The Effect of Settlement Rules on the Incentive to *Bang the Close*

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ABSTRACT

Closing prices on financial exchanges are often used as reference prices in other contracts. As such, the robustness of the process determining closing prices is an important feature of exchanges. This paper examines whether the 2012 change in the Chicago Board of Trade's (CBT) closing price procedure made reference prices more robust, especially regarding potential manipulation. We propose a theoretical model exploring incentives to manipulate reference prices under two alternative closing price regimes. We test several predictions of the model using a proprietary data set comprised of individual transactions in CBT corn futures, and find empirical support for these predictions.

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I. Introduction

In many long-term contracts, the price that will be paid for future deliveries is tied to some criteria based on third-party transactions, such as the observed closing (or *settlement*) price on an exchange, or an index of spot market transactions. Basing a contract's price on third-party transactions is common for swaps (such as the interest-rate swaps tied to London Interbank Offered Rate or LIBOR), and long-term forward contracts in energy and other markets. The goal in tying the price of the contract to these reference prices is typically to allow the contract to adjust to current market conditions, without allowing either party to the contract to influence the contract price (see, e.g., Crocker and Masten, 1991; Hart, 2009). The efficacy of the reference price in achieving this objective depends on how well the reference price actually reflects market conditions. Pagano and Schwartz (2003) note that the explicit purpose of the 1996 and 1998 changes in the settlement procedures on the Paris Bourse was to avoid a situation in which "a few, relatively small orders could change settlement prices in the equity market". [1]

Perhaps the best-known example of an instance in which traders actually influenced the settlement price occurred in the financial contracts that were linked to LIBOR. In the early 2000s, LIBOR was based on a daily survey of a small number of contributing banks, some of whom had portfolios whose values changed with the published LIBOR rate. Recent research, as well as legal settlements, suggests that the incentives created by these portfolios did influence responses to the survey, and hence influenced the published LIBOR rate.[2] In a recent LIBOR-related rate-fixing case, Deutsche Bank agreed to pay the U.S. Commodity Futures Trading

[1] The change on the Paris Bourse was to base settlement prices on a closing-time two-sided auction, rather than on the last-minute trades in the continuous market.

[2] See, e.g., Snider and Youle (2010), or the *Settlement Agreement between the U.S. government and Barclay's Bank.*

Commission (*CFTC*, the U.S. derivatives market regulatory agency) an $800 million fine, which was the largest fine in the CFTC's history.

These examples show that economic agents sometimes have the ability and incentive to influence a particular reference price. The LIBOR legal settlements, in particular, suggest that the economic impact of manipulation of reference prices can be dramatic. There is, however, limited empirical work documenting the significance of these incentives (see Carhart, Kaniel, Musto and Reed (2002), Ni, Pearson and Poteshman (2005), Comerton-Forde and Putnins (2011, 2014), and Atanosov, Davies and Merrick (2015)). One potential reason for the dearth of evidence-based studies of reference price manipulation is a lack of available transaction-level data that would allow a researcher to relate existing positions to trading activity. In the present paper, we make use of a data set from the Chicago Board of Trade's (CBT) corn futures market that allows us to directly relate positions to trading patterns. Moreover, the corn futures market is one in which the initial settlement rules made manipulation relatively attractive, and for which the rules changed (creating a natural experiment we exploit). In combination, these features allow us to examine not only the aggregate effects of the rule change but also, crucially, the behavior of individual traders.

In the LIBOR cases, banks apparently misreported the rates at which they could borrow funds in order to influence the value of their positions in swaps or forward contracts. In other circumstances, though, it may be profitable to make actual trades in order to affect the value of one's overall exposure to an asset price. We demonstrate this point with a theoretical model of trader positions and transactions that incorporates the critical features of a futures market, such as the use of the market to hedge cash market positions. We show that the incentive to manipulate the reference (or *settlement*) price is dependent on a trader's position in that contract, and traders may engage in seemingly uneconomic trades to exert some influence on the settlement price, or what is sometimes referred to as *banging the close*.[3]

Our model also shows that the profitability of manipulation fell when the CBT changed their settlement rules. Specifically, for a group of agricultural products, prior to June 25, 2012, settlement prices were based only on trades made on the CBT exchange floor during the final minute of trading. After that date, all trades made during the final minute of trading were included in settlement price determination -- whether those trades were made on the trading floor or on the CBT's electronic platform.

The first part of our empirical analysis uses aggregate statistics on the corn futures market to evaluate the high-level impact of this important change in the method of settlement price determination.[4] Our model shows that manipulative behavior will result in a "high" volume of floor trading during the settlement period under the old regime, and that rule change would reduce floor volume during the last minute (but not change floor trading at other times of the day). Consistent with the model, we find that, prior to the rule change, trading was especially active during the final minute of trading each day. This was particularly true for floor trading; on average, about 12% of the entire daily floor trading volume in corn occurred during that one minute (the trading day was 3.75 hours long).[5] In contrast, the volume of electronic trading during that same minute averaged about 4.5% of the total daily electronic trading volume. Further, we find that floor trading during that final minute declined dramatically following the

[3] The CFTC Glossary provides the following definition for the phrase *banging the close*: "A manipulative or disruptive trading practice whereby a trader buys or sells a large number of futures contracts during the closing period of a futures contract . . . in order to benefit an even larger position in an option, swap, or other derivative that is cash settled based on the futures settlement price on that day.

[4] The CBT corn futures contract was the largest market that had a rule change on that date. We also looked at the soy bean futures market, which was the second-largest market affected by the rules change. See Appendix B for details.

[5] Previous research has also documented high trading volume towards the end of the trading day in futures (e.g., Eaves and Williams, 2010) and in equities (e.g., Garety and Mulherin, 1992, Jain and Joh, 1988).

change, whereas last-minute trading on the electronic venue and trading at other times on both venues was not materially affected by the rule change.[6]

Theory also implies that the frequency of price reversals (where the direction of the price movement between the settlement price and next day opening price was opposite the movement between the before-closing price and the settlement price) is a measure of manipulation. We find that reversals became less common after the rule change. The aggregate statistics also show that settlement prices become more efficient after the change. In particular, we use a variance ratio test, and find that prices appear to follow a random walk after the rule change, but not under the initial regime.

In this sense, the aggregate statistics suggest that manipulation may have been more common under the initial regime. Our model yields additional implications about individual traders' behavior when manipulation does occur.

(1) The direction of individual trader's trades on the floor during settlement will be positively correlated with their existing positions.

(2) Traders with long positions entering the settlement period will be willing to pay a higher price on a floor trade than on electronic trades (and conversely for traders with short positions). Moreover, the incentive is increasing in the absolute size of those positions.

(3) The amount of overall trading during the settlement period should be increasing in the cost of maintaining a position.

(4) The absolute size of the positions of large traders will be decreasing in the cost of maintaining a position.

[6] The evidence presented is consistent with the reaction of CBT traders. Specifically, a group of traders who apparently were specialized to floor trading sued the exchange over its change in settlement rules. See, *McKerr et al. v. The Board of Trade of the City of Chicago Inc* (McKerr v. Board of Trade, 2012 WL 3544866 (N.D. Ill.)).

Testing these implications enables us to examine whether the mechanism suggested by our model for how manipulation might occur is empirically valid. To test these predictions, we create a unique data set of individual positions and trades for active[7] floor traders during the initial settlement rule period (March 1st, 2012 to June 25th, 2012). We show that the implications arising from our model are supported by the data. For example, we establish empirically that the larger a trader's pre-existing position, the more likely it is that an observed settlement-period floor trade is a buy (rather than a sell). This finding is consistent with the first implication of our model.

In the case of the CBT corn contract, our evidence suggests that the settlement prices determined under the initial settlement rule were more prone to manipulation. Similar to Pagano and Schwartz's (2003) examination of settlement price changes on the Paris Bourse, our study of the effect of the settlement procedure change on the CBT suggests that the change did result in a more robust settlement process.

The remainder of the paper is organized as follows. Section II discusses the basic intuition of manipulation models, and provides some institutional background to show how the incentive to manipulate arises in futures markets. Section III presents the theoretical model and describes the incentives present for traders to influence the settlement price. Section IV describes our unique data set. Section V provides our empirical analysis and results. Section VI deiscusses some policy implications of our analysis. Section VII concludes.

[7] As discussed in detail below, we define a trader as "active" based on his volume of settlement-period floor trading.

II. Incentives to Influence Pricing

The means of, and the motivation for, manipulating prices is a function of the economic and institutional framework of the trading platform. For this reason, we highlight the institutional features of futures markets in sub-section B. At the same time, the underlying economics of manipulation are common across markets. As such, sub-section A outlines previous work, and the relationship of our model to that literature.

A. Related Literature

The premise of manipulation is that traders can affect price though their trading. The profitability of such action comes about through the effect of that price change on the value of the existing position of the trader. To have an effect on price, the counterparties to the would-be manipulator must have finite elasticities of supply. In Kumar and Seppi (1992), the finite elasticity results from the presence of an informed trader. When the manipulator trades in one direction, other uninformed traders cannot distinguish between the manipulator's orders and the informed trader's orders, and hence revise their estimates of the fundamental value when they observe the volume of trading. In other models, the finite elasticity results from different assumptions about trader's utility functions (Hillion and Suominen, 2004), information (Kyle, 1984) or the supply of the underlying product (Pirrong, 2004).

The other requisite condition for profitable manipulation is that the manipulator has a position in an asset whose value is a function of the final settlement price in the manipulated market. For example in Kumar and Seppi, the manipulator has a large position in the futures market, which is valued at the final price that obtains in the spot market.[8] Hence, by changing the spot price, the manipulator changes the value of his position in the futures market. Dutt and Harris (2004) apply this idea in analyzing the incentive of traders in cash-settled options markets, where the options' values are determined by the settlement price on an equity or futures exchange. Dutt and Harris show that traders with sufficiently large positions in such options may attempt to move the price of the underlying equity or futures contract.

There is some empirical evidence regarding the effects of manipulation. Carhart et al. (2002) find evidence suggesting that mutual funds buy additional shares of the stocks in their portfolios during the final trading hour of each quarter in order to raise the price of those stocks, thereby raising the measured quarterly return to the fund. Ni et al. (2005) find evidence that firms with options positions were successful in influencing the closing prices of the associated equities on option expiration dates, so as to increase the value of those firms' options positions. Comerton-Forde and Putnins (2011) look at a series of events in which a US or Canadian court determined that manipulation did occur, and find that "manipulated" stocks had higher returns, larger trading volumes and larger average trade sizes than the control group. Atanosov, et al.(2015) examine prices in two metals futures markets during a period in which a trader was manipulating price (according to a court). The hypothesized mode of manipulation was through excess trading on the floor (which was less liquid than the electronic market). They find that prices for floor trades were higher than on the electronic market on days when the manipulator was trading.[9] While Pagano and Schwartz (2003) do not directly examine manipulation, the experiment they study

[8] In contrast, in Hillion and Suominen (2004), the incentive to manipulate does not arise from asymmetries in positions, but rather from an incentive to improve the relative position of a previous trade; e.g., lower the settlement price in order to make the prices received on earlier sales seem better.

[9] In the futures markets studied by Atanosov et al, the typical number of floor traders was less than 10, suggesting that the floor was an illiquid market. In contrast, there were an average of more than 200 floor traders per day in the US corn futures market in the period we analysis (March- June, 2012).

bears a close relationship to the focus of our paper. As in our study, they examine the effects of a change in the settlement price determination process. Specifically, the Paris Bourse changed to settlement prices that are based on a closing auction, rather than the trades during a continuous end-of- day trading period. They find that measures of market quality rose following the rule change. In particular, they show that the explanatory power of the market model for price movements of individual stocks increases when the settlement rule changes for those stocks.

