The End of an Era: Who Pays the Price when the Livestock Futures Pits Close?

by

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ABSTRACT

This paper evaluates the impact of the Chicago Mercantile Exchange's (CME) decision to close the livestock futures pits on the execution quality of customer orders. Our findings suggest that, prior to its closure, the livestock futures pit offers high immediacy execution and attracts large orders. Since such high immediacy orders generally execute faster and cost more, their migration to the electronic market after the pit closure explains why the execution of electronic orders becomes on average speedier and more expensive for customers who used to be active pit users. However, our results also indicate that these pit-user customers face a lower overall execution cost following the pit closure when we account for all their orders, pit and electronic.

Keywords: customer orders, electronic trading, execution cost, livestock futures, pit trading

JEL Classification: G10, G14

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Up until 2015, futures contracts traded at the Chicago Mercantile Exchange (CME) could be executed on the trading floor (known as pits) or on an electronic platform known as the limit-order book. In February of 2015, the CME announced that it would get rid of almost all floor trading and in July of 2015, the pits closed. While trading in most futures pits had been dwindling even before CME's decision to close the pits, some futures pits (i.e. livestock and treasury futures) were still handling a sizeable market volume (Gousgounis, and Onur 2018). Therefore, while this decision probably made sense from CME's business perspective, it also generated a lot of discussion on whether the CME was getting rid of a trading design that actually had value for at least some market participants (Polansek 2015; Stebbins 2015). This paper explores the value of the pit for customers, the group of market participants most likely to have been affected by the pit closure, focusing on the livestock futures market, which had significant trading activity in the pit prior to its closure.

Market participants in the pits belong mainly to two groups: *locals*, defined as those market participants trading for their own accounts and *customers*, who execute their trades through authorized exchange members as they lack direct representation in the exchange (Sahin, and Sarajoti 2005). Gousgounis, and Onur (2018) show that there is no evidence of locals in livestock futures markets migrating to the electronic market after the pit closure. As a result, our focus is explicitly on livestock futures customers, who are likely to include hedgers and market participants taking larger positions in contrast to locals, who typically behave as market makers in the pit. While not all customers used the pit, those who did generally had a substantial daily trading volume and executed on average more than 30 percent of their trading volume in the pit. Given that they are also the group to have voiced the most complaints,[1] we hypothesize that they may have been significantly impacted by the CME's decision and we therefore evaluate the changes in the execution quality of their orders after the pits closed. To the best of our knowledge, this is the first paper to focus on the group which potentially experiences disutility from the pit closure (or to state more colloquially, who "paid for it") by analyzing both aspects of execution quality; execution speed and cost.

Our analysis is inspired by the theoretical model of Viswanathan, and Wang (2002), which directly compares trading in a limit-order market to a hybrid market structure, where customers also have the option to trade in a dealer market. In the hybrid case, when the number of market makers is sufficiently high, risk averse investors prefer the dealer market for their large orders since it offers lower variance in execution cost. However, Viswanathan, and Wang (2002) also show that the average execution cost in the dealer market are actually higher than the electronic market. In other words, risk averse customers are routing large orders to the dealer market to minimize the variance of their execution cost, but in turn they incur, on average, higher execution cost.

The futures pit resembles the dealer market, as defined by Viswanathan, and Wang (2002), and their analysis offers insights on the effect of the pit closure on the execution quality of customer orders, which is the focus of this study. Our results, which are consistent with Viswanathan, and Wang (2002), can be summarized in three key findings. First, we find that the pit is preferable to the limit-order book when orders are large and the number of market makers is high. Moreover, customers prefer the pit when execution times in the electronic market get lengthier, which suggests the pit offers immediacy. Second, using a difference-in-differences approach where pit closure impacts pit users but not those who only trade in the electronic market (non-pit users), we show that after the pits close, the electronic orders of pit user customers are now executed faster (by 89 seconds per order for live cattle, 47 seconds for lean hogs and 119 seconds for feeder cattle) and with higher execution cost (by roughly 0.5 basis points per order for live cattle and 1 basis point per order for lean hog futures) compared to that of non-pit user customers. We attribute these findings to the migration of high immediacy pit orders to the electronic market. Such orders are likely to enter the electronic market as aggressive orders (i.e. market orders, or marketable limit orders) or as passive orders (limit orders) undercutting the bid ask spread. In both cases, we expect these orders to execute faster, reducing the pit users' average time to execution in the electronic market. The literature shows that high immediacy orders generally face higher execution cost (Gousgounis, Onur, and Tuckman 2020; Collin-Dufresne, Junge, and Trolle 2020). As a result, we expect the orders that previously would have been routed to the pit to be also higher cost orders. Therefore, the migration of those orders to the electronic market increases the average electronic execution cost for customers.[2] Third, we use the same difference-in-differences setup to evaluate how the *overall* execution cost changes after the pit closure for pit users compared to non-pit users. The overall execution cost, which include both pit and electronic orders, are estimated on a per-contract basis in order to correct for the difference in the size of pit and electronic orders, which is caused by the higher incidence of order shredding in the electronic market. We find that compared to the changes experienced by non-pit users, the overall per contract execution cost of pit users in live cattle and lean hog futures markets drops after the pit closure by about 0.5 basis points. This drop can be potentially explained by a few observations. First, in line with VW's theory, transacting in the pit is more costly and similar orders in the electronic market would face a lower execution cost. Second, some pit users may not migrate all of their pit trading to the electronic order book; they may either withdraw from the market or execute a smaller number of high cost, high immediacy orders in the electronic market.

These findings contribute to the literature comparing the execution cost of pit and electronic trading. While some existing work has provided comparison of costs across pit and electronic trading (Bryant, and Haigh 2004; Shah, and Brorsen 2011; Frank, and Garcia 2011; Wang, Garcia, and Irwin 2014; Aidov, and Daigler 2015; Raman, Robe, and Yadav 2017), the findings of Bryant, and Haigh (2004) suggesting an increase in electronic trading costs after a transition away from the pit trading are not corroborated by other studies listed above. However, more recently, Gousgounis, and Onur (2018) show that the electronic execution cost in livestock futures electronic markets increase after the pit closure. Similarly, a study focusing on the impact of the temporary pit closures due to COVID 19 pandemic finds that transaction costs in the electronic market for equities go up as a result (Brogaard, Ringgenberg, and Roesch 2023). Our paper adds to this specific literature by providing an explanation for the increased execution cost in the electronic market following the pit closure: when the pit closes, pit users who were previously routing some of their large orders to the pit are now forced to execute these orders in the electronic market. These orders, which are likely high immediacy orders, enter the limit order book as aggressive orders increasing the average execution cost in the electronic markets.

Conceptual Framework

Our empirical analysis is consistent with the findings of the theoretical model in Viswanathan, and Wang (2002), VW from hereon. Their model compares the utility of customers across three market structures: a pure dealer market, a limit-order book market and a hybrid market structure. In the latter case, customers choose when to route their orders to the dealer market and the electronic order book following a mean-variance utility maximizing trading strategy on the execution cost of each transaction. We focus on the direct comparison of the hybrid market structure, which is comparable to the livestock futures market structure prior to the pit closure, to the limit-order book, which is representative of the market structure of livestock futures markets after the pit closure. Specifically, VW define the dealer market as a market with a uniform-price auction and the limit order market as a discriminatory price auction and they assume strategic competition among liquidity providers. Given that that uniform pricing is an essential feature of a floor exchange (Back, and Baruch 2007), the pit resembles the dealer market as defined in VW and their propositions should largely apply to our setting.

According to the VW model, if the number of market makers is large enough, hybrid markets dominate the limit order book, as risk averse customers prefer to route larger orders to the dealer market. The variance of the execution cost of large orders in the electronic order book can be higher than the respective one in the dealer market, and this uncertainty can outweigh the lower execution cost expected in the electronic order book. Engle, Ferstenberg, and Russell (2012) also show that traders indeed exhibit high risk aversion and highlight that this risk component (the variance) arises from the time it takes to execute an order, especially a large one.[3]

Conclusions in VW could be understood by considering a common functional form of risk aversion, such as the constant absolute risk aversion utility function (CARA), which posits that risk averse traders would always prefer a lower, but certain, payoff to a higher expected payoff with enough variation (uncertainty) in the payoff. This translates quite well into our setup because the pit users we observe choose to trade at the pit when time to execution increases, and we argue in our analysis that time to execution can be a good proxy for uncertainty on whether a customer's limit orders sitting on the book would be executed or not (Dahlström, Hagströmer, and Nordén 2023). Thus, we use time to execution, or the need to trade immediately in order to eliminate execution uncertainty, to capture the risk averse aspect of traders in VW's model.

Our findings are also consistent with Hendershott, and Mendelson (2002) who suggest that impatient traders require assurance of immediacy and thus prefer to trade at the dealer market, while traders who do not put a high value on immediacy prefer to trade on the limit order book (a crossing-network in their case) in order to reduce their execution cost. It is also consistent with Raman, Robe, and Yadav (2023), who show that floor trading increases at times of high market stress, when one would expect the need for immediacy to increase.[4]

Under this light, we hypothesize pits serve a purpose for customers because they can get better immediacy for their large orders (i.e. execute their orders faster or with more certainty), even if the average cost of execution is higher than what they would have paid in the electronic market. Accordingly, we would also expect the pit attractiveness to increase when time to execution in the electronic market increases, because in this case risk averse customers face higher execution uncertainty for their electronic large orders, meaning the level of trading immediacy offered for such orders in the electronic market declines.

H1: When there is a large number of market makers, the pit is preferable to the electronic order book for large orders. The pit becomes even more attractive to customers when the time to execution in the electronic order book increases.

The VW framework also provides some insight on what happens to the execution quality of electronic orders when the pit closes. If the attractiveness of pit trading stems from the provision of immediacy, we would expect pit users to redirect at least some of their high immediacy orders to the electronic order book. Such orders would likely be traded aggressively in the electronic market (i.e. market orders or marketable limit orders), which would translate in a decline in the average time to execution in the electronic market for pit users. Moreover, since high immediacy orders generally cost more (Gousgounis, Onur, and Tuckman 2020; Collin-Dufresne, Junge, and Trolle 2020), we would also expect an increase in pit users' execution cost in the electronic market.

H2: When the pit closes, pit users' electronic trades execute faster, but their execution cost also increases.

As suggested by H2, pit users' high immediacy orders, which were previously executed in the pit, are generally costly and we would therefore expect them to increase the average electronic execution cost once they migrated to the electronic order book. However, the VW model suggests that such orders may be less expensive to execute in the electronic market compared to the pit, but they would face lower immediacy. We hypothesize that pit closure would impact the overall execution cost in two separate avenues. First, directing pit order flow to the electronic market would increase the pit users' overall execution cost, for both electronic and pit orders. Second, it is also likely that pit users may choose not to trade as many high immediacy, high cost orders in the electronic market as they did in the pit after pits close, which would also result in a further decline in the overall the execution cost.

H3: The migration of high immediacy orders from the pit to the electronic market is expected to decrease the overall execution cost on a per-contract basis for pit users.

Finally, we note that since pit orders routed to the electronic market would have been likely shredded into smaller orders, we estimate the overall execution cost in a per contract basis to make them comparable before and after the pit closure.

Data and Summary Statistics

Data Description

Our dataset includes transaction-level data on livestock futures during the time period extending from June 1st 2014 to June 1st 2016. The regulatory dataset is constructed using mostly the Transaction Capture Report database of the Commodity Futures Trading Commission (CFTC). This regulatory dataset includes every transaction executed at the exchange on a given day and includes the price and quantity of every futures trade, an order identifier,[5] the execution venue (i.e. electronic, pit trades), as well as both counterparties to each transaction. Other useful information in the dataset are indicators for the type (market, limit or stop order) of each originating order[6] and whether it is part of a spread (i.e. a calendar spread) or not. The dataset also provides information on whether the order is manual or if it is submitted by an algorithmic program.[7] It also contains a flag for who initiated the trade (buy side vs. sell side) for electronic transactions (aggressor indicator).[8] The dataset allows us to identify which orders originate from customers and which orders originate from locals in the pit, and proprietary traders in the electronic market. Finally, we use contract expiration dates from CFTC's Integrated Surveillance System (ISS) dataset, which we use to estimate time until expiration for each contract traded in the sample.

