

# AJAE APPENDIX FOR “IS LIQUIDITY PROVISION INFORMATIVE? EVIDENCE FROM AGRICULTURAL FUTURES MARKETS”

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# A CME institutional details

## A.1 *Limit order book: Market supply and demand*

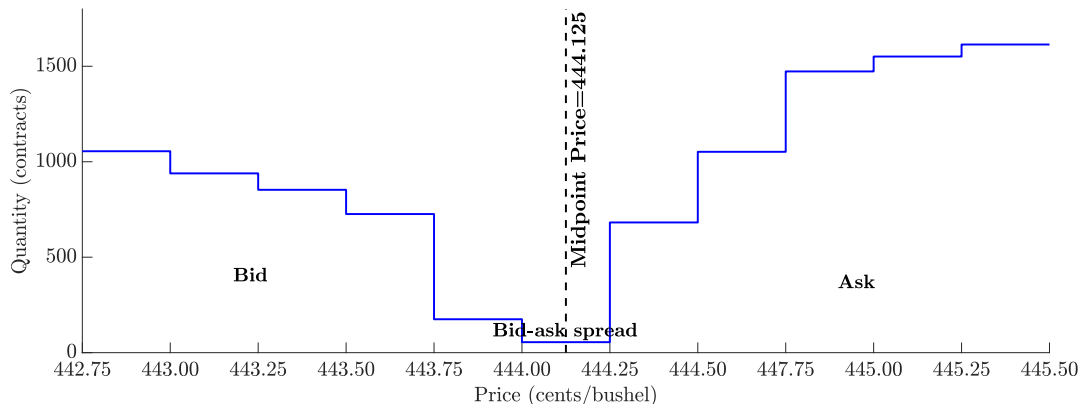


Figure A1: An example of limit order book: Market supply and demand.

This figure displays a hypothetical limit order book (LOB) comprising the agricultural futures market supply (ask side) and demand (bid side). The horizontal axis measures the price in cents/bushel. The vertical axis measures the cumulative quantity in number of contracts. Each level in the step-wise demand and supply functions represents the quantities demanded and supplied at each specific price, respectively. The bid-ask spread is 0.25 cents/bushel, which is the difference between the best ask and best bid prices. The midpoint price is defined as the arithmetic mean between the best bid and best ask prices, and indicated by the vertical dashed line. The tick size is defined as the minimum price increment allowed in the market, which is 0.25 cents in our example. The bid-ask spread represents the minimum transaction cost that traders need to pay to purchase a single contract.

## A.2 An example of limit order book change

Example: New limit order to sell 30 contracts at 444.50 cents/bushel						Example: New market order to sell 20 contracts					
Before			After			Before			After		
Ask			Ask			Ask			Ask		
# Orders	Quantity	Price	# Orders	Quantity	Price	# Orders	Quantity	Price	# Orders	Quantity	Price
16	57	446.50	16	57	446.50	16	57	446.50	16	57	446.50
14	54	446.25	14	54	446.25	14	54	446.25	14	54	446.25
47	348	446.00	47	348	446.00	47	348	446.00	47	348	446.00
22	78	445.75	22	78	445.75	22	78	445.75	22	78	445.75
15	63	445.50	15	63	445.50	15	63	445.50	15	63	445.50
18	78	445.25	18	78	445.25	18	78	445.25	18	78	445.25
72	421	445.00	72	421	445.00	72	421	445.00	72	421	445.00
26	370	444.75	26	370	444.75	26	370	444.75	26	370	444.75
23	627	444.50	23+1	627+30	444.50	23	627	444.50	23	627	444.50
7	55	444.25	7	55	444.25	7	55	444.25	7	55	444.25
22	175	444.00	22	175	444.00	22	175	444.00	22	175	444.00
22	551	443.75	22	551	443.75	22	551	443.75	22	551	443.75
25	127	443.50	25	127	443.50	25	127	443.50	25	127	443.50
15	86	443.25	15	86	443.25	15	86	443.25	15	86	443.25
27	116	443.00	27	116	443.00	27	116	443.00	27	116	443.00
15	84	442.75	15	84	442.75	15	84	442.75	15	84	442.75
17	99	442.50	17	99	442.50	17	99	442.50	17	99	442.50
23	108	442.25	23	108	442.25	23	108	442.25	23	108	442.25
21	79	442.00	21	79	442.00	21	79	442.00	21	79	442.00
20	130	441.75	20	130	441.75	20	130	441.75	20	130	441.75
# Orders	Quantity	Price	# Orders	Quantity	Price	# Orders	Quantity	Price	# Orders	Quantity	Price
Bid			Bid			Bid			Bid		

Figure A2: Two examples of limit order book changes.

This figure displays how a hypothetical limit order book (LOB) changes after a new limit sell order (left panel) and a new market sell order (right panel) enter the market. Boxes show the top of the LOB, which includes the best bid and offer (BBO). The left panel displays a LOB change after a new limit order to sell 30 contracts at 444.50 cents/bushel, which provides liquidity to the market. Thus, the available ask quantity at 444.50 cents/bushel increases by 30 to 657 and the number of orders increases by 1 to 24. The right panel displays a LOB change after a new market order to sell 20 contracts, which consumes liquidity in the opposite (bid) side of the LOB. (Pure) market orders do not generally specify trade prices. Since the market order size (20) is smaller than the available quantity at the best bid (444.00 cents/bushel), the available quantity at the best bid is reduced by 20 to 155. We assume that the quantity of the limit order with the highest priority for execution at the best bid (444.00 cents/bushel) is greater than the size of the new market order (20). Thus, the number of orders does not change in this case.

### A.3 CME Globex sessions and trading hours

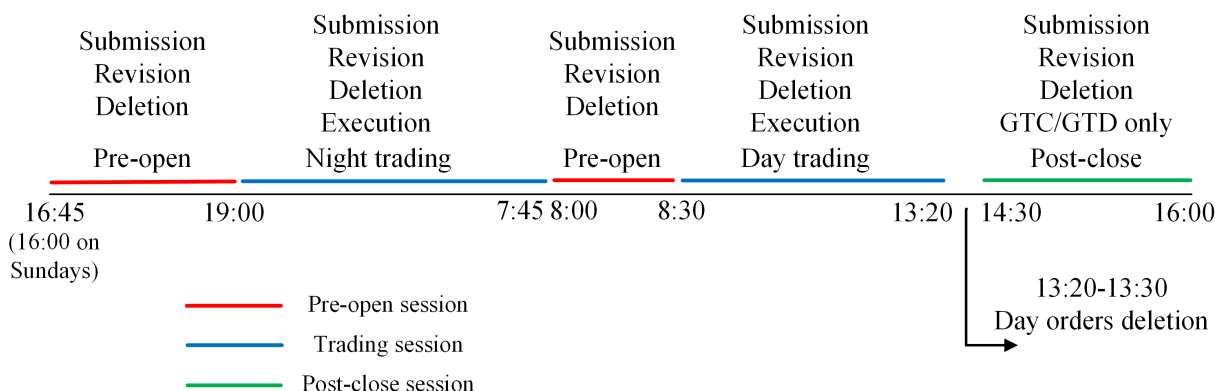


Figure A3: CME Globex sessions and trading hours.

This figure displays the CME Globex sessions and hours over a trading day in U.S. Central Time (CT). The pre-open session starts at 16:00 on Sundays. Batch auctions are held during pre-open and post-close sessions. Only Good-till-cancel (GTC) or Good-till-day (GTD) orders are allowed to participate in post-close sessions. The day trading session is from 8:30 to 13:20 CT and the night session from 19:00 to 7:45 CT. Generally, in our sample markets, CME replaces the continuous trading sessions by batch auctions on national holidays and may also shorten the continuous trading hours on some specific national holidays. Details on CME holiday calendar can be found at <https://www.cmegroup.com/tools-information/holiday-calendar.html>. CME assumes all limit orders automatically expire after the day trading session closes, unless they are flagged as GTC and GTD. Details on order types can be found at <https://www.cmegroup.com/confluence/display/EPICSANDBOX/Order+Types+for+Futures+and+Options>.

## A.4 Examples of trade and execution messages

Table A1: Examples of trade summary and execution messages in the corn futures market from the Market by Order (MBO) data.

This table shows an example of a trade summary and execution messages in MBO data on July 11, 2020. Each row represents a message. In this example, the trade is sell-initiated at 441.50 cents/bushel, and involves 14 orders, including 1 market order and 13 matched limit orders. The total matched quantity is 51 contracts. The trade ID and order ID are not shown for nondisclosure purposes. The first row shows the trade summary message and the rest of rows show the corresponding individual execution messages. The MBO data do not provide the ordering of matched limit orders. All messages are timestamped in nanoseconds and price is expressed in cents/bushel. “Code” shows the base symbol ZC denoting corn, Z denoting the December futures contract and 9 denoting a 2019 contract. “Quantity” indicates the total number of contracts executed (first row) and the number of contracts matched for each limit order (second to last row). “Order” shows the total number of orders involved in a trade (first row) and the number of orders in each of the individual matches is 1 (second to last row). “Msg. Seq. #” stands for message sequence number.

