Liquidity Provision before a Terminal Event

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***Abstract*—We study secondary trading in a short-lived claim whose settlement depends on the identity of the last agent to act. The underlying event is held fixed while the trading protocol and dissemination of an informative signal vary independently. In 864 laboratory markets, clearing in two-second batches reduces the transfer from resting to newly submitted orders by 2.3 credits per round when the signal is public, compared with 0.6 credits when it is private. The difference is 1.7 credits (95% CI 0.4–3.0). Contracts settle against independently coded recordings of four-person applause. Posture is informative about cessation, including in recordings where the last audible contact follows an interval of collective silence. Settling at the apparent end of applause instead changes the payoff on 19 of 288 distinct claims. The change attenuates the estimated protection of resting orders under public disclosure.**

***Index Terms*—market microstructure, batch auctions, adverse selection, event contracts, settlement**

I. Introduction

A trading close is observable to the matching engine. The event on which a claim settles may end less distinctly. A claim on terminal rank depends on who supplies the last action, even if the group appears to have ceased acting. In continuous trading, an order can execute on a public indicator of cessation before the owner of a standing quote can respond. Private information can produce the same execution for a different reason [1]–[3]. Tick data with unidentified news arrivals rarely distinguish these cases [4].

We fix the settlement event and vary the recipients of a signal. The event is seated applause after a recorded performance. The claim pays 100 credits if the person designated on the order screen makes the last hand contact, even if the others have already put their hands down. Previous studies identify dependence in the timing and cessation of applause [5], [6]. We use the order of individual exits.

The clappers never trade. The tape, focal identity and delayed-release packet are identical each time a claim is listed. The order log records commitments at release and executions thereafter. We retain favorable as well as unfavorable fills in the settlement markout.

The design follows experimental work on double auctions and information aggregation [7], [8]. We use small inventory incentives to sustain trade in a binary instrument [9], [10]. Section II describes the claim and Section III specifies the exchange and estimator. Section V considers settlement at the apparent end of the recording.

II. Contract and Information

A. The recording archive

Fifty-two quartets each watched six instrumental excerpts in counterbalanced order. Seated volunteers acknowledged each performance as they would at a recital. We gave no instructions on the cadence or duration of applause. Each seat had an isolated microphone and camera. With consent, the traders saw synchronized silhouettes and heard a mix of the four channels. The volunteers never saw the contract label.

Each recording runs for 20 s from the first hand contact. Eligibility requires a contact from every person by 3 s, at least one contact after 4.2 s and cessation by 16 s. Of 312 clips, 12 fail the first rule, seven of the remainder fail the second and five fail the third. We retain 288. A separate development set of 72 recordings from 12 quartets informed the rules.

An onset qualifies if it coincides with visible hand closure. Coders independently scored candidates from the isolated channels and inspected all contacts in the last 4 s. A hand striking a program is coded separately [11]. A third coder resolved 11 disagreements on the last clapper without access to the contract label or exchange data. Contacts within 8 ms of the last onset form a tie set. A precommitted random ordering of the four seats breaks ties, which occur in five clips.

B. Payoff construction

Before any trading session, the server draws a focal person j_r independently and uniformly over the four screen positions for each recording r. Let J_r denote the terminal person under the protocol above. The unit claim has value

$$V_r = 100 Y_r, \qquad Y_r = \mathbf{1}\{J_r = j_r\}. \tag{1}$$

The exchange lists each tape once per site, omitting its identifier. No trader sees the same tape twice. Before the round, traders see the first 3 s of applause and a snapshot with the focal position boxed. Playback resumes after the close. Traders must predict a relative rank. A claim on whether the focal person claps again would allow multiple winners on the same tape.

At 8.25 s on the exchange clock a card reports whether both of the focal person’s wrists clear the chair arm at 4.2 s on the recording clock. They must clear the line in two of three frames centered on that time. In a public round all eight traders receive the card. In a private round one receives it uniformly at random, and the others see a notice of delivery that conceals the recipient’s identity. The release schedule and disclosure regime appear in the instructions.

We chose the posture variable from five binary candidates in development. Head angle varied little at the cut. Wrist elevation captured a pause with both hands suspended above the chair arms. The

coding sheet distinguishes suspended hands from wrists already at rest [12]. A person holding a program in one hand may still clap below the line.