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). Specifically, we define pit users as customers who had at least one pit transaction during the period of June 1st, 2014 – July 5th 2015, which is the day before the pit closure. Non-pit users have electronic transactions during this timeframe but no pit transactions. 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. As rich as our data are, it does not allow us to track customers who might close their accounts prior to pit closure and open up new ones afterwards. Therefore, when we compare pit users to non-pit users, we only focus on those accounts which we can track both prior to and following the pit closure.

Table 1 presents the trading patterns of all groups of customers in the livestock futures markets separately before and after the pit closure. Results are similar across the three futures contracts. While we focus our analysis on pit users and non-pit users, we also document the trading behavior of new entrants, to confirm that they constitute a small proportion of the total volume. Our summary statistics suggest that pit users were executing over 30 percent of their daily trading volume in the pit across all livestock futures contracts (33.90% for live cattle, 34.32% for lean hog and 34.35% for feeder cattle futures).[9] While the number of pit users is relatively small, those customers appear to be responsible for a substantial trading volume. Prior to the pit closure, live cattle pit user customers trade about 3.5 million contracts, which corresponds to roughly 30 percent of the trading volume; lean hog pit users trade a little over 2.5 million contracts, which corresponds to about 30 percent of the market trading volume; and feeder cattle pit users trade about 315 thousand contracts, which corresponds to about 15% of the market trading volume. Pit user customers also exhibit substantially higher average trading volume than those customers trading exclusively in the electronic market. We also note that the *average daily volume* of a pit user prior to pit closure is 3 to 4.5 times of that of a non-pit trader in our sample: the *average daily volume* for live cattle pit users is 56.4 vs. 12.29 for non-pit users, the *average daily volume* for lean hog pit users is 42.69 vs. 12.54 for non-pit users and the *average daily volume* for feeder cattle pit users is 17.94 vs. 5.29 for non-pit users. Table 1 further reveals that the *average number of active days* for pit users is more than double the *average number of active days* for non-pit users. For example, pit users in the live cattle futures market are active on average for about 39 days whereas non-pit users are active for just 13 days.

Table 1 also shows that pit users place significantly larger orders than non-pit users (around 3-4 times more), probably due to the traditionally larger size of pit orders. However, we notice that after the closure of the pits, the average size of their orders drops by about half to around 6 contracts for live cattle and lean hog futures and to about 4 contracts for feeder cattle. At the same time, pit users increase the *average number of orders* they place by at least 30%, which is consistent with a higher incidence of order shredding, following the migration of the pit users' pit orders to the electronic order book. Pit users are more likely to trade strategies (calendar spreads) than non-pit users, but this finding is more pronounced in live cattle futures contracts. Also, there does not seem to be a difference between pit users, non-pit users and new entrants in terms of the time to expiration of the contracts traded. Moreover, the majority of the volume of customer orders is executed through manual orders, and this is true for all customer groups.

The overall proportion of aggressive orders (i.e. marketable limit orders or market orders) for customers appears to be close to 60%. This number is slightly lower for pit users prior to the pit closure, but their aggressiveness increases after the pit closure, which is consistent with our first hypothesis predicting that high immediacy orders migrate to the electronic market after the pit closure. Table A2 in the supplementary online appendix presents similar statistics for the periods before the announcement of the pit closure and the period after the announcement and until the actual pit closure. *Average pit trading* for pit users seems to have declined gradually after the announcement (from 34.01% to 20.92% for live cattle, from 35.31% to 25.78% for lean hog and from 36.94 to 19.73% for feeder cattle futures) before ceasing completely after the pit closure. At the same time, the pit users' *average daily volume* does not vary before and after the announcement. The *average order size* appears to drop after the pit closure announcement, which is evidence that some orders are routed to the electronic market and shredded into smaller orders.

Market Makers: Locals and High Frequency Traders

The VW theoretical model suggests that the pit can be the most cost-efficient trading venue for large orders if there is a sufficiently high number of dealers providing liquidity. The model does not distinguish the dealers in the pit and the electronic market. However, in practice, the market makers in the pit, often called 'locals', differ from the market makers in the electronic markets. In futures markets we analyze, the electronic market maker category is dominated by high frequency traders (HFTs), who use their fast trading technologies to provide liquidity in the limit order book markets (Menkveld 2013; Kirilenko et al. 2017). In our effort to track the number of dealers in livestock futures markets, we identify those accounts which belong to 'locals' in the pit and HFTs in the electronic market. 'Locals' are identified in the data by a specific indicator that is provided to us by the exchange. Our methodology for identifying HFT accounts follows Brogaard, Hendershott, and Riordan (2019) and is described in detail in the supplementary online appendix.

Panel A of figure 1 presents a smoothed graph of the *number of 'locals'*, active in the pit for each livestock futures contract on a daily basis until the day that the pits closed, as well as the corresponding number of active HFTs until the end of our sample. While there are consistently over 20 'locals' in the pit in live cattle and lean hog futures, the *number of 'locals'* in the feeder cattle pit had been considerably smaller, at around four to six daily. At the same time, the *number of HFTs* ranges from 10 to 20 with small variations through time and across commodities, with the number of feeder cattle HFTs being a little smaller than the other two commodities.[10] Panel B of figure 1 presents a smoothed graph of the *market share of HFTs*, estimated as the proportion of volume executed by HFTs in the electronic market. In line with Haynes, and Roberts (2019), there is an increasing trend in *HFTs' market share*.

Panel A of figure 2 presents a smoothed graph of the proportion of customer *trading against HFTs* for pit users and non-pit users during our sample. The two vertical lines represent the announcement of the pit closure on February 4th, 2015 and the pit closure date on July 6th, 2015. Both pit users and non-pit users trade more frequently against HFTs in the electronic market after the announcement and the pit closure. When we track the pit users' proportion of total volume (pit and electronic) *trading against locals and HFTs*, we observe that the increase in their *trading against HFTs* coincides with the decline of the proportion of their *trading against locals* after the pit closure announcement and the disappearance of locals after the pit closure (Figure 2, panel B).

Execution Quality and Market Characteristics

We evaluate the potential impact of the pit closure on customers' execution cost, which we measure using the *effective half spread* of pit and electronic customer orders, as well as its impact on the *time to execution* of just electronic customer orders.

The *effective half spread* is estimated as:

(1) $$Effective\ half\ spread = 100 * D_i * \left(log\left(P_{t,0}\right) - log\left(P_{t,benchmark}\right)\right),$$

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 for each contract expiration. The variable D_i is a trade direction indicator where $D_i = 1$ for a buy order and $D_i = -1$ for a sell order.[11] Our dataset allows us to track each originating order, which often results in numerous transactions, and to estimate the effective half spread for every order. Customers place a mix of aggressive (market or marketable limit orders) and passive orders (limit orders). We expect that a positive *effective half spreads* corresponds to aggressive orders, while negative *effective half spreads* should correspond to passive orders.[12] We evaluate the execution cost for just a group of market participants, the customers, who sometimes trade against each other and other times trade against other market participants. Therefore, the average execution cost of all customer orders (aggressive and passive) is not equal to zero and provides a complete picture of the average execution cost borne by customers.

We measure the time it takes to execute each electronic order by:

$$Time\ to\ execution = Te - Ts, \tag{2}$$

Where Te is the execution timestamp of the last transaction of the order while Ts is the order submission timestamp (time to execution is measured in seconds). Unfortunately, our dataset does not provide any information on the submission timestamps for pit orders and we are therefore unable to measure the time to execution for them.

Table 2 provides summary statistics on the distribution of the *time to execution* for electronic orders and the *effective half spread* of all orders before and after the pit closure. It also provides summary statistics on the distribution of some market control variables during the two periods for each livestock futures market.

The average *time to execution* for electronic orders seems to decline for all commodities after the pit closure, and this decline is statistically significant, which is in line to the second hypothesis: as pit users re-route their relatively urgent orders to the electronic market after the pit closure, the average *time to execution* of electronic orders drops. At the same time, the overall cost for all customer orders, measured by the *effective half spread*, declines for live cattle and feeder cattle (the decline is statistically significant) and remains stable for lean hog futures.[13,14] It is difficult to know what drives this decline in the *effective half spread* solely based on these summary statistics; some possible drivers include changes in market conditions, the pit users' more cost efficient execution of larger orders in the electronic market, or just a reduction in the number of high immediacy orders reaching the market. Figure 3 compares the average daily *effective half spread* of pit and electronic orders prior to the pit closure and shows that pit orders have a higher *effective half spread* than electronic orders. Looking at relative values of the execution cost in these markets, on average the *effective half spread* in dollars in the pit for live cattle and lean hog futures appears to be less than one tick[15] and is comparable to the execution cost estimates provided in Frank, and Garcia (2011), whereas the respective *effective half spread* for feeder cattle futures is a little over two ticks.[16]

In addition, Table 2 presents the distribution of the market wide variables used in our multivariate analysis as market controls: *volatility*, *trading intensity* and the proportion of aggressive volume on the same side of the market, which proxies order imbalance.[17] To avoid endogeneity in subsequent analysis, all market variables are estimated based on data prior to the time of the order entry in the market, which would represent the information that each trader would have had prior to placing the order. We measure *volatility* with realized volatility, estimated as the square root of the sum of one-minute squared log returns during the hour before the order started executing. We also define *trading intensity* to be the logarithm of the average one-minute volume of futures traded during the hour before the order started executing. Finally, our order imbalance proxy, titled *same side volume*, measures the proportion of aggressive volume on the same side of the market (i.e. buy or sell) during the hour prior to the order.

Trading intensity increases for live cattle and feeder cattle after the pit closure, and it declines for lean hog futures, with all differences being significant. *Volatility* is also higher and statistically significant across all commodities during the period after the pit closure. The proportion of aggressive volume on the same side of the market is lower after the pit closure for live cattle and feeder cattle (statistically significant), but remains unchanged for lean hog futures.

Methodology

Our first hypothesis suggests that pit is preferable to the electronic order book for large orders, when there is a large *number of market makers*. Moreover, the pit becomes even more attractive to customers when the *average time to execution* in the electronic order book increases. We test this hypothesis by employing the following probit regression:

$$E(Y_i = 1) = \Phi(\gamma_0 + \gamma_1 + \gamma_2 Order\ size_{\mathrm{i}} + \gamma_3 NPD_{\mathrm{i}} + \gamma_4 TTE_{\mathrm{i}} + \boldsymbol{z}_{\boldsymbol{i}}'\boldsymbol{\delta}), \tag{3}$$

which models the trader's decision to execute each customer order *i* on the pit (Y_i=1) or in the electronic market (Y_i=0). We analyze our model separately for each one of the three livestock futures markets we analyze. *Order size* is measured by logarithm of the number of contracts in each order, *NPD* represents the *number of pit dealers*, active on the day order *i* is executed, and *TTE* represents the *average time to execution* in the electronic market during the hour preceding the order submission. Based on the first hypothesis, we expect that coefficients of *order size*, *NPD* and *TTE* are positive and significant. Other covariates are denoted with $\boldsymbol{z_i}$ and include time-varying market variables such as *number of HFTs*, *trading intensity*, market *volatility*, *same side volume* (proxying order imbalance) and order characteristics such as *years to expiration* and a *spread dummy*, a binary variable indicating whether the order is a spread or not. Finally, other control variables include a news announcement dummy, and dummies for changes in trading hours and the settlement procedure as well as the hour of the day that each order was placed. $\Phi(.)$ is the cumulative distribution function of the standard normal distribution.

To test our second and third hypotheses, we propose to use difference-in-differences methodology for identification of the impact of pit closure (and pit closure announcement) on pit users' time to execution of their electronic orders, their electronic execution cost, and their overall transaction cost, including both their pit and electronic orders, on per contract basis. In our design, we consider pit users to be the treated group, while the non-pit users are the untreated one. The difference-in-differences estimator is designed to compare the change in the expected value of the measure of interest (i.e. *time to execution*, *effective half spread*) of pit users after pit closure compared to the one prior to the pit closure, with the change in the expected value of the corresponding measure for non-pit users after pit closure compared to the one prior to the pit closure. Our setting assumes that while non-pit users are not directly affected by the pit closure (since they never traded at the pit), pit users lose their ability to choose to trade at the pits, which forces them to route their large immediacy-seeking order to the electronic order book or not trade. Our strategy also rests on the assumption that non-pit users' trading (the control group) will account for unconsidered factors that would have impacted pit traders' trading (the treatment group) after the pit closure.

