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Electronic vs. Open Outcry: Side-by-Side Trading of KCBT Wheat Futures

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This study compares liquidity costs of electronic and open-outcry wheat futures contracts traded side-by-side on the Kansas City Board of Trade. Liquidity costs are considerably lower in the electronic market. Liquidity costs in the electronic market are still considerably lower after eliminating the bias created by splitting orders in the electronic market. Price volatility and transaction size are positively related to liquidity costs, while a negative relation is found between daily volume and liquidity costs. Price clustering at whole cent prices occurs in the open-outcry market which helps explain its higher liquidity costs. Daily volumes were distinctively higher during the Goldman-Sachs roll, but not enough to explain the higher liquidity costs in the open-outcry market. Trade size is larger in the open-outcry market, which suggests large traders prefer open-outcry trading.

Key Words: bid-ask spread, electronic trading, execution costs, KCBT, liquidity

Introduction

Futures and options exchanges worldwide are shifting from conventional open-outcry markets to electronic trading. Reasons for this shift include reduced transaction costs, fewer trading errors, and increased execution speed. Many agricultural markets now offer side-by-side trading of both open-outcry and electronic markets. Users need information about whether to execute orders in the open-outcry or the electronic market and are likely to prefer the market with lower liquidity costs. A liquidity cost is the cost incurred by buyers and sellers when using a market order to liquidate their positions quickly. For example, a person who desires to immediately sell a contract receives the prevailing bid price, while someone wanting to sell immediately would receive the ask price. The difference in price received by an urgent seller and the price paid by an urgent buyer is the liquidity cost.

Previous research has studied the effects of the migration from open-outcry to electronic trading on relative efficiency, execution costs, and informational efficiency, and mostly favors electronic markets. Examples include studies conducted by Ates and Wang (2005); Aitken et al. (2004); Tse and Zabotina (2001); Blennerhasset and Bowman (1998); Frino, McInish, and Toner (1998); Martens (1998); and Pirrong (1996). This past research has largely considered financial futures markets rather than agricultural commodity futures markets. Because some aspects of the microstructure of financial futures markets are different from those of commodity futures markets, it is important to investigate whether findings about financial futures markets are applicable to agricultural commodity futures markets. For instance, commodity futures markets tend to have much lower trading volumes that are more

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concentrated among a few large hedgers than in financial futures markets, and have a relatively higher proportion of informed traders (Foster and Viswanathan, 1996).[1] Thus, the automation of trading may have a different impact on liquidity costs in a commodity futures market than in a financial futures market.

Two studies investigated the transition to electronic trading in commodity futures markets. First, Bryant and Haigh (2004) evaluated the impact on liquidity costs of moving from open-outcry to electronic trading only, using a before-and-after comparison in two London International Financial Futures and Options Exchange (LIFFE) commodity futures markets. In contrast to previous research findings in financial futures markets, they found that liquidity costs increased after the LIFFE market moved to electronic trading. Second, Frank and Garcia (2009, 2011) measured the impact of adding an electronic market alternative to liquidity costs in lean hogs and live cattle futures markets. They report that increased electronic trading reduced liquidity costs. There is no consensus about the impact of electronic trading on liquidity costs in commodity futures markets, which motivates further investigation of the issue. The question of whether or not the findings of financial futures markets are applicable to commodity futures markets remains unanswered. None of the studies of commodity markets compared liquidity costs in electronic versus open-outcry markets with side-by-side trading.

Accordingly, this study compares liquidity costs in side-by-side trading of electronic and open-outcry wheat futures contracts traded at the Kansas City Board of Trade (KCBT). The KCBT introduced electronic trading on the CME Globex® platform on January 14, 2008. At KCBT, electronic and open-outcry markets coexist. Intraday transaction prices are used to estimate liquidity costs since KCBT does not provide bid-ask quotes for the open-outcry wheat futures market and only irregularly provides them for the electronic market. Average absolute price deviation and Roll's (1984) measure based on the autocovariance of prices are used as measures of liquidity cost. A new approach is used to estimate liquidity cost in the electronic market, which eliminates bias due to splitting orders in the electronic market.[2] The study identifies the impact of different factors such as daily volume, volume per trade, and price volatility on liquidity costs. To explain the difference in liquidity costs in the electronic and open-outcry markets, we also examine the degree of price clustering in the two markets. The potential impact of the Goldman-Sachs roll on the KCBT wheat open-outcry market is examined to determine if it is likely to explain much of the difference in liquidity costs in the two markets.

Expected Differences in the Two Markets

A key difference between electronic and open-outcry trading is the different order execution rules. At KCBT, open-outcry trading occurs on a trading floor where members (traders) trade continuously through open outcry. Traders publicly announce bid and ask prices. If a trader finds a bid or ask attractive, the trader simply sells at the bid or buys at the ask price. The transaction price is then made public. Quotes are valid only for a short time. A trader can also request a quote, and then may accept the best price or refuse to trade. When there are multiple traders with the same offer or ask, the buyer or seller can choose with whom to trade.

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[1] An informed trader possesses information not reflected in the current market price, and thus can profit by trading based on that information.

[2] In the electronic market, a large market order is often offset by multiple limit orders (sometimes at different prices). These are reported as multiple transactions, and thus the single market order ends up being split. In the open-outcry market, a large market order is typically offset by a floor trader taking the other side at a single price.

Electronic trading is a continuous auction system with automatic order matching in which traders communicate only via computer screens without revealing their names. The automatic auction mechanism matches market orders with existing limit orders. For multiple identical best bids or asks, the trade is assigned to the order that has been in the system the longest. Unlike the open-outcry system, a bid or ask quote is valid until it is explicitly withdrawn from the system. Large market orders often will be offset with multiple limit orders that are selected according to price and the time the quote entered the system. The electronic system will report the single market order as multiple trades if it is offset by more than one limit order.

The electronic market's splitting of market orders as a result of order matching may create downward bias in estimates of liquidity costs. No previous study of liquidity costs in electronic markets has attempted to account for this bias. To eliminate this bias, probable splits in the data set are identified and aggregated to represent one order, and then estimates of liquidity costs are calculated.