B. Institutional Background

Most of the modeling in theoretical work described above analyzes manipulation in the context of equity markets. While the basic logic of how manipulation can be profitable is general, how it will be implemented depends on institutional specifics. In this sub-section, we briefly describe some features of futures markets that are important for our modeling approach. First, in many futures markets (including corn) the daily settlement price is based a small set of trades. A second key feature is that, because hedgers often have large physical positions in the underlying commodity, they will have consequent large futures positions, leading to asymmetries in position size. A third feature is the practice of daily mark-to-market, and the associated requirement of additional collateral on a daily basis. That is, in futures markets, contracts are "marked to market" each day, so that traders will receive or pay the daily change in the futures prices for each contract held. For example, a 5 cent/bushel increase in the settlement price of corn means that every contract in corn futures is now worth .05 more, and consequently, traders with short positions in corn are required to post additional collateral (called margin) of $.05 per contract, while traders with long positions will have previously-posted collateral of that amount returned. Hence, the daily settlement price will affect a trader's short-term cash flows.[10]

[10] These incentives could conceivably be larger on the last trading day for each contract, as a 5 cent increase in settlement price means a 5 cent increase in the amount the long side has to pay the short side for delivery. However,

Because traders have an economic stake in the settlement price, they might have economic incentives to try to influence the settlement price through trading. For example, if the settlement price is based on the average price in floor trades during the final minute of trading, a trader with a large pre-existing long position might be willing to pay more than market price for his transactions on the floor during that window, in order to influence the required collateral on his remaining position. These trades are "uneconomic" in the sense that they are not profitable in isolation, but rather are profitable because of their effect on the trader's portfolio.

There are some examples of instances in which firms influenced the settlement price in order to avoid margin payment. Most prominently, in 2003, it was revealed that the president of First West Trading, who was a member of the NYBOT exchange committee that determined settlement prices, had influenced daily settlements in order to save itself from paying the mark-to-market margin (see, Klein & Company Futures, Inc. v. Board of Trade, 464, F.3d 255 (2d Cir. 2006)). When the exchange discovered the difference between the settlement prices and actual market values, First West's liability increased from $700 thousand to $4.5 million, which caused First West to default.

Settlement procedures vary between exchanges and over time. The NYBOT procedure in place in 2003 allowed for considerable discretion from committee members. The procedures we evaluate here were those in place on CME's CBT division for corn futures in 2012. By way of background, for CBT futures markets, trades can either be made on the floor of the exchange, or electronically by trading against a standing order in an electronic order book. Trades made in either venue are fungible with those made in the other.

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analysis of the data shows that, in fact, outstanding positions are quite small, and trading volume was zero or very close to zero on those dates during our sample period.

The settlement price procedure for several grain contracts changed on June 25, 2012. Prior to that date, the settlement price was based on trades made during the final minute of trading on the CBT trading floor; equal to the weighted average price of trades made on the floor during that minute. After that date, the settlement price was based on the weighted average of all trades made in that minute, whether on the floor, or through electronic trading.[11]

We view the CBT's decision to change settlement rules as exogenous to the changes in trading that occurred between March and October 2012 (the time period of our sample). The change in settlement rules likely reflects a fundamental shift in the technology of trading. Specifically, electronic trading has largely replaced floor trading on most markets as the technology of trading mechanisms has improved. In the corn futures market, the share of all futures trading that occurred on the exchange floor had fallen 50% over the two years preceding the rule change. It seems likely that the long-term trend away from floor trading meant that settlement prices based on floor-trades alone could be unrepresentative, and the CME rule change reflected this reality.[12] Because we examine a short event window and control for the trend in daily trading, it seems unlikely that the fall in floor trading that occurred during our sample led to the rule change.[13]

Viewing the rule change as exogenous leads to the central premise of our paper; to the extent traders do attempt to influence the settlement price, this rule change will have an impact on both whether and how they do so. Specifically, under the old regime, a trader attempting to influence the closing price would make his trades on the floor, since only those trades would

[11] In addition to the changes to how the settlement price is calculated, the CME also changed the hours of floor trading, effectively altering the minute in which settlement prices are calculated. Prior to June 25, 2012, the settlement period minute was from 1:14 p.m. – 1:15 p.m. and after the change it became 1:59 p.m. – 2:00 p.m..

[12] Statements of CME executives suggest that the increasing volume of electronic trading prompted the change. See, e.g., http://articles.chicagotribune.com/2013-11-04/business/chi-cme-trader-suit-20131104_1_cme-trading-executive-chairman-terrence-duffy-chief-executive-phupinder-gil.

[13] The trend towards electronic trading continued beyond our sample period, which led the CME to close the corn futures trading floor in 2015. See Gousgounis and Onur (2016) for more discussion on the trading floor closure.

affect the settlement price. This incentive to trade on the floor greatly diminishes after the rule change, and we observe this change in our data, as presented in Section V. In the next Section, we formally model how manipulation might occur in this market, and how the ability to affect settlement price varies with the rule change.

III. Modeling Trading Behavior

In this section, we develop a model to formally illustrate how changes in the settlement regime can affect traders' incentives/ ability to influence the settlement price. The model incorporates the salient features of the market described above. We first model hedger behavior and price determination under the initial regime (in which settlement price is based on floor trades only), and then consider how hedger behavior changes when the regime changes. As such, we generate testable implications both for trading patterns observed under the initial regime, and for how the rule change affects trading in the market.

The main intuition of the model is that under the initial regime, the supply of liquidity to the hedger is less elastic than under the new regime. As such, the hedger has greater ability to influence price under the initial regime. In particular, a hedger with a long futures position can increase the settlement price by "over buying" during the settlement period. This increases the value of his existing futures position.

In the model, there are two kinds of traders; hedgers, who have an existing position in the physical commodity, and speculators, who have no such position. We consider a 4-period model, which is the simplest environment to illustrate the effect of trading on intermediate (as opposed to final) prices. Specifically, as illustrated in Figure 1, the model has two trading days. The settlement price at which positions are valued for the overnight is determined by floor trades at t = 2, the final period of day 1. This price is relevant because of the institutional feature described above; traders are required to pay collateral, or can receive a refund of collateral, equal to the change in price between the time their trade is made and the settlement period. From the standpoint of traders on day 1, there is uncertainty about the final price of the good (V) at the end of day 2. No information about V is revealed during the first day of trading – throughout the day, V has a normal distribution with mean $\overline{V}$ and variance σ^2, and the distribution of V is independent of trader activity.

There are $M + h$ total traders. All agents are risk averse; with identical mean/variance utility. Traders can trade on either of two platforms; electronic or floor. Each trader can pay a fixed fee of L at t = 0 (the beginning of day 1) to trade on the floor. Otherwise, they can only trade on the electronic platform. L corresponds to the fixed costs of establishing floor trading operations, such as hiring employees, leasing space and equipment, etc. h of these traders are hedgers, all of whom choose to pay L to have the option of trading on the floor. To simplify the exposition, we assume h = 1.[14] The remaining M traders are "speculators." The distinction between the two classes of traders is that the hedger has an endowment of E physical units of the same good that trades on the futures market. E is known by all trading parties. We make the additional simplifying assumption that speculators who trade on the floor cannot trade electronically.[15] To summarize the order of events:

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[14] The assumption of a single strategic agent - the hedger - simplifies the analysis, but is not essential to our conclusions. The assumption of a single strategic agent allows us to avoid modeling the interaction between strategic agents. The key aspect of our model that carries over to the more general environment is that all strategic agents have an incentive to move the closing price in the direction of their futures position, just as the hedger does in our model. One key difference in the general model is that if there are strategic agents on both sides of the market (some long in the futures markets, some short), the net effect of their trades on closing prices may be ambiguous.

[15] This assumption is stronger than one needs for the equilibrium. The condition needed for the equilibrium is that individual speculator cannot costlessly arbitrage away the entire difference between floor and exchange prices. Having positive trading fees would be sufficient for that condition to hold, but inclusion of trading fees would add additional notation with no additional insight. Atanosov, et al. (2015) show that non-trivial price differences between floor and Globex can exist.

1. At t = 0 (beginning of day 1), traders choose whether to pay a fixed fee, L, to set up trading operations on the floor, rationally anticipating future events.
2. At t = 1 the hedger trades on the electronic venue of the futures market, taking position F. His counterparties are speculators who chose not to pay L at t = 0.[16] All agents fully anticipate the equilibrium at t =2 when making t = 1 decision.
3. At t = 2, trading occurs on the floor. All traders who pay L can trade on the floor, and the hedger trades Q additional contracts at this time. The overnight settlement price is determined by the trades on the floor. No subsequent trading occurs.
4. At t = 3, V is revealed.

To determine the equilibrium, we use backward induction.

- At t = 3, traders realize their gains and losses. The hedger receives

$$(1)\ U = V\,(F + Q + E) - F\,P_1 - Q\,P_2 - r\,F(P_1 - P_2) - \alpha\,(Q + F + E)^2\,\sigma^2/2 - L$$

The expression $r\,F(P_1 - P_2)$ reflects the overnight cost/benefit of the futures position the hedger acquired at t = 1, since P_2 is the end of day price, P_1 is the price on the electronic venue at $t = 1$, and r is the cost per dollar of position held. We assume $r < .5$.

- At t=2, trade occurs on the floor. Given his initial positions, the hedger can trade additional contracts. Equilibrium occurs at the price at which the hedger's demand for

[16] The assumption that all electronic trades take place at t = 1 is expositional, allowing us to characterize the hedger's floor trades as a function of his existing futures' position. As discussed below, modeling all trading as simultaneous does not affect the equilibrium.

additional trading equals the supply of contracts provided by the subset of speculators who are willing to invest L to trade on the floor. Given mean/variance utility, the utility of any speculator who pays L is

$$(2)\ U = \bar{V}x - P_2\, x - \alpha\, (x)^2\, \sigma^2/2 - L + \Omega$$

(where x = position taken at t= 2, and Ω is initial wealth > L)

Each speculator maximizes (2), so that the supply of contracts by each of the m traders who chose to pay L at $t = 0$ is characterized by

$$(3)\ x = \frac{(\bar{V} - P_2)}{\alpha\, \sigma^2}$$

Given his futures position (F) from t =1, the hedger chooses Q to maximize the expected value of (1), which means that he chooses Q to satisfy

$$(4)\ \bar{V} - P_1 - Q\frac{\partial P_2}{\partial Q} + r\, F\frac{\partial P_2}{\partial Q} - \alpha(Q + F + E)\sigma^2 = 0$$

Equilibrium at $t = 2$ requires $Q = -m\, x$, so that (3) implies $\bar{V} - P_2 = -Q\alpha\sigma^2/m$, and that $\frac{\partial P_2}{\partial Q} = \frac{\alpha\sigma^2}{m} > 0$. Hence,

$$(5)\ Q = \frac{r\, F}{2+m} - \frac{m(F+E)}{2+m}$$

It follows that if |*F*| < |*E*| (and *F* and *E* have opposite signs, which will be true in equilibrium), then *Q* will have the same sign as *F*. That is, the hedger will trade in the same direction as his previous futures position.

