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Eleni Gousgounis and Esen Onur

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Eleni Gousgounis and Esen Onur*

ABSTRACT

This paper evaluates how the closure of the futures pits impacted the execution costs of customer orders in the livestock futures market. Our results indicate that the execution cost of electronic orders placed by customers who were active in the pit increase after the pit closure. We find no evidence that this is due to an increase in trading with high-frequency traders. However, we find that the overall per contract unit execution costs, including pit and electronic orders, has declined for pit users, after the pit closure. Our findings suggest that this decline in overall execution costs can be attributed to the complete or partial withdrawal of some pit users from the market, while the detected increase in their execution costs in the electronic market is likely due to the migration of some informed pit orders to the electronic order book.

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*Eleni Gousgounis is a Research Economist and Esen Onur is a Supervisory Economist at the U.S. Commodity Futures Trading Commission. The paper was co-authored by Eleni Gousgounis and Esen Onur. While this paper was produced in the authors' official capacity, the analyses and conclusions expressed here are those of the authors and do not necessarily reflect the views of other Commission staff, the Office of the Chief Economist, or the Commission.

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1. Introduction

In July of 2015, the Chicago Mercantile Exchange (CME) closed down most of its pits, getting rid of floor trading in almost all of its markets. While trading in most futures pits was dwindling even before CME's decision to close the pits, there were some futures pits (i.e. livestock, treasury futures) which were still handling a sizeable market volume (Gousgounis and Onur, 2016). Therefore, while this decision probably made sense from CME's business perspective, it also caused a lot of discussion on whether the CME was getting rid of a trading design that actually had value for at least some customers and market participants[1]. The discussion over the value of the pits has also recently returned to the spotlight following the events of the COVID-19 epidemic, which forced trading to come to a temporary halt at equity, options and metals pits around the world (see Hu and Murphy, 2020; Brogaard, et. al., 2020 for analysis of recent pit closures).

CME's decision to close the pits coincides with an increasing trend in automated trading (Haynes and Roberts, 2018). At the same time, following the closure of the pits, various market participants in agricultural futures markets have been complaining of increasing transaction costs, which they often link to an increase in automated trading. For example, the National Cattlemen's Beef Association's (NCBA) letter to the CME's CEO states that "the effectiveness of cattle futures contracts as a viable risk management tool is being called into question due to the concerns over high frequency trading"[2]. Another loud concern has been voiced by customers

[1] Polanskek, T. (2015, June 24th). CME traders push regulator to delay futures pit closure by 90 days. Reuters. Retrieved on October 12th 2015 from http://www.reuters.com/article/2015/06/24/cme-group-futures-closure-cftc-idUSL1N0ZA2DS20150624
Stebbins C. (2015, July 23rd). CME fields complaints on soy crush spread after futures pits close. Retrieved on October 26th 2015 from http://www.reuters.com/article/2015/07/23/cmegroup-markets-meeting-idUSL1N1031ZH20150723

[2] In an open letter to the president and CEO of the CME, the National Cattlemen's Beef Association (NCBA) voice their concerns about increased volatility in the cattle contracts and indicate that this might be due to high frequency trading: http://www.beefusa.org/CMDocs/BeefUSA/Media/NCBAlettertoCMEreHFT.pdf

of agricultural futures markets at a conference organized jointly by the US Commodity Futures Trading Commission and Kansas State University[3]. While farmers in general agreed that automated markets, and the presence of high frequency traders in these markets, reduces bid-ask spreads, they complained that positions of automated traders on these markets lasted just seconds and that was not resulting in the price discovery required by agricultural traders. Part of the concern was related to the fact that bids and offers placed by automated traders were not staying on the limit order book long enough for agricultural traders to be able to take the other side of these orders. As a result, farmers claimed that their transaction costs have increased due to the increased presence of automated traders.

Motivated by these complaints, we explore how CME's closure of futures pits may have affected execution costs in all three livestock futures markets: live cattle, lean hog, and feeder cattle futures[4]. We focus specifically on customers, who are more likely to have been trading at the pit prior to its closure, and therefore more likely to have been affected by CME's decision. We use transaction level, regulatory data collected by the U.S. Commodity Futures Trading Commission (CFTC), which allows us to further differentiate between those customers who routed at least some of their trades to the pits (pit users), and to those customers who got their fills solely in the electronic marketplace (non-pit users). Since the pit closure is likely to have a greater impact on pit users, we compare the execution cost of each group in the electronic market, as well as their overall execution costs, including accounting for both electronic and pit orders. This approach allows us to identify the changes in marginal cost faced by the pit users, in

[3] The conference, titled "Protecting America's Agricultural Markets," touched upon a number of topics and one of them was the impact of Automated Trading Systems on agricultural derivatives contracts. https://www.iatp.org/blog/CFTC-goes-to-heartland

[4] While these contracts are not the largest commodity futures markets, they are not small either. Total trading volume in 2015 for live cattle futures was 13,440,934 contracts, for lean hog futures 9,575,882 contracts, and for feeder cattle futures 2,493,051 contracts.

comparison to those faced by the non-pit users. Finally, we investigate whether any potential change in execution costs could be attributed to an increase in trading with high frequency traders (HFTs), as suggested by Haynes et al (2017).

Our findings suggest that while execution costs of customers in the electronic feeder cattle market appear unaffected by the pit closure, this is not the case for the two largest livestock futures markets; the live cattle and lean hog futures. While customers in these markets generally experience lower execution costs on their electronic orders following the pit closure, pit users in particular face higher execution costs. Surprisingly, these execution costs appear to be higher irrespective of whether the associated orders were aggressive or passive. Aiming to explain these results, and motivated by the complaints of market participants on high frequency trading, we investigate whether high frequency trading is responsible for this increase. While we find that high frequency trading in livestock futures indeed increased after the pit closure, there is no evidence to suggest that the pit user customer group is facing higher execution costs when they trade against high frequency traders.

A natural extension of our analysis is to track the overall execution costs of customers including both pit and electronic orders. Our goal is to detect whether the increase in execution costs faced by pit users could be attributed to the migration of some inherently more expensive orders (potentially because of their high information content), which would have been routed to the pit if the pits were open, to the electronic market. Any pit order being migrated over to the electronic market is likely to be shredded into smaller orders, which results in pit and electronic orders having unequal sizes (Shah and Brorsen, 2011). To deal with this discrepancy, we translate all orders into contract-unit terms when we compare execution costs of pit and electronic orders together. Interestingly, our results indicate that the execution costs have actually declined for the pit user group for all of three livestock futures contracts. In more detail, execution costs for pit users appear to be on average lower by 1 basis points (bps) in live cattle, 1.7 bps in lean hog and 0.7 bps in feeder cattle futures markets. We show that this finding can be explained by the complete withdrawal of some informed pit users from the market and the partial migration of informed orders of other pit users to the electronic market. Contrary to live cattle and lean hog futures markets, informed pit users mostly withdraw from the feeder cattle market, which explains the absence of a change in the execution costs of pit users in the electronic market and simultaneous decline in their overall costs when we account for both pit and electronic orders.

Overall, our study establishes that pits were serving an important function by handling large, informed and costlier trades, at least in the livestock futures. However, in connection to more recent events, we fail to find support for the claim of the CEO of the Intercontinental Exchange regarding recent closure of pits due to the COVID-19 pandemic, stating that market participants trading in the pits save millions of dollars a day[5]. We also establish that trading costs in the electronic market have gone up for customers overall in two out of three livestock futures markets, but contrary to farmers and ranchers' complaints, we do not find any evidence suggesting this is due to trading with HFTs.

2. Background

This paper is part of the growing literature on the evolution of execution costs in agricultural markets, as electronic trading becomes popular and order flow shifts away from the pit to the electronic order book. In that sense, this paper is closely related to Bryant and Haigh

[5] https://www.reuters.com/article/us-ice-result/nyse-owner-ice-makes-case-for-trading-floor-as-profits-rise-idUSKBN22C22I

(2004), Shah and Brorsen (2011), Frank and Garcia (2011), Wang et. al (2014), and Aidov and Daigler (2015)[6]. Specifically, Bryant and Haigh (2004) evaluate how the transition from pit to electronic trading may have affected liquidity in the coffee and cocoa markets. They find that bid-ask spreads generally widen after moving to electronic only trading, which they attribute to an increase in adverse selection costs enabled by the increased anonymity in electronic market. However, Frank and Garcia (2010) find that bid ask spreads at the livestock pits seems to decline as electronic trading increases and places competitive pressure on prices at the pit. They estimate bid ask spreads using a modified Bayesian methodology and show that they are negatively correlated with total volume and positively correlated with price volatility. Moreover, Shah and Brorsen (2011) compare the liquidity cost of trading red winter wheat futures in the electronic and open outcry market, while they co-exist. Somewhat contradicting the findings of Bryant and Haigh (2004), they find liquidity costs in the electronic market to be lower. However, they also find that trade sizes are larger in the pit, which is preferred by large traders. Wang et al (2014) study the actual bid-ask spreads from the electronically traded corn futures market and provide evidence that "the electronic order book provides sufficient liquidity to maintain execution costs at low and rather stable levels," even during the high volatility period of 2008-2009. The liquidity of electronic futures markets is also documented by Aidov and Daigler (2015), who study the depth of various electronic futures markets (10-year U.S. Treasury note, corn, WTI futures, Euro/U.S. dollar, yen/U.S. dollar and gold futures). They find that electronic market depth is updated faster during the day, when the pit is open, and that generally there is symmetry between the bid and ask sides of each level in the limit order book, but there is no equality across different depth levels.

[6] There are more papers that fall under the heading of microstructure of agricultural markets; these papers are a non-exhaustive sample of that universe.

Gousgounis and Onur (2018) explore how CME's decision to close the futures' pits in July 2015 may have affected electronic treasury and livestock markets. They find more pronounced effects in the livestock electronic markets: overall execution costs in the electronic market increase, while some of the pit users continue to trade in the electronic market[7]. Shang, Mallory, and Garcia (2016) analyze the bid ask spread behavior in the electronic live cattle futures markets and they show that the bid ask spread in the live cattle futures widened during the volatile periods of 2014 and 2015. They also show that adverse selection cost component is small whereas order processing cost is the largest component. Couleau et. al. (2018) identify the market structure noise present in live cattle futures market data and find that the high volatility experienced in this market in 2015 was not due to high frequency trading, but instead it was mainly driven by market fundamentals. Finally, Haynes et. al. (2017) uses the same data set we utilize in our study and analyze the effect of increased algorithmic trading on livestock futures market liquidity and pricing efficiency. While they identify an improvement in market efficiency following the change in settlement rule methodology in live cattle futures, they do not find any conclusive evidence of bid-ask spread improvement.