One obvious difference between the two trading systems is the limit order book.[3] In electronic trading, traders have access to an anonymous limit order book, while in open-outcry trading, no official limit order book exists. However, identities and the behavior of other traders can be observed on the floor. Some researchers have argued that this anonymity of market participants in an electronic market increases adverse selection, which causes higher bid-ask spreads (Glosten, 1994; Bryant and Haigh, 2004). Another important difference between the two trading systems is order execution. In electronic trading, a large order can be matched with several orders from the limit order book at different prices. Also, an electronic market may not have enough orders in the limit order book to offset a large order without a large price impact. Therefore, large trades may have lower liquidity costs in open-outcry markets than in electronic markets.

Prior to the opening of side-by-side trading at the KCBT, Borchardt (2006, p. 13) offered the following explanation for why large traders would prefer open outcry:

> Personally, I truly believe that the liquidity will still rest in the trading pits during open outcry, but what you may see is that some of the small orders, that are more of a nuisance to the pit than they are a help, may bleed over to the electronic system to be executed.… But, the liquidity will still reside in the pit. When I first came to the exchange back in 1982, you'd go down to the floor, and if someone was trading 10 or 20 contracts, that was a pretty good size. And 50 contracts was huge! Now everybody in the pit will trade 50, and most of them will trade 100, and there is a core group of people down there who will trade 300 to 500 contracts at a time. They're the true liquidity providers, the depth that's needed for the big commercials and for the financial monies that are flowing into the exchange.

Price clustering offers alternative hypotheses about the expected differences in liquidity costs in the two markets. With price clustering, transactions occur more at some prices than at other prices. Several past studies across different market structures and financial instruments have observed price clustering at round numbers (Klumpp, Brorsen, and Anderson, 2007). Market participants tend to use round number prices more frequently than fractions, which results in concentration of transaction prices around round numbers. Several hypotheses have been proposed to explain the clustering of prices: the negotiation hypothesis, the attraction hypothesis, the collusion hypothesis, and the economic-cost hypothesis.

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[3] The limit order book is the record of all unexecuted limit orders.

According to the negotiation hypothesis (Harris, 1991), traders use a limited number of price points to simplify and reduce the cost of negotiation. When fewer price points are used, negotiations converge rapidly, thereby avoiding frivolous offers and counteroffers.

The attraction hypothesis (Ascioglu, Comerton-Forde, and McInish, 2007) suggests clustering is due to psychological preferences for some price points. Gwilym, Clare, and Thomas (1998) found a positive relationship between price clustering and bid-ask spreads in LIFFE bond futures and argued that their results generally favored the attraction hypothesis.

The collusion hypothesis (Christie and Schultz, 1994) argues that clustering is caused by implicit collusion of traders. Christie and Schultz found intense clustering in NASDAQ stocks and observed that even though the minimum price fluctuation at NASDAQ was 1/8 cent, the odd eighth quotes were virtually nonexistent in more than 70% of actively traded stocks. They concluded that NASDAQ dealers implicitly colluded to maintain wide spreads. After Christie and Schultz's results were reported, NASDAQ dealers sharply increased their use of odd-eighth quotes and effective spreads fell almost 50%.

The economic-cost hypothesis (Kleidon and Willig, 1995; Grossman et al., 1997), however, suggests that scalpers have a greater tendency to choose rounded quotations when the economic costs of scalping are high. In particular, when price volatility is high, price clustering allows participants to transact quickly in order to reduce risk (Gwilym, Clare, and Thomas, 1998).

Price clustering is more likely in the open-outcry market than in the electronic market. The negotiation and collusion hypotheses can only explain price clustering in the open-outcry market since the electronic market is anonymous. In open-outcry markets, the trades, especially large orders, can be implicitly negotiated in the trading pit by the floor traders. The negotiation hypothesis suggests such a process might lead to a less fine price grid, such as whole cents or half cents. Further, by the economic-cost hypothesis, due to more frequent transactions, scalpers in the electronic market can more easily ascertain the value of their holdings, which would result in less price clustering toward round numbers.[4] The converse can be argued for open-outcry trading. Hence, price clustering—and therefore higher liquidity costs—is expected to be greater in the open-outcry market than in the electronic market.

The three factors expected to affect liquidity costs in both trading systems are daily volume, volatility, and volume per trade. Previous research examining liquidity costs in futures markets finds that liquidity costs decrease as trading volume increases, and increase as price variability increases (Thompson and Waller, 1988; Brorsen, 1989; Thompson, Eales, and Seibold, 1993; Bryant and Haigh, 2004; Frank and Garcia, 2009). The volume effect implies the supply of liquidity services is downward sloping (Brorsen, 1989).[5] Scalpers benefit from economies of size, and these benefits are passed on in the form of lower liquidity costs. The higher volume in the 2008 KCBT electronic market (KCBT, 2008) is one reason why liquidity costs in electronic markets are expected to be lower than those of open-outcry markets. Conversely, holding inventory is risky in a volatile market, so traders increase the bid-ask spread to compensate for the increased risk. Hence, volatility is expected to have a positive correlation with liquidity cost. The third factor believed to affect liquidity costs is volume per trade. In the electronic market, high volume orders may not be filled at a single price. However, in the open-outcry market, a scalper may have a higher bid-ask spread for the largest orders.

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[4] Scalpers are extremely short-term traders who profit by selling at a price slightly above the last transaction and buying at a price slightly below the last transaction. Scalpers are the main liquidity providers in futures markets.

[5] This downward-sloping supply of liquidity services causes futures exchanges to be natural monopolies—likely explaining why competing futures exchanges do not offer identical contracts.