- At *t=1*, the hedger chooses *F* (given his optimal decision rule for *Q* from (5)) to maximize his mean/variance utility. Speculators supply liquidity, with an unbiased estimate of hedger behavior at *t= 2* (i.e., speculators know the decision rule in equation (5)) so that

$$y = \frac{(\bar{V} - P_1) + r(P_1 - P_2)}{\alpha\,\sigma^2}$$

Analogously to what happens at *t =2*, the hedger choose *F* to maximize (1), which implies

$$6)\ \bar{V} - P_0 + (\bar{V} - P_2)\frac{\partial Q}{\partial F} - Q\frac{\partial P_2}{\partial Q}\frac{\partial Q}{\partial F} - r(P_1 - P_2) - \alpha(Q + E)\sigma^2\left(1 + \frac{\partial Q}{\partial F}\right)$$
$$- F[\frac{\partial P_1}{\partial F}(1 + r) - r\frac{\partial P_2}{\partial Q}\frac{\partial Q}{\partial F} + \alpha\sigma^2\left(1 + \frac{\partial Q}{\partial F})\right] = 0$$

Again, we use the equilibrium condition: *F* = - *(M – m) y* = -*μ y* to re-write equation (6) in terms of the fundamental parameters; *m, μ, r, E and σ.*

$$6')\ \frac{-2r}{m(1-r)}Q - \frac{2(r-m)}{(m+2)m}Q - (Q + E)\left(\frac{2+r}{2+m}\right) - F[\frac{2}{\mu} + \frac{rm\ \ +2m - r^2}{m(m+2)}] = 0$$

As long as $\alpha\sigma^2 \neq 0$.

- At t = 0, speculators decide whether to pay L. Given E, and the resultant equilibria (as described above), speculators can calculate their expected utilities from paying L and not paying L. An internal solution for the number of floor traders obtains when the m+1st speculator finds it unprofitable to pay L, while the first m find it profitable do so.

A. Equilibrium in the initial regime (settlement price based on floor trades only)

The following Proposition establishes some properties of the hedger's futures position. (All proofs appear in Appendix A).

Proposition 1: In equilibrium, the hedger chooses to trade in both periods. For E > 0 (signs in a. and c. are reversed for E < 0).

a. F < 0

b. |F| < |E|

c. Q < 0

Proposition 1 establishes that when the hedger is long in the physical product, he takes a short futures position on both venues.

Implication 1: The hedger's trading in the pit and on the electronic venue on a given day will be positively correlated.

We next characterize the equilibrium under the initial regime. To do so, we first define the gain to a speculator from having the ability to trade on the floor. Let $W^*(m)$ be the difference in net utility (i.e., abstracting from L) for a trader between trading on the floor exclusively and on the electronic platform exclusively, as a function of the number of floor traders. W^* is positive because the hedger is willing to pay a premium in his floor trades. Because W^* is decreasing in m (as shown in the Appendix), it follows that an internal solution for the number of traders who choose to pay L exists for a range of possible values of L.

Proposition 2: For $W^*(M-1) < L < W^*(1)$, there will be an equilibrium in which some speculators choose to establish a floor trading business, and the remainder choose not to. In this equilibrium, prices are higher on the floor than the electronic market if the hedger's endowment is negative, and lower on the floor if his endowment is positive (i.e., $P_2 > P_1 > \overline{V}$ for $E < 0$, and $P_2 < P_1 < \overline{V}$ for $E > 0$).

This Proposition establishes that an equilibrium exists in which hedgers are willing to make trades during the settlement period at prices worse than those they could get earlier in the day, in an attempt to influence the settlement price. The benefit to the hedger from making these trades at inferior prices is a better price when marking their existing positions to market, thereby increasing the profit (or reducing the cost) on their overnight position. The next two implications follow directly from Proposition 2,

Implication 2: Hedgers with $F < 0$ will be willing to sell at a lower price on floor trades than on electronic trades (and conversely when $F > 0$). Moreover, the incentive is increasing in $|F|$.

Implication 3: On average, the price movement between $t = 2$ and $t = 3$ will be in the opposite direction as the change between $t = 1$ and $t = 2$.

Because hedgers are willing to overpay in period 2 (when $F > 0$), some speculators are willing to pay an upfront fee (L) for the opportunity to take the opposite side of these trades. A key element in this equilibrium is that the settlement price affects the overnight costs of maintaining a futures position. Not surprisingly, as the overnight cost of holding the position rises, the benefit to changing the settlement price likewise rises, so that the hedger makes more trades in the settlement period, and fewer during the previous trading period, as detailed in Proposition 3.[17]

Proposition 3: For a given E, the higher the cost per dollar of position held (r),

a. The greater will be the hedger's trading ($|Q|$) during the settlement period, holding E fixed.

b. The smaller will be the hedger's trading ($|F|$) during the initial trading period.

As such, Proposition 3 provides additional empirical implications for trading during the regime in which settlement prices were based on floor trades only;

Implication 4: The amount of overall trading during the settlement period should be higher when holding costs are higher.

Implication 5: The effect of trader position on price will be larger when holding costs are higher.

[17] In Proposition 3, we hold m fixed because, unlike F and Q, m will not vary continuous with r, so that statements about the derivative are difficult to interpret. However, directionally, higher r should increase m and reduce μ, which would reinforce the conclusions of Proposition 3.

Implication 6: The absolute size of the positions of large traders will be lower when holding costs are higher.

One interpretation of higher r is as an increase in the length of time between t = 2 and t = 3; that is, the time between the settlement period on one trading day, and the opening price on the following trading day. This logic implies that since settlement only occurs on weekdays, holding costs are higher on Friday than on other days. As such, Implications 4-6 imply different trading patterns on Fridays (e.g., more trading during the settlement period on Fridays)

Note that we model all electronic trading as occurring at t =1, and all floor trading as occurring at t =2. This choice was purely expositional.[18] If instead we allow trading on either venue at either time, then all floor trading would still occur at t = 2, but on the electronic side, both hedgers and speculators would be indifferent between trading at t =1 and t = 2, and the price in electronic trades would be the same in both periods. In this sense, the timing of electronic trades in observed corn trading is determined by factors outside the model. The empirical implication of our model of banging the close is that we would expect a larger share of floor trading to occur in the settlement period than the share of electronic trades.

B. Equilibrium in the new regime (settlement price based on all trades)

To see the effect of the new regime on the incentive to manipulate price, again consider the objective function of the hedger. Because the timing of electronic trades (i.e., whether they occur at t =1 or t = 2) is relevant to the settlement price, here we have to explicitly distinguish between trades at different times. Specifically, the expression P_1^i is the price of electronic trades

[18] The assumption that all electronic trades take place at t =1 means that the hedger knows his net trading in the electronic market prior to making any floor trades. An alternative modeling assumption would be for the hedger to choose floor and electronic trading positions simultaneously. The resulting equilibrium is the same in either case.

at time i, and similarly, P_2^i is the price of floor trades at time i. The settlement price is now the weighted average price of the *t* = 2 floor and electronic trades, or

$$\bar{P} = \frac{P_1^2 F_2 + P_2^2 Q_2}{F_2 + Q_2}$$

Under this regime, equation (1) becomes

$$(1') \quad U = \bar{V}\,(F_1 + Q_1 + F_2 + Q_2 + E) - P_1^2\, F_2 \;\; -P_2^2\, Q_2 \;\; -P_1^1 F_1 \;\; -P_2^1 Q_1 \; - r\,[F_1\,(P_1^1 - \bar{P}) +$$

$$Q_1\,(P_2^1 - \bar{P})\,] \; - \alpha\;\,(F_1 + Q_1 + F_2 + Q_2 + E)^2\, \sigma^2/2 - L$$

To see the effect of the settlement rule change on the incentive to influence the settlement price, suppose the hedger took a short position in at *t* = 1 (analogous analysis applies if the hedger was long at *t* = 1). Under the initial regime, the marginal effect of "overselling" on the floor at *t* = 2 by the hedger had the cost of increasing his hedging cost by $\frac{dP_2^2}{dQ_2} Q_2 + \; P_2$, and the benefit of increasing the amount he receives (or reducing the amount he owes) on his overnight margin by $r(Q_1 + F_1)\;\; \frac{dP_2^2}{dQ_2}$. The profit-maximizing amount of floor trading equates these marginal effects. Under the new regime, the cost of overselling remains the same, but the benefits falls to (approximately) $r(Q_1 + F_1) \quad [\frac{dP_2^2}{dQ_2}\frac{Q_2}{Q_2+F_2} + \frac{dP_1^2}{dQ_2}\frac{F_2}{Q_2+F_2} + \frac{(P_2^2 - P_1^2)F_2}{(F_2+Q_2)^2}]$.[19] Hence, on the margin, overselling on the floor becomes less profitable, and the hedger will do less of it. More specifically, starting at the prices (and quantities) that maximized profit under the old regime, the incentive for the hedger is to revise his hedging pattern in the settlement period,

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[19] When $Q_2 < 0, \frac{dP_1^2}{dQ_2}$, $F_2$and $(P_2^2 - P_1^2)$, will all be less than zero, so that the benefit to overselling is lower under the new regime.

increasing electronic sales and decreasing floor sales in order to reduce hedging cost. This has the effect of narrowing or eliminating the price differential between floor and electronic trades during the settlement period. This yields the final two implications for our empirical analysis.

Implication 7: The share of settlement-period trades that occurs on the floor will be lower than in the regime in which only floor trades are reflected in the settlement price.

Implication 8: In contrast to the floor-trades-only regime, hedgers will not be willing be pay a differential to trade on the floor (e.g., short hedgers will not be willing to sell at a lower price on the floor).

IV. Data and Summary Statistics

As noted, our empirical analysis focuses on the CBT corn futures market. We chose this market in part because it was the largest futures market that had the change in settlement rules on June 25, 2012. In addition, CBT's corn futures is a major futures contract; it is the 9th most traded contract among all the futures contracts traded in the U.S., totaling more than 53 million contracts traded within the nearly eight months examined in this study.[20] The trading floor for corn was active in the "before" period, with an average of more than 200 active traders each day.

We use an intraday transaction-level data set that derives from the Transaction Capture Report (TCR) data reported daily to the CFTC by the exchanges. Variables contained in the data include transaction price and quantity, order type, venue type, trader type (e.g., institutional or local member), and the time and date of each trade. This allows us to determine whether a trade

[20] It is the most traded agricultural futures contract, with more traded volume than equity and interest rate based contracts such as Nasdaq 100 futures and 2 Year Treasury futures contracts respectively.

took place on the floor or electronically, and whether it occurred during the settlement period. This kind of detail is crucial for identifying differences in transaction prices paid on the floor versus prices on the electronic market. The time period we analyze is March 1st, 2012 to October 19th, 2012, so that there are roughly equal periods in the data before and after the rule change.

Due to an important institutional aspect of the settlement procedure, we choose to focus on the "lead month" maturity of the corn contract. While multiple maturities (expiration dates) of futures corn contracts are traded each day, the settlement prices for every maturity are not all based on trades in that maturity. Rather, the CBT's settlement procedure is that settlement prices for all maturities are based on "outright" trades (which contrast with "calendar spread' trades, in which traders take a long position in one maturity, and a short position in another) made in the lead month contract (typically the contract with the greatest volume).[21] Settlement prices for other maturities are based on the lead month price, adjusted for calendar spread trades between the non-lead maturity and the lead maturity[22]. As such, the predictions of our model, which relate to trades that are intended to influence settlement prices, only describe outright trades in the lead month. The analysis which follows is based on those trades only.

Table 1 aggregates the TCR data over all trades made in the lead month contract. As shown in Table 1, this amounts to about 140,000 trades per day (or a total of more than 11 million trades) over the pre-change sample period. It shows trades separately for transactions during the settlement period and during the pre-settlement portion of the trading day (e.g., 9:30

[21] For our sample, the lead month was the May, 2012 contract between March 1 and April 16, became the July, 2012 contract on April 17 and remained so until June 17, and was the December, 2012 contract from June 18 until the end of the sample.