We expect pit users to be impacted in two ways. First, as they route their large and immediacy-seeking orders to the electronic market, the average *time to execution* for their electronic orders will decrease, while the average electronic execution cost, measured by the *effective half spread,* will increase (H2). Second, we expect the execution cost of all of their orders (including pit and electronic), measured by *the effective half spread* on a per contract basis, to decline (H3).

There are two main assumptions needed to make inferences using this methodology (Roth et al. 2023). The baseline assumption is that the average outcomes for pit users and non-pit users would have evolved in parallel if it wasn't for the pit closure (also known as the parallel trends assumption). The second assumption is that pit traders' outcome should not depend on their expectation of a future treatment (in this case, pit closure). This is also known as the no anticipatory effects assumption. In reference to these two assumptions, we present weekly averages of outcome variables (electronic execution cost, *time to execution*, and total per contract execution cost) in Figures 4 and 5. We provide two vertical lines that mark pit closure announcement and pit closure dates in the figures. We note that a distinct difference in trends between the outcome variable averages for pit user and non-pit user customers is not visually different prior to the announcement for the pit closure in Figure 4 and prior to the pit closure in Figure 5, making it hard to reject the parallel trends assumption. However, the fact that a pit closure announcement was made by the CME about 5 months before the pit closure could make the no anticipatory effects assumption hard to hold. Following Antwi, Moriya, and Simon (2013), we include both announcement and closure periods in our difference-in-difference regressions to account for any potential pre-closure drift. Specifically, we run the following OLS regression and we correct for heteroskedasticity using White standard errors:

$$E[\kappa_i] = \beta_0 + \boldsymbol{x_i'\theta_1} + \beta_1 Dclose_i + \beta_2 Dann_{\mathrm{i}} + \beta_3 Dpit_{\mathrm{i}} + \beta_4 Dann_{\mathrm{i}} Dpit_{\mathrm{i}} + \beta_5 Dclose_{\mathrm{i}} Dpit_{\mathrm{i}} + \varepsilon_i, \tag{4}$$

where κ_i is the outcome variable of our regressions for each order (or contract unit in the case of H3) i: namely, *time to execution* in Table 4, electronic execution cost, measured by the *effective half spread*, in Table 5, and per contract overall execution cost (*effective half spread* including pit and electronic transactions) in Table 6. $Dclose$ is an indicator variable equal to one if pits are closed and equal to zero otherwise. Similarly, $Dann$ is an indicator variable equal to one if the exchange has announced pit closure for livestock futures[18], zero otherwise. $Dpit$ is equal to one for pit users, and zero otherwise. Finally, x_i represents our control variables, which are similar to the ones described in Equation (4).

Our identification strategy comes from our assumption that the pit closure should impact our outcome variables for pit users, but not for non-pit users.[19] As shown in Equation (4), coefficient of the interaction term between pit closure announcement and pit user indicator variables, β_4, is our variable of importance. Equally important is the coefficient of the interaction term between pit closure and pit user indicator variables, β_5. If different than zero, β_4 indicates how the announcement of the pit closure impacted pit users compared to non-pit users. Similarly, β_5 indicates how the pit closure itself impacted pit users compared to non-pit users. Therefore, the total effect of the pit closure (when using the pre-announcement period as a reference or benchmark) for pit users compared to non-pit users can be estimated as the sum of β_4 and β_5.

Table A1 in the supplementary online appendix summarizes our hypotheses and the methodology we apply to test each one of them.

Multivariate Results

Evaluating the Decision to Trade in the Pit Prior to the Pit Closure

According to H1, pit orders are more likely to be routed to the pit when they are large and when the *number of market makers* in the pit is high. We also expect that pit orders are preferred when immediacy is required, i.e. when the speed of execution slows down in the electronic market. We test this hypothesis by studying the behavior of customers prior to the pit closure in a probit regression by modeling the *decision to execute an order in the pit vs. the electronic market*.

Table 3 presents the results of the probit regression, which includes all orders placed prior to the pit closure during the time that the pit is open. In line with VW's theoretical predictions, customers are more likely to route their orders in the pit when the orders are large. To account for the *number of market makers*, who may not be the same in the pit and the limit order book, we include in the probit regression both the *number of active pit dealers* ('locals') and *the number of HFTs* on a given day. Consistent with VW, customer orders are more likely to be executed in the pit when the *number of 'locals'* is high. The number of active HFT accounts appears to have a negative and significant effect in the live cattle and lean hog futures market, but it is insignificant in the feeder cattle futures market. To evaluate whether customers prefer the pit for their executions when speed of execution slows down in the electronic market, we include the *average time to execution* in the electronic market in the hour prior to each trade as an explanatory variable. Our rationale is traders are able to see how swiftly orders get executed in the electronic order book and can judge the level of immediacy in the market before placing their own limit orders. The coefficient of the *average time of execution* in the electronic market is positive and significant across all markets, indicating that customers send more orders to the pit when it takes longer to execute an order in the electronic market. This finding is consistent with H1 and the notion that customers prefer the pit because it provides higher immediacy in terms of faster execution.

The probit regression includes several other control variables. *Years to expiration* measures the time until contract expiration in years. Contracts with a longer time to expiration tend to be more illiquid and human intermediation in the pit is helpful in completing such trades. In line with that argument, the coefficient of *years to expiration* is positive for all commodities and it is significant for the smallest two contracts, the lean hog and feeder cattle futures. The decision to route orders to the pit might also be affected by the decision to trade spreads. In order to test this, we include a *spread dummy*, which takes the value 1 if the order is part of a spread, i.e. calendar spread, and zero otherwise.[20] Spreads are more complicated orders, which could benefit from human intermediation. However, our results suggest that spread trades are actually less likely to be routed to the pit, potentially because the automatic spread mechanism of CME's matching engine (Globex) provides a cost-effective execution for livestock futures spreads. We also evaluate whether the order was placed on a day that news announcements were released.[21] Our results indicate that orders are more likely to be routed to the pit on those days, as the corresponding coefficients are positive and significant or insignificant with varying sign. This is consistent with the notion that the pit offers immediacy, as traders usually seek immediacy around the time of news announcements (Boudt, and Patitjean 2014). Additional control variables, in the form of dummies, are included to control for the change in the trading hours and the change in the settlement procedure in December 2014. The exchange reduced the trading hours in the electronic market on October 27th 2014[22] to consolidate trading and improve liquidity. The coefficient of the *trading hours dummy* is negative, indicating that after the change indeed the probability of routing orders to the pit was reduced. In December 2014, the exchange changed the settlement procedure so that the settlement price is not determined based on just the pit transactions,[23] which diverted order flow from the pit to the electronic market, as the negative coefficients suggests. Finally, our probit regressions include proxies for market conditions at the time each order was placed. Our results suggest that generally customer orders are less likely to be routed to the pit when *trading intensity* and *volatility* are high. We also include hourly dummies to control for the fact that the need for faster execution might be changing across different times of the day independently from market conditions, i.e. traders have to complete their trades as closing approaches. Indeed, the coefficients of the hourly dummies indicate that the probability to trade in the pit is highest during the last hour of trading. *Trading intensity* and *volatility* indicate high market activity in the electronic order book, which translates into electronic limit orders being more likely to be executed. Customers are also less likely to be routed to the pit when order imbalance is high. This means that when there is an excess in the proportion of aggressive volume on the same side of the market, which is what our order imbalance proxy measures, traders expect the price to reverse, increasing the probability of the limit order getting filled. For example, an excess in aggressive buy volume would push the price up followed by a price decline which would increase the probability of a limit buy order getting filled. To corroborate our finding, Chordia, Roll, and Subrahmanyam (2005) document that intraday order imbalances are followed by price reversals.

Execution quality in the electronic market: pit users vs. non-pit users

Our results suggest that the pit can be the preferred trading venue for large orders, because it offers immediacy. With the pits closed, customers are now forced to either route such orders to the electronic market or reduce/stop trading. The order migration to the electronic market should result in a drop in the average *time to execution* and an increase in the average execution cost in the electronic market (H2), since large high-immediacy orders tend to execute faster and cost more. We would expect this migration to affect pit users more than non-pit users, since the former were the ones actively using the pit to optimize the routing of their orders to the pit and the electronic order book.

To test this hypothesis, we apply a difference-in-differences approach with the objective to evaluate whether, following the pit closure, pit users' orders execute faster and at a higher cost than non-pit users'.[24] Even though we account for some order characteristics and market conditions, this approach allows us to also control for any other factors that may have affected the execution cost at the time of the pit closure. Specifically, in Table 4 we present the coefficient estimates from an OLS regression where our variables of interest are the *pit user dummy*, the *pit closure announcement dummy*, the *pit closure dummy*, and more importantly the interaction of pit user dummy with each of the latter two variables. These interactions capture the effect that the announcement of the pit closure and the additive effect of the pit closure itself have on pit users' *time to execution* compared to non-pit users. We also control for various order characteristics and market conditions. The p-values reported in the table are based on White standard errors correcting for heteroskedasticity.

The coefficient of the *pit user dummy* is positive and significant, which indicates that electronic orders originating from customers, who were pit users, generally take longer to execute. This is potentially due to the fact that they are larger and they may have higher information content (Easley, and O'Hara 1987). The coefficient of the *pit closure announcement dummy* is negative for live cattle and positive for lean hog and feeder cattle futures, whereas the coefficient of *pit closure dummy* is negative and significant across all commodities, which indicates that the time to execution has generally dropped after the pit closure. This is potentially the result of a more efficient market with consolidated trading in one trading venue. The interaction of the pit user dummy with the pit closure announcement dummy is negative and significant across all commodities, which suggests that pit users' electronic orders are executed faster after the announcement of the pit closure than those of non-pit users'. The coefficient of the *pit user-pit closure dummy interaction*, which measures how pit users' *time to execution* has changed after the pit closure compared to the period between the announcement and the pit closure date, is negative for the live cattle and positive for lean hog and feeder cattle futures. However, the magnitude of these coefficients is smaller than the corresponding one for the interaction between the pit user and the pit closure announcement dummies. This suggests that compared to the period prior to the announcement, the post pit closure *time to execution* of pit users' orders drops more than the corresponding one for non-pit users. Specifically, after the announcement of the pit closure, the *time to execution* declines more than what is observed for non-pit users by 79 seconds in live cattle, 66 seconds in lean hogs and 185 seconds in feeder cattle. For live cattle, this effect declines further to 89 seconds after the pit closure. However, this effect is partially offset after the pit closure, with the net effect being equal to a decline of 49 seconds for lean hogs and 117 second for feeder cattle).

As noted above, most of this decline occurs after the pit closure announcement. Our explanation is that at least some pit users' high immediacy orders, which are executed aggressively, migrate from the pit to the electronic market and this migration starts to happen right after the announcement of the pit closure.

We also include various control variables in our regression. As expected, larger orders take longer to execute. Also, *years to expiration* and the *spread dummy* have a positive and significant coefficient, which could be the result of the lower liquidity in the order book of far out contracts and spreads.[25] Orders executed on news announcement days appear to execute faster, but this effect is only significant for lean hog futures, potentially because orders are more likely to have higher information content on those dates.

The changes in trading hours,[26] meant to consolidate liquidity, are generally negatively related to execution speed, which is indicative of the effectiveness of those changes for the improvement of liquidity in the electronic order book of the livestock futures markets. The change in the settlement procedure switches the trading focus and liquidity to the electronic market. Therefore, we would expect to have a negative effect on time to execution. While the settlement dummy appears to have a negative effect on *time to execution* for lean hog and feeder cattle futures, its effect on live cattle is positive. *Trading against HFTs*, which is measured by the proportion of the order which executed against an HFT account, is negatively related to *time to execution* which is consistent with the HFT literature showing that HFTs improve liquidity in the electronic market (Jarnecic, and Snape 2014).

Other control variables include *same side volume*, the proportion of aggressive volume on the same side of the market, which serves as an order imbalance proxy, market *volatility* and *trading intensity*. At times of high *volatility*, orders take longer to execute because transaction prices can easily move away from the price levels that limit orders are placed at. The proportion of aggressive volume on the same side of the market leads to faster executions, as it increases the probability of those orders getting filled, as the price typically reverses following an order imbalance (Chordia, Roll, and Subrahmanyam 2005). Finally, *trading intensity*, which is indicative of better liquidity (Riordan et al., 2013), is negatively related to execution speed.