3. Methodology Description

3.1 Execution Costs

[7] This study differs from Gousgounis and Onur (2018) in three distinct ways. First, contrary to Gousgounis and Onur (2018) who measure execution costs using the aggressive side of all transactions, this study focuses on the execution costs of customer orders, which may be both aggressive and passive, as customers typically use mixed strategies to execute their orders. Second, while Gousgounis and Onur (2018) identify pit users and track the trading behavior of "locals" at the pit, they do not link pit users' market participation to the execution cost trends following the pit closure. This study focuses on customer pit users and ties their trading behavior to increases in electronic execution costs for customer pit users following the pit closure, which allows us to determine whether any change in execution costs is indeed due to the pit closure. Third, this study evaluates the effect of HFT trading on execution costs for customer pit users.

We explore the potential impact of the pit closure on the liquidity of the electronic market, as measured by customer execution costs. Since our dataset allows us to match transactions with their originating orders, we estimate execution costs for the whole order, which allows us to capture a more realistic measure of the costs faced by market participants, rather than using just the aggressive side of each trade as traditionally done in the literature (Gousgounis and Onur, 2018). In more detail, we proxy execution costs for electronic orders using the effective half spread, which is estimated as:

$$Effective\ half\ spread = 100 * Di\ * (log(P_{t,0}) - log(P_{t,benchmark})),$$

where log represents the natural logarithm, $P_{t,0}$ is the volume weighted transaction price of each order, and $P_{t,benchmark}$ is the average price of trades occurring in the five minute interval preceding the first trade of each order. The variable Di is a trade direction indicator where $Di = 1$ for a buy order and $Di = -1$ for a sell order[8]. Notably, our data allow us to categorize orders into passive and aggressive ones. While we are interested in the total effect on the costs of order execution for customers in the electronic market, we also want to explore whether this potential effect is driven by aggressive or passive orders. We expect aggressive (passive) customer orders to have positive (negative) execution costs. To this extent, we label an order as aggressive (passive), if more (less) than fifty percent of that order's traded volume corresponds to trades initiated by the particular customer[9]. It is possible that aggressiveness level of an order might also capture the urgency of the customer to fill her order (Engle et. al., 2012).

3.2 Estimation Methodology

[8] Our measure is similar to the implementation shortfall measure proposed by Perold (1988), however we only consider the cost associated with executions and abstract away from the cost associated with unfilled orders.
[9] There are very few cases in which the aggressive and passive transactions associated with an order are equivalent in volume. In most cases, orders are composed of mostly aggressive trades or mostly passive trades.

To account for the effect of the aggressiveness level of an order on its execution cost, we choose to model execution costs of customer orders using a two stage regression (Lee 1982, 1983):

$$y_i = z_i'\gamma + u_i$$

$$c_i = x_i'\beta + \varepsilon_i$$

where the first equation estimates the probability that a customer order i was aggressive $(y_i = 1)$ or passive $(y_i = 0)$, where the second equation estimates the execution cost c_i. The errors u_i, ε_i are assumed to be jointly normal with a zero mean, a standard deviations equal to 1 and σ respectively, and correlation ρ. A similar methodology has been applied in studies on block trading in order to control the bias associated with the choice to direct and order in the upstairs vs. the downstairs market (Madhavan and Cheng, 1997, Gousgounis and Srinivasan, 2019).

The first stage of the model is estimated by a probit regression, which models the decision to position each customer order i as aggressive (y_i=1) or passive (y_i=0). The explanatory variables, z_i, include market characteristics, such as realized volatility, trading intensity and a proxy for order imbalance, as well as order characteristics, such as the size of the order and a dummy indicating whether the order corresponds to an outright or a spread. Realized volatility is estimated as the square root of the sum of one minute squared returns during the hour before the order started executing. Trading intensity is measured as the logarithm of the average minute volume of futures traded during the hour before the order started executing. Finally, following the literature, our order imbalance proxy, measures the proportion of volume on the same side of the market during the hour prior to the order.

The second stage of the model estimates the execution costs of customer orders conditional on the order being aggressive or passive[10]:

$$E[c_i|y_i = 1] = x_i'\beta_a + \rho_a \sigma_a \left[\frac{\varphi(z_i'\gamma)}{\Phi(z_i'\gamma)}\right]$$

$$E[c_i|y_i = 0] = x_i'\beta_p + \rho_p \sigma_p \left[-\frac{\varphi(z_i'\gamma)}{1 - \Phi(z_i'\gamma)}\right]$$

where $\varphi(.)$ denotes the standard normal density function, and $\Phi(.)$ denotes the cumulative standard normal distribution. The second terms in each equation correct for selection bias. They represent nonlinear combinations of the variables used to predict the decision to use an aggressive or a passive order. If $\rho_a \sigma_a$ and $\rho_p \sigma_p$ are equal to zero, the selection of using an aggressive or a passive order should not affect execution costs. Furthermore, a negative (positive) sign for $\rho_a \sigma_a$ ($\rho_p \sigma_p$) would indicate that the trader faces a lower execution cost, which can be attributed to the decision to place an aggressive (passive order). The model is estimated for livestock futures contract.

We investigate whether execution costs increased after the pit closure and whether pit users were adversely affected. To the extent that these effects are found, we investigate whether trading with HFTs could be a driving factor. Therefore, the effective half spread, which serves as a proxy for execution costs, serves as our dependent variable. Explanatory variables, x_i, include a dummy indicating whether the order was placed before or after the pit closure, a dummy indicating whether the order belongs to a pit user, as well as their interaction. In a separate specification, we also include the proportion of an order executed against HFTs along with the appropriate interactions with the other explanatory variables.

[10] The model is estimated twice: first aggressive and then for passive orders.

Moreover, similar to Engle et al. (2012), the explanatory variables, x_i, include common market measures (realized volatility, trading intensity), and proxies for order characteristics (order size, the contract's time to expiration, a dummy indicating whether the order is manual). Finally, additional control variables include dummies controlling for the change of the settlement procedure in December 2014, changes in the trading hours, and on whether the order was placed on a Monday or a Friday[11]. The latter two dummies control for the effect of announcements of cash market auction results, which typically occur on Fridays.

4. Data

Our dataset includes transaction data on livestock futures during the time period extending from June 1st 2014 to June 1st 2016. The regulatory dataset, constructed using the Transaction Capture Report database of the CFTC, includes detailed transaction information such as the price and quantity of every futures trade and the execution venue (electronic, pit and block trades). Other useful information in the dataset are indicators for whether a particular trade was part of a spread (i.e. a calendar spread), and a flag for who initiated the trade (buy side vs. sell side) for electronic transactions (aggressor indicator)[12].

Electronic trading in the livestock futures markets takes place on a centralized limit order book. An order placed on the book can be fully executed in a high number of transactions and might take several minutes to complete. To be able to capture the true cost of executing an order, one would have to account for all those transactions, which are potentially being traded at

[11] We control for orders placed on Monday and Friday because generally weekly cattle auction summaries are released on Fridays followed by weekly market recap reports released on Mondays (https://www.ams.usda.gov/market-news/feeder-and-replacement-cattle-summary).
[12] We do not have aggressor indicator for pit trades, which restricts our analysis to simple OLS when we compare the overall transaction costs before and after the pit closure.

differing price levels. The order identifier allows us to track all executions associated with an order and as a result measure the cost of an order with precision.

The dataset also provides some information on the originating orders of the transactions. More specifically, it provides the order type of each originating order, as well as an order identifier, which allows us to bunch trades belonging to the same order[13]. Moreover, the dataset identifies counterparties to a transaction and provides information on market participants, such as the identification number for each trader, and the trading role of each customer account, as measured by the customer type indicator (CTI code)[14]. The trader IDs allow us to classify which traders are HFTs and the CTI codes allow us to distinguish customer trades from proprietary ones.

Being able to identify customers is exceptionally important since most of the complaints that were voiced after the pit closure were from customers, especially in the livestock futures markets. Most of these customers, who are made up of entities using the futures markets for

[13] Our data set excludes stop orders and requests for cross which correspond to less than 2% of our sample of customer orders. In more detail, stop orders (requests for cross) corresponds to 1.7% (1.3%) of the live cattle customer volume. In the lean hog futures market, stop orders (requests for cross) corresponds to 1.3% (1.3%) of the customer volume. In the feeder cattle futures market, stop orders (requests for cross) correspond to 1.8% (1.8%) of the customer volume.

[14] The Chicago Mercantile Exchange (CME) specifies the CTI codes as follows:

"CTI 1: Electronic Trading, Open Outcry and Privately Negotiated – Applies to transactions initiated and executed by an individual member for his own account, for an account he controls, or for an account in which he has an ownership or financial interest. However, transactions initiated and executed by a member for the proprietary account of a member firm must be designated as CTI 2 transactions.

CTI 2: Electronic Trading, Open Outcry and Privately Negotiated – Applies to orders entered or trades executed for the proprietary accounts of a member firm.

CTI 3: Electronic Trading – Applies to orders entered by a member or a nonmember terminal operator for the account of another individual member or an account controlled by such other individual member. CTI 3: Open Outcry and Privately Negotiated – Applies to orders that a member executes on behalf of another individual member, or for an account such other member controls or in which such other member has an ownership or financial interest.

CTI 4: Electronic Trading Open Outcry and Privately Negotiated – Applies to all orders and transactions not included in CTI categories 1, 2 or 3. These typically are orders entered by or on behalf of nonmember entities."

Source: CME Group. (2014, April 2). Market Regulation Advisory Notice, Rule 536.D, Retrieved from www.cmegroup.com/rulebook/files/cme-group-ra1401-5.pdf hedging purposes, cared a lot about the cost of putting on a sizeable hedge to mitigate the risk in the underlying markets. It is also possible that their orders are more informed than those of proprietary traders and as a result might elicit different transaction costs[15]. Our data allow us to capture all these differences by focusing on customer orders.

Finally, knowing which side of the transaction initiates each electronic trade, which is also known as the aggressive side, is also pivotal for our analysis. To adopt this transaction-based specification to our order-based analysis, we calculate a volume-weighted measure of aggressiveness for every order from each transaction that is part of that order. This variable is then used to account for the endogenous decisions of customers to place aggressive or passive orders in our analysis.

5. Descriptive statistics

5.1 Customer orders: Pit users vs. Non-pit users

We start by classifying the customers in our sample into three groups. The two main groups of customers are those who, prior to the pit closure, traded exclusively in the electronic market (non-pit users) and those who were using the pit for at least some of their transactions (pit users)[16]. After the pit closure, we have a third group of customers (new entrants), who appear for the first time in our sample after the pit closure. As expected, some of the customers in the first two groups (pit users and non-pit users) drop from our sample after the announcement of the pit closure.

[15] Gousgounis, Onur, and Tuckman (2019) present similar findings in the Treasury futures market.
[16] We define pit users as customers who had at least one pit transaction during the period of June 1st, 2014 – February 4th 2015, which is the date of the announcement of the pit closure. Non-pit users have electronic transactions during this timeframe but no pit transactions.