[22] For example, on the first day of our sample, the lead month was the May, 2012 maturity contract. Trades made in the May maturity during the settlement period on that date determined the settlement price of the May maturity contract. The settlement price for the July (and subsequent contracts) was based on the lead month price, adjusted for the intermonth "spread" trades made between the May and July contracts.

a.m. - 1:14p.m.)[23], and separately for each venue (electronic (*Globex)*, or on the floor). The last row of Table 1 shows the percentage of trading volume attributable to floor trading. One noteworthy finding in Table 1 is that in the *before the change* period, the percentage of all trades that occurred on the floor during the settlement period is substantially higher than the percentage of trades that are on the floor during the rest of the trading day. While the floor represents a little over 10% of all trades during the entire trading day, that percentage rises to over 30% during the settlement period. A second important feature seen in the table is that once the rule changes, the percentage of floor trading during the settlement period drops to less than 13%, and is comparable to the percentage during the rest of the trading day. This decline in floor trading during the settlement period is consistent with Implication 7 of the model.

The model also has predictions for the behavior of individual traders under the initial regime, and in particular on their floor trades. As Table 1 indicates, the vast majority of trades took place on the electronic platform, and in fact, most of the thousands of corn traders made no trades on the floor, and many of the remaining traders traded very infrequently on the floor. To make the analysis of individual trader behavior manageable, we narrowed the data to include only those traders who trade actively on the floor during the settlement period, whom we refer to as *Active Floor Traders (AFTs).*

We define AFTs as traders who traded more 100 contracts on the floor during the settlement minute in our *before the change* period. We find 208 unique traders who meet this criterion, and some descriptive statistics on them during the *before the change* period are presented in Table 2.[24] Comparing total trading numbers from Table 2 with those from Table 1, we see that AFTs represent 25 percent of all trades in the *before the change* period trading. They

[23] For the *after the rule change* period, the pre-settlement portion becomes 9:30 a.m. - 1:59p.m.
[24] The total number of pit traders each day varies during our sample. On average around 270 traders are active in the pit each day, with a maximum of 387.

represent a particularly large share of floor trades; making 77 percent of all floor trades and 96 percent of all settlement period floor trades during the *before the change* period.

Table 2 shows that floor trading was particularly important to AFTs during the settlement period. One way of seeing this is that AFTs make a substantially larger share of their trades on the floor during the settlement period; increasing from less than 17 percent of all their trading prior to the last minute to nearly 50 percent of their trades during the settlement period.[25] An alternative way of observing this is to note that AFTs made 56% of their floor trades during the settlement period, whereas only 12% of their Globex trades are made during the settlement period. Another difference between AFT behavior during the settlement period and at other times is the average size of their trades. Average trade size on the floor increases from about 30 contracts during the pre-settlement period to nearly 40 during the settlement period. In terms of their daily trading, we observe that AFTs trade nearly 19,000 contracts on average during the *before the change* period. Their most active day involves more than 33,000 contracts traded and their least active day is about 7,500 contracts traded.

After identifying AFTs, we calculate each AFT's total positions in the lead month contract by identifying the first time each AFT trades that maturity and then maintaining a running total of each AFT's position from the time of their first transaction. This allows us to calculate each AFT's position at every trading minute. As a result, we are able to determine each AFT's holdings as he or she enters the settlement period, or at any time (e.g. two minutes) prior to the settlement period. This kind of richness in data allows us to directly test for the relationships between position and trading behavior predicted by our model.

The distribution of AFT's average positions is close to balanced. Across all AFTs for our entire *before the change* period, we find that 35 percent of the observations have a negative

[25] This represents about 200 settlement-period trades per day by AFTs

(short) intraday position entering the settlement period, 42 percent have a positive (long) intraday position and 23 percent of the observations are zero. The average absolute intraday position among AFTs entering the settlement period is 545 contracts, with short traders having slightly larger absolute positions than long traders. To summarize, these descriptive statistics indicate that we have a balanced set of AFTs with long, short and zero intraday positions.

V. Results

In part A of this section, we test several implications of our model for aggregate market behavior. In part B we focus on tests concerning individual trader behavior for AFTs during the *before the change* period. Part C considers some robustness checks on our results.

A. Market-level tests

a. Aggregate Trading

Our model yields several predictions for aggregate prices and trading. In particular, Implication 6 is that the percentage of trading that occurs on the floor during the settlement period will be lower after the rule change than before the change. Implication 2 is that manipulation will be followed by reversals (a reversal occurs when the price movement between the settlement price and the next day opening price has the opposite sign from the price movement between the pre-settlement period price and the settlement price.) In combination with Implication 8 (which suggests that banging the close will not occur in the new regime), this implies that reversals will be less common under the new regime.

Table 1 presented aggregate trading statistics describing the floor and electronic trading before and after the rule. These statistics suggest that floor trading during the settlement period declined dramatically following the rule change.[26]

To formally test this hypothesis, we ran OLS regressions of measures of floor trading against a dummy variable for the old regime (equal to 1 for dates prior to 6/25/2012), as well as a dummy variable for Fridays, and the interaction of those two variables. The inclusion of the *Friday* variable and the interaction allows us to test Implication 4; that manipulation under the initial regime was more prevalent on Fridays. Results are reported in Table 3. The dependent variables in the regressions in columns (1) and (3) are the number of settlement period floor trades and the ratio of settlement period floor trades to all settlement period trades, respectively. In columns (2) and (4) we also include a time trend. In all regressions, the rule change has a negative and significant effect on floor trading. For example, the third column suggests the percentage of trades made on the floor trades during the settlement period dropped by nearly 16 percentage points after the rule change was implemented. The lack of significance of the time trend suggests that the decline in floor trading around the time of the rule change was not a product of the general trend in floor trading. The coefficients on the interaction are positive, but not statistically significant.

b. Reversals

A general implication of manipulation models (see, e.g. Pirrong, 1993), which is also a prediction of our model (Implication 3), is that successful manipulation will be followed by price changes in the opposite direction, or what are termed reversals. The basic idea is that the price prior to the settlement period represents an estimate of the *fundamental price* before

[26] We ran a Wilcoxon two-sample test on the daily quantity of floor trades during settlement period (results not shown here but are available upon request). This nonparametric test suggests that the average daily trading is statistically different for *before the change* and *after the change* periods.

closing on day *t*, and hence that, if manipulation occurred on day *t*, it will be reflected in the differences between the closing price and that fundamental price. Since there is no incentive to manipulate the opening price on day *t+1*, price should revert to the fundamental value for the next day's open.[27]

Our implementation of this idea is to look at the relationship between ($P_{c,t} - P_5$) and ($P_{o,\,t+1} - P_{c,t}$), where $P_{c,t}$ is the closing price on day *t*, $P_{5,t}$ is the volume weighted average price in the 5 minutes before the settlement period on day *t*, and $P_{o,t+1}$ is the opening price on day *t+1*. Of course, many events can cause price to change over that interval. The question we examine is whether the changes from the 5 minutes prior to settlement until close are reversed more frequently under the initial regime than under the new regime. If so, it would suggest that manipulation was more common under the old regime. Specifically, we define a binomial variable which is equal to one if ($P_{c,t} - P_5$) and ($P_{o,\,t+1} - P_{c,t}$) have opposite signs and zero if they have the same sign (we treat observations for which either $P_{c,t} - P_5$ or $P_{o,\,t+1} - P_{c,t}$ are equal to zero as missing). We find that the percentage of reversals falls from 57.3% under the old regime to 48.7% under the new, a decline which is statistically significant at the 1% level. Hence, the data are consistent with Implication 3.

c. Volatility

Our final test based on aggregate data addresses the general question of the robustness of the settlement process. One measure of robustness is the amount of price volatility during the settlement period. We would expect high volatility of prices during the settlement period if small trades can have a substantial impact on prices. While there are many ways to measure volatility, we looked at a simple metric of volatility; the change in price from the first second of

[27] Comerton-Forde and Putnins (2011) find that reversals are more likely following manipulation in equity markets. Shkilko, Van Ness, and Van Ness (2012) use reversals to identify manipulation.

the settlement period that had a trade to the last second of the settlement period that had a trade.[28] The daily series of such differences is displayed in Figure 2. The frequency of large changes is dramatically lower under the new regime; the standard deviation of these differences falls from 5.7 cents to 1.5 cents.

A formal test based on such price changes was developed by Lo and MacKinlay (1988). They show that under the null hypothesis of a random walk in prices, the variance of prices calculated from low-frequency observations (e.g., once per hour) will be equal to the variance from high-frequency observations (e.g., once per minute), scaled by the relative frequencies (e.g., 60). They propose a metric

$$J_r = \frac{\frac{\sigma_L^2}{q}}{\sigma_H^2}$$

where σ_L^2 is the variance of returns measured at low-frequency, σ_L^2 is the variance of the returns measured at high-frequency, and q is the ratio of the frequencies.

The basic logic of their model is that under the null hypothesis that prices follow a random walk, J_r should be about 1. Formally, Lo and MacKinlay (1988) show that under the hypothesis of a random walk, $\sqrt{(nq)}(J_r - 1)$ (where n is the number of observations for the low-frequency variance) will asymptotically approach a normal distribution, with mean 0 and variance 2(q-1).

We implement this test by calculating the volume weighted-average price (vwap) during every second of the settlement period in which there is a settlement-relevant trade (e.g., a pit trade during the initial regime). On average, during the initial regime, there were 8 observations each settlement period. From this we calculate a high frequency variance, equal to the sum of squared returns between successive intra-day observations of the vwap, divided by the number of

[28] This was calculated as part of the variance ratio test, discussed below.

observations. We also calculate a low-frequency variance equal to the squared returns between the vwaps for the first second of trading during the settlement period and the last (i.e., one per day), divided by the number of days (80). To provide a direct comparison, we calculate similar a high-frequency variance for the new regime; calculating the vwap 8 times per day. From this, we calculate J_r - 1 under the two regimes. Because we have the same number of high-frequency observation in each period, the variance of the distribution of $\sqrt{(nq)}(J_r - 1)$ is the same in both periods, so that the standard deviation of the distribution was $\sqrt{14}$, or ~3.74.

Table 4 shows the sum of squared returns calculated at high and low frequency, for the two regimes. Under the old regime, J_r was .134, so that $\sqrt{(nq)}(J_r - 1)$ was -22.01, nearly 6 standards deviations away from zero. This means we can reject the null hypothesis of a random walk with $p < .0001$. Under the new regime, J_r was 1.133, so that $\sqrt{(nq)}(J_r - 1)$ was 3.79, or about 1 standard deviation away from zero. Hence, we cannot reject the null hypothesis of a random walk (at conventional significance levels) under the new regime. This test provides additional evidence that the change in settlement regime did improve the settlement process.

B. Trader-level tests

Some of the implications of our model can only be tested using positions and transactions of individual traders. In this sub-section, we test a number of implications using detailed data on actions of AFTs during the before the change period.

a. Buy vs. Sell

Implication 1 of our model is that the likelihood a hedger's settlement period floor trade is a sell (rather than a buy) should be a function of his or her position. For example, the larger a hedger's short position (in absolute terms), the more likely it is that the trader's settlement-period floor trade will be a sell. Implication 4 also adds that such behavior is more likely when r is higher. One circumstance in which there is a higher effective r is on Fridays, because a position held at the end of the day on Friday requires posting margins for three days rather than one (since marking to market only occurs on weekdays). To test these propositions, we ran a probit regression of the probability a settlement-period trade is a sell against the trader's position, measured just prior to the settlement period, a dummy for Friday, and the interaction of the two.

