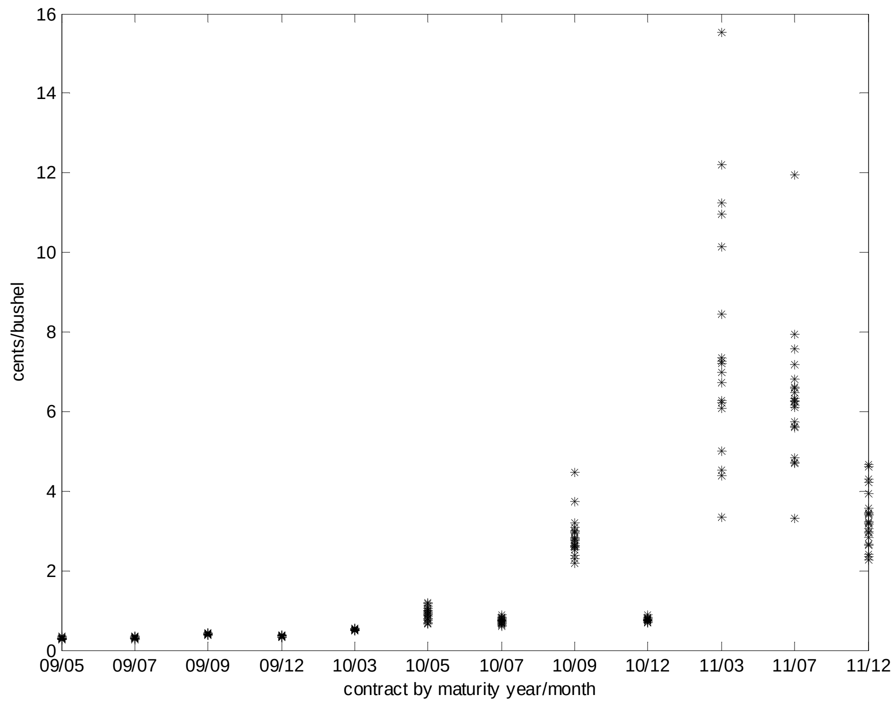


Figure 3 (b). BAS Term Structure in April 2009 (N = 21)

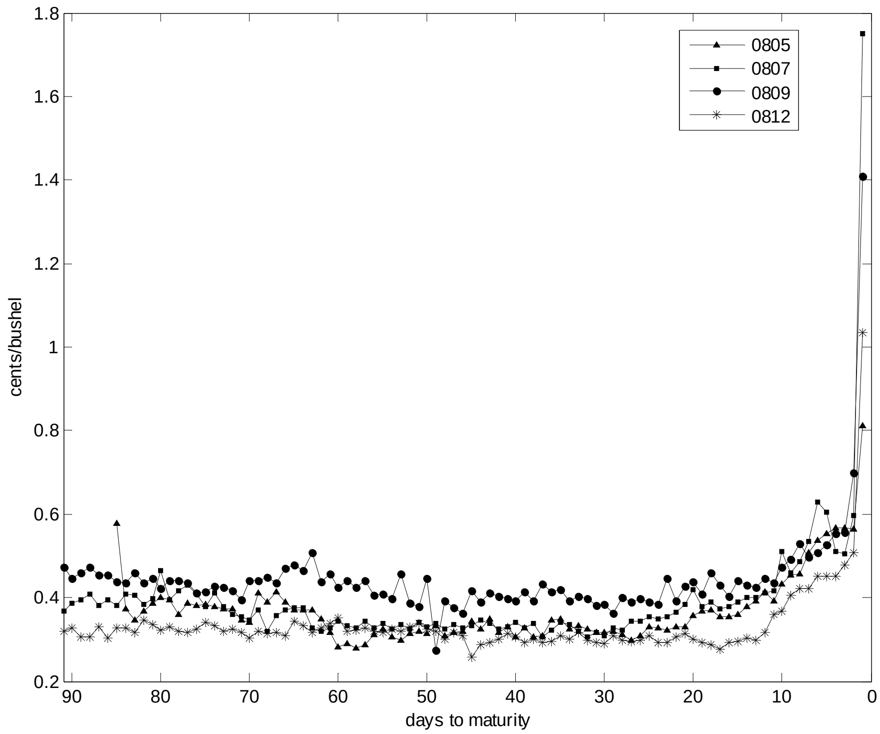


Figure 4 (a). BAS in Last 90 Trading Days for the May, July, September and December 2008 Contracts