Date	Time	Code	Price	Quantity	Order	Aggressor	Trade ID	Order ID	Msg. Seq. #
2019-07-11	11:35:16.131133057	ZCZ9	441.50	51	14	Sell-initiated	215...67		15680189
2019-07-11	11:35:16.131133057	ZCZ9	441.50	11	1			70.....6	15680189
2019-07-11	11:35:16.131133057	ZCZ9	441.50	4	1			70.....7	15680189
2019-07-11	11:35:16.131133057	ZCZ9	441.50	2	1			70.....8	15680189
2019-07-11	11:35:16.131133057	ZCZ9	441.50	5	1			70.....4	15680189
2019-07-11	11:35:16.131133057	ZCZ9	441.50	2	1			70.....5	15680189
2019-07-11	11:35:16.131133057	ZCZ9	441.50	1	1			70.....1	15680189
2019-07-11	11:35:16.131133057	ZCZ9	441.50	14	1			70.....5	15680189
2019-07-11	11:35:16.131133057	ZCZ9	441.50	5	1			70.....6	15680189
2019-07-11	11:35:16.131133057	ZCZ9	441.50	2	1			70.....7	15680189
2019-07-11	11:35:16.131133057	ZCZ9	441.50	2	1			70.....1	15680189
2019-07-11	11:35:16.131133057	ZCZ9	441.50	1	1			70.....3	15680189
2019-07-11	11:35:16.131133057	ZCZ9	441.50	1	1			70.....9	15680189
2019-07-11	11:35:16.131133057	ZCZ9	441.50	1	1			70.....0	15680189

## A.5 *A comparison between MBO and MBP datasets*

The Chicago Mercantile Exchange (CME) broadcasts Globex market data via Market Depth 3.0 platform. CME Market by Price (MBP) dataset records all incremental updates of different price levels (depths) within the limit order book (e.g., [Table A3](#)) as well as trade summary messages (e.g., first row in [Table A1](#)). All messages are timestamped in nanoseconds. The MBP dataset aggregates information at different price levels within the limit order book. However, it does not show which limit orders sit in a specific price level (i.e., which limit orders provide liquidity to a specific price level) within the LOB and does not record complete details of individual limit orders either. Hence, it is impossible to precisely identify limit order activities (e.g., submissions, executions, revisions, and deletions) as the MBP data are recorded based on price levels rather individual limit orders.

Similar to the MBP data, the Market by Order (MBO) data are also timestamped in nanoseconds. However, the MBO data record complete details (history) of each outright limit order, including when a limit order is submitted, executed, revised, and/or deleted. In terms of trades, the MBO dataset does not only provide the trade summary messages like the MBP dataset does, but also records details of all matched limit orders (second to last row in [Table A1](#)).

[Figure A4](#) illustrates the differences between the MBP and the MBO data generally. We plot a hypothetical limit order book where bars indicate available quantity at different price levels and partitions in each bar indicate individual limit orders. The upper panel displays the MBP data, where summary information is shown, but no limit order details are disclosed. The lower panel displays the MBO data, where both the summary information and limit order details are shown.

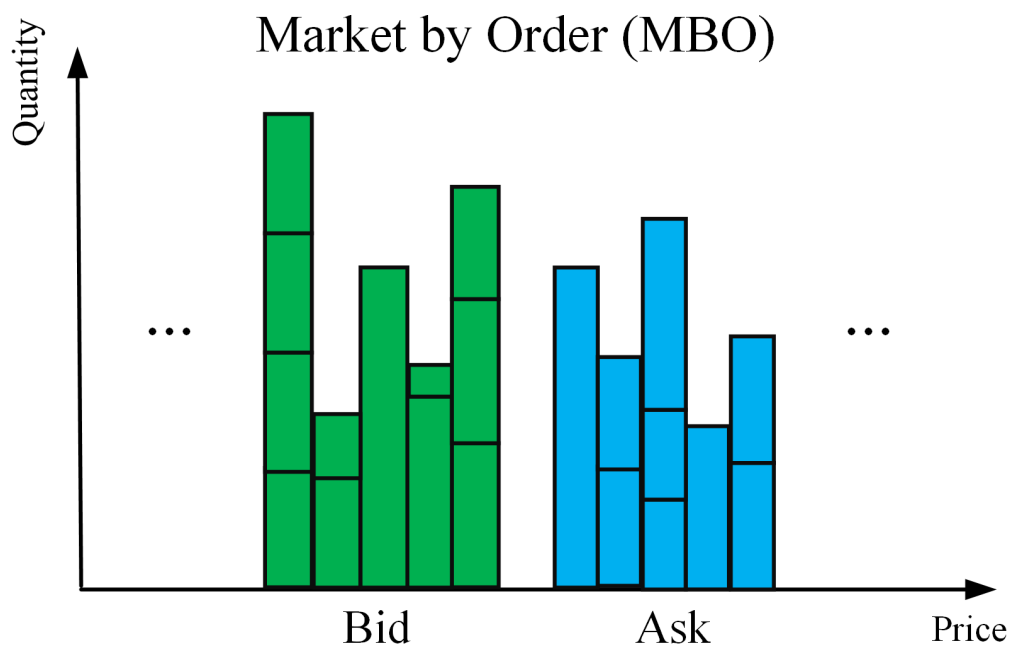
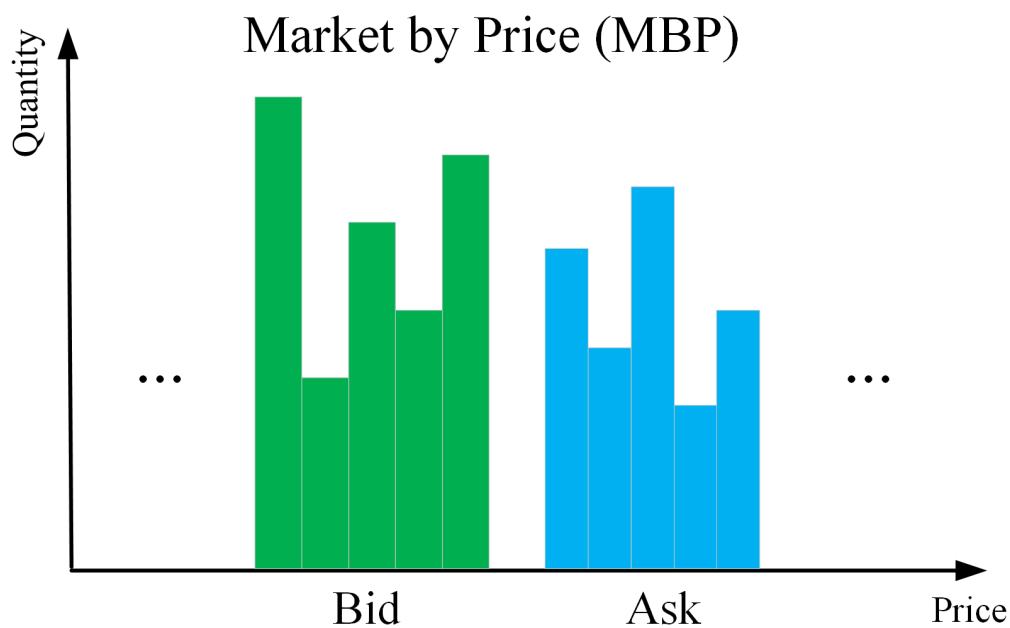


Figure A4: The relationship between MBO and MBP data.

This figure compares between MBP and MBO datasets. We plot a hypothetical limit order book where bars indicate available quantity at different price levels and partitions in each bar correspond to individual limit orders. The upper panel displays the MBP data, where only summary information by price is shown. The lower panel displays the MBO data, where both summary information and limit order details are shown.

Table A2: An example of Market by Order (MBO) data.

This table shows complete details of a limit order in MBO data on July 11, 2020. Each row represents a message. The order ID is not shown for nondisclosure purposes. The order is submitted at the ask side of the limit order book (LOB) for two contracts. Subsequently the order quantity is revised 9 times before it is executed. The last two rows show the messages generated as a result of the execution: an execution message and a deletion message, the latter informing that the order is not sitting in the LOB anymore. We avoid double counting by only considering the execution message. This table shows limited information from the raw data. All messages are timestamped in nanoseconds and price is expressed in cents/bushel. “Code” shows the base symbol ZC denoting corn, Z denoting the December futures contract and 9 denoting a 2019 contract. “Type” indicates order types, including submissions, executions, deletions, and revisions. “Quantity” indicates the number of contracts and “Msg. Seq. #” stands for message sequence number. The MBO data only records order details of outright limit orders.

Date	Time	Code	Type	Side	Price	Quantity	Order ID	Msg. Seq. #
2019-07-11	11:26:47.317228809	ZCZ9	Submission	Ask	441.25	2	70.....50	15493446
2019-07-11	11:26:48.804210097	ZCZ9	Revision	Ask	441.25	1	70.....50	15494002
2019-07-11	11:26:48.919103763	ZCZ9	Revision	Ask	441.25	2	70.....50	15494227
2019-07-11	11:26:49.133200265	ZCZ9	Revision	Ask	441.25	1	70.....50	15494525
2019-07-11	11:26:49.356636129	ZCZ9	Revision	Ask	441.25	2	70.....50	15494867
2019-07-11	11:26:49.556494399	ZCZ9	Revision	Ask	441.25	1	70.....50	15494983
2019-07-11	11:26:49.866882071	ZCZ9	Revision	Ask	441.25	2	70.....50	15495098
2019-07-11	11:26:50.658709257	ZCZ9	Revision	Ask	441.25	1	70.....50	15495150
2019-07-11	11:26:58.961050243	ZCZ9	Revision	Ask	441.25	2	70.....50	15497204
2019-07-11	11:26:59.458905437	ZCZ9	Revision	Ask	441.25	1	70.....50	15497308
2019-07-11	11:27:13.429525689	ZCZ9	Execution		411.25	1	70.....50	15502861
2019-07-11	11:27:13.429525689	ZCZ9	Delete	Ask	411.25	1	70.....50	15502862



Table A3: An example of Market by Price (MBP) data.