Data

The intraday prices used are the tick data for hard red winter wheat futures contracts traded at the Kansas City Board of Trade (KCBT, 2008). At KCBT, wheat futures contracts are traded with five expiration months: March, May, July, September, and December. The database contains a record of each trade price of the five contracts traded in both open-outcry and electronic markets in 2008. This year had unusually high and volatile prices. While we are not aware of any obvious reason why this volatility would affect electronic and open-outcry markets differently, the results need to be viewed with consideration that the year studied is atypical. The KCBT does not record bid and ask price for open-outcry wheat futures markets but, for its electronic wheat futures market, it provides occasional time-stamped bid and/or ask prices. However, because there are too few concurrent observed bid and ask prices to produce accurate estimates of liquidity cost, observed bid-ask spreads are not included. Regular trading hours for open-outcry trading at KCBT are 9:30 a.m. to 1:15 p.m. Monday through Friday. The electronic market operates during regular trading hours and 6:00 p.m. to 6:00 a.m. Sunday through Friday. One trading day for electronic trading is from 6:00 p.m. through 1:15 p.m. of the next day. Daily volumes in number of contracts for each contract in both markets are also from KCBT (2008).

Procedures

The bid-ask spread is an accepted measure of liquidity cost in security and futures markets.[6] If bid and ask prices are recorded, prevailing spread in any market could be directly estimated. However, bid and ask prices usually are not recorded for open-outcry futures markets, which creates a need for indirect measurement of bid-ask spreads. Various estimators have been developed that estimate bid-ask spreads using commonly available transaction data. Spread estimators developed in the literature have mostly used the covariance of successive price changes or have employed averages of absolute price changes. The former include Roll's (1984) measure and extensions of Roll's measure such as that proposed by Chu, Ding, and Pyun (1996), which relaxes the assumption of equal probability of trade direction in Roll's measure. Holden (2007) developed a model that uses both serial correlation like Roll's measure and price clustering to estimate the effective spread. The latter type of estimators, which employ absolute price changes, include average absolute price deviation proposed by Thompson and Waller (1987) and a different average absolute price deviation measure used by the Commodity Futures Trade Commission (CFTC). The CFTC measure includes only nonzero price deviations and price changes that are in the opposite direction of the previous change. Smith and Whaley (1994) suggest a method to estimate effective bid-ask spread from transaction data in futures markets that uses first and second moments of absolute price change distribution. Frank and Garcia (2011) used a modified Bayesian approach proposed by Hasbrouck (2004) to estimate bid-ask spread in commodity futures markets and discussed its performance compared to other estimators. For a comprehensive discussion of performance of various spread estimators, interested readers are directed to Locke and Venkatesh (1997), Bryant and Haigh (2004), and Goyenko, Holden, and Trzcinka (2009).

[6] The preferred measure is the effective spread. The effective spread is the absolute value of the trade price minus the midpoint of the most recently quoted bid and ask prices. The liquidity cost on a round turn, which is what we calculate, is then two times the effective spread.

We are interested in relative behavior of spreads in the two markets rather than individual performance of spread estimators. Considering the objectives of the study and quality of data available, the present study uses only Roll's measure and average absolute price deviation as estimators of bid-ask spread. Moreover, use of these two measures enables comparison of the results of this study with previous studies of Thompson, Eales, and Seibold (1993) and Shah, Brorsen, and Anderson (2009), which used the same measures to estimate liquidity costs in the KCBT wheat futures market.

According to Roll (1984), if markets are informationally efficient, the covariance between price changes is negative and directly related to the bid-ask spread. Roll's measure (*RM*) is designated by:

$$RM = 2\sqrt{-\operatorname{cov}(\Delta F_t, \Delta F_{t-1})}\ , \tag{1}$$

where ΔF_t is the change in price at time *t.* Roll's measure is more precise with more frequent observations since most price movements will then be due to bouncing between bid and ask prices rather than changes in equilibrium prices. Thompson and Waller (1987) suggest the average absolute value of price changes as a measure of average execution costs. Average absolute price changes are calculated as:

$$\textit{Average Absolute Price Change} = \frac{1}{T}\sum_{t=1}^{T} |\,\Delta F_t\,|\,. \tag{2}$$

The liquidity costs for the five contracts are estimated in both electronic and open-outcry futures markets using Roll's measure and average absolute deviations. Each measure is calculated for each day and then averaged for the life of the contract weighted by daily number of trades.

In electronic markets, if the market order is larger than the first-in-line limit order, the large order is split into smaller orders and matched with two or more limit orders, sometimes at different prices, resulting in underestimated liquidity costs. When an order is split, the electronic market data record the transaction as multiple observations, even though it is only one market order. To overcome this bias, all probable splits in the data set are identified. In electronic markets, matched trades are time-stamped with the precision of seconds. We assume the trades at the same second can only be recorded if they are split. The probability of two orders arriving in the same second is small given the number of trades in the KCBT wheat futures market. All trades occurring at the same time (same second) are averaged and treated as a single observation. Then average absolute price deviations are calculated from the reduced data set and referred to as aggregate average absolute price deviations.

To test hypotheses about factors influencing liquidity costs, the following regression equation is estimated using restricted maximum likelihood:

$$L_{mt} = \beta_0 + \beta_1 AV_{mt} + \beta_2 TV_{mt} + \beta_3 V_{mt} + \omega_t + e_{mt}\ , \tag{3}$$

where L_{mt} is liquidity cost of maturity month *m* on day *t*, AV_{mt} is volume (number of contracts) per trade, TV_{mt} is volume, V_t is price volatility measured as the difference between highest price and lowest price (range), and ω_t is random effect of trading day. The error terms ω_t and e_{mt} are assumed independently distributed normal with mean zero and variances σ_ω^2 and σ_e^2. Apart from the fixed effects explained by the first three independent variables in the above model, ω_t explains any random effect of day on liquidity cost. If the estimate of σ_ω^2 is zero, the model is equivalent to ordinary least squares.

Table 1. Descriptive Statistics of Wheat Futures Contracts Traded at KCBT in 2008

	Open-Outcry			Electronic		
Contract	N	Average Trades per Day	Average Volume per Trade	N	Average Trades per Day	Average Volume per Trade
March	51	132.02	57.33 (92.21)	51	1,000.31	23.74 (66.36)
May	93	85.08	45.50 (78.37)	93	610.55	14.12 (42.59)
July	134	167.01	23.67 (13.13)	134	1,194.60	3.67 (2.37)
September	177	84.60	27.89 (36.94)	85	1,417.75	5.24 (5.79)
December	241	72.04	33.97 (21.67)	241	991.13	3.62 (3.04)

Notes: Values in parentheses are standard deviations. Average volume is number of 5,000-bushel contracts.