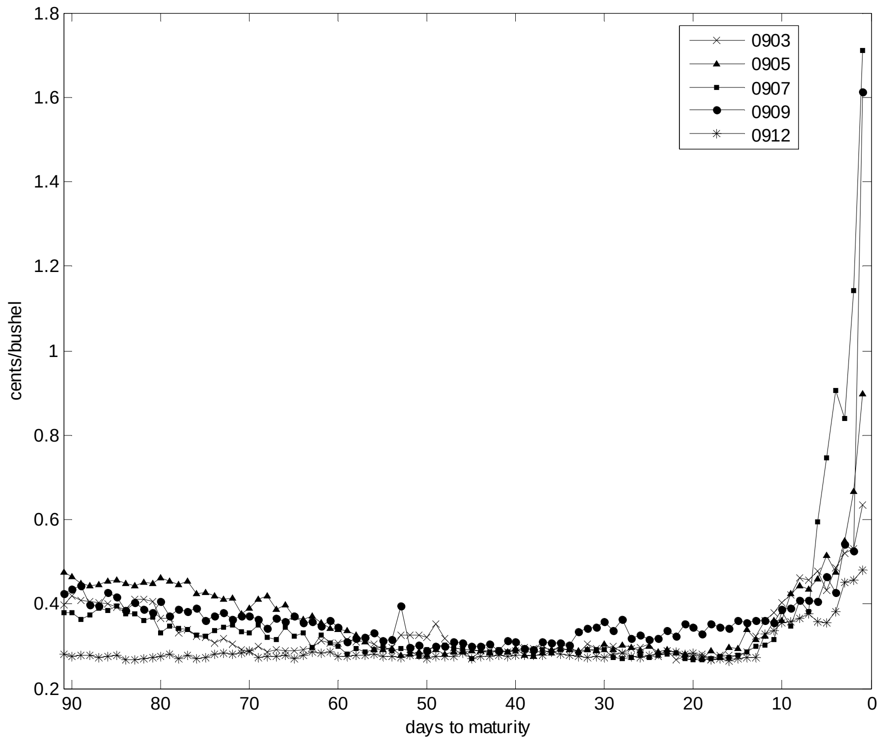


Figure 4 (b). BAS in Last 90 Trading Days for the March, May, July, September and December 2009 Contracts