The focal person wins in 54 of 108 high-card clips and 18 of 180 low-card clips, for 72 wins in 288. Traders learn that the development frequencies, rounded to the nearest five percentage points, were 50% and 10%. These also happen to be the frequencies in the evaluation set. The posterior conditional on the initial footage can differ.

III. Market Design and Estimation

A. Session structure

We recruited 36 cohorts of eight adults across three labs, 12 cohorts per lab. After a quiz and two practice rounds, each cohort completed 24 paying rounds. The server independently permuted the four treatment combinations within every consecutive block of four rounds, holding tape order fixed. Each cell therefore contains six rounds per cohort and 216 in total. The treatment display precedes the clip. The Bastel Institute ethics panel approved the protocol (BA-24-071).

Every trader begins with 125 credits. Four traders drawn independently in each round also receive two shares each. The other four earn four extra credits on their first acquisition, while initial holders earn the same amount on their first sale. The incentive applies once per trader per round. Three randomly selected rounds count toward cash compensation at site-specific, advance-posted conversion rates. Balance and inventory reset between rounds.

Continuous matching follows price and server receipt time, with trades executing at standing prices. In the batch market messages arrive continuously and matching occurs at $t = 2, 4, 6, 8, 10, 12$ s. The engine chooses a uniform price to maximize executable quantity and draws priority within marginal prices. Both designs display the best bid and ask with size on a one-credit grid. The batch book can cross between calls. A reduction preserves the order ID. Increases and price changes require replacement. See Appendix A for clearing and order classification.

The card appears 1.75 s before the first possible batch execution after release and 3.75 s before the close in either market. Participants can cancel in either regime. They know the matching rule before entering the first order. This differs from a comparison between continuous intraday trading and the closing auction on the same exchange [13].

B. Outcomes and inference

We recover both order IDs for every fill. A fill enters the primary outcome when exactly one side was in the book immediately before release and the other side was submitted after release. If p_f is the execution price in credits, q_f is the matched quantity, and s_f is $+1$ for a newly submitted buy and -1 for a newly submitted sell, the outcome for round i is

$$M_i = \sum_{f \in \mathcal{F}_i} q_f s_f \left(V_{r(i)} - p_f \right). \tag{2}$$

A positive value of Eq. (2) is a transfer from old to new orders relative to settlement. Rounds without eligible fills contribute zero. This denominator includes any reduction in trading and avoids the need to infer trade direction from prints [14]. An order is old if it was live at release, irrespective of who placed it.

We examine realized transfers and quote changes separately, following Madhavan et al. [15]. Resting prices may reflect inventory incentives or information from the footage. Treating the signed transfer as a structural adverse-selection premium would require estimating those separate components. We account for the inventory bonus in Section VI.

For treatment means $\mu_{g,e}$, indexed by information scope g and exchange rule e, the primary contrast is

$$\delta = (\mu_{\text{public,continuous}} - \mu_{\text{public,batch}}) - (\mu_{\text{private,continuous}} - \mu_{\text{private,batch}}). \tag{3}$$

We estimate Eq. (3) by differences of cell means. Intervals use a t_{35} reference with two-way clustering by cohort and recording quartet [16]. These clusters are crossed since tapes recur across labs. A supplementary test uses 20,000 block permutations for the sharp null of no treatment effect. Its null differs from a zero interaction with nonzero main effects. Event-time intervals are pointwise.

Our secondary measure is $(p/100 - Y_r)^2$, the Brier loss for the latest price p expressed on the unit interval [17]. We carry the price forward in periods without fills and initialize it at 0.25. The pre-release score uses the last trade strictly before the card. We avoid the midpoint, since opposing orders can wait at crossed prices in the batch book.

IV. Results

A. Transfers at release

In the public condition batching lowers the mean transfer by 2.3 credits (95% CI 1.5–3.1). The corresponding decline is 0.6 credits with private disclosure (95% CI −0.4–1.6). The estimated interaction in Eq. (3) is 1.7 credits (95% CI 0.4–3.0). Table I gives the cell means and Fig. 1 locates the difference in time.