In previous literature, several measures of volatility—such as range, variance, and standard deviation of prices—were used to determine the impact of volatility on liquidity cost. Variance and standard deviation of intraday prices, however, would measure almost the same thing as our dependent variable. Hence, daily range of prices is used as a measure of volatility. The daily price range is included to measure uncertainty about the underlying asset value. Since the dependent variable must be positive, the residuals are not truly normal as assumed, but statistical tests are asymptotically valid as long as residuals are asymptotically normal. Separate regressions are estimated for open-outcry, the electronic market, and the electronic market with aggregate trades. Pooling of data from the open-outcry and electronic markets was rejected using a Chow test (F-statistic= 37.75).[7]

Results

Total volume traded in wheat electronic futures markets during 2008 at KCBT was 1,882,302 contracts, compared to 1,033,741 contracts in open-outcry markets (KCBT, 2008). Table 1 reports the number of trades and volumes by contract month. Average trades per day in the electronic markets are larger than for open-outcry markets. However, average volumes per trade for electronic markets are considerably lower than those for open-outcry markets. The small trade size in the electronic market might be partly due to splitting of large orders with electronic trading. Also, as argued by Martens (1998), traders may trade differently in electronic markets and they could choose to enter several small orders rather than a single large order when trading in the electronic market.

Figure 1 shows monthly volumes for electronic and open-outcry markets. Figure 2 presents the daily volume of the July 2008 contract for electronic and open-outcry contracts. The results for the July contract are representative of all five contract months and only the results from the July contract data are presented. Daily volumes of July electronic contracts are higher than those of open-outcry contracts throughout the life of the contracts, with a few exceptions.

[7] When the model was estimated by combining data sets for both markets and using a dummy variable that was equal to zero for the electronic market and equal to one for the open-outcry market, the dummy variable had a significant coefficient of 0.77, indicating higher liquidity costs in the open-outcry market.

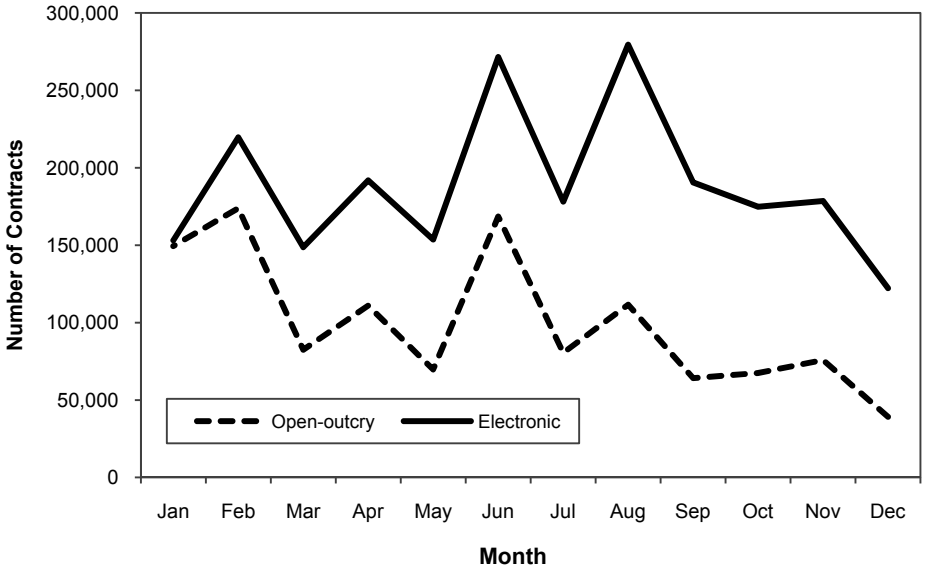


Figure 1. Monthly volume of KCBT wheat futures contracts in 2008

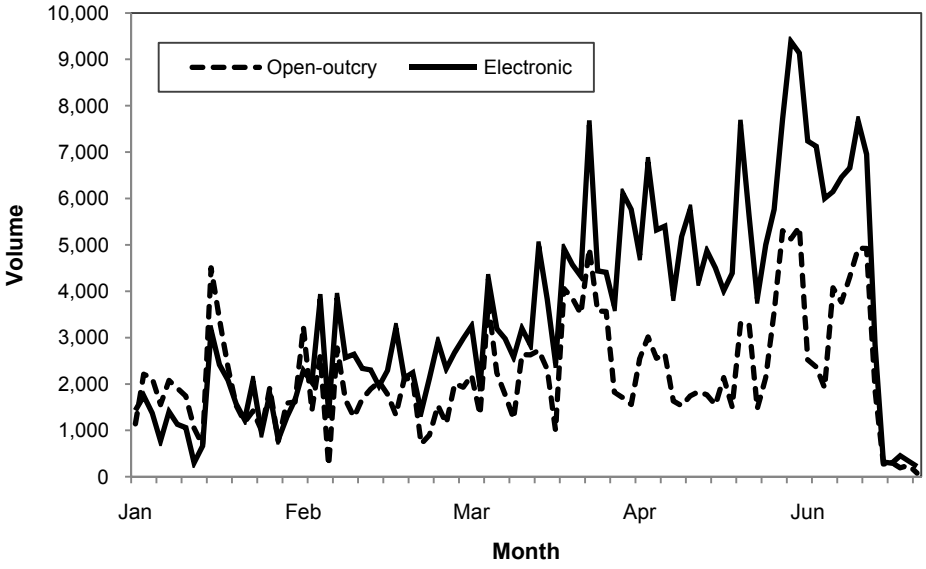


Figure 2. Daily volume of electronic and open-outcry July 2008 wheat futures contracts at KCBT

Table 2. Measures of Liquidity Costs (cents/bushel) in Wheat Futures Contracts Traded at KCBT in 2008

	Open-Outcry		Electronic		
Contract	Roll's Measure	Average Absolute Price Change	Roll's Measure	Average Absolute Price Change	Aggregate Average Absolute Price Change
March	1.41	1.31	0.41	0.38	0.52
	(1.76)	(19.97)	(0.58)	(0.56)	(0.67)
May	2.17	2.14	0.78	0.70	0.89
	(1.61)	(9.03)	(0.80)	(0.29)	(0.37)
July	1.18	1.23	0.47	0.41	0.51
	(0.87)	(9.98)	(0.39)	(0.27)	(0.32)
September	1.38	1.35	0.27	0.26	0.33
	(1.79)	(12.25)	(0.18)	(0.12)	(0.15)
December	1.56	1.44	0.26	0.30	0.40
	(1.73)	(10.50)	(0.33)	(0.29)	(0.36)

Note: Values in parentheses are standard deviations.