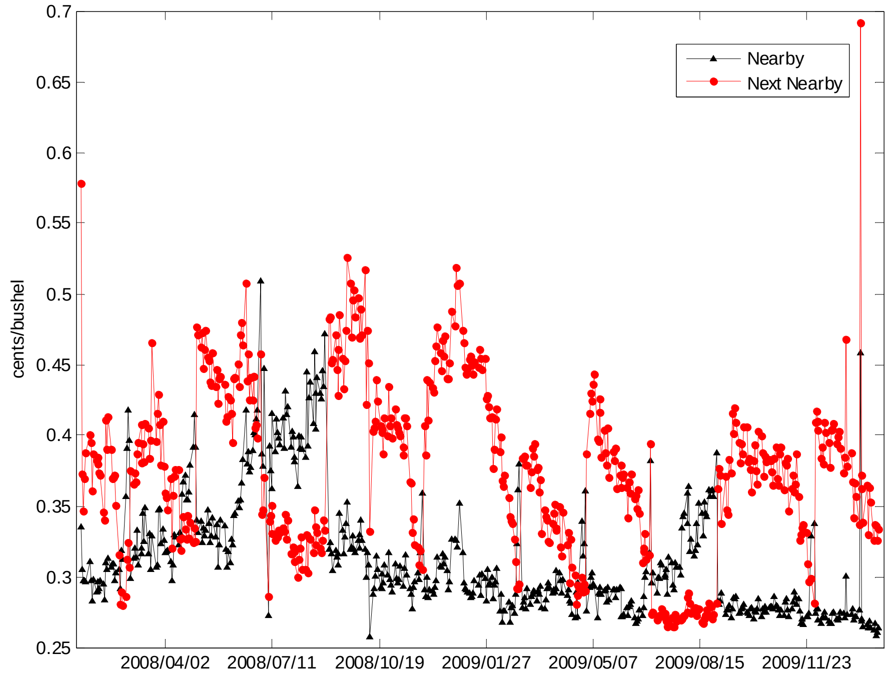
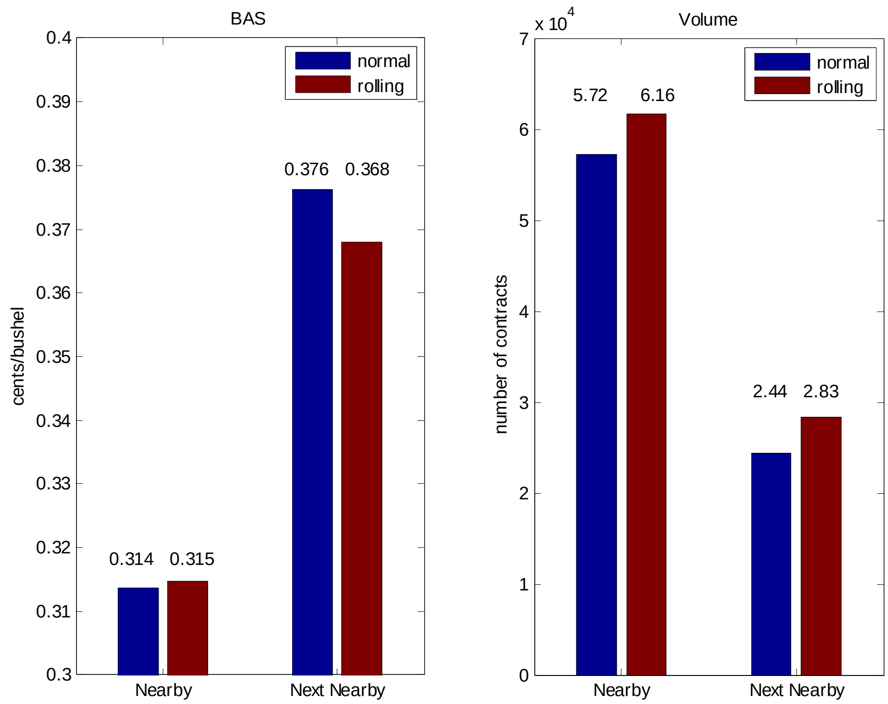
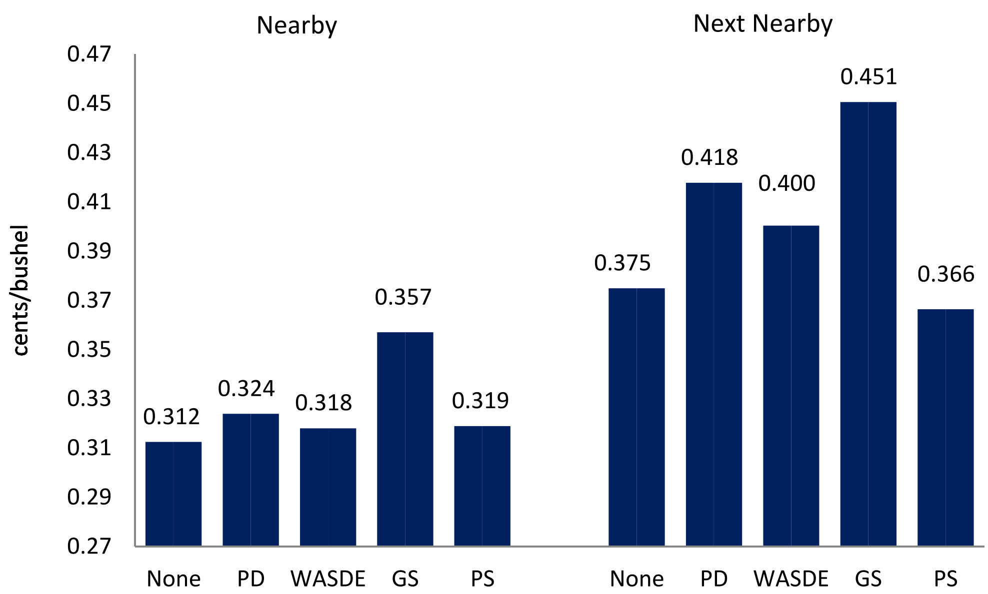


Figure 5. Daily Average BAS for the Nearby and Next Nearby Contracts



Note: The numbers above each column are the average values of the BAS and volume on the roll and normal days.

Figure 6. BAS and Average Daily Volume in Rolling and Normal Periods



Note: The numbers above each column are the average values of the BAS on announcement days. There are 12 Crop Production reports (PD), 25 WASDE reports, 8 Grain Stock reports (GS), 72 Crop Progress reports (PS), and 412 non-announcement days. Due to the late release time, the PS announcement days correspond to the following trading day.

Figure 7. BAS on Announcement and Non-announcement Days