Table 1 presents the trading patterns of all groups of customers in the livestock futures markets. Results are similar across the three futures contracts. While the trading behavior of new entrants is documented in the table, we focus our analysis on pit users and non-pit users, both of which are responsible for most of the volume. Our summary statistics suggest that pit users were executing at least one third of their daily trading volume at the pit across all livestock futures contracts. While the number of pit users is relatively small, those customers appear to be responsible for a substantial trading volume (around 30 percent for live cattle and lean hog futures and 15 percent for feeder cattle futures) and exhibit substantially higher average trading volume compared to those customers trading exclusively in the electronic market[17]. Pit users place larger number of orders compared to non-pit users, and these orders are on average larger in size, due to the traditionally larger size of pit orders[18]. However, we notice that after the closure of the pits, pit users have increased the number of orders they place by at least 30%, while the average size of their orders has dropped by about half. This is indicative of a change in trading strategy caused by the pit users' migration to an electronic only environment. Nevertheless after the pit closure, the average size of pit users' orders, which are now electronic, remains higher than that of non-pit users. Moreover, pit users are more likely to trade strategies (calendar spreads) than non-pit users, but this phenomenon is more pronounced in live cattle and feeder cattle futures contracts. Interestingly, most customer orders are manual, and this is true for all groups of customer orders. We also observe that after the pit closure, more than 25% of the customers' trading volume is executed against HFTs. The proportion of trading against HFTs

[17] Average daily volume of a pit trader is 3 – 4.5 times of that of a non-pit trader in our sample.
[18] The larger order size for pit users is driven by the order size discrepancy between their pit and electronic orders. In more detail, the average live cattle customer pit order prior to the pit closure was 27.6 contracts, while the average live cattle electronic order for pit users was 6 contracts. The average lean hog customer pit order prior to the pit closure was 25.2 contracts, whereas the average lean hog customer electronic order for pit users was 6.5 contracts. The average feeder cattle customer pit order size prior to the pit closure was 10.5 contracts, whereas the respective electronic orders placed by pit users had an average size of 3.3 contracts.

appears to have increased after the pit closure and this increase is more pronounced for pit users, as they potentially migrate their pit orders to the electronic order book. Finally, the overall aggressive proportion of aggressive orders for customers appears to be close to 60%. This number was a little lower for pit users prior to the pit closure.

Next, we move on to comparing average execution costs across the three markets we analyze. The proportion of aggressive orders from Table 1 also suggests that our execution cost analysis should also take into account the changes in the order placement choices of customers: hence, we extend our analysis to also study aggressive and passive customer orders separately. The Appendix describes graphically the evolution of the execution costs during our sample. Figure A1 in the Appendix shows that aggressive orders exhibit on average a positive effective half spread while passive orders exhibit on average a negative effective half spread. While not surprising, we note that the choice between passive and aggressive orders have significant implications for cost of trading. Moreover, while execution costs fluctuate, there is no discernable pattern in the effective half spread of aggressive and passive trades before and after the pit closure. However, as shown in Table 1, customers, and especially pit users, appear to have somewhat increased their proportion aggressive trading in the electronic order book, which could be potentially increasing their net execution costs. Therefore, even if the average cost of an aggressive (passive) order has changed, a change in the composition of aggressive and passive orders used could be resulting in a change the average cost of execution.

5.2 High Frequency Traders

It has been suggested that the presence of high frequency traders may be contributing to an increase in execution costs. In order to address this concern, we identify high frequency traders in livestock futures markets. Following Brogaard et al (2019), for each contract and each date, we first mark accounts as engaging in high frequency trading activity when: (i) they make up more than 0.25% of the daily trading volume; (ii) have an end-of-day inventory of less than 20% of their trading volume; and (iii) never hold more than 30% of their daily trading volume at one time within the trading day[19]. In order to be classified as an HFT, a trading account should engage in high frequency trading activity in at least 50% of the various maturity contracts they trade, and for at least 75% of their trading days.

Table 2 presents some descriptive statistics for the trading accounts classified as HFTs in our sample for each livestock futures contract and compares them to all other accounts in the market. We present these measures for the full sample, but we also track how the trading characteristics of these accounts may have changed after the pit closure. Generally the number of accounts identified as HFTs is small, whereas there are thousands of non-HFT accounts in each market. Contrary to those accounts, HFTs trade regularly in the market, and handle large trading volumes. Their average daily market volume share appears to range from 2.5% for live cattle to 4.5% for feeder cattle, with little variation before and after the pit closure. The absolute end of day position does not surpass 2.5% of their trading volume. The HFTs' running position for live cattle and lean hog futures is less than 10% of their daily total volume and this number is around 12% for feeder cattle.

Our HFT statistics are qualitatively similar to those in Brogaard et al (2019). They identify 13 HFTs per each stock-day. In comparison, in live cattle futures, we identify a little over 20 HFTs per day on average (50*209/500 = 20.9). With similar calculation, we identify 15 HFTs per day on average for lean hog futures and 12 HFTs for feeder cattle futures.

[19] This identification methodology is similar to the one used in Kirilenko et al. (2017).

Additionally, we find that HFTs have a market share of around 20%, which is in the middle of the range reported in Brogaard et al (2019) for the 15 securities they investigate.

In Figure 2, we present HFTs' market share, estimated as the proportion of volume executed by HFTs in the electronic market. We observe a general increasing trend in HFTs' market share, which is in line with Haynes and Roberts (2018). We also observe potential jumps around the time of the pit closure announcement and the pit closure itself, which could have been driven by the expected migration of order flow from the pit. This is consistent to the increase in the average proportion of customer volume executed against an HFT, as reported in Table 1. While both pit users and non-pit users trade more frequently against HFTs after the pit closure, the magnitude of this increase is greater for pit users. As pit users trade exclusively in the electronic market after the pit closure, the ratio of orders executed by pit users and non-pit users against HFTs has become comparable. Figure 2 also presents the proportion of customer trading against HFTs for pit users and non-pit users, exclusively in the electronic market before and after the pit closure date. While there seems to be an increasing trend, we do not observe any clear difference between pit users and non-pit users, which suggests that any difference in the execution costs between the two groups in the electronic market might not be due to an increase in trading against HFTs.

6. Multivariate results

6.1 Execution costs after the pit closure: Pit users vs. Non-Pit users

In order to properly evaluate the effect of the pit closure on the execution costs faced by customers in the livestock futures market, we employ the two stage regression to evaluate the effect of the pit closure on execution costs. In the first stage we use a probit regression to evaluate the decision to place an aggressive (vs. a passive) order using order characteristics and market variables, also used by Lo and Sapp (2010). In the second stage, we evaluate the effect of the pit closure on execution costs accounting for the selection bias arising from the decision to place an aggressive (vs. a passive) order. We examine the overall execution costs, as well as aggressive and passive orders separately. We also control for those accounts that were active pit users prior to the closure of pits, as we expect the pit closure to have a direct and pronounced effect on pit users compared to other customers.

Table 3 presents the results of the first stage probit regression for each livestock futures contract. It describes the factors behind the customer choice to place an aggressive or a passive order. Large orders appear to be more likely to be aggressive, while trading strategies are more likely to be placed as passive orders. Customers appear to prefer passive orders when trading intensity increases. Volatility appears to be positively related to the probability of placing an aggressive order for live cattle futures, but negative for lean hogs and feeder cattle. Finally, similar to the findings in Lo and Sapp (2010), aggressive orders are positively related to the proportion of volume on the same side of the market.

Table 4 presents the results of our second stage regression, which describes the execution costs of customers in the live cattle market, measured by the effective half spread. The first two columns show the results for the unconditional effective half spread, followed by the results of the respective second stage regressions for aggressive and passive orders. The pit closure dummy takes the value one after the pit closure and zero in the time period before July 6th 2015. The pit user dummy takes the value one for orders originating from pit users and zero otherwise. The effect of the pit closure on the execution cost of all orders appears to be negative and significant, which suggests that the overall execution costs have declined following the pit closure. Pit users, in particular, face higher execution cost, which increase further after the pit closure. The coefficient of the pit closure dummy is positive for aggressive orders, which is outweighed by the negative sign of the corresponding coefficient for passive orders. After the pit closure, execution costs increase for both aggressive and passive orders placed by pit users. The coefficient of the inverse mills ratios confirm the presence of selection bias and the need to adjust for it. The selection correction variables are negative (positive) for aggressive (passive) orders, which indicates that traders choose optimally between aggressive and passive orders to minimize execution costs[20]. Effective half spread is also higher (lower) for manual, aggressive (passive) orders and orders with relatively longer time to expiration. Realized volatility and trading intensity are associated with higher effective half spread for both aggressive and passive orders. Order size appears to be associated with lower execution costs, which may seem counterintuitive. However, one should keep in mind that this is not the total effect of order size on execution costs, as order size also affects execution costs indirectly through the decision to place an aggressive order. This holds for all variables included in the probit regression as independent variables. We also control for news announcements by including a Friday and Monday dummy; the latter has a positive effect on execution costs. Finally, we control for changes in trading hours and the rule change on settlement, which preceded the announcement of the pit closure[21].

Tables 5 present our results for the lean hog futures market. Table 5 shows that, similar to the live cattle futures market, the sign of the pit closure dummy for all orders and for passive orders is negative. This suggests that overall execution costs are lower after the pit closure,

[20] The selection correction variables include the mills ratios included in the regressions for aggressive and passive orders. In the unconditional regression the selection correction variables include the interaction of mills ratios with the aggressor dummy as indicated in our model.

[21] Haynes et. al (2017) explore the effect of the change in the settlement process on liquidity.

which is exclusively driven by passive orders. Pit users face higher (lower) execution costs for aggressive (passive) orders, but contrary to the live cattle futures market the net effect is negative. However, the interaction between the pit user dummy and the pit closure dummy has a positive effect on execution costs for all orders and for both aggressive and passive orders. Therefore, the pit closure is associated with higher execution costs for pit users in the lean hog futures market.

Interestingly, our results on the feeder cattle futures market, reported in Table 6, indicate that aggregate execution costs have not changed after the pit closure for any group of market participants. In more detail, the effect of the pit closure on all orders appears to be negative but insignificant, while the corresponding coefficient is positive and significant for aggressive, and negative for passive orders. These findings indicate that aggressive orders face a higher effective half spread after the pit closure, which is offset by a higher compensation of liquidity providing passive orders. Moreover, while the interaction of the pit closure dummy with the pit user dummy has a negative effect on execution costs for aggressive orders, this effect is offset by an increase in execution costs for passive orders.