Prob (trade i is a sell) = f(POS, Fri, POS*Fri).

We expect negative signs both on POS and the interaction term; the bigger a trader's position entering the settlement period, the less likely that a trade he makes during the settlement period will be a sell, and this effect should be larger on Fridays. The results of a probit regression of this relationship are reported in the first column in Table 5. The results provide support for the model's implication; the relationship between the likelihood of a sell and position is negative, and the absolute effect of trader position is larger on Fridays.

To get a feel for the economic magnitude of this effect, note that the average absolute position of institutional exchange members (which roughly corresponds to our notion of hedger) is about 2,000 contracts. For a trader who enters the settlement period with a zero position (and hence no incentive to influence price), our estimates indicate that the likelihood that his trade would be a sell is about 53%. If that trader instead had a short position of 2,000 entering the settlement period, on the average day, the implied probability of a sell would increase to about 57%, while a trader with a long position of 2,000 would have a probability of a sale of about

49%. Hence, the difference between the likelihood of sale for a trader with a typical-sized position would differ by about 8 percentage points depending on whether he was long or short. The largest observed absolute positions are about 12,000 contracts, and the implied difference between a long and a short with a position of 12,000 is about 45 percentage points.

Similarly, the effect of the Fridays on the probability of a sell depends on the trader's position, since the interaction effect is larger than the direct effect. For a seller with a long position of 2,000 contracts, the likelihood of a sell on a Friday is about 42%, while the likelihood is 50% on other days.

Of course, the estimated effect could reflect a variety of factors other than an attempt to affect settlement prices.   One test to distinguish between the effect described in the model, and other motivations is to look at trading on Globex. The basic premise of this test is that Globex trades during the settlement period reflect incentives other than to influence settlement price. Hence, if the relationship between existing position and direction of trade were the same for Globex and floor trading, then the results in the first column of Table 5 could be interpreted as something other than an attempt to influence settlement prices. To test whether position had differential effects on Globex and floor trading, we ran the following regression.

Prob (trade i is a sell) = f(POS, Fri, POS*Fri, floor dummy, floor dummy * POS).

If the effects shown in the first column were due to the trader's attempt to obtain a given position during the settlement period, then the coefficient on position would be negative, but the interaction between position and the floor dummy would be close to zero. Conversely, a negative coefficient on the interaction between position and the floor dummy would indicate that the trader has a preference to obtain its position by trading on the floor. Results are shown in the second column of Table 5. As indicated there, the coefficient on position is positive, while the interaction between the dummy for floor trading and position is indeed negative and larger in absolute value than the coefficient on position. That is, in contrast to his floor trading, the larger a trader's position, the more likely his *electronic* trade will be a sell.

b. Price Effects

Implication 2 follows from Proposition 2; the position of a hedger entering the settlement period affects that trader's pricing decisions during the settlement period. In particular, a hedger with a large negative position is willing to sell at a lower-than-market price on the floor in the settlement period in order to influence the settlement price (and conversely for a hedger with a large positive position will be willing to buy at a higher-than-market price). This implies a positive relationship between the position of a hedger (whether long or short) and the price differentials at which the trader will transact during the settlement period.[29] We also expect large short hedgers to accept lower prices on their Friday sells, since the effect of any change in settlement prices would have a greater effect on their cash flow because there is no marking to market during the weekend (see Implication 4). For the same reason, we expect long hedgers to pay higher price on Fridays.

As such, our empirical methodology is to run regressions of the following form (separately) for floor sales by hedgers with short positions and purchases by hedgers with long positions,

$$\frac{P_{i,t} - P_{S,t}}{P_{S,t}} = \alpha_0 + \alpha_1 POS + \alpha_2 Fri + \epsilon$$

[29] For example, for a trader with a short (i.e., negative) position, the closer to zero his or her position, the less willing he/she is to take a below-market price on a sale.

where $P_{i,t}$ is the price in trade i on date t, $P_{S,t}$ is the settlement price on date t, *POS* is the position of the trader, *Fri* is a dummy variable for whether the trading day is a Friday. Inclusion of $P_{S,t}$ controls for prevailing market prices, and converting to a ratio minimizes heteroscedasticity.

Our OLS estimates of this equation are reported in Table 6. For both long and short hedgers, the coefficient on position is positive and statistically significant. This provides some evidence that long (short) traders are willing to buy (sell) at higher (lower) prices on the floor than contemporaneous prevailing market prices. The *Friday* coefficients are negative in both regressions (but not significant), whereas the model predicts a negative sign for short traders, and a positive sign for long traders.

Another way to look at the relationship between price differences and positions is to look at traders who trade on both the floor and Globex during the settlement period on the same day. That is, our theory suggests that traders with a large long (short) position pay more (accept less) when they buy (sell) in the floor than when they buy on the same date on Globex. In either case, we expect a positive relationship between trading price and position. This test requires that a trader trade on both venues on the same date, which necessarily entails a substantial reduction in sample size. In particular, we find 42 instances in which a trader had a short position entering the settlement period, and then sold on both the floor and Globex during the settlement period, and 61 instances in which a trader had a long position entering the settlement period, and then bought on both venues during the settlement period.

Table 7 shows results for this test. Columns (1) and (2) show the relationship between a short trader's position and the difference between the floor price and Globex price he receives when selling. A positive sign means that the larger the short position, the lower the price he is willing to take on floor sales, consistent with the theory. Columns (1) and (2) differ in that column (2) prices are weighted by the quantity sold in the floor transaction. The coefficients in both regressions are positive and statistically significant at the 5% level. Columns (3) and (4) show analogous regressions for traders with long positions and their buys. We again see positive coefficients on position (consistent with the theory), although statistical significance is low in these regressions.

c. Changes in Overnight Margin Costs

Implications 4 - 6 all relate to the effect of changes in the overnight cost of holding a position. Implication 4 is that as the cost of posting margin (*r*) increases, traders will have a greater incentive to influence the settlement price. We test this implication in several ways. First, as noted above, the effective *r* is higher on Fridays. Hence, Tables 4 and 5 test whether the effect of positions on settlement-period behavior is more pronounced on Fridays.

Implication 6 has the empirical prediction that traders will have smaller positions at the end of trading on Friday than other days. To test this, we calculate the ratio of a trader's day *t* position to their average position, and then compare the average ratio on Fridays to other days. Using the ratio mitigates the effect of agent heterogeneity (i.e., one large trader would have a large effect if we used absolute position).[30] We find that the ratio is 2.86 on Fridays vs. 2.93 on other days, and the t-test implies that this is significant at the 5% level.

Finally, we examine the effect of higher holding costs using a different approach. In particular, another way in which a trader might have higher costs of posting additional margin is if his margin requirement rose recently. Specifically, traders who have lost a large amount of money since the last trading day must come up with a substantial amount of money today to pay

[30] We limited the comparison to observations in which the ratio was positive, so that we only look at observations for which the trader's long/ short is the typical one. The actual direction is the same as the average direction for about 75% of the observations.

the requisite margin, and may face a high cost of obtaining additional money to use as margin (essentially, a high *r*). Our second test of Implication 4 is to examine whether traders whose futures positions have recently declined significantly in value are more inclined to engage in "uneconomic" trades. To test this, we first calculated the change in value for each trader's position between the settlement period on day *t-1* and just prior to the settlement on day *t*. We then evaluate the relationship between the one-day decline in the value of the trader's position and trading behavior on day *t*. Specifically, we regress the price received in a sell (buy) for a trader with a short (long) position against the size of the one-day loss, for all traders who lost money on day *t*.

The change in value on day *t* for trader *i* is calculated as the previous day's end-of-day position for trader *i*, multiplied by difference between day *t-1*'s settlement price and day *t*'s trading price immediately prior to the settlement period. We then ran the following regression separately for buys and sells:

$$\frac{P_{i,t}-P_{S,t}}{P_{S,t}} = \alpha_0 + \alpha_1 \Delta V_{i,t} + \epsilon$$

where $P_{i,t}$ is the price in trade *i* during the settlement period on date t, $P_{S,t}$ is the settlement price on date t, and $\Delta V_{i,t}$ is the absolute value of the loss, as described above.

The results of these regressions are presented in Table 8. We find that for buyers, the bigger a trader's loss (in absolute terms), the more likely it is that the trader is willing to pay more (relative to settlement price) to purchase contracts on the floor during settlement period. Similarly, for sellers, the bigger a trader's loss (in absolute terms), the more likely it is that the trader is willing to sell for less (relative to settlement price) on the floor during settlement. The coefficient estimates imply that for a trader holding a short 2,000 corn futures contracts position (which, as suggested above, would be a typical position), the losses due to a 10 cents increase in price relative to the previous day would mean that trader winds up selling 1 cent below the settlement price for his sales on the floor during the settlement period.

C. Robustness

a. Comparison with Other Markets

In total, our findings are consistent with the premise that, prior to the rule change, some traders had attempted to influence the settlement price by making uneconomic floor trades during the settlement period. This is not to say that there are no alternative explanations of the pattern of trades that we observe. One alternative explanation can be that the observed change in floor trading might reflect some other factors that were coincident with the rule change. While it is difficult to rule out such a conflating effect, we attempt to do so by comparing corn futures with live cattle futures. We chose live cattle as the control because it was the largest agricultural futures market for which the settlement price rule did not change during our sample period. Figure 3 shows floor trading as a percentage of all trading during the settlement period for corn futures and live cattle futures. What we observe is a clear drop in floor trade percentages for corn futures on the day of the rule change but no obvious change for live cattle futures.[31]

To quantify the effect of the rule change on the ratio of floor trading during the settlement period, we run the following simple difference-in-difference regression.

$$Floor\ Trading\ Ratio = \alpha + \beta_1 Rule\ Change + \beta_2 Corn + \beta_3 Rule\_Corn$$

[31] As shown in Appendix B, nearly-identical pattern can be seen in the other agricultural futures markets whose rules changed on the same date. In particular, the change in soybean futures trading patterns (the second-largest futures market affected by the change) is very similar to the change in corn futures trading patterns. We also find that, similar to live cattle futures, other agricultural futures markets whose rules did not change on that date had no discernable change in trading patterns.

where the dependent variable is the ratio of floor trading to total trading during the settlement period, *Before Change* is a dummy variable equal to 1 during the period in which the original settlement rule was in effect, *Corn* is a dummy variable representing the treatment group (live cattle futures is the control group) and *Rule_Corn* is the interaction term between these two independent variables. The regression results are presented in Table 9. The coefficient of the *Corn* dummy variable is negative and significant, indicating that live cattle futures had a higher ratio of floor trading during the settlement period than corn futures even before the rule change. The coefficient of primary interest is the interactive term. The coefficient of .125 suggests that relative to live cattle (our proxy for what we would have expected absent the rule change), we find that the ratio of floor trading to total trading during the settlement period for corn futures was about 12.5 percentage points higher before the rule change. Hence, we conclude that the rule change was not due to a coincident general shift in futures market trader behavior or technology, since live cattle futures did not experience a similar change in trading patterns.

b. "Basis" Risk Reduction

A specific alternative explanation of the decline in floor trading is that some traders have an incentive to make their trades at settlement prices for other reasons. For example, some traders may really be agents of investors (individuals or institutions who are not exchange members). In this case, the futures positions of such traders simply reflect obligations of those traders to other investors (as might occur if the trader was a commodity ETF). Such traders would have an incentive to trade on the settlement venue (e.g., the floor during the before change period) during the settlement period to minimize the "basis" risk associated with investor purchases or redemptions during the day. Such basis risk can arise because the trader is obligated to redeem or credit all customer purchases during the day at the daily closing price, and trades made earlier in the day expose the trader to price changes that occur over the interim.