Next, we turn to the question of how execution cost was impacted by the pit closure change (and its announcement) in the three markets we analyze. Table 5 presents the results of the regression of the execution cost (*effective half spread*) of electronic orders on the *pit user dummy*, the *pit closure dummy* and the *pit closure announcement dummy*, as well as and the interaction of the pit user dummy with each of the latter two variables. Similar to the regression of Table 4, the interactions compare the expected value of the pit user execution cost after the treatment date (pit closure announcement or pit closure itself) minus the expected value of the pit user execution cost before the treatment, with the expected value of the non-pit user execution cost after the treatment minus the expected value of the non-pit user execution cost before it. Also, similar to the regression of Table 4, we control for various order characteristics and market conditions. The p-values reported in the table are based on heteroskedasticity corrected White standard errors.

The coefficient of the *pit closure announcement dummy* is positive for all commodities and significant for live cattle and lean hog futures, which suggests that the electronic execution cost increases for everyone after the announcement of the pit closure. The coefficient of the pit closure dummy suggests that there is no change in the electronic execution cost for live cattle and feeder cattle futures, but a drop is observed for lean hog futures. The coefficient of the *pit user dummy* is commodity dependent. Pit users face a lower execution cost in lean hog and feeder cattle futures markets, while there does not seem to be any significant difference between pit user and non-pit user execution cost in the live cattle futures market.

Nevertheless, one of our main focus variables is the interaction of the pit user and pit closure announcement dummies, which is positive and significant for all commodities. This suggests that the execution cost for pit users increases more than the execution cost of the non-pit users following the announcement of the pit closure, after conditioning on all other variables in the model. To understand the total effect, one has to combine the impact of pit closure with its announcement. The coefficient of the *pit user-pit closure interaction* is positive for live cattle, indicating that pit users pay even more than non-pit users after the pit closure itself. However, the corresponding coefficient for lean hogs and feeder cattle is negative and significant indicating a reversal in the increasing gap in the execution cost of pit users and non-pit users after the pits shut down. The magnitude of the reversal is relatively small for lean hogs and the net effect is positive and significant when we compare the post-pit closure period to the pre-announcement period. Specifically, pit users' *effective half spread* in live cattle futures increases by 0.31 basis points more than non-pit users' after the announcement and an additional 0.18 basis points after the pit closure, which corresponds to $1.34/contract after the announcement and $2.15/contract in total after the pit closure.[27] The respective numbers for lean hog futures are $3.63/contract after the announcement and a total of $2.97 after the pit closure itself.[28] This is consistent with our prediction of potentially more aggressive, higher cost pit orders migrating to the electronic market after the pit closure.

This key finding of how execution cost changes for pit users after pit closure sets live cattle futures apart from the other two contracts. Live cattle had the biggest amount of pit activity before the closure and had the largest number of locals, which could explain the differences we observe in our results. Also, noteworthy, the pit users' execution cost increases in all three markets after the pit closure announcement, the largest jump observed in lean hog futures. Moreover, this increase persists after the pit closure for the two largest livestock futures contracts (live cattle and lean hogs).

The control variables indicate that larger orders have higher execution cost, which is expected since large orders often execute at multiple price levels. Orders on contracts with longer time to expiration also have higher execution cost for the largest two contracts, which can be attributed to the reduced liquidity of deferred contracts. In the case of feeder cattle, there does not seem to be any significant difference, which reflects the fact that feeder cattle contract listing frequency is different than the other two. We would expect spread orders (i.e. calendar spreads) to face a higher liquidity cost,[29] but the coefficient of the *spread dummy* is positive and significant just for live cattle and feeder cattle futures, and negative and significant for lean hog futures. The *news dummy* alternates sign across commodities (negative for live cattle, positive for lean hogs and insignificant for feeder cattle), which suggests that news announcements do not have a consistent effect on execution cost.

The changes in trading hours were expected to improve the liquidity in the market. However, orders following these changes, have lower execution cost just in the lean hog futures market. It is possible, however, that a shorter trading day may require orders to become more aggressive, leading to an increase in execution cost, which is consistent with our results in the live cattle and lean hog futures markets. The change in settlement procedure consolidates trading around the settlement period and has potentially attracted more HFTs in this market, which would predict an increase in execution cost. However, execution cost after the settlement change increases just for lean hog futures. Finally, *trading against HFTs* increases execution cost, potentially because they are able to detect larger orders and trade in the same direction increasing cost (Van Kervel, and Menkveld 2019).

The proportion of aggressive volume on the same side of the market is positively related to the execution cost. *Trading intensity*, which indicates higher liquidity and lower risk, is negatively related to the *effective half spread* across all commodities. We would expect *volatility* to have a positive effect on execution cost (Engle, Ferstenberg, and Russell 2012), but the coefficient of *volatility* is positive just for lean hog futures.

Overall execution cost after the pit closure: pit users vs. non-pit users

Our results suggest that pit users' electronic execution cost has increased after the pit closure for two out of three markets we analyze. We attribute this increase to the migration of some large high cost, high immediacy orders from the pit to the electronic order book. VW argue that pit orders would have executed at a lower cost had they been routed in the electronic market. After the pit closure, the migration of at least some of the pit orders to the electronic market would contribute to a reduction of the overall execution cost faced by pit users, including all their pit and electronic orders. We should note that the migration of 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 in Table 2, which is consistent with a higher incidence of order shredding. Finally, the pit closure could also have prompted some pit users to reduce some of their costly high immediacy orders, especially if they cannot execute them efficiently in the electronic market. This would also result in a reduction in the overall execution cost for pit users.

We aim to evaluate whether execution cost has declined 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 smaller than 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 large orders into smaller bits. This makes it challenging to compare the pit orders prior to the pit closure to the corresponding migrated electronic orders after the pit closure.[30] To address this issue, we switch our measurement unit from orders to contract units.[31] Namely, we evaluate whether the execution cost for pit users after the pit closure has declined on a per contract unit basis, accounting for all contracts traded both in the pit and on the electronic order book.[32]

Table 6 presents the results of the regression on overall execution cost, measured by the *effective half spread*, on a per contract unit basis, for all contracts traded. Similar to Tables 4 and 5, we include the *pit closure announcement dummy*, the *pit closure dummy*, the *pit user dummy* and its interaction with each of the former two dummies. While the pit closure announcement has positive effect on the per contract execution cost of lean hog and feeder cattle futures for the whole market (it is insignificant for live cattle), the pit closure itself has mixed associations with the per-contract execution cost across markets (positive for live cattle, negative for lean hogs and insignificant for feeder cattle). Moreover, focusing on the per-contract execution cost of pit users in the market, they enjoy on average a lower per-contract execution cost in lean hog and feeder cattle futures, but not live cattle.

Focusing on our diff-in-diff results, and in line with our electronic market cost, the per-contract execution cost after pit closure announcement increases compared to that of non-pit users for all commodities except live cattle. For pit closure, we find that pit users face a lower execution cost on a per contract unit basis, compared to what non-pit users face, after the pit closure for all futures markets we study. Taken together, these results suggest that the per-contract execution cost for pit users, compared to non-pit users, has gone down after pit closure, but not before increasing for lean hog and feeder cattle futures after the pit closure announcement. [33]

Specifically, the overall per contract execution cost of pit users does not change after the pit closure announcement compared to non-pit users, but it declines on average by 0.4 basis points after the pit closure. However, in the case of lean hogs and feeder cattle the overall per contract execution cost of pit users temporarily increases after the announcement compared to non-pit users (by 0.6 basis for lean hogs and 0.88 for feeder cattle), but later drops even further after the pit closure (by 1.1 basis points for lean hog and 0.72 basis points feeder cattle), resulting in a negative net effect for lean hogs (a decline by 0.5 basis points) and an insignificant net effect for feeder cattle.[34] The relative decline in the pit users' execution cost after the pit closure could potentially be at least partly due to the migration of at least some of their pit orders to the more cost-efficient electronic market. Another potential reason for the decline in cost could be the reduction in the number of these costly high immediacy orders entering the market, especially if pit users are not able to execute them successfully. The results of Tables 4 and 5 are consistent with that we observe some order migration to the electronic market, which seems to start after the announcement of the pit closure. However, the results of Table 6 suggest that the overall execution cost does not decline until after the pit closure, which could be suggestive of some pit users withdrawing from the market after the pit closure. [35]

The control variables included in this regression have similar signs with the regression of Table 5, which analyzes the execution cost of electronic orders. The only exception is *volatility*, which in this case is positively related to execution cost, which is consistent with the literature (Engle, Ferstenberg, and Russell 2012).

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 quality of customer orders in the livestock futures market. Empirically, we make use of a rich, regulatory transaction level data that allow us to have identifiers for the large customer orders transacted in these markets and measure the effect of pit closure on customer orders' execution cost.

There are three main findings we show in our paper. First, the pit is preferable to the limit-order book when orders are large, the number of market makers is high, and time to execution in the electronic market is high. We provide evidence that pits have been beneficial for certain customers, because they offer immediacy for large orders, albeit at a higher cost. Second, we show that time to execution declines and execution cost increases for electronic orders after the announcement of the pit closure due to the migration of at least some of the high cost/high immediacy orders from the pit to the electronic order book. Third, we find that the overall per contract execution cost of pit users, including both pit and electronic orders, actually decreases mainly for live cattle and lean hog futures markets.

The economic value of the pits our findings point to can be explained in two prongs. First, we note that the pits were often preferred by pit users, especially for their large orders and when time to execution at the electronic market was high. At a high level, pits were beneficial for hundreds of traders who chose to trade there, even when they had access to the electronic market. This is also supported by recent literature finding that suspension of New York Stock Exchange's (NYSE) pit trading due to the Covid-19 outbreak, liquidity and price efficiency in the equity market deteriorated and the quality of opening and closing auctions worsened (Brogaard, Ringgenberg, and Roesch 2023). Second, the loss of access to the pits (and hence immediacy) translates to an increased urgency in pit users' electronic market trades, measured by decreased time to execution compared to that of non-pit users, and is associated with increased execution cost for pit users' electronic trades. However, we also show that despite this increased electronic market execution cost, pit users' overall per contract unit execution cost, including both their pit and electronic orders, has actually declined compared to non-pit users' by about 0.5 basis points after the live cattle and lean hog futures pits closed. This is a sizeable decline given that before the pit closure, the average effective half spread for pit orders was 1.64 basis points for live cattle and 1.85 basis points for lean hog futures. We argue that the reason for this decline is the partial migration of pit users' high immediacy, high cost orders from the pit to the electronic market. On one hand, some of these migrated orders might have received more cost-effective executions (while losing some immediacy). On the other hand, some high immediacy, high cost orders probably never migrated to the electronic market, causing the overall per contract unit execution cost to decline.

Overall, our findings suggest that prior to the pit closure, the pits offered immediacy to certain customers, who preferred to route their larger orders to the pit, especially if there were enough market makers present. When the pits closed, those customers, who used to be active in the pit, had to direct their order flow to the electronic market. While this change resulted in a lower overall execution cost for pit users, they probably also experienced a loss in immediacy. Our findings, coupled with findings on the value of pits in different markets (Brogaard, Ringgenberg, and Roesch 2023), suggest pits added an option value to many customers. However, we leave it to market participants and regulators to decide whether this value was large enough to warrant continuation of pits or not.