TABLE I

TRANSFERS AND ACTIVITY BY ASSIGNED MARKET CELL. UNITS AND CREDITS ARE PER MARKET ROUND. THE FINAL TWO COLUMNS REFER TO FILLS WHOSE ORDERS STRADDLE RELEASE. ZERO-FILL ROUNDS ARE RETAINED.

Card	Protocol	Rounds	Transfer	95% CI	Eligible units	Rounds with eligible fill
Public	Continuous	216	3.4	2.8–4.0	0.72	118
Public	Batch	216	1.1	0.6–1.6	0.42	76
Private	Continuous	216	5.1	4.3–5.9	0.88	139
Private	Batch	216	4.5	3.6–5.4	0.79	127

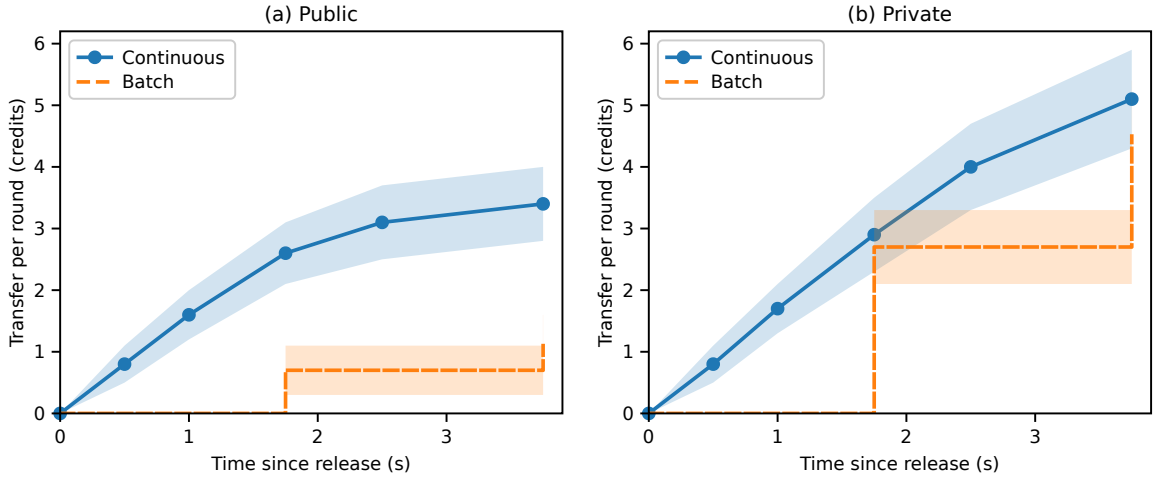


Fig. 1. Cumulative realized transfer following card release. The batch increments occur at 1.75 s and 3.75 s after release. Intervals are pointwise 95% confidence intervals.

In public continuous rounds the mean transfer reaches 0.8 credits after half a second and 2.6 by the first batch time. The first public batch clears with a transfer of 0.7 credits. At least one old order is canceled by that point in 136 of the 216 public continuous rounds and 177 of the public batch rounds. The difference is smaller in private rounds (124 and 143). An executed order cannot subsequently be canceled, so these counts describe exposure to execution and cancellation together.

With a high public card, a buyer can submit against the old quote while the seller is still reading the posture classification. A seller who never sees a private card can withdraw at release to avoid trading against a recipient, but that seller cannot condition the decision on the wrists. Displayed prices and quantities can also convey some information after release [18], [19].

The mean transfer per eligible unit is 4.7 credits with public continuous trading and 2.6 with public batching, using the rounded means in Table I. With private release the ratios are 5.8 and 5.7. These ratios condition on execution and describe different traded quantities.

B. *Price information*

Pre-release scores range from 0.183 to 0.185. The constant forecast 0.25 scores 0.1875 over the full archive. The frozen forecast using the card alone scores 0.150. The smallest mean closing error is in public batch markets (Table II). The improvement over public continuous trading is 0.006 (95% CI −0.002–0.014).

TABLE II

PRICE SCORES AND TRADING COVERAGE. SQUARED ERRORS AVERAGE ACROSS ALL 216 ASSIGNED ROUNDS IN EACH CELL AND USE 0.25 BEFORE THE FIRST TRADE. COVERAGE COUNTS ANY EXECUTION BY THE CLOSE.