One implication of this premise is that total settlement period trading by such traders would not be altered by the rule change, although such trading might shift to the electronic venue. Under the rules that applied after June 25, 2012, these traders could guarantee prices that are close to the settlement price by trading either on the floor or on Globex during the settlement period. Thus, any reduction in settlement period floor trading would be offset by an increase in their trading on Globex during that period. Hence, to examine this alternative, we compared total settlement-period trading by our 208 AFTs before and after the rule change. The results do not support the contention that floor settlement-period trading by these traders represented an effort to mitigate their basis risk. Of the 208 AFTS, 46 did not trade in the settlement period at all after the rule change. In total, the 208 traders' Globex trading during the settlement period declined by more than 50% following the change. Total settlement period trading volume (floor + Globex) of these traders declined by nearly 70%. Hence, most AFTs were trading on the floor during the settlement for reasons other than to make trades at closing prices.

VI. Policy Implications

The specific experiment we study is whether a switch from settlement prices based on pit trades to settlement prices based on all trades affects trading patterns, and we draw inferences about price efficiency from that evidence. Examining this natural experiment has implications both for the use of floor trades to determine settlement prices, and for evaluating settlement procedures more generally. In regard to the use of floor trades to determine settlement prices, we note that while the US futures exchanges have, for the most part, moved away from pit trading[32], some exchanges in other parts of the world still base their settlement prices on floor trades. One important such exchange is the London Metal Exchange (LME). The LME is the price-forming venue for industrial metals, and $10 trillion worth of trading takes place there annually.[33] The LME Official Price and the LME Official Settlement Price are two important prices determined by the LME; the former is used as the global reference price for physical contracts and the latter is the price at which all LME futures contracts are settled. The LME Official Price is based on the last bid and offer quoted during the second open-outcry session, and the LME Official Settlement Price is the last cash offer price during that session. Our findings suggest that such settlement procedures can be susceptible to price manipulation.

More generally, our findings also suggest that settlement procedures might affect the efficiency of settlement prices. As Pagano and Schwartz (2003) argue, inappropriate settlement rules can result in settlement prices that can be influenced by a small number of trades. Trying to avoid this effect was the explicit goal of the rule change they examine. The literature suggests last-trade settlement mechanisms (such as VWAP of trades prior to closing) are less efficient than other mechanisms (see, e.g., Cordi et al., 2015). The evidence provided by the natural experiment in the corn market underscores that settlement procedures are important, and in particular, settlement prices that are based on a small subset of trades (or quotes) may be subject to manipulation.

[32] Contrary to the trend in the US futures markets, Box Options Exchange was recently granted approval by the SEC to open an open-outcry trading floor. See, https://www.bloomberg.com/news/articles/2017-08-02/new-trading-floor-to-open-in-chicago-bucking-automation-trend.
[33] https://www.lme.com/~/media/Files/Brochures/A%20Guide%20to%20the%20LME.pdf

VII. Conclusion

Trading patterns evolve. For example, futures contracts were once exclusively traded on exchange floors, but electronic trading has come to dominate most U.S. futures markets. Exchanges will see the quality of their markets deteriorate unless they alter their rules to reflect these changes. We study the consequences of such a change in the settlement procedure on the Chicago Board of Trade. Settlement procedures, used for determining settlement prices, are an important function of any exchange since settlement prices are used to value assets, and any misrepresentation in them can lead to gains and losses for traders. Our study suggests that the rule change made by CBT on June 25, 2012 likely improved the settlement price determination process. Prior to that date, floor trades executed during the final minute of CBT's floor trading were the only ones included in determining the settlement price. After the change, all final-minute trades were included in settlement price determination, whether those trades were made on the trading floor or on the CBT's electronic platform. This paper provides evidence that this change created a more robust settlement price process not only by incorporating a higher percentage of transactions into the settlement price, but also reducing the incentives for manipulation relative to the previous settlement procedure.

To help guide our inquiry we develop a model of trader behavior under the CBT institutions. One important conclusion from the model is that manipulation of settlement price is easier under the initial settlement procedure. Among other things, this suggests that floor trading during the settlement period will decline following the rule change.

We use market-level data to analyze this and several other aspects of how settlement period trading transformed with the rule change. In regard to trading volume, we find that the rule change substantially altered the nature of trading during the settlement period. In particular, floor trading represented about 12% of all trading during the settlement period under the initial procedure, but only about 4.5% of all trading during the settlement period under the new one. In regard to manipulation, price reversals are one metric of manipulation. We find that reversals became less common after the rule change. Finally, we use a variance ratio test to measure whether price movements during the settlement period follow a random walk, which would indicate a robust process. We show that prices during the settlement period appear to follow a random walk under the new settlement procedure, but do not under the initial procedure.

The model has a number of additional implications for testing for manipulation under the initial regime. For example, it shows that individual trader's trades on the floor during settlement should be positively correlated with their existing positions. We use a rich, trader-level data set to test this and other predictions, and provide evidence that the predictions are supported by the data. The estimates suggest the magnitudes can be significant. For example, in regard to the implication about a positive correlation between position and trades, we find that a trade during the settlement period by a trader who entered the period holding a long 12,000 corn futures contract position is 45% more likely to be a sell than a trade by a trader who entered with a short position of 12,000 contracts.

The specific example studied here concerns a market in which majority of trading had migrated from the floor to electronic trading, but the settlement price determination process had not yet reflected that change. Our analysis of the effect of changing the settlement process in this case suggests that basing the settlement price on all trades was indeed more efficient and robust. Our approach can be generalized, in a broader sense, to analyzing how well modifications in rules set by the exchanges (e.g., periodic auctions vs. continuous trading, circuit breakers), reflect important changes in the market place, so that the markets remain efficient and robust.

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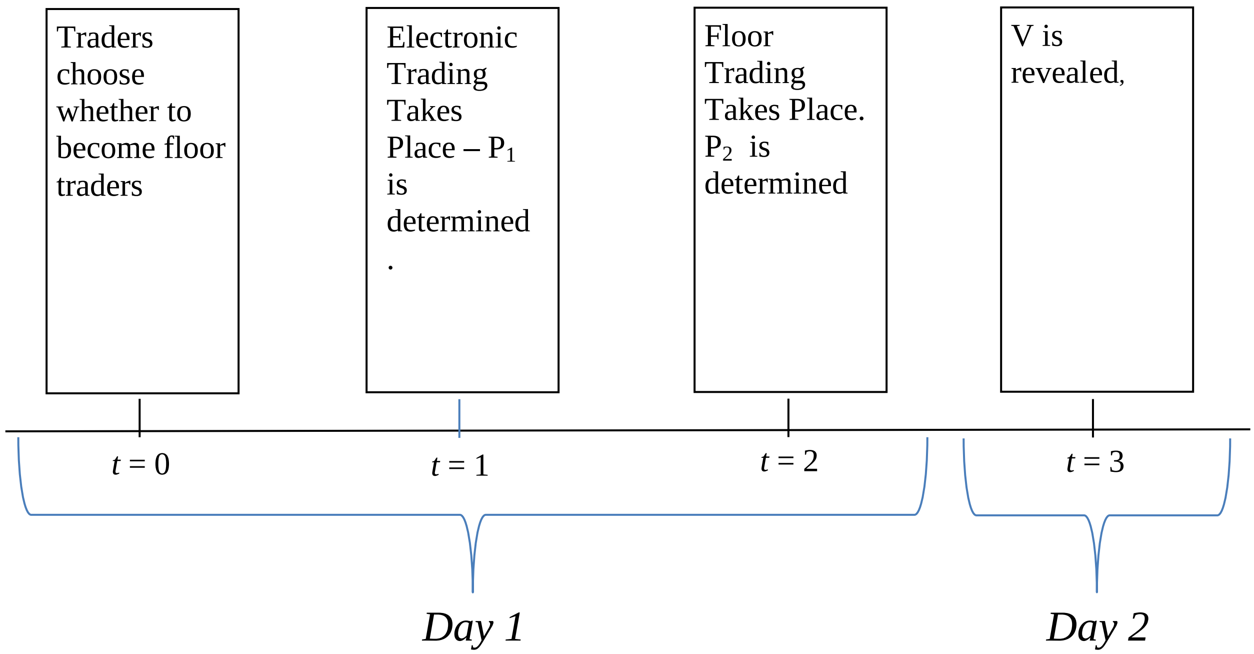
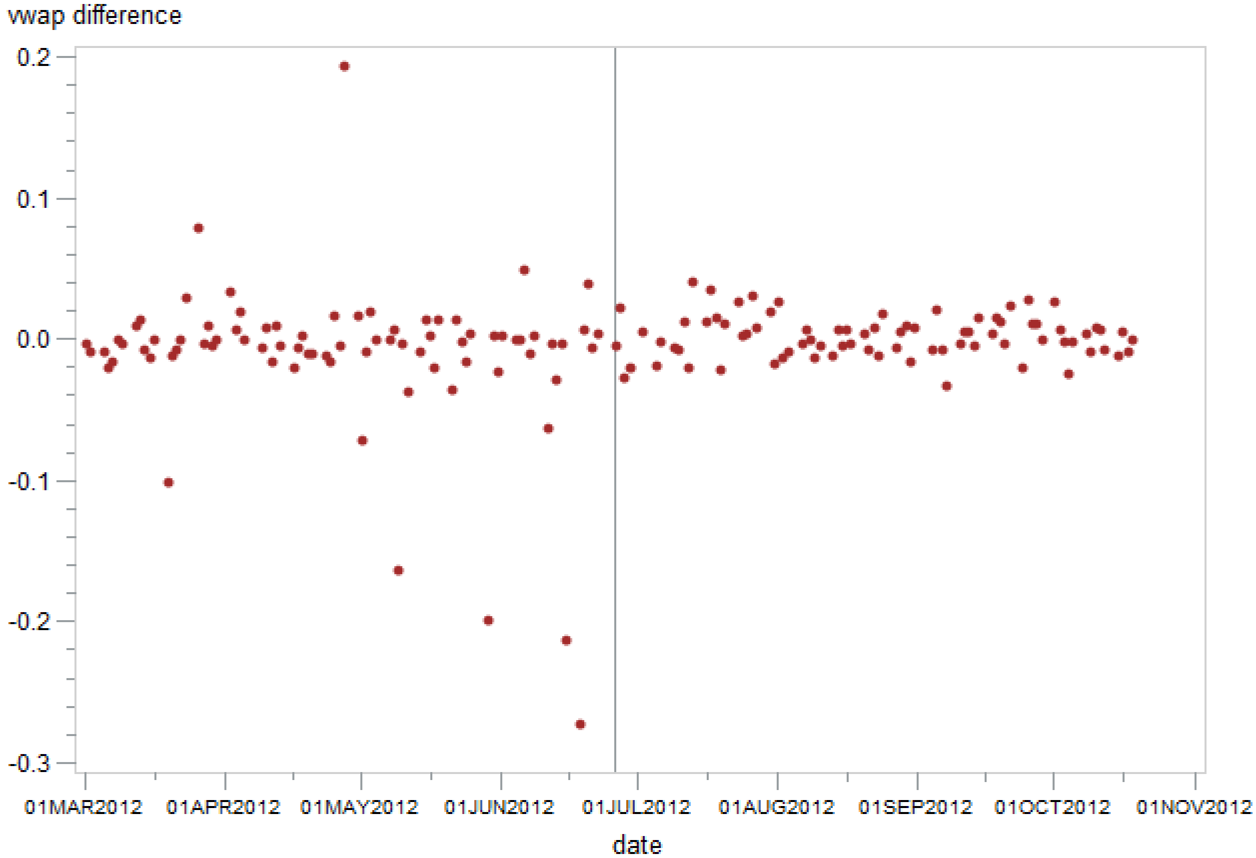
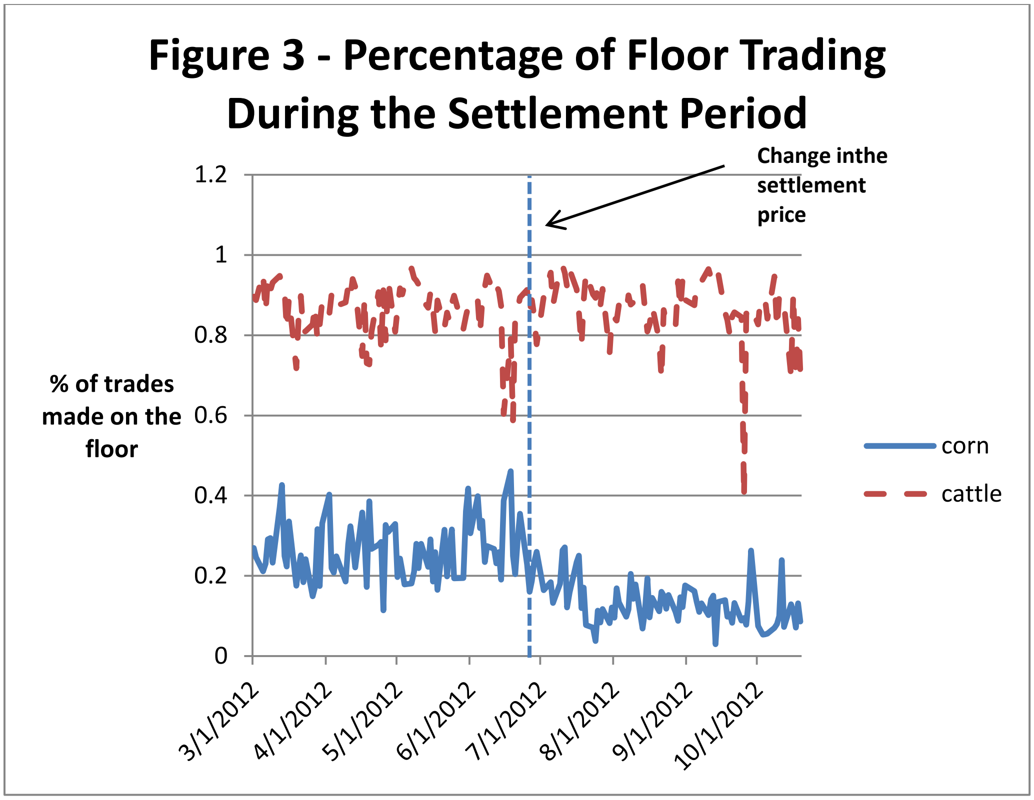