This table shows several example messages in MBP data on July 11, 2020. Each row is called a message. In the first row, the available quantity at the 4th depth (441.25 cents/bushel) of the ask side is revised to 46 (15) contracts (orders) and only outright liquidity participates. Subsequently, the available quantity at the 5th depth (441.50 cents/bushel) of the ask side is revised to 25 (10) contracts (orders) and only outright liquidity participates. The rest of messages can be interpreted analogously. This table only shows limited information from the raw data. All messages are timestamped in nanoseconds and price is expressed in cents/bushel. “Code” shows the base symbol ZC denoting corn, Z denoting the December futures contract and 9 denoting a 2019 contract. “Type” indicates activities at each price level, including submissions, deletions, and revisions. “Quantity” shows the number of contracts and “order” indicates how many orders sit at a price level (depth) within the limit order book (LOB). “Depth” means at which price level a message happens within the LOB. “Msg. Seq. #” stands for message sequence number. “Outright/Implied” shows whether the liquidity is provided through outright liquidity or implied liquidity. CME does not define the number of orders involved in implied liquidity, thus the “order” column for implied orders is left blank.

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Date	Time	Code	Type	Side	Price	Quantity	Order	Depth	Msg. Seq #	Outright/Implied
2019-07-11	11:26:47.317228809	ZCZ9	Revision	Ask	441.25	46	15	4	15493446	Outright
2019-07-11	11:26:47.317289017	ZCZ9	Revision	Ask	441.50	25	10	5	15493447	Outright
2019-07-11	11:26:47.520016753	ZCZ9	Revision	Ask	440.50	25	6	1	15493457	Outright
2019-07-11	11:26:47.520883553	ZCZ9	Submission	Bid	440.25	9	1	1	15493458	Outright
2019-07-11	11:26:47.521097861	ZCZ9	Revision	Bid	440.25	15	2	1	15493465	Outright
2019-07-11	11:26:47.521098583	ZCZ9	Revision	Ask	440.75	100		2	15493466	Implied
2019-07-11	16:26:47.521100417	ZCZ9	Revision	Bid	438.50	126	10	8	15493467	Outright
2019-07-11	16:26:47.521152883	ZCZ9	Revision	Bid	440.00	107	14	2	15493469	Outright
2019-07-11	16:26:47.521165549	ZCZ9	Revision	Bid	439.75	96		2	15493470	Implied
2019-07-11	16:26:47.521301269	ZCZ9	Revision	Ask	440.50	20	5	1	15493471	Outright
2019-07-11	16:26:47.521322667	ZCZ9	Revision	Bid	439.75	55	13	3	15493472	Outright
2019-07-11	16:26:47.521440849	ZCZ9	Revision	Bid	440.00	62		1	15493473	Implied

## B Price, realized volatility, and trading volume

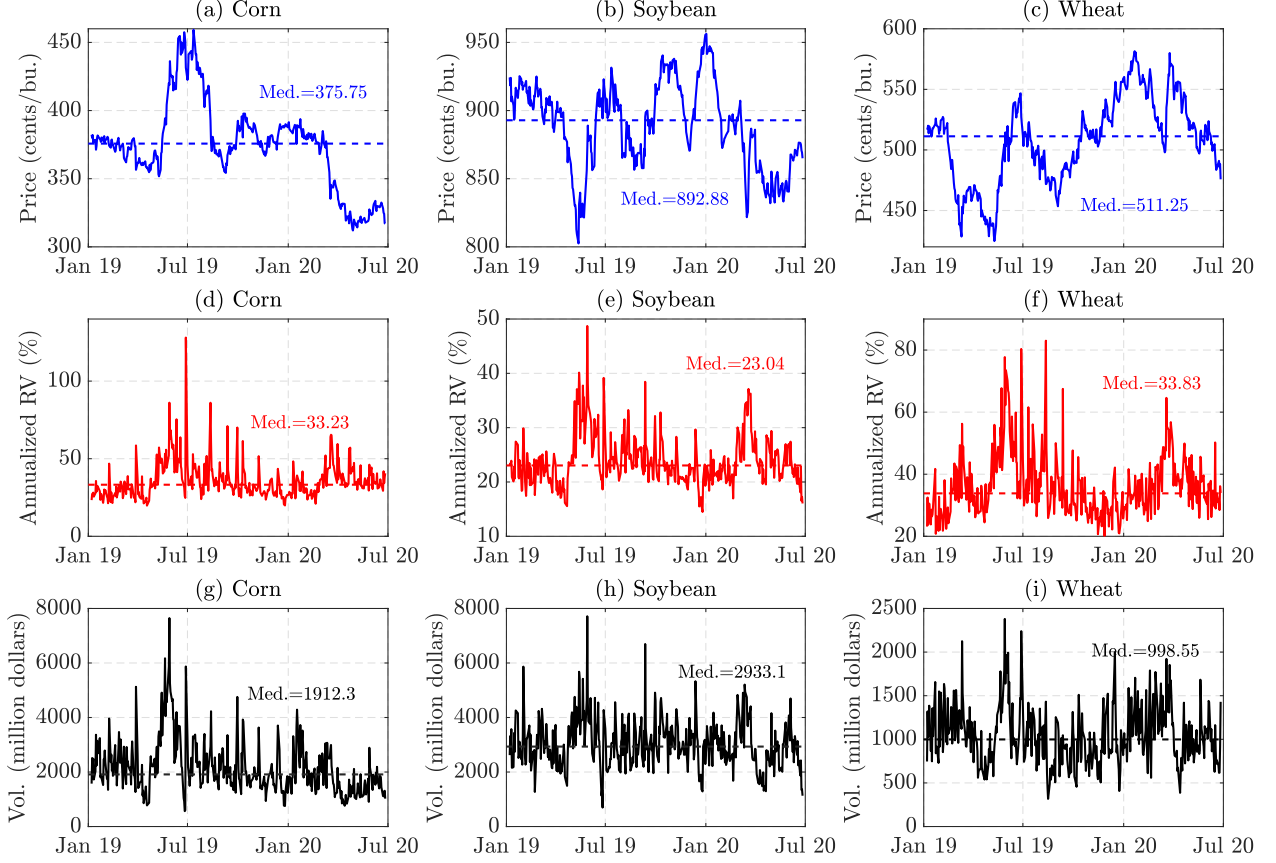


Figure B1: Price, realized volatility, and trading volume in CME corn, soybean, and wheat markets.

This figure displays the daily settlement prices, annualized realized volatility (RV), and dollar trading volume in CME corn, soybean, and wheat futures markets. The three different markets are organized by columns. Dashed lines represent the medians over the sample period. All settlement prices are quoted in cents/bushel. Realized volatility (RV) is calculated as  $\sqrt{\sum_{t=1}^T (\log p_t - \log p_{t-1})^2}$ , where  $p_t$  are intraday trade prices, and scaled to an annual figure by multiplying by  $\sqrt{252}$ .  $t = 1, \dots, T$  represents the number of trades within a trading day. Dollar trading volume is defined as the total trading volume in a trading day expressed in million dollars. Our sample spans from January 7, 2019 to June 26, 2020, comprising 372 trading days. Price data are from Bloomberg. Realized volatility and trading volume are based on intraday trade data from the CME.

## C Messages during continuous trading sessions

Table C1: Message distribution during continuous trading sessions.

This table displays summary statistics for the proportion (in percentage) of different types of messages relative to the total population of messages for continuous (day and night) trading sessions. Panels A, B and C present details for corn, soybean and wheat, respectively. Submission indicates outright limit orders submitted to markets. Execution represents all matched outright limit orders. An order revision implies a quantity and/or price change of an existing limit order. Deletion represents the deletion of the whole limit order initiated by traders. Our sample spans from January 7, 2019 to June 26, 2020.

Type	Mean	Std. Dev	Min.	P25	Median	P75	Max
<i>Panel A: Corn futures market.</i>							
Submission	26.47%	2.28%	20.13%	24.99%	26.41%	27.88%	33.57%
Execution	33.56%	4.39%	15.69%	30.82%	33.55%	36.52%	44.37%
Revision	12.83%	4.32%	5.44%	9.93%	11.70%	14.93%	34.92%
Deletion	27.14%	2.20%	19.66%	25.89%	27.15%	28.40%	33.85%
<i>Panel B: Soybean futures market.</i>							
Submission	28.60%	2.01%	21.39%	27.27%	28.70%	30.15%	33.25%
Execution	22.07%	2.99%	11.99%	20.31%	22.00%	23.99%	30.11%
Revision	22.50%	4.78%	10.14%	18.93%	22.27%	25.42%	39.84%
Deletion	26.83%	2.29%	18.66%	25.16%	26.91%	28.55%	32.17%
<i>Panel C: Wheat futures market.</i>							
Submission	30.13%	2.02%	24.65%	28.71%	29.97%	31.29%	36.28%
Execution	28.42%	3.46%	17.49%	26.22%	28.61%	30.77%	38.86%
Revision	13.05%	3.65%	5.79%	10.79%	12.77%	14.78%	32.65%
Deletion	28.39%	2.26%	21.50%	26.80%	28.24%	29.74%	35.59%