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Tables

Table 1: Summary Statistics for Pit Users vs. Non-Pit Users Before and After Pit Closure

Pit closure status	Pit user status	*Total volume*	*Number of accounts*	*Average daily volume*	*Average number of active days*	*Average number of orders*	*Average order size*	*Average pit trading (%)*	*Average spread trading (%)*	*Average years to expiration*	*Average manual trading (%)*	*Average aggressive trading (%)*
Live cattle (48)												
After	New	1,323,408	8,844	11.6	7.61	55.84	2.77	0.18%	21.64%	0.43	94.89%	62.63%
Before	Non-pit	8,242,235	23,708	12.29	13.43	132.35	2.84	0.00%	23.03%	0.43	95.85%	60.80%
After	Non-pit	6,682,307	11,178	14.54	17.68	234.15	3.17	0.04%	22.61%	0.42	95.42%	61.09%
Before	Pit	3,571,452	1,138	56.4	39.46	325.19	12.14	33.90%	40.76%	0.42	98.67%	55.17%
After	Pit	2,313,432	669	45.23	43.13	478.28	6.05	1.68%	45.43%	0.44	96.65%	57.86%
Lean hog (LN)												
After	New	1,248,115	9,594	10.10	7.81	60.36	2.34	0.17%	21.56%	0.34	94.27%	59.84%
Before	Non-pit	6,691,733	21,611	11.40	12.54	137.19	2.60	0.00%	24.24%	0.36	95.60%	57.31%
After	Non-pit	5,568,825	11,409	12.33	16.98	222.04	2.79	0.03%	21.28%	0.35	95.54%	56.99%
Before	Pit	2,646,640	1,147	42.69	33.31	255.76	11.39	34.32%	29.83%	0.33	98.30%	57.49%
After	Pit	1,306,384	650	34.63	38.26	327.96	5.84	1.75%	31.79%	0.32	96.71%	60.73%
Feeder cattle (62)												
After	New	359,233	5,006	6.49	6.51	41.63	1.99	0.04%	18.82%	0.35	94.13%	57.75%
Before	Non-pit	1,675,290	15,331	5.49	9.87	63.71	2.1	0.00%	17.34%	0.36	96.60%	56.99%
After	Non-pit	1,351,155	6,807	6.63	14.2	116.51	2.21	0.00%	15.56%	0.33	96.02%	55.55%
Before	Pit	314,981	441	17.94	26.05	150.24	5.66	34.35%	23.71%	0.34	97.75%	52.24%
After	Pit	155,201	224	18.54	26.04	202.35	3.6	1.02%	29.65%	0.3	94.85%	55.86%

Note: This table describes the trading behavior of customers during the period of June 1st 2014 to June 1st 2016. 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, while average number of active days measures the number of days a particular group of customers traded. *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 years to expiration* measures the average time to expiration in years. *Average manual trading* is the percentage of transactions that carry a manual indicator. *Average aggressive trading* is the percentage of trading volume where the customers initiate the trades.

Table 2: Summary Statistics of Market Wide Measures in Livestock Futures Markets

Code	Variable	Pit Closure	Mean	Median	1st Pctl	99th Pctl	Std Dev	Diff	p-value
Live cattle (48)	*Time to execution*	Before	371	4	0	7814	1728		
		After	304	2	0	6949	1304	-68	<.0001
	Effective spread	Before	-0.0063	0.001	-0.4722	0.3458	0.1419		
		After	-0.0067	0.0002	-0.5709	0.4516	0.1711	-0.0004	0.0003
	Trading intensity	Before	3.5806	3.8093	-0.5108	6.1719	1.2696		
		After	3.845	3.975	0.2231	6.672	1.1895	0.2644	<.0001
	Volatility	Before	0.0039	0.0036	0.0007	0.0106	0.0021		
		After	0.0055	0.0046	0.0007	0.0215	0.0039	0.0016	<.0001
	Same side volume	Before	50.46%	50.38%	21.24%	81.46%	11.42%		
		After	50.19%	50.18%	24.34%	76.58%	10.02%	-0.27%	<.0001
Lean hog (LN)	*Time to execution*	Before	318	2	0	7168	1521		
		After	294	2	0	6942	1298	-23	<.0001
	Effective spread	Before	-0.0062	0.0031	-0.6988	0.5374	0.2112		
		After	-0.0062	0.0036	-0.7184	0.5328	0.2196	0	0.7947
	Trading intensity	Before	3.0728	3.2812	-0.8362	5.5759	1.2704		
		After	2.9906	3.129	-0.5108	5.5363	1.2164	-0.082	<.0001
	Volatility	Before	0.0063	0.0057	0.0012	0.0171	0.0038		
		After	0.0067	0.006	0.0013	0.0188	0.0035	0.0004	<.0001
	Same side volume	Before	50.59%	50.49%	19.37%	83.87%	12.58%		
		After	50.59%	50.56%	20.00%	82.14%	11.78%	0.00%	0.8738
Feeder cattle (62)	Time to execution	Before	506	7	0	9310	2060		
		After	374.392	4	0	7907	1441.2	-132	<.0001
	Effective spread	Before	-0.0068	0.0015	-0.6113	0.4864	0.1828		
		After	-0.0086	0.0022	-0.7881	0.6147	0.2339	-0.002	<.0001
	Trading intensity	Before	1.9448	2.096	-1.8971	4.9488	1.2713		
		After	2.292	2.3671	-1.0498	5.1358	1.1514	0.3472	<.0001
	Volatility	Before	0.0046	0.004	0.0005	0.0136	0.0025		
		After	0.0067	0.0057	0.001	0.025	0.0043	0.0021	<.0001
	Same side volume	Before	50.65%	50.42%	14.29%	90.00%	14.33%		
		After	50.28%	50.14%	18.12%	83.33%	12.28%	-0.37%	<.0001

Note: This table presents the distribution of various variables during the period of June 1st 2014 to June 1st 2016, before and after the pit closure for each commodity. *Time to execution* describes the number of seconds from the entry of each electronic order to the last transaction in the order. *Effective spread* represents the effective half spread estimated as log difference of each order's vwap and the prevailing price prior to each order multiplied by a dummy taking the value of one for a buy order and minus one for a sell order. *Trading intensity* is measured as the logarithm of the average one-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* indicates the percentage of volume initiated on the same side of the order during the hour preceding the order.

Table 3: Results From Probit Regression Estimating the Decision to Route an Order to the Pit Prior to Pit Closure

	Decision to route an order to the pit (probit)								
	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	-2.4324	2550	<.0001	-2.5997	2208	<.0001	-3.8341	809	<.0001
Order size	0.5665	60234	<.0001	0.5882	54317	<.0001	0.6405	8481	<.0001
Years to expiration	0.0171	2	0.2174	0.1217	50	<.0001	0.2097	25	<.0001
Spread dummy	-0.2842	2043	<.0001	-0.6036	6318	<.0001	-0.6612	1136	<.0001
News dummy	-0.0039	0	0.7136	0.0438	12	0.0004	0.0470	3	0.0615
Trading hours dummy 1	-0.0464	22	<.0001	-0.0483	17	<.0001	-0.0356	2	0.1908
Settlement dummy	-0.1559	193	<.0001	-0.1835	253	<.0001	-0.0959	11	0.0008
Same side volume	-0.3963	192	<.0001	-0.2419	72	<.0001	-0.2345	17	<.0001
Trading intensity	-0.0965	553	<.0001	-0.0811	359	<.0001	-0.1226	134	<.0001
Volatility	-14.8353	55	<.0001	-0.5463	0	0.5327	29.1129	45	<.0001
Number of pit dealers	0.0073	83	<.0001	0.0048	48	<.0001	0.0761	216	<.0001
Number of HFTs	-0.0136	48	<.0001	-0.0196	44	<.0001	0.0032	0	0.7541
Avg time to execution (electronic)	0.0001	13	0.0004	0.0003	109	<.0001	0.0002	18	<.0001
Dummy 10am	0.0013	0	0.8928	0.0337	10	0.002	0.1379	23	<.0001
Dummy 11am	-0.0301	9	0.0035	0.1055	87	<.0001	0.2564	79	<.0001
Dummy 12pm	0.4098	2046	<.0001	0.4702	2130	<.0001	0.9239	1392	<.0001
Number of Obs	2,768,027			2,578,482			761,013		

Note: This table presents the estimates for probit regressions for three livestock futures contracts prior to the pit closure (June 1st 2014 to July 6th, 2015). The dependent variable is equal to 1 if the customer chooses to execute their order in the pit. *Order size* denotes the logarithm of the number of contracts in the order. *Years to expiration* measures the time to expiration for each contract in years. *Spread dummy* is equal to 1 if the order is part of a spread. *News dummy* is equal to 1 if there was a news release (WASDE or Cattle on Feed reports for live cattle and feeder cattle and WASDE or Hogs and Pigs reports for Lean Hogs) on a given day and 0 otherwise. *Trading hours dummy 1* takes the value 1 if the trade is placed after the change of the trading hours at CME. *Settlement change dummy* is equal to 1 once procedure of calculating the settlement price is changed in December 2014. *Trading intensity* is measured as the logarithm of the average one-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* indicates the percentage of volume initiated on the same side of the order during the hour preceding the order. *Number of pit dealers* denotes the number of market makers active in the pit. *Number of HFT accounts* denotes the number of firms marked as HFTs in the limit order market. *Avg time to execution* measures the average time it takes to execute an electronic order in the hour prior to the execution time of a particular order. *Dummy 10am* is equal to 1 for orders between 10 am and 11 am. *Dummy 11 am* is equal to 1 for orders between 11 am-12am. *Dummy 12pm* is equal to 1 for orders between 12pm-13pm.

Table 4: Results From Time to Execution Regression of Electronic Orders

Time to execution for pit users and non-pit users in the electronic market						
	Live cattle (48)		Lean hog (LN)		Feeder cattle (62)	
Variables	Estimate	Pr > |t|	Estimate	Pr > |t|	Estimate	Pr > |t|
Intercept	639.8624	<.0001	499.6602	<.0001	453.3609	<.0001
Order size	123.3151	<.0001	154.1705	<.0001	187.0225	<.0001
Years to expiration	48.8071	<.0001	28.9829	<.0001	93.6607	<.0001
Spread dummy	231.7426	<.0001	186.2367	<.0001	317.3012	<.0001
News dummy	-2.7931	0.1829	-5.3665	0.0185	-4.4383	0.2992
Trading hours dummy 1	-51.0722	<.0001	24.2916	<.0001	-24.2229	0.0001
Trading hours dummy 2	-117.7513	<.0001	-7.1970	0.0464	-115.5466	<.0001
Settlement dummy	30.1716	<.0001	-17.0538	<.0001	-62.1514	<.0001
Same side volume	-273.0778	<.0001	-266.3900	<.0001	-106.8299	<.0001
Trading intensity	-86.8073	<.0001	-83.6652	<.0001	-81.4727	<.0001
Volatility	2037.9933	<.0001	4686.0728	<.0001	10657.0000	<.0001
Trading against HFTs	-92.7310	<.0001	-66.1318	<.0001	-37.7553	<.0001
Pit closure dummy	-19.8862	<.0001	-19.1885	<.0001	-81.6207	<.0001
Pit user dummy	96.6474	<.0001	110.6473	<.0001	195.2998	<.0001
Pit user - pit closure interaction	-9.4381	0.0698	19.5159	0.0005	67.3723	<.0001
Pit closure announcement dummy	-4.2062	0.0650	4.9041	0.0281	25.6674	<.0001
Pit user- pit closure announcement interaction	-79.1157	<.0001	-66.8686	<.0001	-184.5395	<.0001
Number of Observations	6,284,973		5,873,199		1,832,680	
R-Square	0.0195		0.0186		0.0169	

Note: This table presents estimates for *time to execution* of an electronic order in livestock futures during the period of June 1st 2014 to June 1st 2016. *Order size* is the logarithm of the number of contracts in the order. *Years to expiration* represents the time until the contract expires, expressed in years. *News dummy* is equal to 1 if there was a news release (WASDE or Cattle on Feed reports for live cattle and feeder cattle and WASDE or Hogs and Pigs reports for Lean hog futures) on a given day and 0 otherwise. *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. *Trading against HFTs* is measured by the proportion of the order which executed against an HFT account. *Pit user dummy* is equal to 1 if the order belongs to a pit user customer and zero otherwise. *Pit closure announcement dummy* is equal to 1 once the CME announced the plan to close futures pits on February 4th, 2015 and zero prior to that date. *Pit closure dummy* is equal to 1 once pits are closed on July 6th, 2015 and zero prior to that. *Trading intensity* is measured as the logarithm of the average one-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.