Figure 1 – Timing of Events

Figure 2 - Daily VWAP Difference



This figure shows the change in price from the volume weighted average price (vwap) of the first second of the settlement period that had a trade to the vwap of the last second of the settlement period that had a trade each day. The vertical line indicates the date of the rule change.



This figure shows floor trading as a percentage of all trading during the settlement period for corn futures and live cattle futures.

Table 1 – Corn Trading Patterns

	Before the rule change		*After the rule change*	
	Prior to Last Minute	Last Minute	Prior to Last Minute	Last Minute
Globex	120,458	4,547	134,245	3,981
Floor	14,280	2,016	16,644	559
Total	134,738	6,563	150,889	4,540
Floor as % of Total	10.6%	30.7%	11%	12.3%

This table shows the average number of contracts traded per day under two different settlement regimes; one which was in effect March 1 to June 24, 2012, and a second that was in effect June 25 to October 19, 2012. For each period, the number of contracts is reported separately by venue (floor or Globex), and for the settlement period and the rest of the trading day.

Table 2 – Average Daily Number of Lead Month Contracts Traded by Active Floor Traders

		Settlement period	Prior to last minute	Settlement as % of total
Venue				
	Globex	4,482	31,853	12%
	Floor	4,116	3,193	56%
Floor % of total		47.87%	9.11%	

The table shows trading *before the rule change* by the 208 *Active Floor Traders* in our sample on the floor and on Globex.

Table 3 - Settlement Period Trading Regressions

	Number of Settlement Period Floor Trades		Ratio of Floor to Total Settlement Period Trades	
	(1)	(2)	(3)	(4)
Independent Var.				
Constant	547.62 (< .001)	10829.25 (.760)	.147 (< .001)	1.21 (.851)
Before Change	1431.78 (< .001)	1495.46 (< .001)	.158 (<.001)	.166 (<.001)
Friday	54.17 (.796)	53.40 (.799)	-.011 (.779)	-.011 (.778)
Friday*Change	128.00 (.655)	127.78 (.655)	.033 (.521)	.033 (.522
Trend		.59 (.748)		.00007 (.833)
Adj R^2	51.9	51.6	29.1	28.6
Obs	149	149	149	149

The table shows OLS regression results testing for the effect of the CBT settlement rule changes. Dependent variables in the regressions are both measured daily, and are respectively, the total number of settlement period floor trades, and the ratio of floor trades to total trades in the settlement period. The explanatory variables are dummy variable for the rule (1 is the pre-change period), a dummy variable for Fridays, the interaction of the two, and a time trend. P-values are reported in parentheses.

Table 4 – Variance Ratio Test

	Before the rule change	*After the rule change*
J_r	0.134	1.133
$\sqrt{(nq)}\,(J_r - 1)$	-22.01	3.79
P-value	<.0001	0.312

This table shows the results of variance ratio test proposed by Lo and MacKinlay (1988) under two different settlement regimes; one which was in effect March 1 to June 24, 2012, and a second that was in effect June 25 to October 19, 2012. J_r represents the ratio of the variance of returns measured at low-frequency to the variance of returns measured at high-frequency. $\sqrt{(nq)}\,(J_r - 1)$ is a measure that asymptotically approaches a normal distribution with mean zero and a variance of 2(q-1). The p-value tests the null hypothesis that prices follow a random walk (the null implies $J_r = 1$).

Table 5 – Direction of Trade and Positions

	Dependent Variable	
	Probability that a Trade is a Sell	Probability that a Trade is a Sell
Constant	0.083	-0.220
	(<.001)	(<.001)
Trader's Net Position (000)	-0.017	0.064
	(.057)	(<.001)
Friday	-0.016	0.051
	(.601)	(<.001)
Friday*Position (000)	-0.082	0.034
	(<.001)	(<.001)
Floor Trading Dummy		0.290
		(<.001)
Floor Dummy*Position (000)		-0.097
		(<.001)
Pseudo R^2	0.16	1.57
Likelihood Ratio χ^2	22.26	1485.16
Obs	10,381	69,275

The table shows probit regression results for the probability that a settlement-period trade is a sell. The regression in the first column is based on floor trades only, and explanatory variables include the trader's position entering the settlement period, a dummy for the last trading day in the week, and a term for the interaction of those two terms. The regression in the second column is based on all settlement period trades, and adds a dummy for whether the trade in made on the floor, and an interactions between that dummy and a trader's position. P-values are reported in parentheses.

Table 6 – Floor Prices and Positions

	Longs	Shorts
Constant	0.00003	-.0005
	(.15)	(<.001)
Trader's Position (000000)	0.007	0.0099
	(<.001)	(<.001)
Friday	-0.005	0.001
	(.46)	(.19)
Adj. R^2	1.02%	5.41%
Obs	1850	1555

The table shows results from OLS regressions of the adjusted trade price on last-minute floor buy trades (for longs, or sell trades for shorts) against the trader's position and a dummy variable for Fridays. The adjusted price is measured as the price in the specific trade minus that day's settlement price, divided by the settlement price. Each trader's position is measured just prior to the settlement period. P-values are reported in parentheses.

Table 7 – Prices on floor vs. Globex for AFTs

	Short		Long	
	(1) Unweighted	(2) Weighted	(3) Unweighted	(4) Weighted
Constant	0.0014	0.0178	0.0178	0.0178
	(.386)	(.320)	(.320)	(.320)
Trader's Position (000000)	2.62	43.62	0.040	10.51
	(.024)	(< .001)	(.663)	(.682)
Adj R2	9.85	22.27	-1.36	-1.40
Obs	42	42	61	61

The left-hand side variable in the regressions reported in this table is the difference between the average price paid (or received) during the settlement period in floor trades and Globex trades by a trader who traded in both venues on the same day. For traders that had long positions entering the settlement period, it examines the relationship between the difference in price *paid* and the size of the trader's long position, while for traders that had short positions, it examines the relationship between the difference in price *received* and position. The second and fourth columns differ from the first and third in that the price difference is weighted by the quantity traded on the floor during the settlement period. P-values are reported in parentheses.

Table 8 – Floor vs. Transaction Prices and One-Day Loss

	Buys	Sells
Constant	-0.000031	.000983
	(.769)	(<.001)
Trader's P&L	-0.000019	0.000019
	(.008)	(<.001)
Adj. R^2	.17%	.34%
Obs	3629	4223

The table shows results from OLS regressions of the adjusted trade price on a trader's one-day loss. The adjusted price is measured as the price in the specific trade minus that day's settlement price. The one-day loss for trader *i* is defined as his day *t* end-of-day position, multiplied by difference between the settlement price on day *t-1* and day *t*'s trading price immediately prior to the settlement period. Only the positions that have did not gain money are included in these regressions. P-values are reported in parentheses.

Table 9 – Settlement Period Trading Patterns in Corn and Live Cattle

	% of settlement-period trades made on exchange floor
Independent variables	
Constant	0.857
	(<.001)
Before Change	0.008
	(.621)
Corn Dummy	-0.724
	(<.001)
Before Change * Corn Dummy	0.125
	(<.001)
Adj R^2	94.21
Obs	324

The table shows regression results measuring the effect of the change in CBOT's settlement rule on floor trading in corn and live cattle. The dependent variable is the percentage of settlement-period trades that are made on the exchange floor. The Before Change variable equals one for days before June 25, 2012. The interactive term tests whether the pre-June 25 period exhibit different patterns for the two commodities. P-values are reported in parentheses.

Appendix A: Proofs

Proposition 1: In equilibrium, the hedger chooses to trade in both periods. For E > 0 (all signs in a. and c. are reversed for E < 0). As long as r $\leq$ .5

a. F < 0

b. |F| < |E|

c. Q < 0

Proof:
a and b. Define Z as

$$Z \equiv \frac{2r}{m(1-r)} + \frac{2r}{(m+2)m} + \left(\frac{r}{(m+2)}\right) = \frac{r}{m}[1 + \frac{2}{1-r}],$$

So that equation (6') becomes

$$7)\ -ZQ - \frac{2+r}{2+m}E = F[\frac{2}{\mu} + \frac{rm \quad +2m- r^2}{m(m+2)}],$$

Using equations (5) and (7), we have

$$F = -\left[\frac{r+2\ -mZ}{r+2-mZ+rZ-\frac{r^2}{m}+\frac{2(m+2)}{\mu}}\right]E = -\left[\frac{r+2\ -mZ}{r+2-mZ+\frac{2r^2}{m(1-r)}+\frac{2(m+2)}{\mu}}\right]E = -\left[\frac{2(1-2r)}{2(1-2r)+\frac{2r^2}{m}+\frac{2(1-r)(m+2)}{\mu}}\right]E$$

The expression in brackets will be between 0 and 1 as long r < ½.

c. Directly follows from equation 5, using the result in Lemma 1. ■

■

Lemma A.1: The profitability of being a floor trader (*W*(m)*) is decreasing in the number of floor traders.