# D Limit order submissions, executions, deletions, and revisions

## D.1 Session distributions

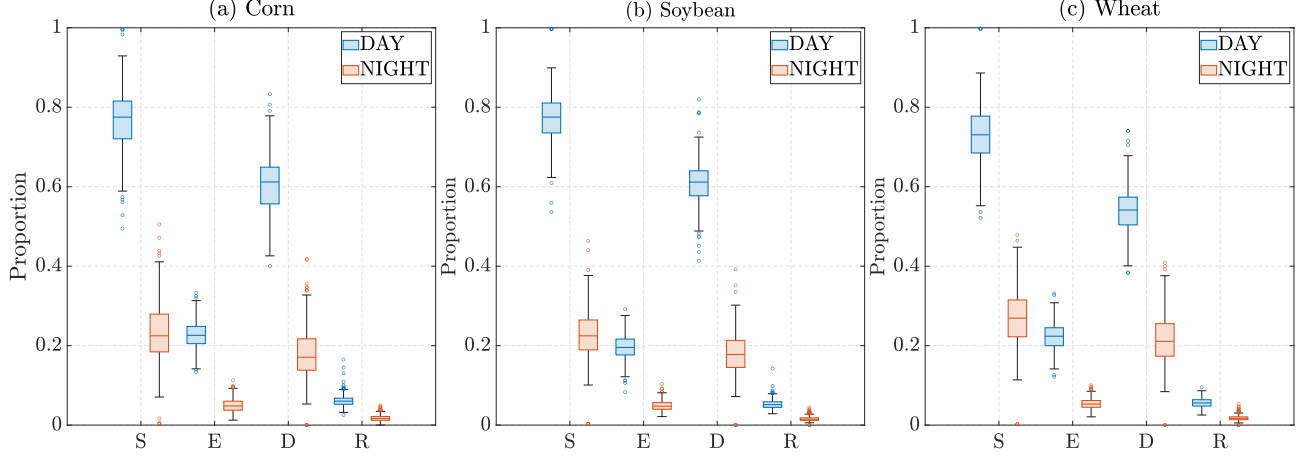


Figure D1: Distribution of limit order submissions (S), executions (E), deletions (D), and revisions (R) across day and night trading sessions.

This figure displays the boxplots showing the distribution of limit order submissions, executions, deletions, and revisions across day and night trading sessions for the sample period in CME corn, soybean, and wheat futures markets, respectively. The three different markets are organized by columns. Proportions of limit order submissions, executions, deletions, and revisions are defined as the number of limit orders submitted, executed, deleted, and revised within each session over the total number of limit orders submitted across the two sessions, respectively. Our sample spans from January 7, 2019 to June 26, 2020, comprising 372 day trading sessions and 368 night trading sessions.

## D.2 Time distributions

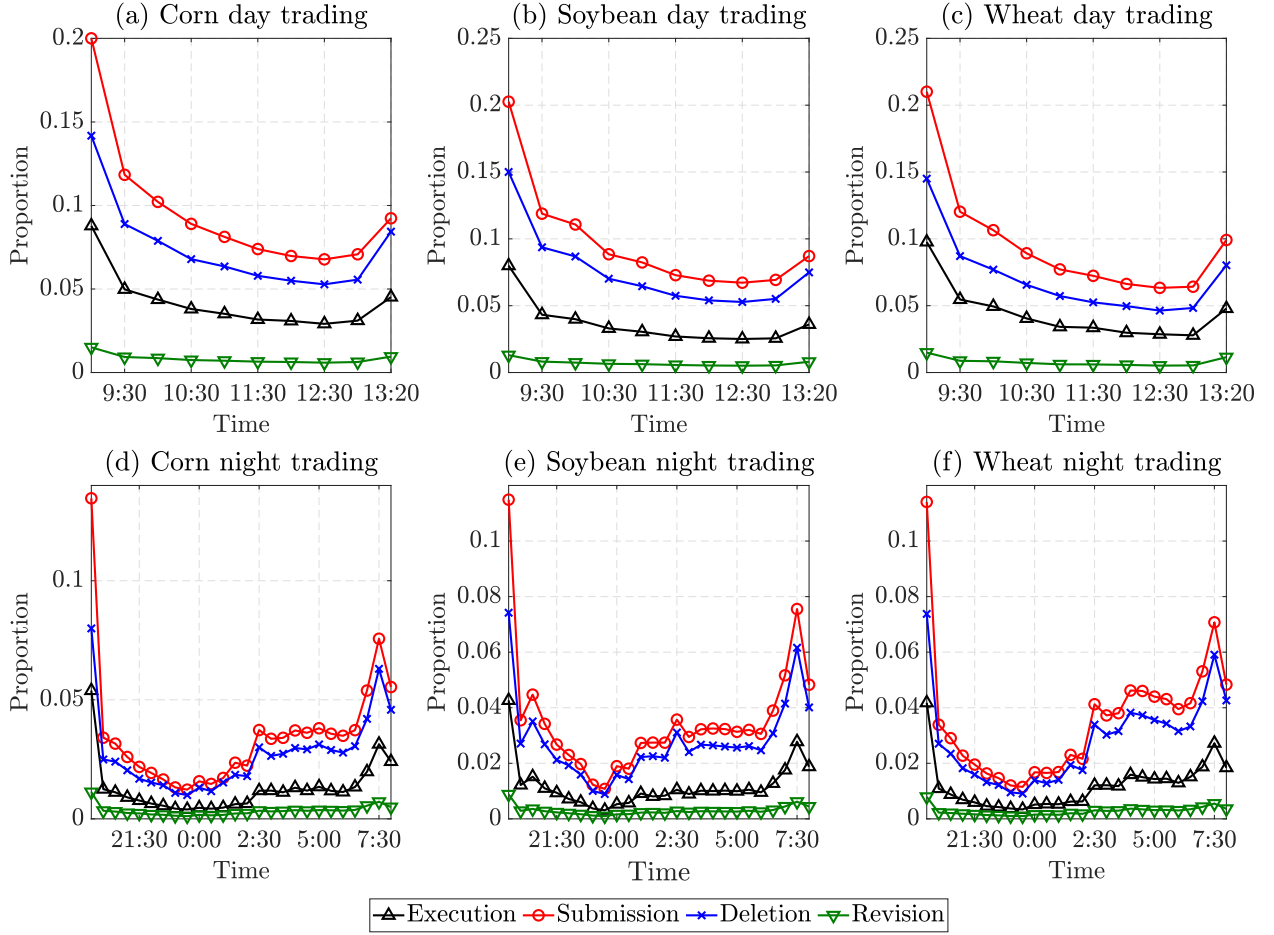


Figure D2: Distribution of limit order submissions, executions, deletions, and revisions within the day and night trading sessions.

This figure displays the distribution of limit order submissions, executions, deletions, and revisions by 30-minute intervals through the whole continuous (day and night) trading sessions in CME corn, soybean, and wheat futures markets. The upper panel represents day trading sessions and the lower panel night trading sessions. The three different markets are organized in columns. The proportion of limit order submissions, executions, deletions, and revisions are measured as the number of limit orders submitted, executed, deleted, and revised in each 30-min intervals over the total number of limit orders submitted for the whole trading session, respectively. Median values for each 30-min interval across all trading days in the sample are shown in the figure. All time is U.S. Central Time. Our sample spans from January 7, 2019 to June 26, 2020, comprising 372 day trading sessions and 368 night trading sessions.

## E Limit order duration

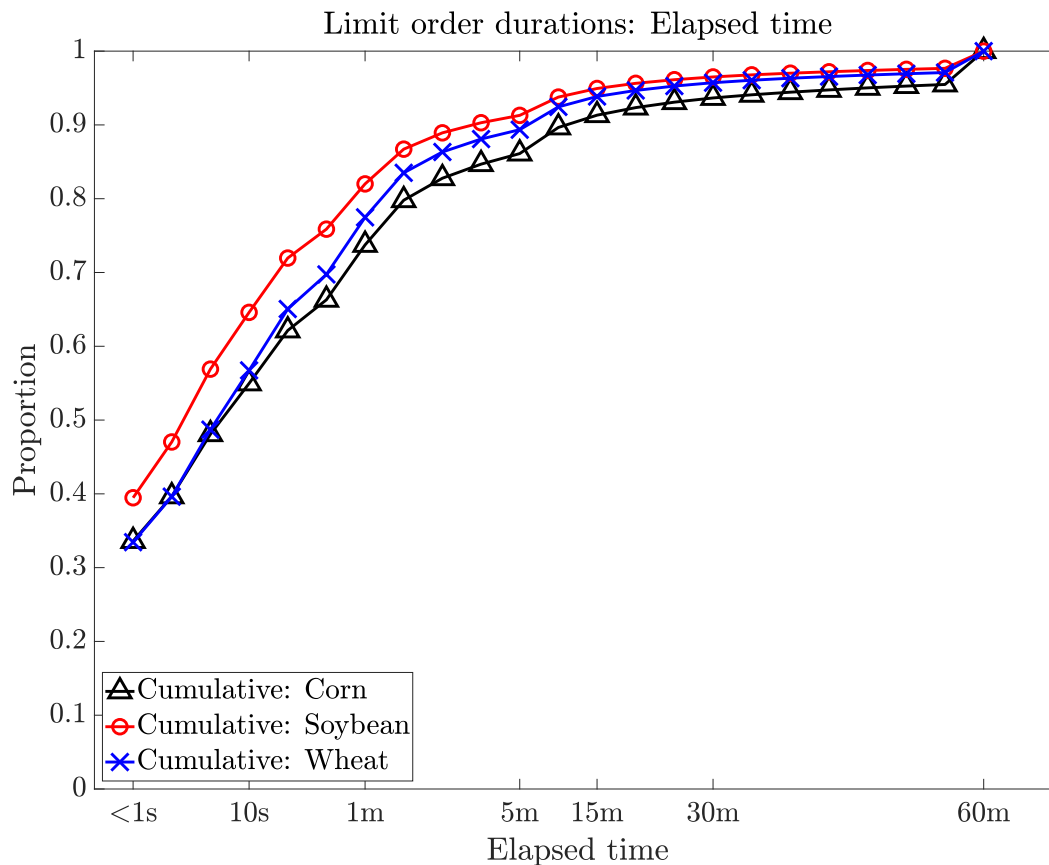


Figure E1: Cumulative distributions of limit order duration.