Table 5: Results From Effective Half Spread Regression of Electronic Orders

Effective spread for pit users and non-pit users in the electronic market						
	Live cattle (48)		Lean Hog (LN)		Feeder cattle (62)	
	Estimate	Pr > |t|	Estimate	Pr > |t|	Estimate	Pr > |t|
Intercept	-0.0736	<.0001	-0.1009	<.0001	-0.0930	<.0001
Order size	0.0030	<.0001	0.0036	<.0001	0.0068	<.0001
Years to expiration	0.0092	<.0001	0.0136	<.0001	-0.0012	0.1665
Spread dummy	0.0017	<.0001	-0.0030	<.0001	0.0067	<.0001
News dummy	-0.0008	0.0002	0.0017	<.0001	-0.0005	0.3723
Trading hours dummy 1	0.0013	<.0001	-0.0027	<.0001	0.0016	0.0011
Trading hours dummy 2	0.0015	<.0001	0.0001	0.8907	0.0014	0.0604
Settlement dummy	-0.0031	<.0001	0.0011	0.0220	-0.0024	0.0030
Same side volume	0.1273	<.0001	0.1830	<.0001	0.1698	<.0001
Trading intensity	-0.0011	<.0001	-0.0022	<.0001	-0.0032	<.0001
Volatility	-0.3994	<.0001	0.3239	<.0001	-0.2382	0.0010
Trading against HFTs	0.0081	<.0001	0.0128	<.0001	0.0092	<.0001
Pit closure dummy	0.0001	0.4606	-0.0017	<.0001	-0.0002	0.7145
Pit user dummy	0.0003	0.4465	-0.0079	<.0001	-0.0032	0.0013
Pit user - pit closure interaction	0.0018	0.0003	-0.0022	0.0062	-0.0058	<.0001
Pit closure announcement dummy	0.0018	<.0001	0.0008	0.0435	0.0012	0.1116
Pit user- pit closure announcement interaction	0.0031	<.0001	0.0121	<.0001	0.0072	<.0001
Number of Observations	6,255,879		5,829,692		1,802,651	
R-Square	0.0088		0.0118		0.0124	

Note: This table presents estimates for *effective spread*, measured by the effective half spread of an order in livestock futures during the period of June 1st 2014 to June 1st 2016. *Order size* is the logarithm of the number of contracts in the order. *Years to expiration* represents the time until the contract expires, expressed in years. *News dummy* is equal to 1 if there was a news release (WASDE or Cattle on Feed reports for live cattle and feeder cattle and WASDE or Hogs and Pigs reports for Lean Hogs) on a given day and 0 otherwise. *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. *Trading against HFTs* is measured by the proportion of the order which executed against an HFT account. *Pit user dummy* is equal to 1 if the order belongs to a pit user customer and zero otherwise. *Pit closure announcement dummy* is equal to 1 once the CME announced the plan to close futures pits on February 4th, 2015 and zero prior to that. *Pit closure dummy* is equal to 1 once pits are closed on July 2015. *Same side volume* indicates the percentage of volume initiated on the same side of the order during the hour preceding the order. *Trading intensity* is measured as the logarithm of the average one-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.

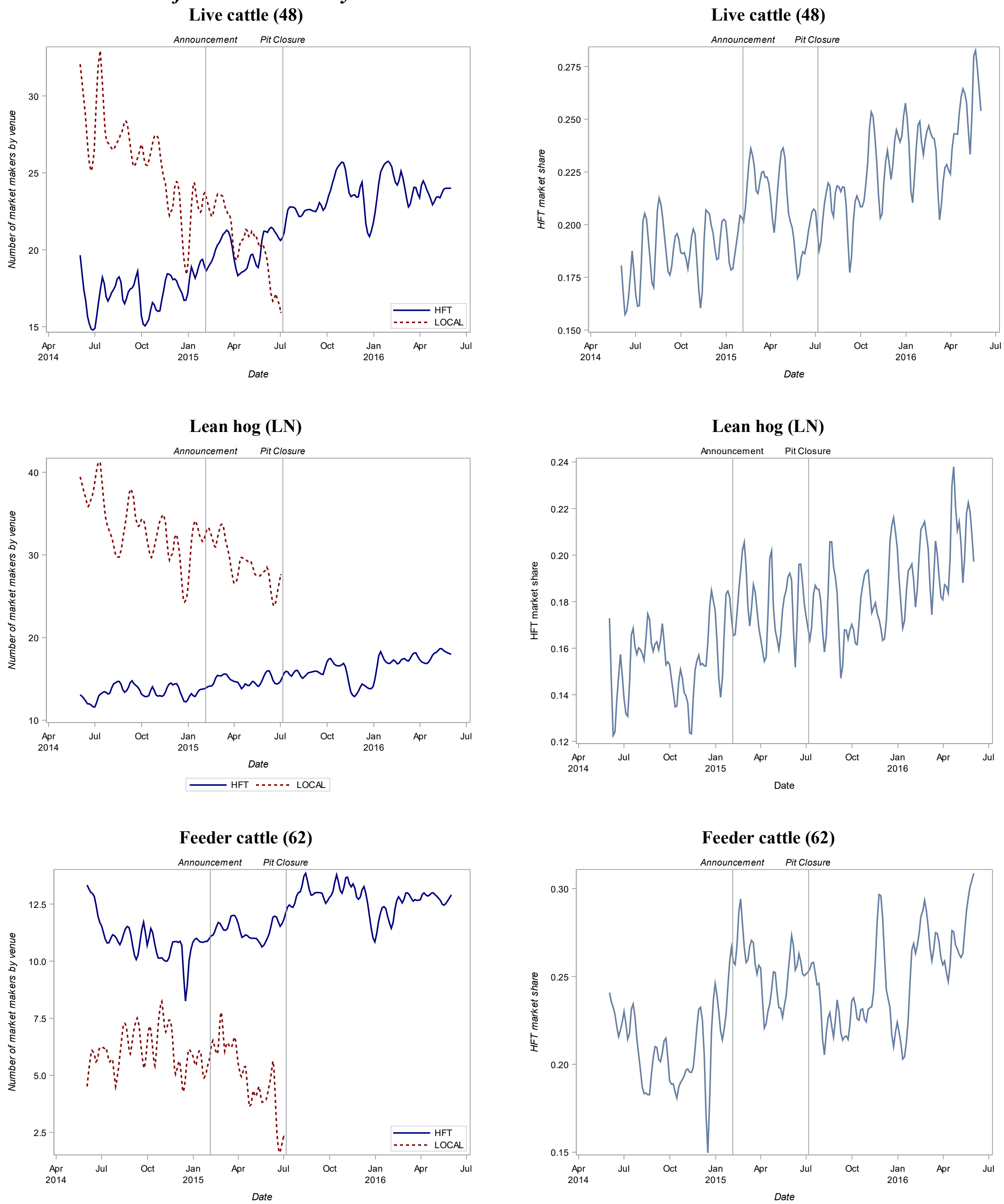
Table 6: Results From Regression of Effective Half Spread for Pit Users and Non-Pit Users

Effective spread for all pit and electronic orders						
	Live cattle (48)		Lean hog (LN)		Feeder cattle (62)	
	Estimate	Pr > |t|	Estimate	Pr > |t|	Estimate	Pr > |t|
Intercept	-0.084	<.0001	-0.112	<.0001	-0.1001	<.0001
Order size	0.004	<.0001	0.007	<.0001	0.0062	<.0001
Years to expiration	0.016	<.0001	0.033	<.0001	0.0033	<.0001
Spread dummy	-0.003	<.0001	-0.009	<.0001	0.0015	<.0001
News dummy	-0.002	<.0001	0.003	<.0001	-0.0030	<.0001
Trading hours dummy 1	0.002	<.0001	-0.007	<.0001	0.0026	<.0001
Trading hours dummy 2	0.002	<.0001	-0.001	0.0105	0.0029	<.0001
Settlement dummy	-0.001	<.0001	0.004	<.0001	-0.0046	<.0001
Same side volume	0.146	<.0001	0.212	<.0001	0.1839	<.0001
Trading intensity	-0.003	<.0001	-0.006	<.0001	-0.0045	<.0001
Volatility	0.643	<.0001	0.729	<.0001	0.6021	<.0001
Trading against HFTs	0.009	<.0001	0.016	<.0001	0.0090	<.0001
Trading against locals	0.048	<.0001	0.110	<.0001	0.0505	<.0001
Pit user dummy	0.000	0.9566	-0.012	<.0001	-0.0044	<.0001
Pit closure dummy	0.001	<.0001	-0.002	<.0001	0.0003	0.3704
Pit user - pit closure interaction	-0.004	<.0001	-0.011	<.0001	-0.0072	<.0001
Pit closure announcement dummy	0.000	0.4467	0.001	0.0028	0.0018	0.0003
Pit user - pit closure announcement interaction	0.000	0.8329	0.006	<.0001	0.0088	<.0001
Number of Observations	20,358,101		15,830,746		3,359,812	
R-Square	0.0105		0.0148		0.014	

Note: This table presents estimates for *effective spread*, measured by the effective half spread of an order in livestock futures markets during the period of June 1st 2014 to June 1st 2016. The dataset includes both pit and electronic orders. *Order size* is the logarithm of the number of contracts in the order. *Years to expiration* represents the time until the contract expires, expressed in years. *News dummy* is equal to 1 if there was a news release (WASDE or Cattle on Feed reports for live cattle and feeder cattle and WASDE or Hogs and Pigs reports for Lean hog futures) on a given day and 0 otherwise. *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. *Trading against HFTs* is measured by the proportion of the order which executed against an HFT account. *Trading against locals* is measured by the proportion of the order which executed against a 'local' account. *Pit user dummy* is equal to 1 if the market participant traded on the pits before their closure. *Pit closure announcement dummy* is equal to 1 once the CME announced the plan to close futures pits on February 4th, 2015 and zero prior to that. *Pit closure dummy* is equal to 1 once pits are closed on July 2015. *Same side volume* indicates the percentage of volume initiated on the same side of the order during the hour preceding the order. *Trading intensity* is measured as the logarithm of the average one-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.

Figure 1: ***Number of locals*** **and** ***high frequency traders***

Panel A. ***Number of market makers by venue*** **Panel B.** ***HFT market share***

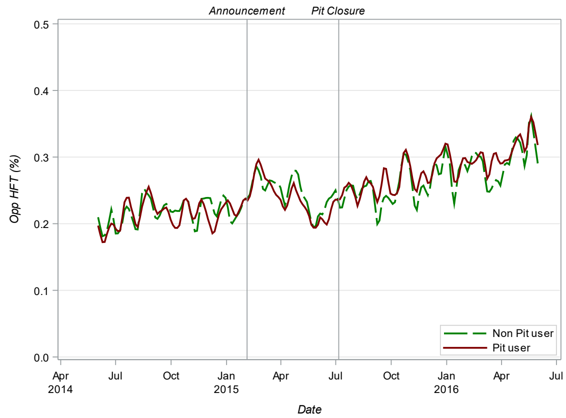


Note: Panel A of Figure 1 presents the *number of market makers* in the electronic limit order market (HFT) and in the pit (Local) customers during the period of June 1st 2014 to June 1st 2016. HFTs are shown using the blue, solid line and Locals are shown using the dotted, red line. Panel B of Figure 1 presents the *HFT market share* in the electronic market per commodity. The first vertical line corresponds to February 4th, 2015 announcement of the pit closure. The second vertical line represents the closing of the pits on July 6th, 2015. All graphs have been smoothed using SAS's Loess procedure.