In summary, our results indicate that execution costs, following the pit closure, have generally increased for aggressive customer orders and declined for passive ones. Specifically, the net aggregate effect is negative for live cattle and lean hog and insignificant of feeder cattle futures. However, execution costs for pit users, in live cattle and lean hog futures in particular, seem to increase after the pit closure[22]. In the case of live cattle futures, this can be attributed to an increase of execution costs for passive orders. In the lean hog futures, positive net increase in

[22] Gousgounis and Onur (2018) find that execution costs of aggressive transactions increase after the pit closure for livestock futures. While this paper focuses on just customer orders, which are separated into pit users and non-pit users, it provides qualitatively similar results for the aggressive orders: execution costs in electronic markets appear to increase for all customers after the pit closure. However, this study goes a step further and also evaluates the execution costs of passive orders, as well as the overall execution costs for pit users and none pit users.

execution costs for pit users is driven by an increase in the execution costs of both aggressive and passive orders. The question that arises is whether these higher execution costs (or lower in the case of feeder cattle futures) for pit users arise from trading with HFTs after the pit closure or whether they just reflect orders with inherently higher costs, which have potentially migrated from the pit to the electronic order book.

6.2 The role of HFT trading

Our results from the previous section indicate that the pit closure has negatively affected pit users trading live cattle and lean hog futures contracts, who face higher execution costs for both their aggressive and passive orders. Motivated by the complaints of market participants on HFT trading and our summary statistics (table 2, figure 3), indicating an increase in pit user trading against HFTs following the pit closure, we explore whether this increased HFT trading may have resulted in higher execution costs for pit users. To this end, we repeat the regressions of tables 4-6, adding the proportion of each order executed against HFTs (*Opp HFT*) as an independent variable. We also include the interaction of *Opp HFT* with the pit closure dummy and a triple interaction with the pit closure dummy and the pit user dummy.

Table 7 presents the results for live cattle futures. Trading against HFTs is generally associated with higher execution costs, as indicated by the positive sign of the *Opp HFT* variable. However, the overall execution costs do not seem to increase after the pit closure for pit users or non-pit users, as both interaction terms with the pit closure dummy in the all orders regression are not significant. In more detail, aggressive orders by pit users trading against HFTs after the pit closure face lower execution costs, which are, however, offset by higher execution costs of passive orders during the same time. This could suggest that HFTs serve as liquidity providers, leading to a lower the bid-ask spread and thus allowing pit users to fill their aggressive orders at more favorable prices. At the same time, the presence of HFTs potentially increases competition for pit users placing passive orders, resulting in higher costs for those orders. However, the net effect is not significant and trading against HFTs does not explain why pit users face higher execution costs after the pit closure: the sign of the interaction of the pit closure dummy with the pit user dummy remains positive and significant for all orders and also for aggressive and passive orders.

Table 8 presents the lean hog futures regression results. Similarly, we do not find any evidence pointing to HFTs being responsible for the increase in execution costs for pit users following the pit closure. Trading against an HFT is generally associated with higher execution costs for both aggressive and passive orders. The positive sign of the interaction of *Opp HFT* with the pit closure dummy suggests that non-pit users face higher execution costs after the pit closure. However, this does not seem to be the case with pit users, as the sign of the triple interaction is negative and not significant. Moreover, the positive sign and significance of the interaction of the pit user dummy with the pit closure dummy suggests that HFTs are not responsible for the increase in the pit users' execution costs after the pit closure.

Even though our results show that there is no significant increase in execution costs for feeder cattle futures following the pit closure (Table 6), we repeat our analysis including trading against HFTs for consistency. We present the regression results in Table 9 and they are similar to the other livestock futures contracts. Trading against HFTs is generally associated with higher execution costs. However, while there appears to be an increase execution costs for non-pit users trading against HFTs, as evidenced by the positive interaction of *Opp HFT* with the pit closure dummy, there is no such evidence for pit users.

Therefore, our results suggest that the higher execution costs faced by pit users when they trade in the electronic market after the pit closure cannot be attributed to an increase in trading against HFTs.

6.3 Are execution costs for pit users really higher?

So far, our results suggest that overall execution costs of orders placed by pit users on live cattle and lean hog futures contracts increase after the pit closure, while overall execution costs for feeder cattle appear unaffected. While high frequency trading also increases during the same time, we do not find pit users to be adversely affected when they trade with HFTs. Then, why do pit users in the two largest livestock contracts face higher execution costs in the electronic market after the pit closure? A potential explanation lies in the nature of pit orders, which are, after the pit closure, forced to be routed to the electronic market or withdrawn. Pit orders are generally associated with higher execution costs compared to electronic ones (Appendix, Figure A2). This is potentially because they have higher information content[23]. Additionally, since pit users appear to use both venues prior to the pit closure and since they had the option to route pit orders to the electronic market, but chose not to, it is possible that these orders might have been more expensive to execute in the electronic market[24]. Therefore, the increase in execution costs for pit users in electronic markets following the pit closure could potentially be reflecting the migration of the inherently more expensive orders to the electronic market. Moreover, this migration of the order flow to the electronic market is coupled with a change in the pit users' trading strategy: after the pit closure, pit users place a larger number of smaller orders, as shown

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[23] Fishe and Smith (2012) analyze 12 futures markets from 2000 and mid-2009 to identify informed traders and find floor brokers/traders to be over-represented in the overnight informed traders group. Cooney and Sias (2004) provide evidence showing how informed investors in the equity market prefer to use a floor broker instead of trading in the limit order book.

[24] Of course, it is also possible that pit users expected their pit orders to be more expensive, had they been routed to the electronic order book but at the end they were not.

in Table 2, which is consistent with a higher incidence of order shredding, with these smaller orders being a mixed combination of aggressive and passive orders.

To explore the validity of this explanation, we aim to evaluate whether the execution costs have increased for pit users accounting for all orders, pit and electronic. However, even though they represent a significant portion of the trading volume, we know that the number of large pit orders observed in our sample is relatively small compared to the number of electronic orders. This means the weight placed on these orders in a simple regression would be small and the regression coefficients would not reflect the true cost of large pit orders. Additionally, we know that pit users change their trading strategy after pit closure and they slice their order flow migrating to the electronic market into smaller orders[25], making it challenging to compare the pit orders prior to the pit closure to the corresponding migrated electronic orders after the pit closure, both in terms of size and execution costs. To address this issue, we switch our measurement unit from orders to contract units[26]. Namely, we evaluate whether execution cost for pit users after the pit closure have indeed increased on a per contract unit basis, accounting for all contracts traded, both at the pit and on the electronic order book. In more detail, our sample of contract units is created by repeating the information of every order as many times as the number of contracts in that order. For example, for an order with a size of 10 contracts, our revised sample for this part of the analysis contains 10 repeated observations, each representing one traded contract unit.

[25] Shah and Brorsen (2011) also document that the more frequent splitting of orders in the electronic market, can be an issue in comparing the execution costs in the pit and the electronic order book.
[26] Bootstrapping would be an alternative way to solve the under-sampling problem associates with pit orders. However, it would not address the problems arising from the fact that pit and electronic orders are non-comparable, as electronic orders as typically sliced into much smaller pieces. Hence, we choose to transform our orders into contract units, which we believe addresses both issues.

Table 10 presents the results of an OLS regression on overall effective half spreads, on a per contract unit basis, for all contracts traded. Note that since our data set does not provide an aggressor indicator for pit orders, and we are not able to run a two stage regression similar to our previous analysis[27]. The first column presents the regression results for live cattle, followed by lean hogs and feeder cattle. While the sign of the pit closure dummy alternates across markets (positive for live cattle, negative for lean hogs and insignificant for feeder cattle), the pit user dummy has a positive and significant effect on overall execution costs. It suggests that pit users' overall execution costs are reduced on average by 1 bps for live cattle, 1.7 bps for lean hog and 0.7 bps for feeder cattle futures. This potentially reflects the higher cost nature of orders placed by pit users, who may be more informed. Interestingly, the coefficient of the interaction between the pit user dummy and the pit closure dummy is negative and significant across all markets, which suggests that pit users actually face lower overall costs on a per contract unit basis, in comparison to the cost of their pit and electronic orders prior to the pit closure. An explanation for the decline in overall execution costs for pit users could be their withdrawal from the market after the pit closure. Then, the overall execution costs of pit users would decline, as at least some of them reduce the high cost potentially informed orders, which they would be inclined to direct to the pit prior to its closure. However, this latter explanation does not explain why execution costs of electronic orders increases for pit users in live cattle and lean hog futures markets after the pit closure. It is also possible that at least some pit users successfully migrate their pit order flow to the electronic market as they potentially become more efficient at executing electronic orders, as evidenced by the fact that they place a larger number of smaller orders. If this order flow has high information content, the electronic execution costs would increase, even if pit users now execute these orders efficiently in the electronic market.

[27] However, standard errors have been corrected for heteroscedasticity.

We explore the trading behavior of pit users aiming to provide evidence supporting these potential explanations. We separate pit users in each commodity (live cattle, lean hog, feeder cattle) in four groups depending on their trading motives (informed vs. uninformed) and whether they remain active in the electronic market after the pit closure or they withdraw from the market. To identify informed and uninformed pit users, we use an approach similar to Korajcyk and Murphy (2019). We measure the potential returns of each pit order, estimated as the percentage difference between the settlement price of the day and the volume weighted average price of the order. Then, for each pit user, we estimate the volume weighted average return of all pit orders during the year prior to the pit closure. The median volume weighted average return for all pit users, in all contracts is zero. Therefore, pit users with an overall positive return are considered informed and otherwise uninformed. We also track each pit user to determine if they remain active in the electronic market after the pit closure. We focus just on those pit users who have been active in the pit for at least 20 day during the year preceding the pit closure. They comprise 80%, 82% and 84% of the total pit volume in the live cattle, lean hog and feeder cattle futures market during the same time period. We provide summary statistics for those four groups in Table 11. We observe that in live cattle futures markets, informed traders account for 82% of the pit volume. Those informed pit users who remain active in the electronic market after the pit closure account for 49% of the pit volume, while those who leave the market[28] account for 33% of the pit volume. Moreover, those who stay appear to be executing a little less than half of their volume in the electronic market even before the pit closure, while those who leave the market appear to be primarily trading at the pit, as their pit trading accounts for 90% of their total volume. There is a similar pattern for the uninformed. Moreover, those who leave the market

[28] Our assumption is that those accounts, which disappear from our sample, represent market participants who chose to leave the market after the pit closure. However, it is possible that some of these participants close down their accounts and opened new ones to trade in the electronic markets.

appear to have a higher average daily pit volume on the days they trade. For those who remain active, we observe that that informed pit users increase their trading in the electronic market after the pit closure and they exhibit a smaller decline in the total volume compared to uninformed. This indicates that informed traders are more likely than uninformed to migrate their order flow to the electronic market after the pit closure. However, given that informed traders, who withdraw from the market account for 33% of the total pit volume prior to its closure, it is likely that the reduction in execution costs for pit users after the pit closure, suggested by the regression results in Table 10, is driven both by the withdrawal of some informed pit traders and the migration of others' order flow. Results are qualitatively similar for the lean hog futures market. Informed pit users who remain active after the pit closure account for 39% of the pit volume and execute 61% of their order flow in the pit, they appear to increase their electronic trading more than the uninformed market participants. At the same time the informed (uninformed) pit users who withdraw from the lean hogs market account for 27% (20%) of the pit volume and execute on average 79% (83%) of their trading volume at the pit. Therefore, pit users who leave the market after the pit closure appear to be primarily pit traders. Our results for feeder cattle provide a different picture. Informed traders who remain active in the electronic market account for just 11% of the pit volume and do not seem to migrate any of their order flow in the electronic market, as they decrease both their total and their electronic daily volume after the pit closure. At the same time, informed who leave the market account for 25% of the pit volume. Therefore, informed pit users in the electronic market are more likely to leave the market which would explain why overall execution costs for feeder cattle pit users decline (as suggesting in Table 10), while execution costs in the electronic market remain unchanged.