This figure displays the cumulative distributions of limit order duration during continuous trading sessions in CME corn, soybean, and wheat futures markets. The duration is truncated to 60 minutes to enhance visibility. The limit order duration is defined as the elapsed time between order placement and order conclusion. CME continuous trading sessions include both day trading and night trading sessions. Our sample spans from January 7, 2019 to June 26, 2020.

## F Non-matrix representation of the structural VAR model

The equation of midpoint returns can be expressed as follows

$$\begin{aligned}
 r_t = & \sum_{i=1}^p \alpha_i^1 r_{t-i} + \sum_{i=1}^p \beta_i^{1,1} Trades_{t-i}^{same} + \sum_{i=0}^p \beta_i^{1,2} Trades_{t-i}^{change} + \sum_{i=0}^p \beta_i^{1,3} Submit_{t-i}^{improve} + \\
 & \sum_{i=1}^p \beta_i^{1,4} Submit_{t-i}^{BBO} + \sum_{i=1}^p \beta_i^{1,5} Submit_{t-i}^{Non-BBO} + \sum_{i=0}^p \beta_i^{1,6} Cancel_{t-i}^{worsen} + \sum_{i=1}^p \beta_i^{1,7} Cancel_{t-i}^{BBO} + \\
 & \sum_{i=1}^p \beta_i^{1,8} Cancel_{t-i}^{Non-BBO} + \mu_t^1.
 \end{aligned}$$

The rest of equations can be expressed as follows

$$\begin{aligned}
 Trades^{same} &= \sum_{i=1}^p \alpha_i^2 r_{t-i} + \sum_{i=1}^p \beta_i^{2,1} Trades_{t-i}^{same} + \dots + \sum_{i=1}^p \beta_i^{2,8} Cancel_{t-i}^{Non-BBO} + \mu_t^2, \\
 Trades^{change} &= \sum_{i=1}^p \alpha_i^3 r_{t-i} + \sum_{i=1}^p \beta_i^{3,1} Trades_{t-i}^{same} + \dots + \sum_{i=1}^p \beta_i^{3,8} Cancel_{t-i}^{Non-BBO} + \mu_t^3, \\
 Submit^{improve} &= \sum_{i=1}^p \alpha_i^4 r_{t-i} + \sum_{i=1}^p \beta_i^{4,1} Trades_{t-i}^{same} + \dots + \sum_{i=1}^p \beta_i^{4,8} Cancel_{t-i}^{Non-BBO} + \mu_t^4, \\
 Submit^{BBO} &= \sum_{i=1}^p \alpha_i^5 r_{t-i} + \sum_{i=1}^p \beta_i^{5,1} Trades_{t-i}^{same} + \dots + \sum_{i=1}^p \beta_i^{5,8} Cancel_{t-i}^{Non-BBO} + \mu_t^5, \\
 Submit^{Non-BBO} &= \sum_{i=1}^p \alpha_i^6 r_{t-i} + \sum_{i=1}^p \beta_i^{6,1} Trades_{t-i}^{same} + \dots + \sum_{i=1}^p \beta_i^{6,8} Cancel_{t-i}^{Non-BBO} + \mu_t^6, \\
 Cancel^{worsen} &= \sum_{i=1}^p \alpha_i^7 r_{t-i} + \sum_{i=1}^p \beta_i^{7,1} Trades_{t-i}^{same} + \dots + \sum_{i=1}^p \beta_i^{7,8} Cancel_{t-i}^{Non-BBO} + \mu_t^7, \\
 Cancel^{BBO} &= \sum_{i=1}^p \alpha_i^8 r_{t-i} + \sum_{i=1}^p \beta_i^{8,1} Trades_{t-i}^{same} + \dots + \sum_{i=1}^p \beta_i^{8,8} Cancel_{t-i}^{Non-BBO} + \mu_t^8, \\
 Cancel^{Non-BBO} &= \sum_{i=1}^p \alpha_i^9 r_{t-i} + \sum_{i=1}^p \beta_i^{9,1} Trades_{t-i}^{same} + \dots + \sum_{i=1}^p \beta_i^{9,8} Cancel_{t-i}^{Non-BBO} + \mu_t^9.
 \end{aligned}$$

For all,  $\alpha$  is the coefficient on the midpoint returns, lagged one to  $p$  events.  $\beta$  is the coefficient on the trade and limit order variables.

## G Messages around the USDA WASDE announcements

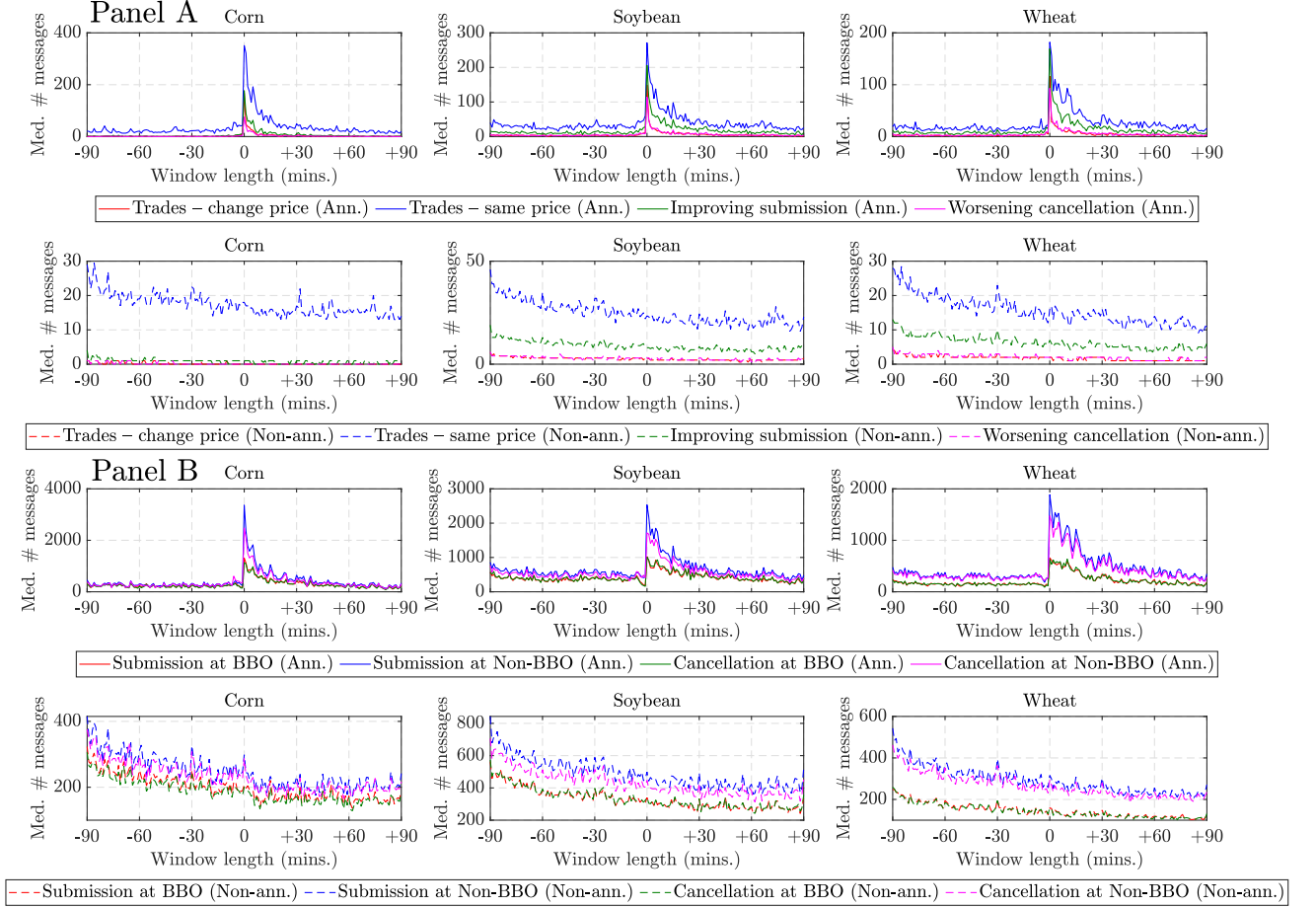


Figure G1: Number of messages around the USDA WASDE announcements.

This figure displays the number of messages from 90 minutes before (negative numbers in the horizontal axis) to 90 minutes after (positive numbers in the horizontal axis) for both the USDA announcement and non-announcement days. USDA WASDE report is released monthly at 11:00 U.S. Central Time and denoted by 0 in the horizontal axis. The solid (dashed) line in Panel A shows the median number of trades and aggressive limit order messages per 1-minute bin across announcement (non-announcement) days. The solid (dashed) line in Panel B shows the median number of non-aggressive limit order messages per 1-minute bin across announcement (non-announcement) days.