Card	Protocol	Before release	At close	Rounds with execution
Public	Continuous	0.184	0.166	202
Public	Batch	0.184	0.160	195
Private	Continuous	0.185	0.176	204
Private	Batch	0.183	0.179	196

In Fig. 2 the public score changes soon after release under continuous trading and at the first clear under batching. The private batch price changes little after the first clear. Resting orders at the second clear still yield positive markouts to the new side.

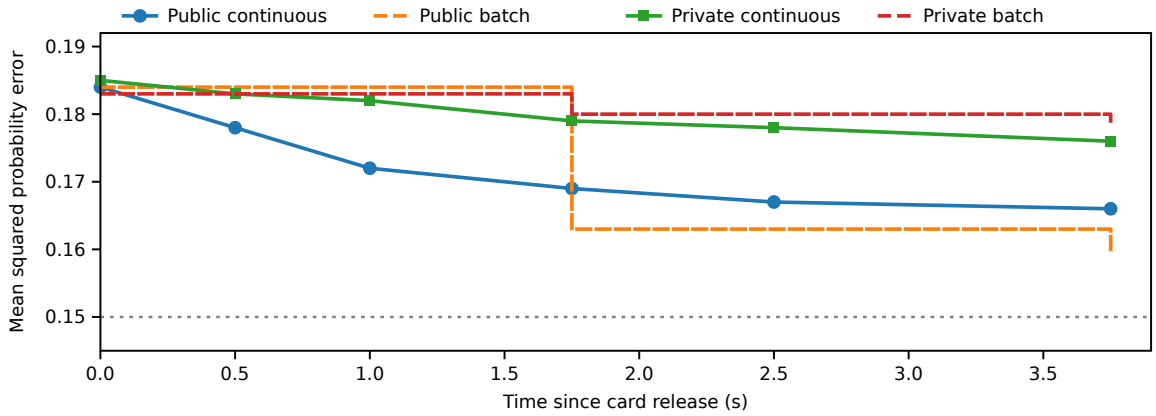


Fig. 2. Squared probability error of the most recent transaction. The last price is carried forward. Batch prices are observed at clears. The dotted line is the card-only forecast.

V. Settlement after Apparent Cessation

The mixed channel sometimes falls below room noise between the last two contacts. Isolated tracks can still register a subsequent clap. A dropped program can produce the opposite problem, with acoustic energy and no eligible contact. We recode settlement using the remaining contact sequence after removing the last one if it follows a gap of at least g. This is a retrospective label change on the original orders.

At $g = 0.75$ s the rule removes 44 final contacts (Fig. 3). In 36 clips this changes the identity of the terminal person. In 19 it reverses the claim payoff. The difference consists of cases where one nonfocal clapper replaces another. Ten positive payoffs become zero and nine zero payoffs become positive, leaving 71 wins.

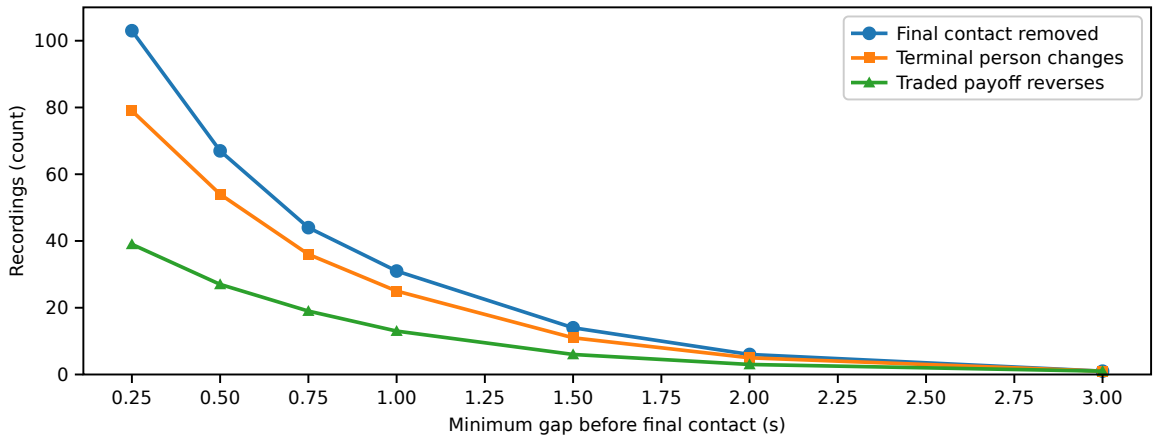


Fig. 3. Sensitivity of the settlement label to the treatment of isolated final contacts. Counts refer to distinct recordings, with each recording counted once at a given threshold.