7. Conclusion

The closure of pits by the CME in July of 2015 was a significant change for many market participants. In this paper we ask how this change impacted execution costs for customer orders in the livestock futures market. We make use of a rich, regulatory transaction level data and measure the effect of pit closure on execution costs of customer orders, measured by the effective half spread.

Our results indicate that while the overall execution costs of orders in the two largest livestock markets (live cattle and lean hogs) appear to be lower after the pit closure, customers placing aggressive orders in the livestock market appear to be paying a premium to execute their orders. At the same time, customers who were also active users of the pit face higher execution costs after pits closed, irrespective of their orders being passive or aggressive. However, our findings suggest that this increase in execution costs cannot be attributed to the increased HFT trading, observed after the pits closed. Instead, our results suggest that it is likely due to the partial migration of some informed orders from the pit to the electronic market. We also observe that the overall execution costs of pit users, when their pit and electronic orders are taken into account together, have declined, which can potentially be attributed to the complete withdrawal of some informed pit users from market.

Our results can provide insights on the effect of recent floor closures due to the global COVID-19 pandemic. To provide a few examples, on March 13th, 2020, CME closed its trading floors and on March 23rd, 2020, NYSE closed its trading floor. While these pit trading closures are temporary, our results, to the extent they can be applied to financial trading on different pits, would suggest that certain type of customers might be disadvantaged during the time of these temporary closures[29]. While pits are starting to be gradually operational as we prepare this manuscript, we leave it for future research to show whether the temporary break from pit trading was long enough to cause certain customers to choose not to return to trading on the pits.

[29] Dermot and Hu (2020) provides a different argument suggesting that temporary closure of NYSE pits due to COVID-19 pandemic allowed NYSE closing auction quality to improve, claiming that existing of the pit deteriorates the exchange's closing auction quality.

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Tables

Table 1: Summary statistics for customers in livestock futures markets.

Table 1 describes the trading behavior of customers. Pit closure status indicates the period before and after the pits closed. Pit user status indicates which customers are new to the market after pit closure (new entrant), which customers never used the pits to trade (non-pit user) and which customers traded on the pits before they closed (pit user). Total volume is the total number of contracts traded. Number of accounts represents the number of in each group. Average daily volume is the average daily number of contracts traded by each account in each group. Average number of orders represents the number of orders placed on average by each account in each group. Average daily order size is the average daily size of orders per account in each group, measured in terms of number of contracts. Average pit trading is the percentage of trading volume in the pit for each group. Average spread trading is the percentage of daily volume corresponding to spreads for each group. Average manual trading is the percentage of transactions that carry a manual indicator. Average trading against HFT is the proportion of trades done with an HFT account. Average aggressive trading is the percentage of trading volume where the customers initiate the trades.

Pit closure status	Pit user status	Total volume	Number of accounts	Average daily volume	Average number of orders	Average order size	Average pit trading (%)	Average spread trading (%)	Average manual trading (%)	Average trading against an HFT (%)	Average aggressive trading (%)
					Live cattle (48)						
After	New	1,323,408	8,844	11.60	55.84	2.77	0.18%	21.64%	94.89%	33.12%	62.63%
Before	Non-pit	8,242,235	23,708	12.29	132.35	2.84	0.00%	23.03%	95.85%	24.31%	60.80%
After	Non-pit	6,682,307	11,178	14.54	234.15	3.17	0.04%	22.61%	95.42%	30.91%	61.09%
Before	Pit	3,571,452	1,138	56.40	325.19	12.14	33.90%	40.76%	98.67%	16.65%	55.17%
After	Pit	2,313,432	669	45.23	478.28	6.05	1.68%	45.43%	96.65%	28.97%	57.86%
					Lean hogs (LN)						
After	New	888,882	6,201	12.69	59.78	2.60	0.25%	26.87%	92.96%	28.26%	61.26%
Before	Non-pit	5,898,580	16,287	13.49	152.70	2.74	0.00%	28.49%	94.67%	21.99%	57.85%
After	Non-pit	4,217,670	6,607	17.68	263.38	3.32	0.05%	28.54%	93.37%	27.31%	58.28%
Before	Pit	2,501,092	941	48.67	275.15	13.33	39.30%	31.14%	98.15%	13.76%	57.90%
After	Pit	1,151,183	471	42.08	356.37	6.90	2.02%	33.12%	96.19%	25.37%	63.02%
					Feeder cattle (62)						
After	New	359,233	5,006	6.49	41.63	1.99	0.04%	18.82%	94.13%	35.80%	57.75%
Before	Non-pit	1,675,290	15,331	5.49	63.71	2.10	0.00%	17.34%	96.60%	28.21%	56.99%
After	Non-pit	1,351,155	6,807	6.63	116.51	2.21	0.00%	15.56%	96.02%	34.61%	55.55%
Before	Pit	314,981	441	17.94	150.24	5.66	34.35%	23.71%	97.75%	19.44%	52.24%
After	Pit	155,201	224	18.54	202.35	3.60	1.02%	29.65%	94.85%	30.21%	55.86%

Table 2: HFT trading: Summary statistics.

Table 2 shows various statistics on the trading characteristics of HFT accounts. The pit closure status signals whether the corresponding data refer to the full sample (all), the sample covering the time period before the pit closure (before) or the time period after the pit closure (after). Average number of active days is the number of days HFTs trade at least one contract. Total volume is the total number of contracts all HFT accounts traded in the associated period. Average daily volume is the number of contracts traded on average by an HFT on an average day. Average daily spread volume is the percentage of traded volume that corresponds to spreads. Average daily market share is the percentage of the market volume traded by an HFT on average. Average absolute end of day position is the average of the end of day position of HFTs scaled by their daily trading volume. Average daily running position is the average intraday position of HFTs scaled by their daily trading volume.

Pit closure status	User status	Number of accounts	Number of active days	Total volume	Average daily volume	Average daily market share (%)	Average absolute EOD position (%)	Average absolute running position (%)
Live cattle (48)								
All	HFT	50	208.90	10,800,146	787.72	2.49%	1.27%	7.82%
All	Non-HFT	36,949	24.09	43,071,420	15.87	0.16%	83.28%	90.01%
Before	HFT	39	100.90	5,165,813	796.16	2.71%	0.63%	6.90%
Before	Non-HFT	27,056	13.37	23,870,873	17.09	0.18%	83.82%	90.29%
After	HFT	37	108.00	5,634,333	882.82	2.58%	1.46%	8.46%
After	Non-HFT	22,578	10.72	19,200,547	16.79	0.16%	84.45%	90.70%
Lean hog (LN)								
All	HFT	35	216.91	6,158,198	608.99	3.06%	0.58%	8.13%
All	Non-HFT	26,217	24.58	31,456,074	17.14	0.31%	81.99%	89.33%
Before	HFT	29	109.69	3,295,303	688.12	3.11%	0.41%	6.90%
Before	Non-HFT	19,163	14.08	18,711,597	18.59	0.34%	82.32%	89.47%
After	HFT	27	107.23	2,862,895	580.42	3.10%	0.74%	9.54%
After	Non HFT	14,853	10.50	12,744,477	18.81	0.31%	83.01%	89.90%
Feeder cattle (62)								
All	HFT	35	171.00	2,264,397	225.87	4.29%	2.26%	12.23%
All	Non-HFT	23,522	18.31	7,599,073	6.92	0.37%	85.76%	91.62%
Before	HFT	29	87.60	1,106,186	223.61	4.51%	2.42%	11.99%
Before	Non-HFT	17,805	10.18	4,061,722	6.74	0.41%	86.85%	92.23%
After	HFT	21	83.40	1,158,211	278.00	4.48%	2.46%	12.05%
After	Non-HFT	13,437	8.12	3,537,351	7.74	0.38%	85.56%	91.54%

Table 3: First Stage Probit Regression

Table 3 presents the estimates for the first stage probit regressions for three livestock futures contracts where the dependent variable is equal to 1 if the customer chooses to place an aggressive order. Order size denotes the number of contracts in the order. Spread dummy is equal to 1 if the order is part of a spread. Trading intensity is measured as the logarithm of the average minute volume of futures traded during the hour before the order started executing. Volatility is estimated as the square root of the sum of one minute squared returns during the hour before the order started executing. Same side volume prop indicates the percentage of volume initiated on the same side of the order during the hour preceding the order.

	Live cattle (48)			Lean Hog (LN)			Feeder cattle (62)		
Parameter	Estimate	Wald X^2	Pr > X^2	Estimate	Wald X^2	Pr > X^2	Estimate	Wald X^2	Pr > X^2
Intercept	-0.1036	902	<.0001	-0.4453	13554	<.0001	0.1701	1059	<.0001
Order size	0.1077	34233	<.0001	0.0800	12427	<.0001	0.1326	7791	<.0001
Spread dummy	-0.2317	53713	<.0001	-0.0055	22	<.0001	-0.4244	52231	<.0001
Trading intensity	-0.0556	17496	<.0001	-0.0563	11592	<.0001	-0.0899	11704	<.0001
Volatility	1.6461	105	<.0001	-3.4623	413	<.0001	-2.7371	92	<.0001
Same side volume prop	0.6246	17418	<.0001	0.8239	28546	<.0001	0.5998	7186	<.0001
Number of Obs	6,763,477			4,920,980			2,033,736		

Table 4: Effective half spread – Live cattle futures

Table 4 presents estimates for effective half spread of an order in live cattle futures. Order size is the number of contracts in the order. Manual order dummy is equal to 1 if order is entered manually. Years to expiration represents the time until the contract expires, expressed in years. Monday (Friday) dummy is equal to 1 if the day of the week is Monday (Friday). Trading hours change dummies control for the CME's decision to change trading hours during our sample. Settlement change dummy is equal to 1 once procedure of calculating the settlement price is changed in December 2014. Pit closure dummy is equal to 1 once pits are closed on July 2015. Trading intensity is measured as the logarithm of the average minute volume of futures traded during the hour before the order started executing. Volatility is estimated as the square root of the sum of one minute squared returns during the hour before the order started executing. Aggressor dummy is equal to 1 if order is placed using a market order. Mills ratios come from the first stage probit regression. Pit user dummy is equal to 1 if the market participant traded on the pits before their closure.