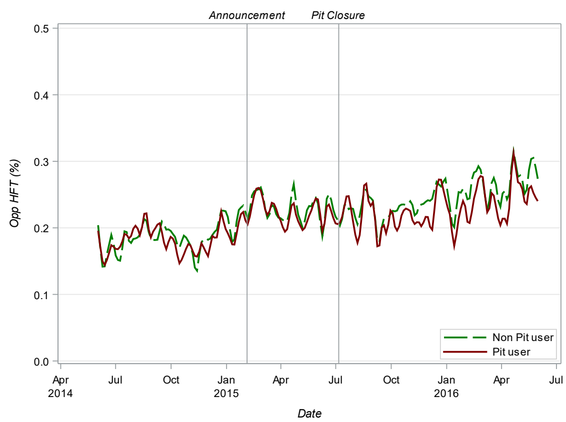
Figure 2: ***Trading against high frequency traders and locals***

Panel A. ***Trading against HFTs*****: pit vs. non-pit users**

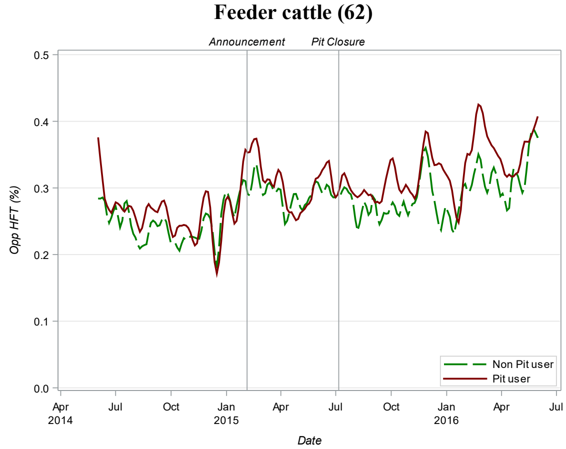
Live cattle (48)



Lean hog (LN)

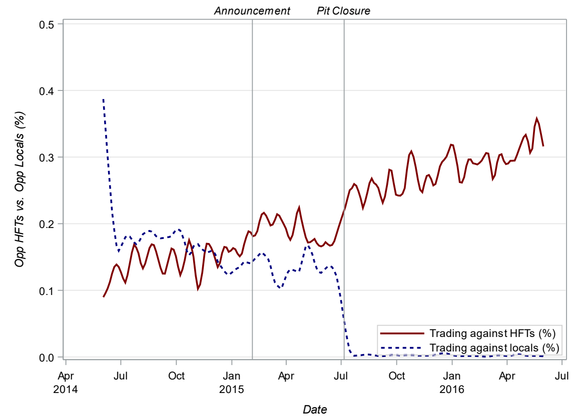


Feeder cattle (62)

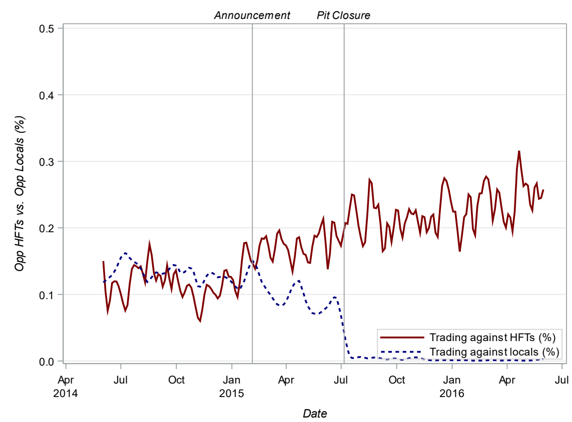


Panel B. Pit users ***trading against HFTs*** **and** ***locals***

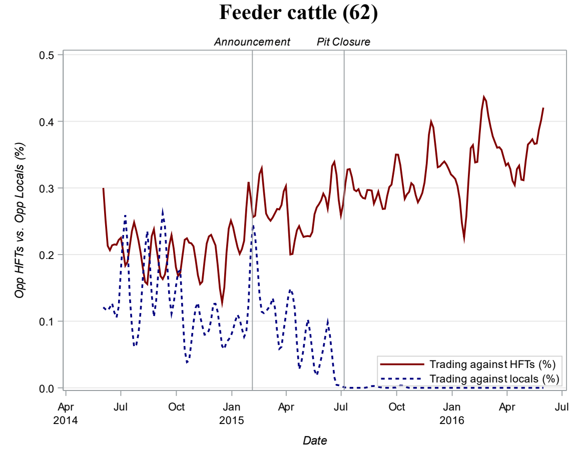
Live cattle (48)



Lean hog (LN)



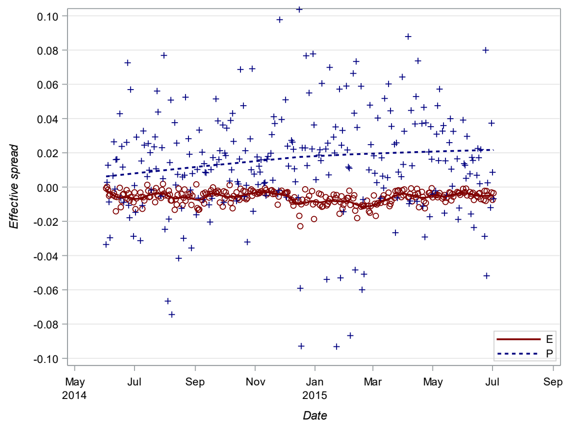
Feeder cattle (62)



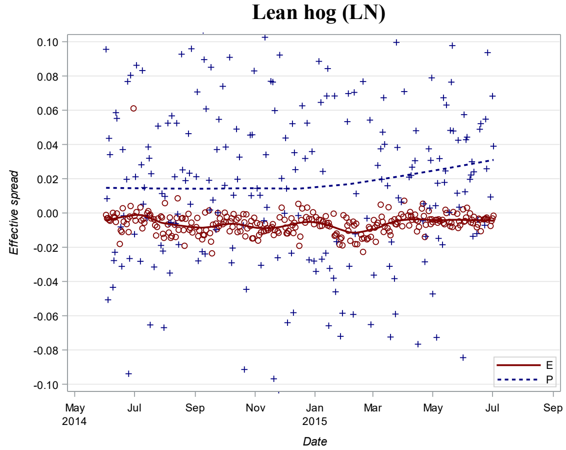
Note: Panel A of figure 2 presents the percentage of electronic trading volume with HFTs, *Opp HFT (%)*, by two groups of customers, pit users and non-pit users, in the electronic market for each livestock futures contract. The solid line represents the percentage for pit users and dotted line represents the percentage for non-pit users. Panel B on the right presents the percentage of total customer trading volume against HFTs (*Opp HFTs*) and Locals (*Opp Locals*). The solid red line represents *trading against HFTs*, whereas the dotted blue line represents *trading against locals*. The sample is from June 1, 2014 until June 1, 2016. The first vertical line corresponds to February 4th, 2015 announcement of the pit closure. The second vertical line represents the closing of the pits on July 6th, 2015. All graphs have been smoothed using SAS's Loess procedure.

Figure 3: Execution cost by venue prior to the pit closure

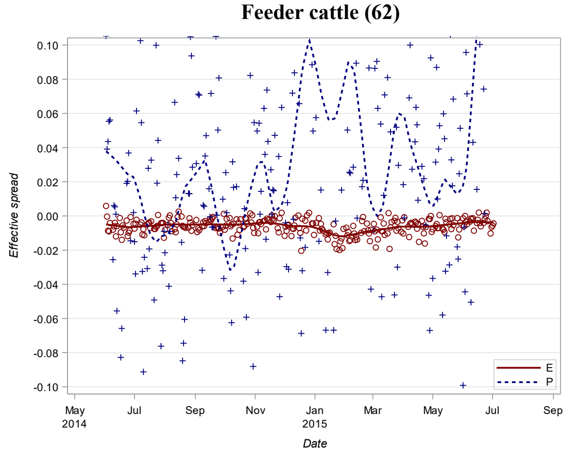
Live cattle (48)



Lean hog (LN)



Feeder cattle (62)

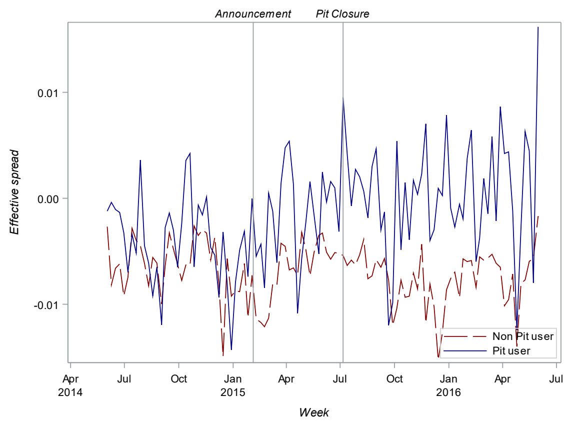


Note: Figure 3 presents the *effective spread*, measured by the *effective half spread*, for orders trading in the electronic market and the pit, prior to the pit closure. Red (blue) line shows the *effective spread* for electronic (pit) orders, smoothed using SAS's Loess procedure The sample is from June 1st, 2014 until July 6th, 2015, prior to the pit closure.

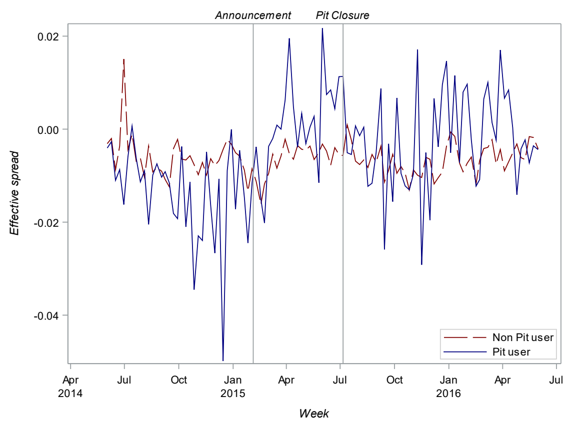
Figure 4: Weekly pre-trends: Average *effective spread* cost and *time to execution*

Panel A. *Effective spread*

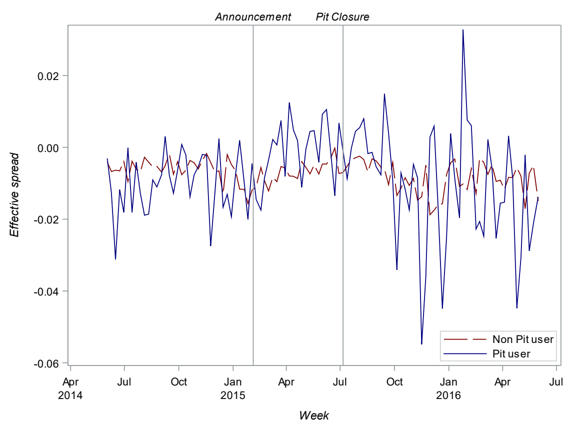
Live cattle (48)



Lean hog (LN)

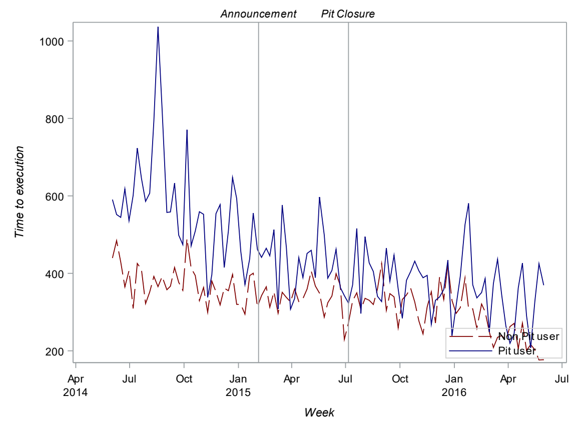


Feeder cattle (62)

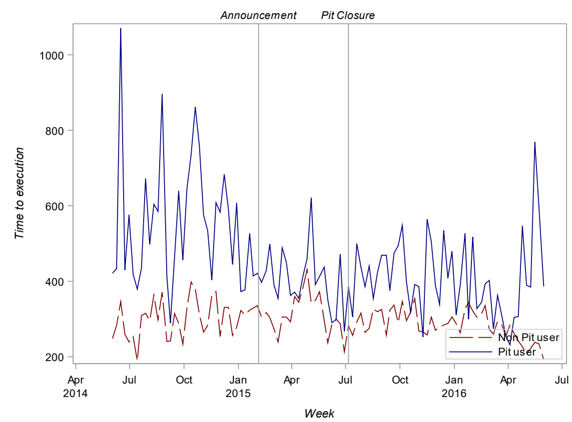


Panel B. *Time to execution*

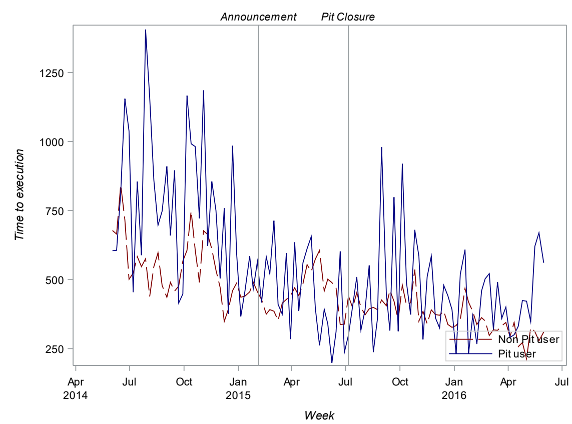
Live cattle (48)



Lean hog (LN)



Feeder cattle (62)

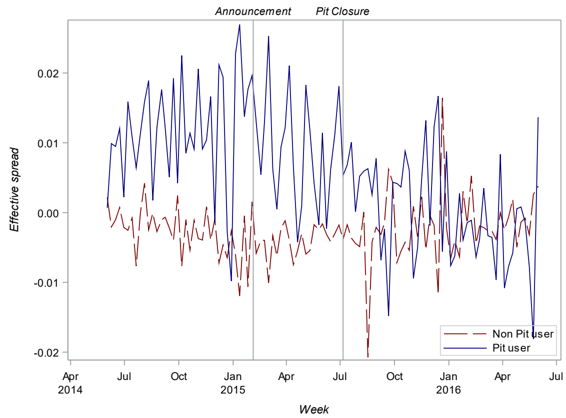


Note: Panel A of figure 4 presents the *effective spread*, measured by the average weekly *effective half spread* of orders placed by pit users and non-pit users in the electronic market. Panel B present the average weekly *time to execution* of orders placed by pit users and non-pit users in the electronic market. The solid line represents the percentage for pit users and dotted line represents the percentage for non-pit users. The sample is from June 1, 2014 until June 1, 2016. The two vertical lines corresponds to the week of the announcement of the pit closure (Feb 4th 2015) and the actual pit closure date (July 6th 2015).