On one recording, three people put down their hands after two roughly simultaneous claps. The fourth is starting to lower the right hand while the left remains above the chair arm. Both wrists were still high at the card frame. Their last contact follows 3.12 s of silence. In a private continuous round the informed buyer takes one unit from a resting two-unit offer at 31. The settlement markout is 69 credits. Settling on the preceding contact assigns the same buyer a loss of 31.

For all orders, let $Q_i = \sum_{f \in \mathcal{F}_i} q_f s_f$ denote new net demand within eligible fills. We calculate the counterfactual transfer $M_i(g)$ under the earlier settlement label $Y_r(g)$. The price term cancels:

$$M_i(g) - M_i = 100 \left[Y_{r(i)}(g) - Y_{r(i)} \right] Q_i. \tag{4}$$

Even if revisions in both directions are equally common, signed demand can differ between them. Table III reports the cell means after applying Eq. (4).

TABLE III
SETTLEMENT SENSITIVITY AT A GAP OF 0.75 S. ESTIMATES ARE MEAN CREDITS PER ASSIGNED ROUND, HOLDING PRICES, ORDER TIMES AND QUANTITIES FIXED.

Card	Protocol	Contractual label	Earlier label	Revision
Public	Continuous	3.4	2.8	−0.6
Public	Batch	1.1	1.0	−0.1
Private	Continuous	5.1	4.8	−0.3
Private	Batch	4.5	4.4	−0.1

The public protocol gap falls from 2.3 to 1.8 credits under earlier settlement. The private gap falls from 0.6 to 0.4. The interaction is 1.4 credits (95% CI 0.1–2.7). Of the 57 listings with revised claims many have no eligible fill. At $g = 0.50$ s, 27 labels change, with protocol gaps of 1.6 and 0.4. A rule known before trading might change the value of the signal and the provision of inventory.

VI. Additional Checks

In 213 of 432 private rounds the recipient starts with inventory. The private protocol contrast is 0.9 credits in this subset and 0.3 in the other 219 rounds. These subgroup contrasts are imprecise. Adding observed bonuses on eligible fills changes the main interaction by 0.1 credits.

A recipient can leave a profitable old order active after reading the card. Counting all post-release fills from the card recipient’s side, including old orders, yields a mean settlement surplus of 3.7 credits under continuous trading and 3.3 credits under batching. The difference of 0.4 credits (95% CI −0.5–1.3) is consistent with a small effect on private information rents.

The sharp-null test gives a two-sided randomization probability of 0.012 for an interaction at least as extreme as observed. The reassignment preserves each cohort’s sequence of recordings. It assumes that any treatment history would produce the same outcomes under this null. The interaction using only the first 12 rounds per cohort is 1.5 credits (95% CI −0.1–3.1).

Expanding the timing tolerance from 8 to 12 ms changes three of 288 payoffs under the precommitted tie ordering. The interaction rounds to the same tenth of a credit. The treatment of isolated final contacts matters more here than uncertainty about near-simultaneous ones.

VII. Discussion

The batch protocol makes a cancellation window available in either information regime. Only in the public regime can both sides use that window to respond to the card. The gap between regimes diminishes when settlement excludes the final isolated contact. Aggregate counts of claps are insufficient for that comparison. We need the identity of the person who loses or gains the terminal rank and the signed flow at the affected fills.

Traders cannot add a clap to the settlement file. With audience participation in the exchange, a shareholder could retain the option to wait until everyone else sets down their hands. The resulting market would price both the ability to act last and the record of who exercised that option. Our result also pertains to a 1.75-s interval between the card and the next batch. A shorter window may prevent a human operator from using a disclosure, even when public. We cannot use these results to choose an optimal batch length.

A recording rule can specify how long to continue after the room goes quiet. Where the final clap carries the entire payout, the audit file needs to retain the interval in which one person can still change the answer.