Live cattle (48)						
	All orders		Aggressive		Passive	
Variable	Estimate	Pr > |t|	Estimate	Pr > |t|	Estimate	Pr > |t|
Intercept	-0.0085	<.0001	0.1586	<.0001	0.0393	<.0001
Order size	-0.0009	<.0001	-0.0078	<.0001	0.0047	<.0001
Manual order dummy	-0.0133	<.0001	0.0051	<.0001	-0.0277	<.0001
Years to expiration	0.0132	<.0001	0.0031	<.0001	0.0212	<.0001
Monday dummy	0.0023	<.0001	-0.0010	<.0001	0.0050	<.0001
Friday dummy	-0.0003	0.0305	-0.0005	0.0007	-0.0005	0.0188
Trading hours change dummy 1	0.0021	<.0001	-0.0003	0.1191	0.0035	<.0001
Trading hours change dummy 2	0.0014	<.0001	-0.0003	0.3241	0.0016	0.0007
Settlement change dummy	-0.0027	<.0001	0.0009	<.0001	-0.0050	<.0001
Pit closure dummy	-0.0008	<.0001	0.0018	<.0001	-0.0029	<.0001
Trading intensity	0.0010	<.0001	0.0073	<.0001	-0.0036	<.0001
Volatility	-0.4208	<.0001	0.2935	<.0001	-0.8956	<.0001
Aggressor dummy	0.1702	<.0001				
Mills ratio aggressive interaction	-0.1480	<.0001				
Mills ratio passive interaction	0.0218	<.0001				
Mills ratio			-0.1743	<.0001	0.0624	<.0001
Pit user dummy	0.0006	0.0131	0.0019	<.0001	-0.0018	<.0001
Pit user - pit closure interaction	0.0033	<.0001	0.0005	0.2591	0.0056	<.0001
Number of Observations	6,255,879		2,679,205		3,849,140	
R-Square	0.0222		0.0333		0.008	

Table 5: Effective half spread – Lean hog futures

Table 5 presents estimates for effective half spread of an order in lean hog futures. Order size is the number of contracts in the order. Manual order dummy is equal to 1 if order is entered manually. Years to expiration represents the time until the contract expires, expressed in years. Monday (Friday) dummy is equal to 1 if the day of the week is Monday (Friday). Trading hours change dummies control for the CME's decision to change trading hours during our sample. Settlement change dummy is equal to 1 once procedure of calculating the settlement price is changed in December 2014. Pit closure dummy is equal to 1 once pits are closed on July 2015. Trading intensity is measured as the logarithm of the average minute volume of futures traded during the hour before the order started executing. Volatility is estimated as the square root of the sum of one minute squared returns during the hour before the order started executing. Aggressor dummy is equal to 1 if order is placed using a market order. Mills ratios come from the first stage probit regression. Pit user dummy is equal to 1 if the market participant traded on the pits before their closure.

Lean hog (LN)						
	All orders		Aggressive		Passive	
Variable	Estimate	Pr > |t|	Estimate	Pr > |t|	Estimate	Pr > |t|
Intercept	-0.2756	<.0001	0.2286	<.0001	-0.2601	<.0001
Order size	-0.0111	<.0001	-0.0066	<.0001	-0.0152	<.0001
Manual order dummy	-0.0196	<.0001	0.0103	<.0001	-0.0420	<.0001
Years to expiration	0.0107	<.0001	0.0012	0.0321	0.0246	<.0001
Monday dummy	0.0030	<.0001	-0.0015	<.0001	0.0066	<.0001
Friday dummy	0.0000	0.9336	0.0000	0.9858	-0.0001	0.7123
Trading hours change dummy 1	-0.0001	0.7085	-0.0015	<.0001	0.0002	0.6774
Trading hours change dummy 2	0.0037	<.0001	-0.0064	<.0001	0.0102	<.0001
Settlement change dummy	-0.0018	<.0001	0.0046	<.0001	-0.0041	<.0001
Pit closure dummy	-0.0034	<.0001	0.0003	0.3584	-0.0086	<.0001
Trading intensity	0.0089	<.0001	0.0120	<.0001	0.0067	<.0001
Volatility	1.3473	<.0001	1.9954	<.0001	0.8221	<.0001
Aggressor dummy	0.5355	<.0001				
Mills ratio aggressive interaction	-0.2771	<.0001				
Mills ratio passive interaction	-0.3294	<.0001				
Mills ratio			-0.2765	<.0001	-0.3384	<.0001
Pit user dummy	-0.0027	<.0001	0.0052	<.0001	-0.0142	<.0001
Pit user - pit closure interaction	0.0075	<.0001	0.0078	<.0001	0.0080	<.0001
Number of Observations Used	4,532,008		1,881,039		2,650,969	
R-Square	0.0293		0.0219		0.0155	

Table 6: Effective half spread– Feeder cattle futures

Table 6 presents estimates for effective half spread of an order in feeder cattle futures. Order size is the number of contracts in the order. Manual order dummy is equal to 1 if order is entered manually. Years to expiration represents the time until the contract expires, expressed in years. Monday (Friday) dummy is equal to 1 if the day of the week is Monday (Friday). Trading hours change dummies control for the CME's decision to change trading hours during our sample. Settlement change dummy is equal to 1 once procedure of calculating the settlement price is changed in December 2014. Pit closure dummy is equal to 1 once pits are closed on July 2015. Trading intensity is measured as the logarithm of the average minute volume of futures traded during the hour before the order started executing. Volatility is estimated as the square root of the sum of one minute squared returns during the hour before the order started executing. Aggressor dummy is equal to 1 if order is placed using a market order. Mills ratios come from the first stage probit regression. Pit user dummy is equal to 1 if the market participant traded on the pits before their closure.

Feeder cattle (62)						
	All orders		Aggressive		Passive	
Variable	Estimate	Pr > |t|	Estimate	Pr > |t|	Estimate	Pr > |t|
Intercept	0.0320	<.0001	0.1421	<.0001	0.0956	<.0001
Order size	0.0034	<.0001	-0.0033	<.0001	0.0089	<.0001
Manual order dummy	-0.0106	<.0001	0.0084	<.0001	-0.0278	<.0001
Years to expiration	-0.0027	0.002	-0.0007	0.3985	-0.0005	0.7085
Monday dummy	0.0039	<.0001	-0.0033	<.0001	0.0097	<.0001
Friday dummy	-0.0003	0.4184	-0.0008	0.0215	0.0004	0.4918
Trading hours change dummy 1	0.0008	0.0925	-0.0025	<.0001	0.0031	<.0001
Trading hours change dummy 2	-0.0011	0.1249	-0.0046	<.0001	-0.0013	0.2319
Settlement change dummy	-0.0013	0.0074	0.0061	<.0001	-0.0075	<.0001
Pit closure dummy	-0.0003	0.4568	0.0037	<.0001	-0.0026	<.0001
Trading intensity	-0.0024	<.0001	0.0113	<.0001	-0.0119	<.0001
Volatility	-0.2194	0.0022	1.8507	<.0001	-1.4911	<.0001
Aggressor dummy	0.1303	<.0001				
Mills ratio aggressive interaction	-0.1209	<.0001				
Mills ratio passive interaction	0.0810	<.0001				
Mills ratio			-0.1539	<.0001	0.1214	<.0001
Pit user dummy	-0.0006	0.3915	-0.0045	<.0001	0.0017	0.1151
Pit user - pit closure interaction	0.0000	0.9874	-0.0030	0.0157	0.0032	0.0680
Number of Observations	1,802,651.00		647,326.00		1,155,325.00	
R-Square	0.0247		0.0567		0.0081	

Table 7: The effect of trading with HFTs – Live cattle futures

Table 7 presents estimates for effective half spread of an order in live cattle futures. Order size is the number of contracts in the order. Manual order dummy is equal to 1 if order is entered manually. Years to expiration represents the time until the contract expires, expressed in years. Monday (Friday) dummy is equal to 1 if the day of the week is Monday (Friday). Trading hours change dummies control for the CME's decision to change trading hours during our sample. Settlement change dummy is equal to 1 once procedure of calculating the settlement price is changed in December 2014. Pit closure dummy is equal to 1 once pits are closed on July 2015. Trading intensity is measured as the logarithm of the average minute volume of futures traded during the hour before the order started executing. Volatility is estimated as the square root of the sum of one minute squared returns during the hour before the order started executing. Aggressor dummy is equal to 1 if order is placed using a market order. Mills ratios come from the first stage probit regression. Pit user dummy is equal to 1 if the market participant traded on the pits before their closure. Opp_HFT represents the proportion of the order is executed against an HFT.

Live cattle (48)						
	All orders		Aggressive		Passive	
Variable	Estimate	Pr > |t|	Estimate	Pr > |t|	Estimate	Pr > |t|
Intercept	-0.0067	<.0001	0.1592	<.0001	0.0432	<.0001
Order size	-0.0006	<.0001	-0.0079	<.0001	0.0053	<.0001
Manual order dummy	-0.0132	<.0001	0.0051	<.0001	-0.0271	<.0001
Years to expiration	0.0131	<.0001	0.0032	<.0001	0.0209	<.0001
Monday dummy	0.0023	<.0001	-0.0010	<.0001	0.0050	<.0001
Friday dummy	-0.0003	0.0229	-0.0005	0.0159	-0.0005	0.0159
Trading hours change dummy 1	0.0020	<.0001	-0.0003	<.0001	0.0034	<.0001
Trading hours change dummy 2	0.0010	0.0007	-0.0001	0.0323	0.0010	0.0323
Settle change dummy	-0.0027	<.0001	0.0009	<.0001	-0.0053	<.0001
Pit closure dummy	-0.0009	<.0001	0.0020	<.0001	-0.0028	<.0001
Trading intensity	0.0008	<.0001	0.0074	<.0001	-0.0041	<.0001
Volatility	-0.4238	<.0001	0.2869	<.0001	-0.9229	<.0001
Aggressor dummy	0.1659	<.0001				
Mills ratio aggressive interaction	-0.1463	<.0001				
Mills ratio passive interaction	0.0261	<.0001				
Mills ratio			-0.1746	<.0001	0.0712	<.0001
Opp HFT	0.0071	<.0001	-0.0034	<.0001	0.0131	<.0001
Opp HFT – pit closure interaction	-0.0001	0.7513	0.0001	0.2637	-0.0005	0.2637
Pit user dummy	0.0007	0.0118	0.0019	<.0001	-0.0017	<.0001
Pit user - pit closure interaction	0.0029	<.0001	0.0019	<.0001	0.0033	<.0001
Pit user - pit closure - Opp HFT interaction	0.0011	0.1428	-0.0049	<.0001	0.0069	<.0001
Number of Observations	6,255,879		2,406,739		3,849,140	
R-Square	0.0226		0.0336		0.0089	

Table 8: The effect of trading with HFTs – Lean hog futures

Table 8 presents estimates for effective half spread of an order in lean hog futures. Order size is the number of contracts in the order. Manual order dummy is equal to 1 if order is entered manually Years to expiration represents the time until the contract expires, expressed in years. Monday (Friday) dummy is equal to 1 if the day of the week is Monday (Friday). Trading hours change dummies control for the CME's decision to change trading hours during our sample. Settlement change dummy is equal to 1 once procedure of calculating the settlement price is changed in December 2014. Pit closure dummy is equal to 1 once pits are closed on July 2015. Trading intensity is measured as the logarithm of the average minute volume of futures traded during the hour before the order started executing. Volatility is estimated as the square root of the sum of one minute squared returns during the hour before the order started executing. Aggressor dummy is equal to 1 if order is placed using a market order. Mills ratios come from the first stage probit regression. Pit user dummy is equal to 1 if the market participant traded on the pits before their closure. Opp_HFT represents the proportion of the order is executed against an HFT.