## H Transitory pricing errors (noise)

We complement our price discovery analysis by quantifying the relationship between market and limit orders and transitory pricing errors. We first estimate transitory pricing errors (noise), denoted as  $s_t$ , as follows. We use the vector moving-average (VMA) representation in equation 3 in the main text to generate  $\tilde{\Phi}_1(1)$ , which is assumed to be constant within each day. We then focus on the equation 4 in the main text. For each observation  $t$  within a day, we generate 1,000 random shocks  $\epsilon \sim i.i.d.(\mathbf{0}, \mathbf{I})$  and derive a sample of 1,000 noise observations ( $\eta_t$ ) by keeping  $\mathbf{y}_t$  constant. We use the sample average of  $\eta_t$  as the transitory pricing errors  $s_t$  associated to the observed midpoint returns ( $r_t$ ). We then estimate the following regression in each market:

$$s_t = \alpha_0 + \alpha_1 s_{t-1} + \alpha_2 |Trades_t^{same}| + \alpha_3 |Trades_t^{change}| + \alpha_4 |Submit_t^{improve}| + \alpha_5 |Submit_t^{BBO}| + \alpha_6 |Submit_t^{Non-BBO}| + \alpha_7 |Cancel_t^{worsen}| + \alpha_8 |Cancel_t^{BBO}| + \alpha_9 |Cancel_t^{Non-BBO}| + e_t,$$

where  $|\cdot|$  denotes the absolute values of trades and limit orders, which assumes symmetric effects of buy and sell-initiated trades and changes in the bid and ask sides of the LOB. Using OLS, we estimate the regression for every trading day for each market and we report the median estimated coefficients and the proportion of statistically significant coefficients at the 5% level over the entire sample period.

[Table H1](#) reports the regression results for transitory pricing errors during the day trading session. Consistent with existing literature (e.g., [Hansen and Lunde 2006](#)) highlighting the persistence of noise, our results reveal that the autoregressive component of transitory pricing errors is statistically significant in at least 90% of the sample days. Non-aggressive limit orders are weakly correlated with transitory pricing errors as their coefficients are close to zero, have mixed signs and are only statistically significant in a marginal portion of the sample period (around 5% of the days across markets). This aligns with the notion that non-aggressive limit orders have a marginal impact on price discovery. Similarly, trades

priced at the BBO are only significant in around 5%-7% of the sample days. In contrast, aggressive trades and limit orders are statistically significant in a larger proportion of sample days (12%-19% for submissions; 15%-22% for trades; and 26%-28% for cancellations moving the BBO). An aggressive 1-million-dollar trade induces a 0.017 and 0.052 bps increase in transitory pricing errors in soybean and wheat markets, respectively, with a negligible impact in the most liquid corn market. This aligns with the corn market high liquidity and resiliency (He, Serra, and Garcia 2021), which reduces liquidity constraints that may prevent the market price from reaching a new equilibrium. Hence, the efficient price is discovered much faster and transitory pricing errors are much less. The correlation between a 1-million-dollar aggressive limit order submission and transitory pricing errors in corn, soybean, and wheat markets is  $-0.003$  bps,  $-0.016$  bps, and  $-0.084$  bps, respectively. This suggests that aggressive order submissions contribute to tightening the bid-ask spread, with wider spreads being associated to larger pricing errors (e.g., Putniņš 2013). A 1-million-dollar aggressive cancellation, resulting in a widening of the bid-ask spread, leads to increased pricing errors of 0.053 bps in the soybean and 0.149 bps in the wheat markets. However, aggressive cancellations are negatively correlated with transitory pricing errors in the most liquid corn market ( $-0.073$  bps), supporting the argument on liquidity and resiliency in this market.

In Table H2, we report the regression results for transitory pricing errors during the night trading session. The magnitude of the effects in the night trading session where liquidity is reduced, is generally larger than the day trading session, especially for aggressive trades and limit orders. In contrast to the day trading session, aggressive liquidity submissions are positively correlated with transitory pricing errors in corn and soybean markets, while the effect is still negative in the wheat market. Liquidity cancellations that move the BBO reduce pricing errors in soybean and wheat markets, while the opposite is true in corn market. The results show that the effect of aggressive limit orders may be conditional on the overall liquidity condition.

Table H1: Transitory pricing errors (noise) during the day trading session: Trades and limit orders.

This table reports the regression results of transitory pricing errors (noise) on all trades and limit order variables during the day trading session in our sample in the CME corn, soybean, and wheat futures markets. The three different markets are organized by columns. The transitory pricing errors are extracted from the VMA representation of our structural VAR model. Our regression specifications are as follows

$$s_t = \alpha_0 + \alpha_1 s_{t-1} + \alpha_2 | \text{Trades}_t^{\text{same}} | + \alpha_3 | \text{Trades}_t^{\text{change}} | + \alpha_4 | \text{Submit}_t^{\text{improve}} | + \alpha_5 | \text{Submit}_t^{\text{BBO}} | + \alpha_6 | \text{Submit}_t^{\text{Non-BBO}} | + \alpha_7 | \text{Cancel}_t^{\text{worsen}} | + \alpha_8 | \text{Cancel}_t^{\text{BBO}} | + \alpha_9 | \text{Cancel}_t^{\text{Non-BBO}} | + e_t,$$

where  $s_t$  is the transitory pricing error at event time  $t$  and  $s_{t-1}$  is its first-lag value.  $|\cdot|$  denotes absolute values.  $\text{Trades}_t^{\text{change}}$  represents trades that deplete full liquidity at the BBO and  $\text{Trades}_t^{\text{same}}$  represents trades that do not deplete full liquidity at the BBO.  $\text{Submit}_t^{\text{improve}}$ ,  $\text{Submit}_t^{\text{BBO}}$ , and  $\text{Submit}_t^{\text{Non-BBO}}$  denote limit orders that tighten the bid-ask spread, add liquidity at the BBO, and add liquidity behind the BBO, all in million dollar values, respectively.  $\text{Cancel}_t^{\text{worsen}}$ ,  $\text{Cancel}_t^{\text{BBO}}$ , and  $\text{Cancel}_t^{\text{Non-BBO}}$  denote limit orders that widen the bid-ask spread, reduce the liquidity at the BBO, and reduce the liquidity behind BBO, all in million dollar values, respectively. Newey-West standard errors are reported in model (2). We estimate the model for each trading day. We report the median estimated coefficients and the proportion of statistically significant coefficients at the 5% level in parentheses over the entire sample period. ‘Avg. # events’ denotes the average number of events (observations) per regression, and ‘Avg. Adj.  $R^2$ ’ is the adjusted  $R^2$  averaged across all regressions. Our sample spans from January 7, 2019 to June 26, 2020, comprising 372 day trading sessions and 368 night trading sessions.

	Corn		Soybean		Wheat	
	(1)	(2)	(1)	(2)	(1)	(2)
$s_{t-1}$	-0.014 (89.95%)	-0.015 (92.93%)	-0.015 (94.57%)	-0.015 (95.65%)	0.008 (75.00%)	0.008 (91.03%)
$  \text{Trades}_t^{\text{same}}  $		-0.004 (5.71%)		0.003 (4.62%)		0.003 (6.52%)
$  \text{Trades}_t^{\text{change}}  $		0.000 (18.75%)		0.017 (22.01%)		0.052 (15.22%)
$  \text{Submit}_t^{\text{improve}}  $		-0.003 (12.23%)		-0.016 (16.85%)		-0.084 (19.02%)
$  \text{Submit}_t^{\text{BBO}}  $		-0.001 (2.45%)		0.002 (7.61%)		-0.002 (3.80%)
$  \text{Submit}_t^{\text{Non-BBO}}  $		0.000 (4.08%)		-0.001 (4.35%)		-0.004 (4.89%)
$  \text{Cancel}_t^{\text{worsen}}  $		-0.073 (28.26%)		0.053 (27.99%)		0.149 (25.82%)
$  \text{Cancel}_t^{\text{BBO}}  $		0.000 (5.71%)		0.000 (4.62%)		-0.010 (4.89%)
$  \text{Cancel}_t^{\text{Non-BBO}}  $		0.001 (4.89%)		-0.001 (5.43%)		0.006 (5.43%)
Intercept	0.000 (4.89%)	0.000 (4.89%)	0.000 (6.52%)	0.000 (4.89%)	0.001 (4.35%)	0.000 (5.16%)
Avg. # events	378,121	378,121	589,257	589,257	359,047	359,047
Avg. Adj. $R^2$	0.0011	0.0012	0.0009	0.0009	0.0001	0.0002

Table H2: Transitory pricing errors (noise) during the night trading session: Trades and limit orders

This table reports the regression results of transitory pricing errors (noise) on all trades and limit order variables during the night trading session in our sample in the CME corn, soybean, and wheat futures markets. The three different markets are organized by columns. The transitory pricing errors are extracted from the VMA representation of our structural VAR model. Our regression specifications are as follows

$$s_t = \alpha_0 + \alpha_1 s_{t-1} + \alpha_2 |Trades_t^{same}| + \alpha_3 |Trades_t^{change}| + \alpha_4 |Submit_t^{improve}| + \alpha_5 |Submit_t^{BBO}| + \alpha_6 |Submit_t^{Non-BBO}| + \alpha_7 |Cancel_t^{worsen}| + \alpha_8 |Cancel_t^{BBO}| + \alpha_9 |Cancel_t^{Non-BBO}| + e_t,$$

where  $s_t$  is the transitory pricing error at event time  $t$  and  $s_{t-1}$  is its first-lag value.  $|\cdot|$  denotes absolute values.  $Trades_t^{change}$  represents trades that deplete full liquidity at the BBO and  $Trades_t^{same}$  represents trades that do not deplete full liquidity at the BBO.  $Submit_t^{improve}$ ,  $Submit_t^{BBO}$ , and  $Submit_t^{Non-BBO}$  denote limit orders that tighten the bid-ask spread, add liquidity at the BBO, and add liquidity behind the BBO, all in million dollar values, respectively.  $Cancel_t^{worsen}$ ,  $Cancel_t^{BBO}$ , and  $Cancel_t^{Non-BBO}$  denote limit orders that widen the bid-ask spread, reduce the liquidity at the BBO, and reduce the liquidity behind BBO, all in million dollar values, respectively. Newey-West standard errors are reported in model (2). We estimate the model for each trading day. We report the median estimated coefficients and the proportion of statistically significant coefficients at the 5% level in parentheses over the entire sample period. ‘Avg. # events’ denotes the average number of events (observations) per regression, and ‘Avg. Adj.  $R^2$ ’ is the adjusted  $R^2$  averaged across all regressions. Our sample spans from January 7, 2019 to June 26, 2020, comprising 372 day trading sessions and 368 night trading sessions.