Table 2 presents the liquidity costs for the five contracts in both electronic and open-outcry futures markets. The electronic market has substantially lower liquidity cost. The average Roll's measure for electronic markets ranges from 0.26 cents per bushel to 0.78 cents per bushel, while open-outcry measures range from 1.18 cents per bushel to 2.17 cents per bushel. In a study of side-by-side trading in financial futures markets, Pirrong (1996) also found lower liquidity costs in the electronic market. Shah, Brorsen, and Anderson (2009) estimated the same measures for the July 2007 open-outcry wheat futures contract. They report a Roll's estimate of 0.45 cents per bushel and average absolute mean deviation of 0.49 cents per bushel.

Thompson, Eales, and Seibold (1993) also estimated the same measures for selected 1985 KCBT wheat contracts. Their estimates of average absolute deviations are 0.26–0.29 cents per bushel for highly traded contracts,[8] but are about double these values for lightly traded contracts such as the March contract during March or the September contract in February. Our estimates of Roll's measure and average absolute mean deviation for the July 2008 open-outcry contract are 1.18 and 1.23 cents per bushel, respectively. Lower volumes, higher prices, and higher volatility in 2008 likely led to higher liquidity costs than in 2007. The total trading volumes for the wheat futures markets in 2007 at the KCBT were 4,318,007 contracts and only 3,778,266 contracts in 2008 (KCBT, 2008). With the higher prices and higher price volatility in 2008, the risk associated with scalping clearly increased, which resulted in higher liquidity costs.

The average absolute deviations are also considerably lower in electronic markets than in open-outcry markets. The average absolute price deviations for electronic markets range from 0.26 to 0.70 cents per bushel (table 2). The frequency of the number of trades occurring at the same time in both electronic and open-outcry markets is presented in table 3. In each half of table 3, the first column reports the number of trades occurring at the same second. The other two columns indicate the frequency of those occurrences in the electronic and open-outcry

[8] The data set used by Thompson, Eales, and Seibold (1993) only recorded observations when prices changed. When the zero price changes are deleted, our estimates of liquidity costs increase by 42.63% and 46.16% in open-outcry and electronic markets, respectively.

Table 3. Frequency of Number of Trades Occurring at the Same Time in Wheat Futures Contracts at KCBT in 2008

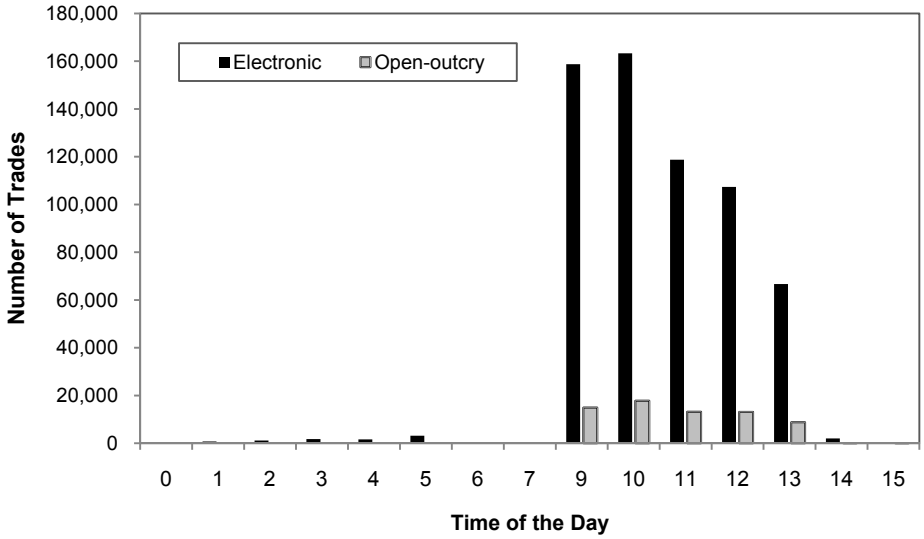
No. of Trades at the Same Time	Frequency		No. of Trades at the Same Time	Frequency	
	Electronic Market	Open-Outcry Market		Electronic Market	Open-Outcry Market
1	321,527	69,083	13	49	0
2	73,885	137	14	39	0
3	23,075	1	15	24	0
4	8,915	0	16	15	0
5	3,827	0	17	14	0
6	1,970	0	18	10	0
7	1,019	0	19	5	0
8	577	0	20	1	0
9	318	0	21	1	0
10	191	0	22	1	0
11	120	0	23	1	0
12	88	0			

Notes: In each half of the table, the first column indicates number of trades occurring at the same second in the data set. The remaining two columns show the frequency of those occurrences in electronic and open-outcry markets, respectively.

markets, respectively. For example, the third row in the table shows that three trades at the same second were observed 23,075 times in the electronic market, while three trades at the same second were observed only one time in the open-outcry market during 2008. The numbers reveal a much higher number of trades occurring at the same second in the electronic market than in the open-outcry market. This result is evidence of the splitting of large orders in the electronic market. To mitigate the bias of average absolute price deviation estimates created by splitting larger orders in the electronic market, aggregate average absolute price deviations are used (table 2). The estimates of aggregate average absolute price deviation range from 0.33 to 0.89 cents per bushel, which are higher than the nonaggregate trades, but still lower than those for the open-outcry market.