Lean hog (LN)						
	All orders		Aggressive		Passive	
Variable	Estimate	Pr > |t|	Estimate	Pr > |t|	Estimate	Pr > |t|
Intercept	-0.2780	<.0001	0.2285	<.0001	-0.2619	<.0001
Order size	-0.0109	<.0001	-0.0066	<.0001	-0.0149	<.0001
Manual order dummy	-0.0192	<.0001	0.0103	<.0001	-0.0409	<.0001
Years to expiration	0.0124	<.0001	0.0014	<.0001	0.0270	<.0001
Monday dummy	0.0030	<.0001	-0.0015	<.0001	0.0065	<.0001
Friday dummy	-0.0001	0.6200	0.0000	0.4368	-0.0003	0.4368
Trading hours change dummy 1	0.0000	0.9214	-0.0014	0.4811	0.0004	0.4811
Trading hours change dummy 2	0.0032	<.0001	-0.0065	<.0001	0.0096	<.0001
Settle change dummy	-0.0021	<.0001	0.0045	<.0001	-0.0043	<.0001
Pit closure dummy	-0.0041	<.0001	0.0001	<.0001	-0.0096	<.0001
Trading intensity	0.0088	<.0001	0.0120	<.0001	0.0063	<.0001
Volatility	1.3222	<.0001	1.9966	<.0001	0.7545	<.0001
Aggressor dummy	0.5365	<.0001				
Mills ratio aggressive interaction	-0.2789	<.0001				
Mills ratio passive interaction	-0.3280	<.0001				
Mills ratio			-0.2768	<.0001	-0.3343	<.0001
Opp HFT	0.0152	<.0001	0.0018	<.0001	0.0216	<.0001
Opp HFT – pit closure interaction	0.0011	0.0214	0.0004	0.0067	0.0018	0.0067
Pit user dummy	-0.0030	<.0001	0.0051	<.0001	-0.0143	<.0001
Pit user - pit closure interaction	0.0080	<.0001	0.0102	<.0001	0.0059	<.0001
Pit user - pit closure - Opp HFT interaction	-0.0012	0.4210	-0.0099	0.0002	0.0085	0.0002
Number of Observations	4,532,008		1,881,039		2,650,969	
R-Square	0.0301		0.022		0.017	

Table 9: The effect of trading with HFTs – Feeder cattle futures

Table 9 presents estimates for effective half spread of an order in feeder cattle futures. Order size is the number of contracts in the order. Manual order dummy is equal to 1 if order is entered manually. Years to expiration represents the time until the contract expires, expressed in years. Monday (Friday) dummy is equal to 1 if the day of the week is Monday (Friday). Trading hours change dummies controls for the CME's decision to change trading hours during our sample. Settlement change dummy is equal to 1 once procedure of calculating the settlement price is changed in December 2014. Pit closure dummy is equal to 1 once pits are closed on July 2015. Trading intensity is measured as the logarithm of the average minute volume of futures traded during the hour before the order started executing. Volatility is estimated as the square root of the sum of one minute squared returns during the hour before the order started executing. Aggressor dummy is equal to 1 if order is placed using a market order. Mills ratios come from the first stage probit regression. Pit user dummy is equal to 1 if the market participant traded on the pits before their closure. Opp_HFT represents the proportion of the order is executed against an HFT.

Feeder cattle (62)						
	All orders		Aggressive		Passive	
Variable	Estimate	Pr > |t|	Estimate	Pr > |t|	Estimate	Pr > |t|
Intercept	0.0342	<.0001	0.1440	<.0001	0.1007	<.0001
Order size	0.0039	<.0001	-0.0035	<.0001	0.0099	<.0001
Manual order dummy	-0.0106	<.0001	0.0086	<.0001	-0.0275	<.0001
Years to expiration	-0.0015	0.0765	-0.0013	0.5765	0.0007	0.5765
Monday dummy	0.0041	<.0001	-0.0033	<.0001	0.0101	<.0001
Friday dummy	-0.0003	0.4171	-0.0008	0.4376	0.0004	0.4376
Trading hours change dummy 1	0.0008	0.1145	-0.0025	<.0001	0.0030	<.0001
Trading hours change dummy 2	-0.0017	0.0261	-0.0043	0.0986	-0.0018	0.0986
Settle change dummy	-0.0017	0.0005	0.0063	<.0001	-0.0078	<.0001
Pit closure dummy	-0.0007	0.1604	0.0039	<.0001	-0.0041	<.0001
Trading intensity	-0.0031	<.0001	0.0115	<.0001	-0.0133	<.0001
Volatility	-0.2403	0.0008	1.8532	<.0001	-1.5437	<.0001
Aggressor dummy	0.1220	<.0001				
Mills ratio aggressive interaction	-0.1165	<.0001				
Mills ratio passive interaction	0.0890	<.0001				
Mills ratio			-0.1552	<.0001	0.1359	<.0001
Opp HFT	0.0130	<.0001	-0.0044	<.0001	0.0207	<.0001
Opp HFT- pit closure interaction	0.0016	0.0344	-0.0010	<.0001	0.0049	<.0001
Pit user dummy	-0.0003	0.6798	-0.0045	0.0243	0.0024	0.0243
Pit user - pit closure interaction	-0.0009	0.5270	-0.0038	0.3686	0.0019	0.3686
Pit user - pit closure – Opp HFT interaction	0.0021	0.3497	0.0032	0.5050	0.0020	0.5050
Number of Observations	1,802,651		647,326		1,155,325	
R-Square	0.0255		0.057		0.0099	

Table 10: Accounting for pit and electronic orders

Table 10 presents simple OLS estimates for effective half spread of an order in the three livestock futures contracts. Order size is the number of contracts in the order. Manual order dummy is equal to 1 if order is entered manually. Years to expiration represents the time until the contract expires, expressed in years. Monday (Friday) dummy is equal to 1 if the day of the week is Monday (Friday). Trading hours change dummies controls for the CME's decision to change trading hours during our sample. Settlement change dummy is equal to 1 once procedure of calculating the settlement price is changed in December 2014. Pit closure dummy is equal to 1 once pits are closed on July 2015. Trading intensity is measured as the logarithm of the average minute volume of futures traded during the hour before the order started executing. Volatility is estimated as the square root of the sum of one minute squared returns during the hour before the order started executing. Aggressor dummy is equal to 1 if order is placed using a market order. Mills ratios come from the first stage probit regression. Pit user dummy is equal to 1 if the market participant traded on the pits before their closure.

	All pit and electronic orders					
	Live cattle (48)		Lean hog (LN)		Feeder cattle (62)	
	Estimate	Pr > |t|	Estimate	Pr > |t|	Estimate	Pr > |t|
Intercept	-0.072	<.0001	-0.087	<.0001	-0.0905	<.0001
Order size	0.006	<.0001	0.011	<.0001	0.0076	<.0001
Same side volume (%)	0.143	<.0001	0.205	<.0001	0.1831	<.0001
Spread dummy	-0.005	<.0001	-0.013	<.0001	-0.0004	0.0728
Manual order dummy	-0.013	<.0001	-0.029	<.0001	-0.0098	<.0001
Years to expiration	0.017	<.0001	0.036	<.0001	0.0025	0.0001
Monday dummy	0.004	<.0001	0.005	<.0001	0.0069	<.0001
Friday dummy	0.000	0.7857	0.002	<.0001	0.0004	0.1705
Trading hours change dummy 1	0.001	<.0001	-0.009	<.0001	0.0023	<.0001
Trading hours change dummy 2	0.001	<.0001	-0.001	0.0002	0.0022	0.0001
Settle change dummy	-0.001	<.0001	0.006	<.0001	-0.0024	<.0001
Pit closure dummy	0.001	<.0001	-0.005	<.0001	0.0002	0.5577
Trading intensity	-0.004	<.0001	-0.008	<.0001	-0.0048	<.0001
Volatility	0.674	<.0001	0.874	<.0001	0.5294	<.0001
Pit user dummy	0.007	<.0001	0.003	<.0001	0.0042	<.0001
Pit user - pit closure interaction	-0.010	<.0001	-0.017	<.0001	-0.0067	<.0001
Number of Observations	20,360,335		13,474,835		3,359,812	
R-Square	0.0042		0.0139		0.0137	

Table 11: What happens to active pit users after the pit closure?