	Corn		Soybean		Wheat	
	(1)	(2)	(1)	(2)	(1)	(2)
$s_{t-1}$	0.001 (43.21%)	0.001 (72.28%)	0.005 (78.26%)	0.005 (83.15%)	0.006 (48.64%)	0.006 (87.50%)
$ Trades_t^{same} $		-0.007 (7.61%)		-0.006 (7.34%)		-0.007 (4.08%)
$ Trades_t^{change} $		0.116 (24.46%)		0.037 (23.37%)		0.018 (13.86%)
$ Submit_t^{improve} $		0.016 (16.58%)		0.083 (20.11%)		-0.070 (11.41%)
$ Submit_t^{BBO} $		-0.001 (3.53%)		0.010 (5.43%)		-0.064 (4.89%)
$ Submit_t^{Non-BBO} $		0.004 (5.71%)		0.000 (6.25%)		-0.002 (7.34%)
$ Cancel_t^{worsen} $		0.202 (20.38%)		-0.196 (21.47%)		-0.366 (16.58%)
$ Cancel_t^{BBO} $		-0.001 (5.71%)		0.010 (4.89%)		-0.017 (4.62%)
$ Cancel_t^{Non-BBO} $		-0.003 (5.43%)		0.004 (4.08%)		0.024 (5.71%)
Intercept	-0.001 (5.43%)	0.000 (5.43%)	0.000 (9.78%)	-0.001 (6.25%)	-0.001 (7.07%)	0.000 (6.52%)
Avg. # events	113,852	113,852	163,714	163,714	113,971	113,971
Avg. Adj. $R^2$	0.0002	0.0003	0.0005	0.0005	0.0001	0.0001

# I Robustness

## I.1 Alternative measure of trade and limit order variables

Table I1: Permanent price impacts: Robustness to an alternative measure of trade and limit order variables.

This table reports the summary statistics of daily price impacts (bps) of trades and limit orders during the day trading session (Panel A), and night trading session (Panel B) across all trading days in our sample in the CME corn, soybean, and wheat futures markets. The three different markets are organized by columns. Permanent price impacts are calculated as the cumulative impulse responses of midpoint returns to trades and limit orders up to 150 events. All results are obtained based on the estimated SVAR model in equation (1) in the main text and **A** matrix is detailed in equation (2) in the main text.  $r_t$  denotes log midpoint returns.  $Trades_t^{change}$  represents trades that deplete full liquidity at the BBO and  $Trades_t^{same}$  represents trades that do not deplete full liquidity at the BBO. All trade variables are signed +1 for buy-initiated trades and -1 for sell-initiated trades, and expressed in number of hundred contracts.  $Submit_t^{improve}$ ,  $Submit_t^{BBO}$ , and  $Submit_t^{Non-BBO}$  denote limit orders that tighten the bid-ask spread, add liquidity at the BBO, and add liquidity behind the BBO, all in number of hundred contracts, respectively.  $Cancel_t^{worsen}$ ,  $Cancel_t^{BBO}$ , and  $Cancel_t^{Non-BBO}$  denote limit orders that widen the bid-ask spread, reduce the liquidity at the BBO, and reduce the liquidity behind BBO, all in number of hundred contracts, respectively. All submission variables are signed +1 for bids and -1 for asks and all cancellation variables are signed -1 for bids and +1 for asks. The SVAR model and permanent price impacts are estimated every trading day in each market, and the summary statistics of permanent price impacts across days are presented. We calculate the proportion of statistically significant price impacts across all trading days in our sample based on the 95% confidence interval by bootstrapping with 1,000 replications and results are shown in column “% sig.”. We calculate the proportion of statistically significant price impacts across all trading days in our sample based on the 95% confidence interval by bootstrapping with 1,000 replications and results are shown in column “% sig.”. Our sample spans from January 7, 2019 to June 26, 2020, comprising 372 day trading sessions and 368 night trading sessions.

	Corn (bps.)				Soybean (bps.)				Wheat (bps.)			
	Mean	Std.	Med	% sig.	Mean	Std.	Med	% sig.	Mean	Std.	Med	% sig.
<i>Panel A: Day trading session.</i>												
<i>Trades – change price</i>	5.99	2.43	5.82	100.00%	9.38	2.69	8.95	100.00%	20.70	6.17	20.17	99.19%
<i>Trades – same price</i>	1.32	0.67	1.19	100.00%	2.55	0.94	2.37	100.00%	5.08	2.21	4.92	99.73%
<i>Improving submission</i>	3.93	1.71	3.77	99.46%	7.33	2.79	7.03	100.00%	13.34	6.28	12.47	98.92%
<i>Submission at BBO</i>	0.25	0.23	0.17	98.92%	1.01	0.65	0.85	100.00%	2.95	1.81	2.60	100.00%
<i>Submission at Non-BBO</i>	-0.03	0.02	-0.02	56.18%	-0.06	0.04	-0.06	51.88%	-0.12	0.08	-0.48	26.88%
<i>Worsening cancellation</i>	7.42	4.82	6.96	88.17%	11.28	5.28	10.47	98.12%	18.59	8.05	17.49	96.51%
<i>Cancellation at BBO</i>	0.06	0.09	0.02	17.47%	0.33	0.40	0.20	43.01%	1.43	1.01	1.24	80.38%
<i>Cancellation at Non-BBO</i>	0.10	0.10	0.07	86.83%	0.36	0.25	0.34	97.85%	0.63	0.34	0.56	79.57%
<i>Panel B: Night trading session.</i>												
<i>Trades – change price</i>	14.28	8.27	11.97	98.64%	14.16	5.78	13.49	99.73%	35.51	12.86	33.76	99.18%
<i>Trades – same price</i>	1.84	1.13	1.56	89.67%	2.58	1.41	2.37	95.38%	6.71	3.39	5.98	96.74%
<i>Improving submission</i>	9.66	6.59	8.18	98.64%	8.55	4.49	7.55	100.00%	21.44	12.31	19.21	100.00%
<i>Submission at BBO</i>	0.46	0.48	0.28	74.18%	1.57	0.91	1.41	99.73%	4.24	2.62	3.78	99.18%
<i>Submission at Non-BBO</i>	-0.03	0.04	-0.03	4.35%	-0.04	0.06	-0.04	9.24%	0.02	0.12	0.01	1.90%
<i>Worsening cancellation</i>	18.29	12.87	15.15	90.22%	17.04	9.15	16.61	97.83%	32.26	18.82	31.04	94.29%
<i>Cancellation at BBO</i>	0.33	0.31	0.24	52.99%	1.00	0.62	0.83	86.41%	2.61	1.66	2.23	77.45%
<i>Cancellation at Non-BBO</i>	0.19	0.16	0.16	52.99%	0.42	0.21	0.40	81.79%	0.84	0.54	0.77	66.30%

Table I2: Information shares: Robustness to an alternative measure of trade and limit order variables.

This table reports summary statistics of the daily information shares (*ISs*) of trades and limit orders during the day trading session (Panel A), and night trading session (Panel B) across all trading days in our alternative sample in the CME corn, soybean, and wheat futures market. The three different markets are organized by columns. Information shares are calculated based on the estimated SVAR model in equation (1) in the main text and **A** matrix is detailed in equation (2) in the main text.  $r_t$  denotes log midpoint returns.  $Trades_t^{change}$  represents trades that deplete full liquidity at the BBO and  $Trades_t^{same}$  represents trades that do not deplete full liquidity at the BBO. All trade variables are signed +1 for buy-initiated trades and -1 for sell-initiated trades, and expressed in number of hundred contracts.  $Submit_t^{improve}$ ,  $Submit_t^{BBO}$ , and  $Submit_t^{Non-BBO}$  denote limit orders that tighten the bid-ask spread, add liquidity at the BBO, and add liquidity behind the BBO, all in number of hundred contracts, respectively.  $Cancel_t^{worsen}$ ,  $Cancel_t^{BBO}$ , and  $Cancel_t^{Non-BBO}$  denote limit orders that widen the bid-ask spread, reduce the liquidity at the BBO, and reduce the liquidity behind BBO, all in number of hundred contracts, respectively. All submission variables are signed +1 for bids and -1 for asks while all cancellation variables are signed -1 for bids and +1 for asks. The SVAR model and *ISs* are estimated every trading day in each market, and the summary statistics of *ISs* across days are presented. We assess whether the median aggregated information shares of *improving submission* and *worsening cancellation* are statistically equal to those of *trades - change price* using the Wilcoxon signed rank test with *p*-values shown in row “Limit total vs. Trades”. The same test is used to examine whether the distributions of information shares of *improving submission* are statistically different from those of *worsening cancellation* with *p*-values shown in row “Improve vs. Worsen”. Our sample spans from January 7, 2019 to June 26, 2020, comprising 372 day trading sessions and 368 night trading sessions.