Figure 3 shows the number of trades by time of day. The open-outcry market opens at 9:30 a.m. and closes at 1:15 p.m., and most of the electronic market trading occurs during open-outcry trading. The possibility of arbitrage opportunities between the two markets should cause the prices to move together closely. Average liquidity costs at different times of the day are calculated by segmenting total trading hours in one-hour intervals (figure 4). The figure shows that liquidity costs are larger in the open-outcry market at both the open and the close. Ekman (1992) argues that informed traders are more likely to trade at the open and close, causing more price movements. The changes in equilibrium prices during these time periods could cause liquidity costs to be overestimated near the open and close. The electronic market shows greater liquidity costs outside open-outcry trading hours, which could be explained by the small volume.

Index funds mimicking the Goldman-Sachs Commodity Index traded substantial long positions during 2008. When the funds rolled positions into the next contract month (Goldman-Sachs, 2009), it could have also caused greater price movement, especially at the close. The Goldman-Sachs roll occurs on the fifth through the ninth business day of the month prior to the expiration month in the open-outcry market at KCBT. Figure 5 presents average daily



Note: For the open-outcry market, the first bar represents 30 minutes of trading and the last bar represents 15 minutes; the other bars represent one hour of trading.

Figure 3. Number of trades at different times of the day at KCBT in 2008

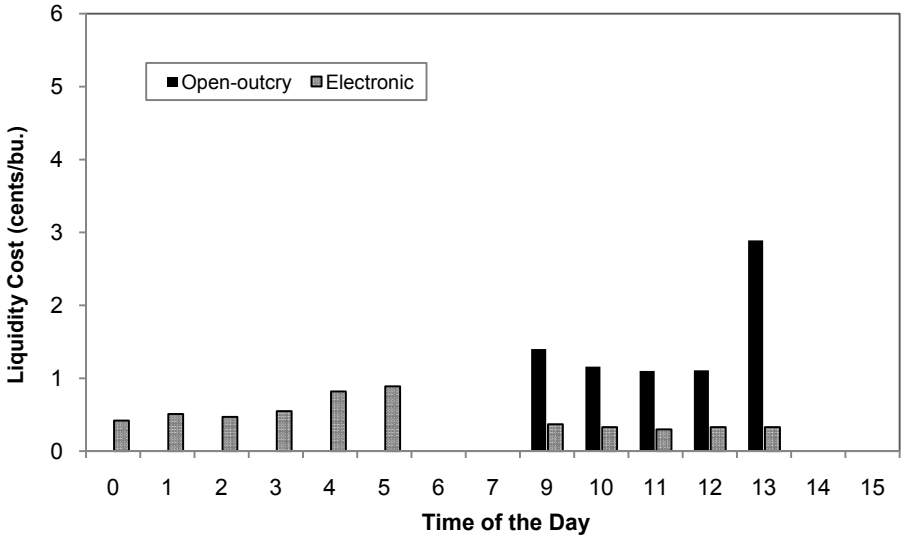


Figure 4. Liquidity costs at different times of the day at KCBT in 2008

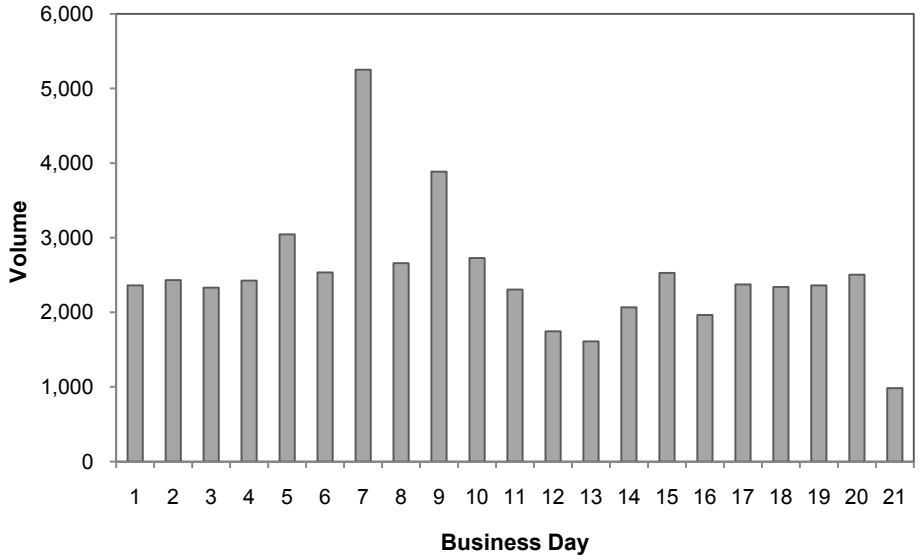


Figure 5. Average daily volume in penultimate (next-to-last) contract months of KCBT HRW wheat open-outcry contracts in 2008

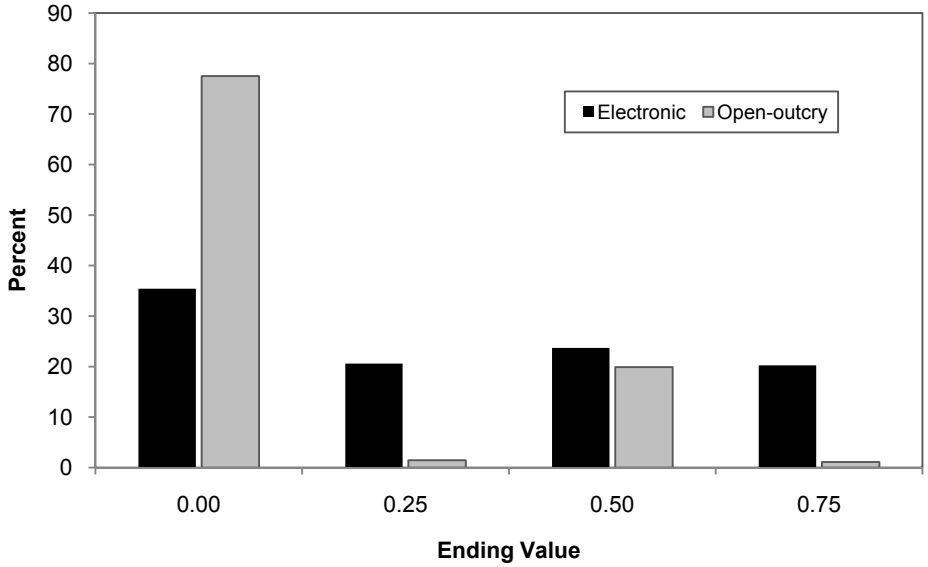


Figure 6. Ending values of trade price in electronic and open-outcry markets at KCBT in 2008