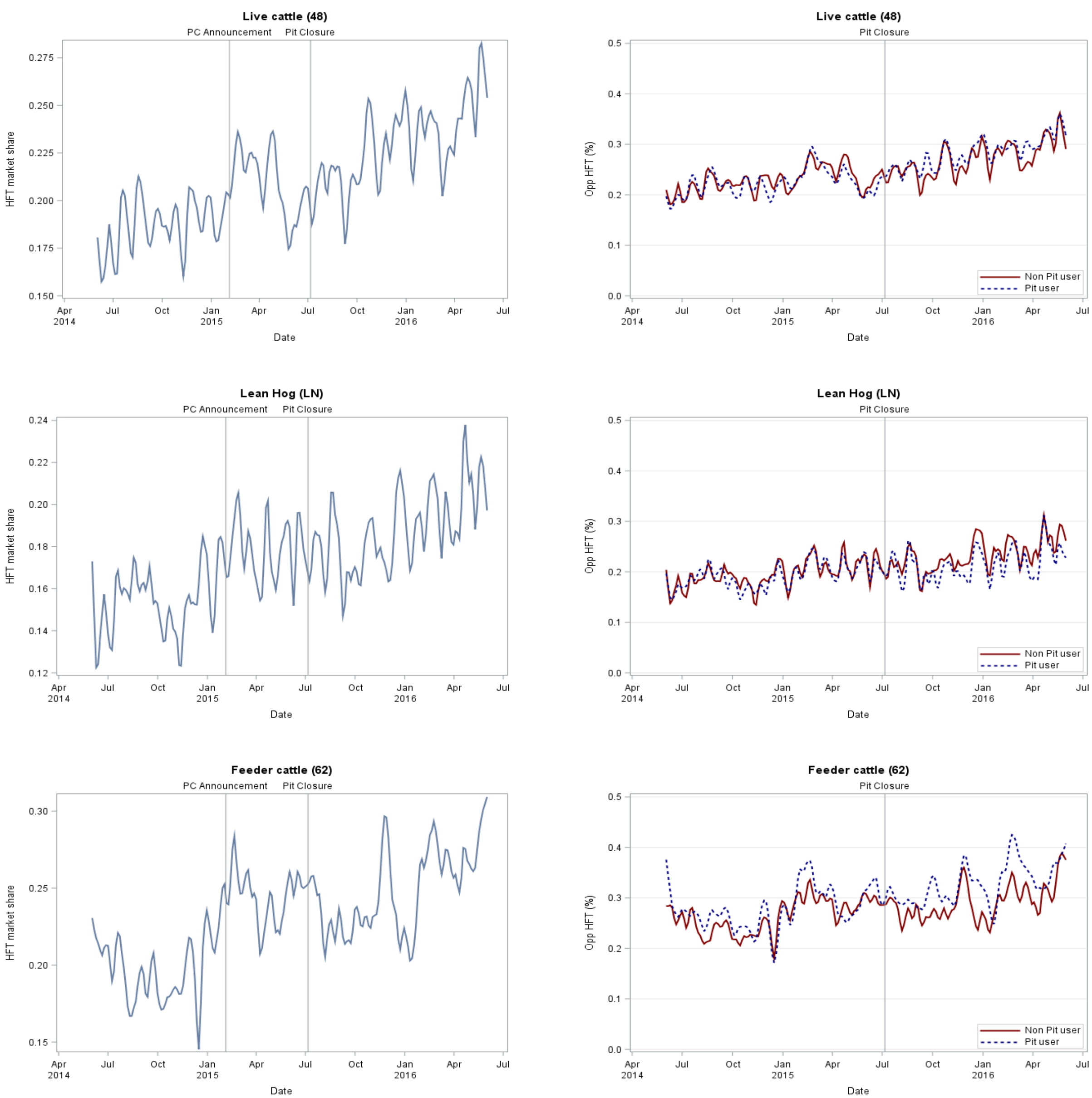
Table 11 describes the trading behavior of those pit users, who were once active at the pit, after the pit closed. It includes only those traders who, during the year prior to the pit closure, traded at least 20 days at the pit. Pit users are separated in four groups based on their trading motives and on whether they remain active in the electronic market after the pit closes. Informed (Inf.) pit users are those pit users with pit trades resulting in positive average daily returns, defined as the average log difference between the settlement price and the vwap of the order. Uninformed (Uninf.) pit users engage in pit trades resulting in negative average daily returns. "Remains active" indicates that a pit user remains active in the electronic market after the pit closes, while "Becomes non active" indicates that a pit user disappears from the corresponding market after the pit closes. Total pit volume corresponds to the total pit volume of all active pit users in the each of the four groups and is presented both as a number of contracts and a percentage. Average daily pit trading is the average daily pit volume, prior to the pit closure, estimated as proportion of each pit users' total trading, averaged across all pit users in the group. Average Δ(daily volume) is the change of each pit user's average total daily volume after the pit closure, averaged across all pit users in each group. Average Δ(daily electronic volume) is the change of each pit user's average daily electronic volume after the pit closure, averaged across all pit users in each respective group. The number of pit users indicates the number of pit users in each group, who traded for at least 20 days at the pit during the year prior to the pit closure.

	Live cattle (48)				Lean Hog (LN)				Feeder cattle (62)			
	Remains active	Remains active	Becomes non active	Becomes non active	Remains active	Remains active	Becomes non active	Becomes non active	Remains active	Remains active	Becomes non active	Becomes non active
	Uninf.	Inf.	Uninf.	Inf.	Uninf.	Inf.	Uninf.	Inf.	Uninf.	Inf.	Uninf.	Inf.
Total pit volume	104,359	397,201	48,377	266,166	99,154	265,311	133,293	184,418	76,612	22,617	61,574	53,948
Total pit volume (%)	0.13	0.49	0.06	0.33	0.15	0.39	0.20	0.27	0.36	0.11	0.29	0.25
Average daily pit trading (%)	0.58	0.56	0.81	0.90	0.55	0.61	0.83	0.79	0.88	0.45	0.96	0.76
Average daily pit volume	54.62	55.36	84.75	92.49	36.33	78.37	90.33	46.90	68.10	27.34	83.91	61.97
Average Δ(daily volume)	-36.32	-2.24	-124.53	-104.75	-29.40	-19.12	-98.98	-54.35	8.59	-44.90	-88.34	-73.34
Average Δ(daily electronic volume)	13.62	50.31	-39.77	-12.26	4.95	49.82	-8.65	-7.45	38.00	-17.56	-4.43	-11.36
Pit user no	18	47	11	25	28	29	18	42	7	7	8	10

Figures

Figure 1: The role of HFTs in the electronic order book

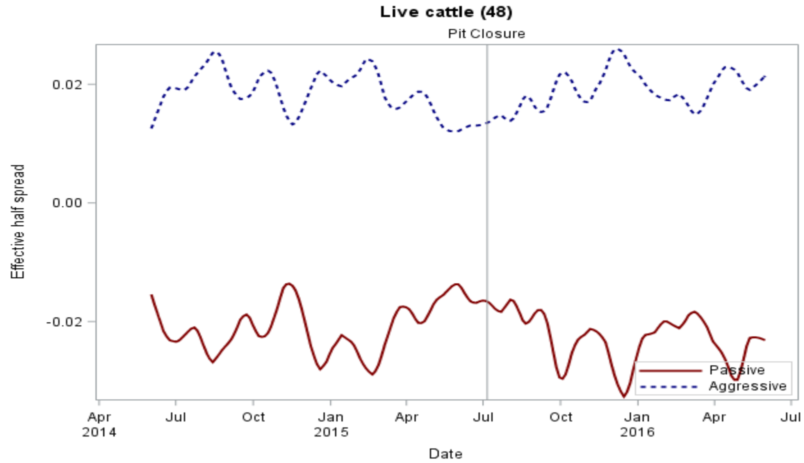
Figure 1 presents the HFT market share and the percentage of trading with HFTs by customers in the electronic market. The three graphs on the left present the HFT market share during the period of May 1st 2015-July 1st 2016 for live cattle, lean hog and feeder cattle futures contracts. HFT market share is the proportion of trading volume executed by HFTs compared to the trading volume of the total volume of the electronic market. The two vertical lines correspond to the announcement date of the pit closure (February 4th 2015) and the pit closure itself (July 6th 2015). The three graphs on the left present the percentage of transactions traded with HFTs by customers in the three livestock futures contracts in the electronic market. Solid line represents the percentage for non-pit users and dotted line represents the percentage for pit users. The sample is from June 1, 2014 until June 1, 2016.

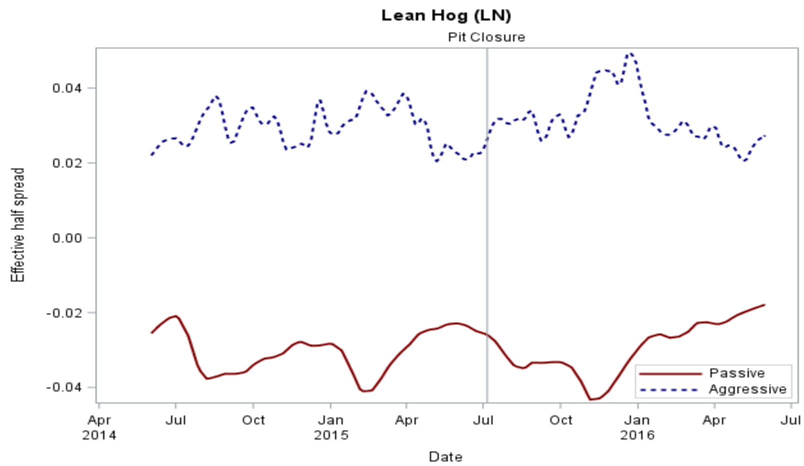


Appendix

This appendix provides a series of graphs of the execution costs of customers during our sample. Execution costs are proxied by the effective half spread, which in turn is measured as the difference between the natural logarithm of the volume weighted transaction price of each order and the natural logarithm of the average price of trades occurring in the five minute interval preceding the first trade of each order, adjusted for the direction of the order, and then multiplied by 100. Our data allow us to distinguish passive from aggressive electronic orders. Figure A1 presents smoothed graphs of the average effective half spread for all aggressive and passive customer orders by commodity. In Figure A2 we compare the average overall effective spread of pit users in the electronic market and the pit.

Figure A1: Effective half spread for customer aggressive and passive orders by commodity
Figure A1 presents the effective half spread for aggressive (blue) and passive(red) orders in the three livestock futures contracts. The sample is from June 1, 2014 until June 1, 2016.





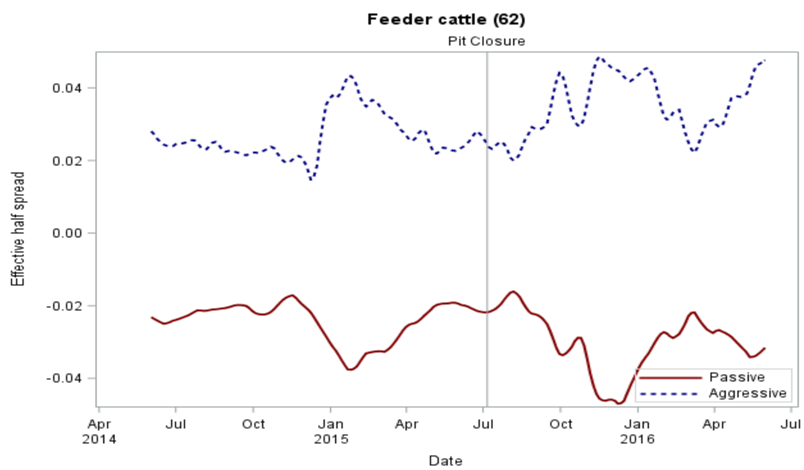


Figure A2: Execution costs by venue prior to the pit closure

Figure A2 presents the effective half spread for orders trading in the electronic market and the pit, prior to the pit closure. Red (blue) line shows the effective half spread for electronic (pit) orders. The sample is from June 1, 2014 until June 1, 2016.