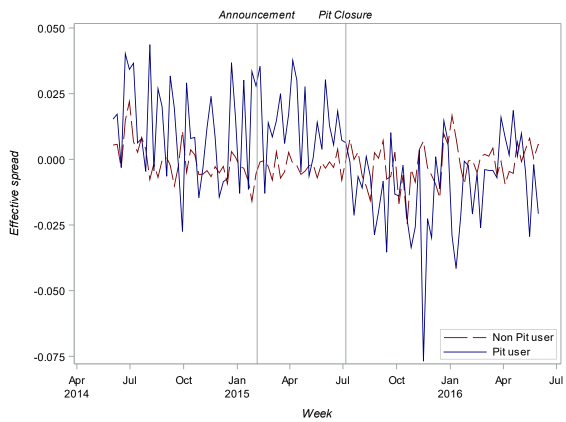
Figure 5: Weekly pre-trends: Average *effective spread* for pit user and non-pit user in contract units

Panel A. ***Effective spread***

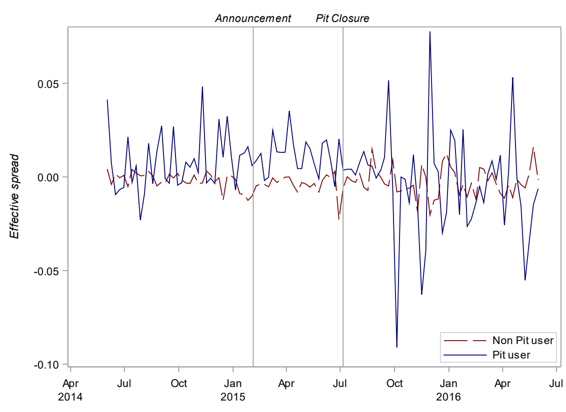
Live cattle (48)



Lean hog (LN)



Feeder cattle (62)



Note: Figure 5 presents the *effective spread*, defined as the average weekly *effective half spread* in contract units for all orders placed by pit users and non-pit users both in the electronic market and the pit. The solid line represents the percentage for pit users and dotted line represents the percentage for non-pit users. The sample is from June 1, 2014 until June 1, 2016. The two vertical lines corresponds to the week of the announcement of the pit closure (Feb 4th 2015) and the actual pit closure date (July 6th 2015).

[1] https://www.farmforum.net/story/news/columnists/2021/06/09/shultz-cmes-electronic-only-trading-has-drawbacks-family-farmers/7601885002/

[2] We note that a bulk of these changes actually occur right after the announcement of the pit closure, which happens five months prior to the actual pit closure.

[3] In the electronic market, *time to execution* increases when traders strategically place limit orders instead of clearing the depth of the book with market orders and when they break larger orders in smaller orders.

[4] We should clarify here that while one could generally think of the limit order book as a high immediacy trading venue with market orders executing instantaneously, this may not always be applicable: for example, large orders routed to the electronic market often require substantial book depth and face front running risk, and as a result they are typically split in successive smaller orders (both market and limit orders). Thus, for such orders the dealer market could actually offer higher immediacy.

[5] The order identifier allows us to bunch executed trades in the orders they originated from. However, our dataset does not provide information on orders that were placed but were never executed.

[6] We only keep limit and market orders when estimating *time to execution* and execution cost (*effective half spread*).

[7] Manual orders are either pit orders or electronic orders that are not submitted to the order book by an algorithmic program but are rather considered a human submission.

[8] Unfortunately, we do not have an aggressor indicator for pit trades.

[9] As noted in Gousgounis, and Onur (2018), there is still some pit trading after the futures pits close. This corresponds trading by options pit traders, who were permitted to execute futures in the pit as a hedge for their options strategies.

[10] It is hard to know exactly how many market makers are needed to make the pit a preferred trading market for hybrid customers. Viswanathan, and Wang (2002) offer a simulation in their model, according to which the hybrid market is always preferred when the *number of market makers* is at least 8. The smaller *number of locals* feeder cattle futures could explain why pit trading volume for feeder cattle futures was substantially lower than in live cattle and lean hog futures, as documented in Gousgounis, and Onur (2018).

[11] Our measure is similar to the implementation shortfall measure proposed by Perold (1988). However, we only consider actual executed orders.

[12] Our dataset provides an aggressor indicator for the electronic orders, which allows us to confirm that *effective half spread* for aggressive orders is indeed positive, while the *effective half spread* for passive orders is negative. The average daily *effective half spread* for aggressive and passive electronic orders is presented in Figure A1.

[13] Negative *effective spreads* indicate that the orders are on average limit orders that are executed against market orders or other marketable limit orders. The cost of such orders is negative as these orders are providing liquidity. Thus, the negative cost could be interpreted as compensation for providing liquidity. A decline in negative *effective spreads* can be interpreted as an increase in compensation for providing liquidity in the market.

[14] The decline in *time to execution* starts after the announcement of the pit closure as evidenced by the summary statistics in Table A3 of supplementary online appendix A.

[15] A tick is the minimum amount that a price of a futures contract can fluctuate. For live cattle, lean hog and feeder cattle futures one tick corresponds to 0.00025 cents per pound. Since each live cattle and lean hog futures contract corresponds to 40,000 pounds, the minimum allowable fluctuation for the corresponding futures contracts is equal to \$10. The minimum allowable fluctuation for one feeder cattle futures contract is \$12.50, since each feeder cattle futures contracts corresponds to 50,000 pounds of feeder cattle.

[16] Before the pit closure, the average *effective half spread* for pit orders (in %) is 0.0164 for live cattle, 0.0185 for lean hog and 0.0324 for feeder cattle futures. Around the time of the pit closure, the lead contract's price for live cattle futures is around 110 cents/lb, the price for lean hog futures is around \$75 cents/lb and the price of feeder cattle futures is around 180 cents/lb. Multiplying these benchmark prices with the estimated *effective half spread* in percentage, we get and effective half spread of 0.018 cents/lb for live cattle, 0.014 cents/lb for lean hog and 0.058 cents/lb for feeder cattle. The first two are comparable with the bid ask spread estimates during the period of 2005-2008 of Frank, and Garcia (2011), which utilize Hasbrouck (2004)'s Bayesian estimator (HAS). These estimates correspond to a timeframe during which the pit was the dominant trading venue.

[17] Engle, Ferstenberg, and Russell (2012) use similar market variables in their execution cost modeling.

[18] The pit closure was announced for all livestock futures markets on February 4th, 2015. All livestock future pits closed on July 6th, 2015.

[19] The closure of the pit does not force non-pit users to change their trading behavior, hence we consider them to be the control group. By definition, non-pit users have not traded in the pit for a whole year prior to the pit closure, if ever at all. We acknowledge that there may theoretically be some indirect effect to non-pit users, i.e. the transfer of pit orders to the electronic market could have some effect on the market dynamics of the electronic order book, which we are not accounting for. However, even though the proportion of pit volume was substantial for pit users (i.e. close to 33% based on Table 1 estimates), the aggregate market pit volume comprised a small percentage to the total market volume, i.e. around 10% of market volume (Gousgounis, and Onur 2018). Moreover, given that only a fraction of this volume likely transferred to the electronic order book, it is unlikely that it caused major changes in the electronic order book, and especially the trading behavior of other customers, such as the non-pit users.

[20] Additional statistics on trading of spreads and outrights (individual futures contracts) are reported in Table A4 of supplementary appendix A.

[21] For live cattle and feeder cattle futures, news announcement dates include the dates that WASDE and Cattle on Feed reports are released. For lean hog futures, news announcement dates include the dates that WASDE and Hogs and Pigs reports are released.

[22] CME reduced the trading hours for livestock futures on October 27th, 2014 (https://www.wsj.com/articles/cme-plans-to-slash-trading-hours-for-livestock-futures-1412346491)

[23]CME changed the settlement procedure on December 15th, 2014. (https://www.cmegroup.com/tools-information/lookups/advisories/market-regulation/SER-7213.html)

[24] Our definition of pit users includes customers who had at least one pit transaction during the period of June 1st, 2014 – July 6th 2015. To reduce any endogeneity concerns, we repeat our regression analysis defining pit users as those customers who had at least on pit transaction during the year prior to the start of our sample (June 1st, 2013 – June 2014). The number of observations is smaller (because of higher account attrition), but results are qualitatively very similar and we therefore do not report them.

[25] The majority of the daily outright trading volume concentrated in the lead contract, which is usually the nearby contract in livestock future markets, while contracts with longer times to maturity are less liquid. In regards to spreads, Gousgounis, and Onur (2018) show that during our sample period about half of the livestock futures volume corresponds to spread trades. However, spreads are expected to be less liquid than outrights, as each spread trade involves at least two futures contracts, which need to be executed simultaneously. We would expect that finding trading matches generally takes longer and potentially costs more. This is also supported by the statistics presented in Table A4 of the supplementary online appendix, which shows that spreads take much longer to execute compared to outrights.

[26] CME reduced the trading hours for livestock futures on October 27th, 2014 (https://www.wsj.com/articles/cme-plans-to-slash-trading-hours-for-livestock-futures-1412346491). They further reduced the trading hours on Feb 29th, 2016 (https://www.reuters.com/article/cme-livestock-hours-idAFL2N15P15P)

[27] The dollar estimates are calculated using the respective prices of the lead contract around the time of the pit closure: \$1.1/lb for live cattle. Each contract corresponds to 40,000lb.

[28] The dollar estimates are calculated using the respective prices of the lead contract around the time of the pit closure: \$0.75/lb for lean hog futures. Each contract corresponds to 40,000lb.

[29] We expect spreads to face a higher liquidity cost as trading spreads involves taking positions in at least two futures contracts simultaneously, which should increase the time it takes to find a trading match and potentially costs more.

[30] 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 cost in the pit and the electronic order book.

[31] 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.

[32] 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.

[33] This reversal in the execution cost we observe is in line with some of the "learning-by-trading" theories found in the literature (Seru, Shumway, and Stoffman 2009; Linnainmaa 2011); the idea that traders learn about their ability by trading in the market and their initial trades could be more costly than their later trades.

[34] Following similar calculations to our analysis on the execution cost of electronic orders, these estimates suggest that after the pit closure, pit users' overall *effective half spread* is reduced by $1.76/contract for the live cattle futures and $1.5/contract for lean hog futures compared to non-pit users.

[35] Independently of the results presented in the tables and graphs, we also tracked the most active pit users in each of the three livestock commodity markets, defined as those pit users trading at least 20 days in the year prior to pit closure. We find that 65% of live cattle pit users remain active after the pit closure, 49% of lean hog pit users remain active after the pit closure and 44% of feeder cattle pit users remain active after the pit closure. While our data does not indicate whether inactive pit users remain active but open new accounts, our statistics are consistent with the weaker findings in the feeder cattle futures market.