Table 4. Regressions with Average Absolute Price Change as Dependent Variable

Market	N	Intercept	Range	Volume per Trade	Total Volume	R^2
Open-Outcry	675	0.868 (< 0.001)	0.050 (< 0.001)	0.040 (< 0.001)	−0.0006 (< 0.001)	0.309
Electronic	594	1.031 (< 0.0001)	0.009 (< 0.001)	0.025 (< 0.001)	−0.0002 (< 0.001)	0.325
Electronic (aggregate)	594	1.110 (< 0.001)	0.012 (< 0.001)	0.020 (< 0.001)	−0.0002 (< 0.001)	0.334

Notes: Numbers in parentheses are *p*-values. OLS estimation was used to produce R^2 values. All parameters remain significant with low *p*-values if White's heteroskedasticity-consistent covariance matrix is used to compute standard errors.

volume in the month prior to expiration for the five contracts under investigation. The roll period appears to have higher trading volume compared to the rest of the month, especially the seventh business day. However, no significant difference in liquidity costs is found during the roll period. Hence, the Goldman-Sachs roll does not explain the higher liquidity costs in the open-outcry market.[9]

At KCBT, wheat contracts are traded in increments of 2/8, 4/8, or 6/8 of a cent. Hence, the ending digits after the decimal point of any price can only be 0, 25, 50, or 75. Figure 6 shows the frequency of prices ending in the four possible digits. The figure indicates that the clustering of prices to whole numbers is much more prevalent in the open-outcry market than in the electronic market. In the open-outcry market, almost 78% of prices are whole numbers compared to 35% in the electronic market. Chung and Chiang (2006) also found more price clustering in open-outcry index futures compared to E-mini index futures.

To determine the interrelationships among liquidity cost, volatility, average volume per trade, and total daily volume of the contract, we estimated the model in equation (3) using restricted maximum likelihood. As a proxy for liquidity costs, both Roll's measure and average absolute price change were used as dependent variables. The measures produced similar results. However, the regression with average absolute price change had more observations and thus larger *t*-values compared to using Roll's measure as the dependent variable.[10] Hence, only the results of the regression with average absolute price change as the dependent variable for open-outcry and electronic markets are presented in table 4. The results show a significant negative effect of daily volume on the liquidity costs for both electronic and open-outcry markets. The negative effect of volume is consistent with higher volumes reducing the risk of holding contracts, which results in lower liquidity costs. A significant positive impact of price volatility on liquidity costs is found in both markets. However, the sensitivity of liquidity cost to price volatility is less in electronic than in open-outcry markets. The effects of total volume and volatility are consistent with findings reported by Thompson and Waller (1987), Thompson, Eales, and Seibold (1993), and Bryant and Haigh (2004). The average volume per trade shows a positive significant impact on liquidity costs, indicating traders face more risk in holding a larger number of contracts, which results in higher liquidity cost.

[9] The average liquidity costs during the Goldman-Sachs roll period are 0.39 cents higher than those during the non-roll period. However, this difference is not significant (*t*-statistic = 0.69).

[10] With Roll's measure, numbers of observations were low because on several trading days, covariances of price changes were positive—resulting in non-real values for Roll's measure. The positive covariance occurred in 115 (out of 594) observations for electronic trading and in 291 (out of 675) observations for open-outcry trading.

Summary and Conclusion

This study sought to determine whether liquidity costs were larger in the open-outcry futures market or the electronic futures market. Intraday prices of five hard red winter wheat futures contracts traded on the Kansas City Board of Trade during 2008 are used. Roll's measure and average absolute price deviations are used to estimate liquidity costs. The average Roll's measure for electronic markets ranges from 0.26 cents per bushel to 0.78 cents per bushel, with a corresponding range for open-outcry markets of 1.18 cents per bushel to 2.17 cents per bushel. Both measures of liquidity costs are considerably lower in the electronic market than in the open-outcry futures market. The order matching system in electronic markets splits large orders into smaller orders when the corresponding limit order is for a smaller size, thus creating a downward bias in estimates of liquidity costs. After correcting for this bias, liquidity costs are still considerably less in the electronic market. Trading volumes are higher in open-outcry markets during the Goldman-Sachs roll period, but the Goldman-Sachs roll cannot explain the higher liquidity costs in the open-outcry market. More price clustering is found in the open-outcry market, which helps explain the higher liquidity costs in the open-outcry market. Higher trading volume in the electronic market is one explanation for its lower liquidity costs. The regression results suggest a negative relation between liquidity costs and daily volume, while volume per trade has a positive impact on liquidity costs in both electronic and open-outcry markets.

The results clearly show that the electronic wheat futures market has lower liquidity costs for all but the largest traders at KCBT. The key to continued existence of the open-outcry market appears to be its ability to handle large orders. One question is how can exchanges redesign electronic markets so that they are more attractive to large traders? A move to entirely electronic markets may require the largest orders to be executed off the exchange or may require large traders to take on the role of the scalper and submit a series of smaller orders to be executed sequentially rather than all at once. Agricultural producers and others submitting small market orders, however, should prefer the electronic market due to its lower liquidity costs.

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References

Aitken, M. J., A. Frino, A. M. Hill, and E. Jarnecic. "The Impact of Electronic Trading on Bid-Ask Spreads: Evidence from Futures Markets in Hong Kong, London, and Sydney." *J. Futures Mkts.* 24(2004):675–696.

Ascioglu, A., C. Comerton-Forde, and T. H. McInish. "Price Clustering on the Tokyo Stock Exchange." *Finan. Rev.* 42(2007):289–301.