Proof: A sufficient condition for *W*(i)* to be decreasing in *i* is that $\frac{dP_2}{dm} < 0$ for $E < 0$, and $\frac{dP_2}{dm} > 0$ for $E > 0$.

$\frac{dP_2}{dm} = \frac{\partial P_2}{\partial m}|_Q + \frac{\partial P_2}{\partial Q}\frac{\partial Q}{\partial m} = \frac{\alpha\sigma^2}{m}(-Q + \frac{\partial Q}{\partial m})$. The term out front is positive, while the term in parentheses is ambiguous. We can write $\frac{dP_2}{dm}$ as

$\frac{dP_2}{dm} = \frac{\alpha\sigma^2}{m}\left(\frac{-\left(rF-m(F+E)\right)}{(m+2)} - \frac{\left(rF+2(F+E)\right)}{(m+2)^2}\right) = \frac{\alpha\sigma^2}{m(m+2)^2}\big((m+2)(m(E+F)-rF)-2(E+F)-$
$rF\big) = \frac{\alpha\sigma^2}{m(m+2)^2}(m^2+2m-2)(E+F)-(m+3)rF\big)$
$= \left(\frac{\alpha\sigma^2}{m(m+2)^2}\right)((m^2+2m-2)(1-\beta)+(m+3)r\beta)E$

Hence, $\frac{dP_2}{dm}$ has the sign of *E*. That is, more competition (higher *m*) leads to lower compensation for speculators on the floor. ■

Proposition 2: For $W^*(M-1) < L < W^*(1)$, there will be an equilibrium in which *m* speculators choose to establish a floor trading business, and $\mu = M - m$ choose not to. In this equilibrium, $P_2 > P_1 > \bar{V}$ for $E < 0$, and $P_2 < P_1 < \bar{V}$ for $E > 0$.

Proof: The essence of the proof is that since, by Lemma A.1, $W^*(i+1) < W^*(i)$, then if we show that $W^*(1) > 0$ it follows that for $L \,\varepsilon\, (W^*(M-1), W^*(1))$ there will be an equilibrium in which some speculators choose to pay *L* and some do not.

For the case in which $E > 0$, a sufficient condition for $W(1) > 0$ is that $P_2 < P_1 < \bar{V}$, since $P_2 < P_1 < \bar{V}$ implies that $U(x(\bar{V} - P_2) > U(y(\bar{V} - P_1)$. To see that that $P_2 < P_1 < \bar{V}$, note that $P_1 - P_2 = \frac{\alpha\sigma^2}{1-r}\left(\frac{F}{\mu} - \frac{Q}{m}\right)$. Since *F* and *Q* are < 0, $P_2 < P_1$ requires $|Q/m| > |F/\mu|$, or $F/Q < \mu/m$.

When $m = 1$,

$\mathrm{F} = -\left[\frac{2(1-2r)}{2(1-r)+2r^2+\frac{6(1-r)}{\mu}}\right]E \equiv -\beta E$, and $Q = \frac{rF-E-F}{3} = -\frac{(r-1)\beta+1}{3}E$,so that $\frac{F}{Q} = \frac{3\beta}{(r-1)\beta+1}$.

When $r = 0$, $\beta = \frac{\mu}{\mu+3}$, so that $\frac{F}{Q} = \mu$. Since $\frac{d(\frac{F}{Q})}{dr} < 0$, it follows that $\frac{F}{Q} < \mu$ for $r > 0$.

A parallel argument applies for $E < 0$.

It follows that for any $W^*(M-1) < L < W^*(1)$, there is some $m < M$ such that $W^*(m+1) < L < W^*(m)$. This means that if $m - 1$ other traders have chosen to pay *L*, and $M - m$ have chosen not to, trader i will choose to pay *L*, and conversely if *m* other traders have chosen to pay *L*, and $M - m - 1$ have chosen not to, trader *i* will not pay *L*. Hence, it is an equilibrium for exactly *m* traders to pay *L*. ■

Proposition 3:

The higher the cost per dollar of position held (*r*),

a. the smaller the hedger's trading (|*F*|) during the initial trading period.

b. the greater the hedger's trading (|Q|) during the settlement period

Proof:

a.

$$F = -[\frac{2(1-2r)}{2(1-2r)+\frac{2r^2}{m}+\frac{2(1-r)(m+2)}{\mu}}]E$$

so that $\frac{dF}{dr} = 8\left[\frac{r}{m}(2-3r)+\frac{2+m}{\mu}r\right]\frac{E}{[2(1-2r)+\frac{2r^2}{m}+\frac{2(1-r)(m+2)}{\mu}]^2}$

This expression takes the sign of E. Hence, for $E > 0$ (which implies $F < 0$), F becomes larger (closer to zero) as r increases, and similarly for $E < 0$, F becomes smaller as r increases.

b.

$$\frac{dQ}{dr} = \frac{\partial Q}{\partial r}|_F + \frac{\partial Q}{\partial F}\frac{\partial F}{\partial r} = \frac{F}{2+m} - \frac{rm}{2+m}\frac{dF}{dr}$$

For $F < 0$, $Q < 0$, and the first term implies that Q gets absolutely larger as r rises, holding F fixed. Lemma 2 shows that $\frac{dF}{dr}$ has the opposite sign as F, and hence it too implies that for $F < 0$, the absolute value of Q is increasing in r. The same conclusion holds for $F > 0$. ■

Appendix B: Changes in Trading for other Agricultural Futures Markets

In the paper, we show that the composition of aggregate trading in corn futures changed dramatically following the June 25, 2012 rule change, whereas there was no discernable change in live cattle futures trading. We focused on these two futures markets because they were the largest agricultural futures market for which (respectively), the rules changed and did not change on that date. In this Appendix, we provide figures analogous to Figure 3 for the second-largest futures market that had a change on that date (soy beans), and the second-largest futures market that did not have such a change (lean hogs). The similarity of these figures to Figure 3 demonstrates that our conclusion – namely that the rule change affected futures trading - is more general than the comparison of corn to live cattle might suggest.

Figure B.1

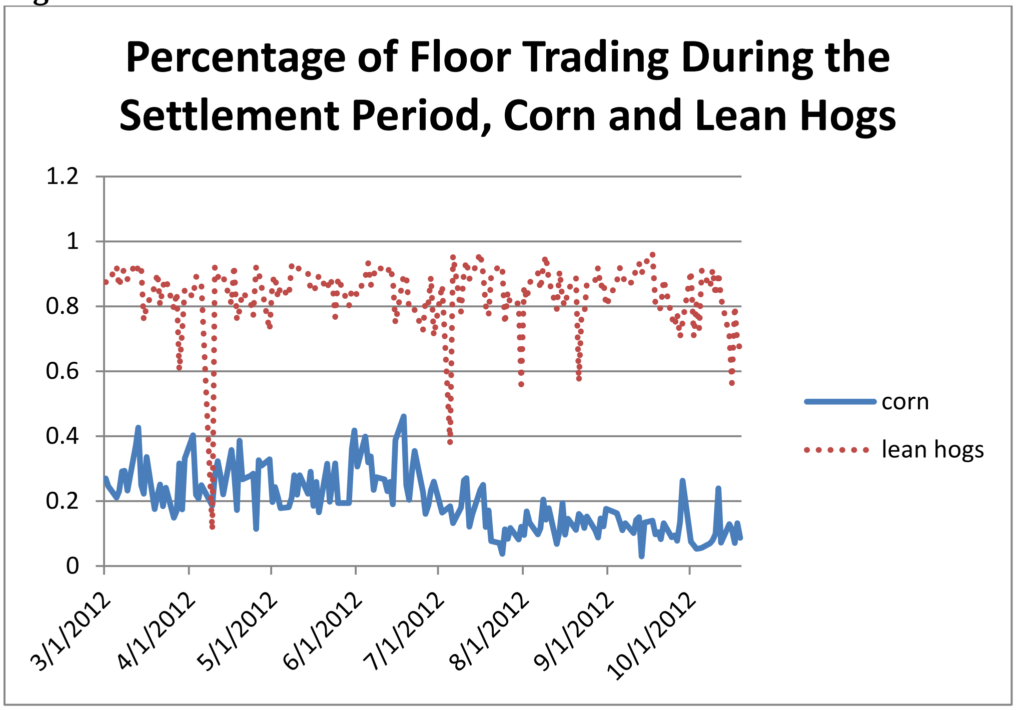


Figure B.1 shows the percentage of settlement-period trading that occurs in the floor for corn and lean hogs. As in Figure 3, we find that the percentage of trading that occurs in the pit declines markedly for corn following the rule change, but not for the comparison product.

Figure B.2

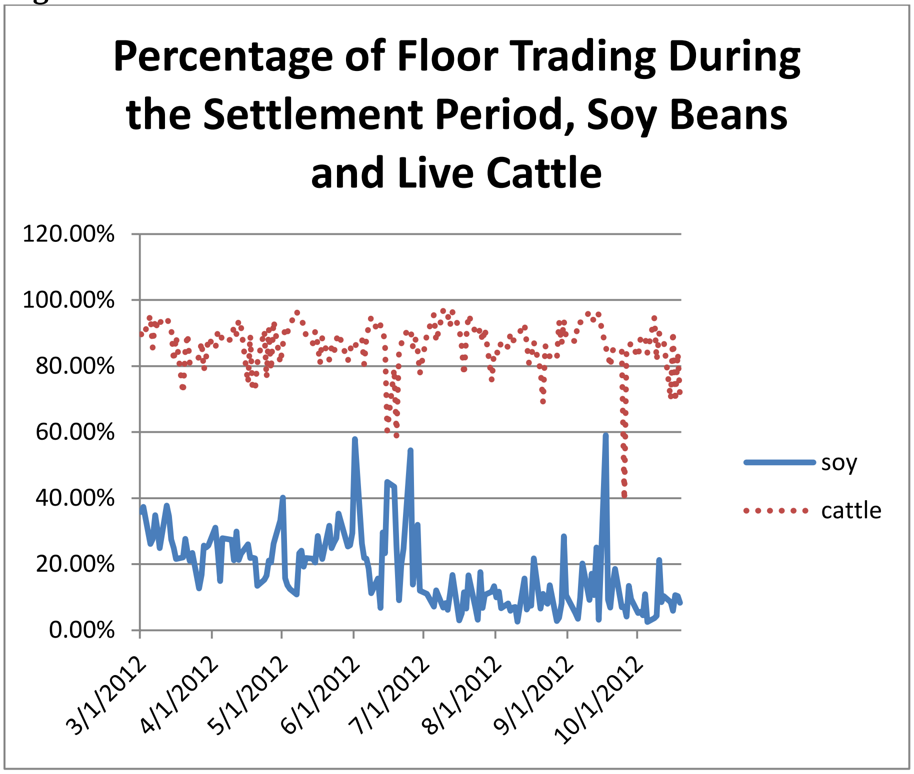


Figure B.2 shows a similar comparison, this time for soy beans and live cattle. As in the previous figures, we find that the percentage of trading that occurs in the floor declines dramatically for the product experiencing the rule change, but not for the comparison product.