	Corn			Soybean			Wheat		
	Mean	Std.	Med	Mean	Std.	Med	Mean	Std.	Med
<i>Panel A: Day trading session.</i>									
<i>Trades – change price</i>	33.96%	18.76%	31.63%	32.39%	13.92%	31.58%	43.12%	15.52%	42.17%
<i>Trades – same price</i>	2.08%	2.33%	1.21%	2.59%	1.78%	2.16%	2.89%	2.25%	2.35%
<i>Improving submission</i>	15.91%	11.65%	12.80%	20.14%	11.71%	17.74%	18.31%	10.85%	16.58%
<i>Submission at BBO</i>	0.09%	0.15%	0.03%	0.46%	0.53%	0.27%	1.02%	1.13%	0.71%
<i>Submission at Non-BBO</i>	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
<i>Worsening cancellation</i>	45.55%	23.15%	46.58%	43.73%	16.34%	43.47%	34.19%	15.03%	32.87%
<i>Cancellation at BBO</i>	0.01%	0.02%	0.00%	0.08%	0.15%	0.01%	0.25%	0.33%	0.15%
<i>Cancellation at Non-BBO</i>	0.02%	0.03%	0.01%	0.06%	0.07%	0.04%	0.05%	0.05%	0.03%
Limit total vs. Trades ( <i>p</i> -value)	< 0.001			< 0.001			< 0.001		
Improve vs. Worsen ( <i>p</i> -value)	< 0.001			< 0.001			< 0.001		
<i>Panel B: Night trading session.</i>									
<i>Trades – change price</i>	34.72%	21.62%	30.55%	36.12%	19.55%	33.77%	44.60%	21.41%	40.06%
<i>Trades – same price</i>	1.00%	1.57%	0.45%	1.41%	1.38%	1.00%	1.90%	1.96%	1.32%
<i>Improving submission</i>	17.02%	15.47%	12.50%	14.20%	11.40%	11.16%	16.80%	12.93%	13.75%
<i>Submission at BBO</i>	0.08%	0.19%	0.02%	0.52%	0.53%	0.36%	0.75%	0.82%	0.46%
<i>Submission at Non-BBO</i>	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
<i>Worsening cancellation</i>	46.59%	23.44%	47.77%	47.14%	21.51%	47.16%	35.56%	19.96%	33.73%
<i>Cancellation at BBO</i>	0.03%	0.06%	0.01%	0.23%	0.28%	0.13%	0.28%	0.33%	0.19%
<i>Cancellation at Non-BBO</i>	0.01%	0.03%	0.00%	0.04%	0.05%	0.03%	0.03%	0.04%	0.02%
Limit order vs. Trades ( <i>p</i> -value)	< 0.001			< 0.001			< 0.001		
Improve vs. Worsen ( <i>p</i> -value)	< 0.001			< 0.001			< 0.001		

## I.2 *Alternative sample period*

Table I3: Permanent price impacts: Robustness of the corn results to an alternative sample period.

This table reports the summary statistics of daily price impacts (bps) of trades and limit orders during the day trading session (Panel A), and night trading session (Panel B) across all trading days in our alternative sample in the CME corn futures market. Permanent price impacts are calculated as the cumulative impulse responses of midpoint returns to trades and limit orders up to 150 events. All results are obtained based on the estimated SVAR model in equation (1) in the main text and  $\mathbf{A}$  matrix is detailed in equation (2) in the main text.  $r_t$  denotes log midpoint returns.  $Trades_t^{change}$  represents trades that deplete full liquidity at the BBO and  $Trades_t^{same}$  represents trades that do not deplete full liquidity at the BBO. All trade variables are signed +1 for buy-initiated trades and -1 for sell-initiated trades, and expressed in million dollar values.  $Submit_t^{improve}$ ,  $Submit_t^{BBO}$ , and  $Submit_t^{Non-BBO}$  denote limit orders that tighten the bid-ask spread, add liquidity at the BBO, and add liquidity behind the BBO, all in million dollar values, respectively.  $Cancel_t^{worsen}$ ,  $Cancel_t^{BBO}$ , and  $Cancel_t^{Non-BBO}$  denote limit orders that widen the bid-ask spread, reduce the liquidity at the BBO, and reduce the liquidity behind BBO, all in million dollar values, respectively. All submission variables are signed +1 for bids and -1 for asks and all cancellation variables are signed -1 for bids and +1 for asks. The SVAR model and permanent price impacts are estimated every trading day, and the summary statistics of permanent price impacts across days are presented. We calculate the proportion of statistically significant price impacts across all trading days in our sample based on the 95% confidence interval by bootstrapping with 1,000 replications and results are shown in column “% sig.”. We calculate the proportion of statistically significant price impacts across all trading days in our sample based on the 95% confidence interval by bootstrapping with 1,000 replications and results are shown in column “% sig.”. Our alternative sample spans from May 7, 2018 to July 27, 2018, comprising 58 day trading sessions and 57 night trading sessions.

	Permanent price impacts (bps.)			
	Mean	Std.Dev.	Med	% sig.
<i>Panel A: Day trading session.</i>				
<i>Trades – change price</i>	2.85	1.37	2.45	100.00%
<i>Trades – same price</i>	0.58	0.31	0.50	100.00%
<i>Improving submission</i>	1.56	0.71	1.45	98.28%
<i>Submission at BBO</i>	0.07	0.07	0.06	94.83%
<i>Submission at Non-BBO</i>	-0.01	0.01	-0.01	39.66%
<i>Worsening cancellation</i>	2.94	2.13	2.62	79.31%
<i>Cancellation at BBO</i>	0.05	0.07	0.03	39.66%
<i>Cancellation at Non-BBO</i>	0.06	0.05	0.05	93.10%
<i>Panel B: Night trading session.</i>				
<i>Trades – change price</i>	5.77	4.12	4.74	100.00%
<i>Trades – same price</i>	0.97	0.71	0.79	91.23%
<i>Improving submission</i>	4.60	3.37	3.57	100.00%
<i>Submission at BBO</i>	0.21	0.18	0.14	87.72%
<i>Submission at Non-BBO</i>	-0.02	0.02	-0.02	8.77%
<i>Worsening cancellation</i>	7.08	5.16	5.92	91.23%
<i>Cancellation at BBO</i>	0.18	0.17	0.12	59.65%
<i>Cancellation at Non-BBO</i>	0.13	0.09	0.09	80.70%

Table I4: Information shares: Robustness of the corn results to an alternative sample period.

This table reports summary statistics of the daily information shares ( $IS$ s) of trades and limit orders during the day trading session (Panel A), and night trading session (Panel B) across all trading days in our alternative sample in the CME corn futures market. Information shares are calculated based on the estimated SVAR model in equation (1) in the main text and  $\mathbf{A}$  matrix is detailed in equation (2) in the main text.  $r_t$  denotes log midpoint returns.  $Trades_t^{change}$  represents trades that deplete full liquidity at the BBO and  $Trades_t^{same}$  represents trades that do not deplete full liquidity at the BBO. All trade variables are signed +1 for buy-initiated trades and -1 for sell-initiated trades, and expressed in million dollar values.  $Submit_t^{improve}$ ,  $Submit_t^{BBO}$ , and  $Submit_t^{Non-BBO}$  denote limit orders that tighten the bid-ask spread, add liquidity at the BBO, and add liquidity behind the BBO, all in million dollar values, respectively.  $Cancel_t^{worsen}$ ,  $Cancel_t^{BBO}$ , and  $Cancel_t^{Non-BBO}$  denote limit orders that widen the bid-ask spread, reduce the liquidity at the BBO, and reduce the liquidity behind BBO, all in million dollar values, respectively. All submission variables are signed +1 for bids and -1 for asks while all cancellation variables are signed -1 for bids and +1 for asks. The SVAR model and  $IS$ s are estimated every trading day, and the summary statistics of  $IS$ s across days are presented. We assess whether the median aggregated information shares of *improving submission* and *worsening cancellation* are statistically equal to those of *trades - change price* using the Wilcoxon signed rank test with  $p$ -values shown in row “Limit total vs. Trades”. The same test is used to examine whether the distributions of information shares of *improving submission* are statistically different from those of *worsening cancellation* with  $p$ -values shown in row “Improve vs. Worsen”. Our alternative sample spans from May 7, 2018 to July 27, 2018, comprising 58 day trading session and 57 night trading sessions.

	Information shares		
	Mean	Std.Dev.	Med
<i>Panel A: Day trading session.</i>			
<i>Trades - change price</i>	36.68%	17.28%	34.62%
<i>Trades - same price</i>	1.83%	1.63%	1.29%
<i>Improving submission</i>	13.55%	10.74%	10.53%
<i>Submission at BBO</i>	0.03%	0.05%	0.01%
<i>Submission at Non-BBO</i>	0.00%	0.00%	0.00%
<i>Worsening cancellation</i>	37.42%	21.49%	32.49%
<i>Cancellation at BBO</i>	0.02%	0.05%	0.00%
<i>Cancellation at Non-BBO</i>	0.02%	0.02%	0.01%
Limit total vs. Trades ( $p$ -value)	0.012		
Improve vs. Worsen ( $p$ -value)	<0.001		
<i>Panel B: Night trading session.</i>			
<i>Trades - change price</i>	30.69%	21.70%	25.65%
<i>Trades - same price</i>	1.26%	1.70%	0.71%
<i>Improving submission</i>	22.52%	19.49%	16.66%
<i>Submission at BBO</i>	0.05%	0.06%	0.03%
<i>Submission at Non-BBO</i>	0.00%	0.00%	0.00%
<i>Worsening cancellation</i>	42.74%	22.48%	48.15%
<i>Cancellation at BBO</i>	0.05%	0.09%	0.02%
<i>Cancellation at Non-BBO</i>	0.02%	0.03%	0.01%
Limit total vs. Trades ( $p$ -value)	<0.001		
Improve vs. Worsen ( $p$ -value)	<0.001		



## References

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