Ates, A., and G. H. K. Wang. "Information Transmission in Electronic vs. Open-Outcry Trading Systems: An Analysis of U.S. Equity Index Futures Markets." *J. Futures Mkts.* 14(2005):391–419.

Blennerhasset, M., and R. G. Bowman. "A Change in Market Microstructure: The Switch to Electronic Trading on the New Zealand Stock Exchange." *J. Internat. Finan. Mkts.* 8(1998):261–276.

Borchardt, J. C. "Kansas City Board of Trade: 150 Years of Commodity Market Evolution." Western Historical Manuscript Collection, University of Missouri, Columbia, 2006. Online. Available at http://web2.umkc.edu/WHMCKC/publications/KIMBALL/CNKPDF/Borchardt-04-19-2006.pdf.

Brorsen, B. W. "Liquidity Costs and Scalping Returns in the Corn Futures Market." *J. Futures Mkts.* 9(1989): 225–236.

Bryant, H. L., and M. S. Haigh. "Bid-Ask Spreads in Commodity Futures Markets." *Appl. Finan. Econ.* 14(2004):923–936.

Christie, W. G., and P. H. Schultz. "Why Do NASDAQ Market Makers Avoid Odd-Eighth Quotes?" *J. Finance* 49(1994):1813–1840.

Chu, Q., D. Ding, and C. Pyun. "Bid-Ask Bounce and Spreads in the Foreign Exchange Futures Market." *Rev. Quant. Fin. and Accounting* 6,1(1996):19–37.

Chung, H., and S. Chiang. "Price Clustering in E-Mini and Floor-Traded Index Futures." *J. Futures Mkts.* 24(2006):337–357.

Ekman, P. D. "Intraday Patterns in the S&P 500 Index Futures Market." *J. Futures Mkts.* 12(1992):365–381.

Foster, F. D., and S. Viswanathan. "Strategic Trading When Agents Forecast the Forecasts of Others." *J. Finance* 51,4(1996):1437–1478.

Frank, J., and P. Garcia. "Bid-Ask Spreads, Volume, and Volatility: Evidence from Livestock Markets." Paper presented at Agricultural and Applied Economics Association annual meeting, 26–28 July 2009.

———. "Bid-Ask Spreads, Volume, and Volatility: Evidence from Livestock Markets." *Amer. J. Agr. Econ.* 93(2011). doi:10.1093/ajae/aaq116.

Frino, A., T. McInish, and M. Toner. "The Liquidity of Automated Exchanges: New Evidence from German Bond Futures." *J. Internat. Finan. Mkts., Institutions, and Money* 54(1998):1901–1915.

Glosten, L. R. "Is the Electronic Open Limit Order Book Inevitable?" *J. Finance* 49,4(1994):1127–1161.

Goldman-Sachs. "Roll Period." 2009. Online. Available at http://www2.goldmansachs.com/services/securities/products/sp-gsci-commodity-index/roll-period.html.

Goyenko, R., C. Holden, and C. Trzcinka. "Do Liquidity Measures Measure Liquidity?" *J. Finan. Econ.* 92,2(2009):153–181.

Grossman, S., M. Miller, D. Fischel, K. Cone, and D. Ross. "Clustering and Competition in Dealer Markets." *J. Law and Econ.* 40(1997):23–60.

Gwilym, O., A. Clare, and S. Thomas. "Price Clustering and Bid-Ask Spreads in International Bond Futures." *J. Internat. Finan. Mkts., Institutions, and Money* 8,3–4(1998):377–391.

Harris, L. "Stock Price Clustering and Discreteness." *Rev. Finan. Stud.* 4(1991):389–415.

Hasbrouck, J. "Liquidity in the Futures Pits: Inferring Market Dynamics from Incomplete Data." *J. Finan. and Quant. Analy.* 39,2(2004):305–326.

Holden, C. "New Low-Frequency Liquidity Measures." Unpub. work. pap., Indiana University, 2007.

Kansas City Board of Trade. Wheat futures contracts trades, historical data. 2008. Online. Available at http://www.kcbt.com/historical_data.asp.

Kleidon, A., and R. Willig. "Why Do Christie and Schultz Infer Collusion from Their Data?" Report, Cornerstone Research, Menlo Park, CA, 1995.

Klumpp, J. M., B. W. Brorsen, and K. B. Anderson. "Producers' Preferences for Round Number Prices." *Agr. Fin. Rev.* 67(2007):377–385.

Locke, P. R., and P. C. Venkatesh. "Futures Market Transaction Costs." *J. Futures Mkts.* 17,2(1997):229–245.

Martens, M. "Price Discovery in High and Low Volatility Periods: Open-Outcry versus Electronic Trading." *J. Internat. Finan. Mkts., Institutions, and Money* 8(1998):243–260.

Pirrong, C. "Market Liquidity and Depth on Computerized and Open-Outcry Trading System: A Comparison of DTB and LIFFE Bund Contracts." *J. Futures Mkts.* 16(1996):519–544.

Roll, R. "A Simple Implicit Measure of the Effective Bid-Ask Spread in an Efficient Market." *J. Finance* 39,4(1984):1127–1139.

Shah, S., B. W. Brorsen, and K. B. Anderson. "Liquidity Costs in Futures Options Markets." In Proceedings of the NCCC-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management, St. Louis, MO, 2009.

Smith, T., and R. E. Whaley. "Estimating the Effective BID/ASK Spread from Time and Sales Data." *J. Futures Mkts.* 14,4(1994):437–455.

Thompson, S., J. S. Eales, and D. Seibold. "Comparison of Liquidity Costs Between the Kansas City and Chicago Wheat Futures Contracts." *J. Agr. and Resour. Econ.* 18(1993):185–197.

Thompson, S. R., and M. L. Waller. "The Execution Cost of Trading in Commodity Futures Markets." *Food Res. Institute Stud.* 20(1987):141–163.

———. "Determinants of Liquidity Costs in Commodity Futures Markets." *Rev. Futures Mkts.* 7(1988):110–126.

Tse, Y., and T. Zabotina. "Transaction Costs and Market Quality: Open-Outcry versus Electronic Trading." *J. Futures Mkts.* 21(2001):713–735.