Appendix A. Matching and Order Classification

The price grid runs from 1 to 99 credits. Bids reserve cash at limit price times quantity, and asks reserve units. Traders can have orders open on only one side at a time. The server breaks timestamp ties by sequence number and rejects new orders after the close. Order age is measured at dispatch of the card. The 95th percentile of the within-round range of receipt times on the eight displays in public markets is 23 ms.

For batch clearing, if $D(p)$ and $S(p)$ are total live bid and ask quantities willing to execute at tick p, we compute

$$Q(p) = \min\{D(p), S(p)\}. \tag{5}$$

Among prices maximizing Eq. (5), the engine minimizes absolute imbalance $|D(p) - S(p)|$, then distance to the previous clearing price (initially 25). If still tied it selects the lower price. Each side executes in price priority with a committed independent draw within equal limits. A maximum of zero leaves the last price unchanged. Unfilled quantities remain live unless canceled.

Reductions inherit the old order ID, while price changes and quantity increases get new IDs. We reclassified replacements at the same price within 250 ms as old up to the previously resting quantity. The interaction under this treatment of short interruptions is 1.6 credits.

Analysis Material

Anonymized event logs link accepted and rejected messages, card assignments and hand-contact times by seat. Masked recording keys link each clip’s three listings. The event logs, deidentified onset tracks and scripts are available from the corresponding author. Full camera views remain with the recording staff.

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References

[1] L. R. Glosten and P. R. Milgrom, “Bid, ask and transaction prices in a specialist market with heterogeneously informed traders,” *Journal of Financial Economics*, vol. 14, pp. 71–100, 1985.

[2] A. S. Kyle, “Continuous auctions and insider trading,” *Econometrica*, vol. 53, pp. 1315–1335, 1985.

[3] E. Budish, P. Cramton, and J. Shim, “The high-frequency trading arms race: Frequent batch auctions as a market design response,” *The Quarterly Journal of Economics*, vol. 130, pp. 1547–1621, 2015.

[4] M. Aquilina, E. Budish, and P. O'Neill, “Quantifying the high-frequency trading arms race,” *The Quarterly Journal of Economics*, vol. 137, pp. 493–564, 2022.

[5] Z. Néda, E. Ravasz, Y. Brechet, T. Vicsek, and A.-L. Barabási, “The sound of many hands clapping,” *Nature*, vol. 403, pp. 849–850, 2000.

[6] R. P. Mann, J. Faria, D. J. T. Sumpter, and J. Krause, “The dynamics of audience applause,” *Journal of the Royal Society Interface*, vol. 10, pp. 20130466, 2013.

[7] V. L. Smith, “An experimental study of competitive market behavior,” *Journal of Political Economy*, vol. 70, pp. 111–137, 1962.

[8] C. R. Plott and S. Sunder, “Efficiency of experimental security markets with insider information: An application of rational-expectations models,” *Journal of Political Economy*, vol. 90, pp. 663–698, 1982.

[9] H. B. Senet and M. Pardi-Ulloa, “Inducing one-sided liquidity demand in binary security markets,” Celleneuve Centre for Experimental Economics, Tech. Rep. 21-04, 2021.

[10] N. Pai-Okabe and E. Villarrán, “Finite-horizon order provision with randomly assigned inventories,” *Review of Experimental Market Design*, vol. 8, pp. 67–104, 2023.

[11] A. L. Belme and N. Kirabayashi, “Parallel annotation of manual onset in small-group performance recordings,” Centre Auduel de Mesure Acoustique, Tech. Rep. 22-11, 2022.

[12] M. Leroux-Ricalde and T. R. Vennari, “Postural predictors of individual cessation in seated audience response,” *Annals of Performance Acoustics*, vol. 13, pp. 219–240, 2024.

[13] D. Cushing and A. Madhavan, “Stock returns and trading at the close,” *Journal of Financial Markets*, vol. 3, pp. 45–67, 2000.

[14] C. M. C. Lee and M. J. Ready, “Inferring trade direction from intraday data,” *The Journal of Finance*, vol. 46, pp. 733–746, 1991.

[15] A. Madhavan, M. Richardson, and M. Roomans, “Why do security prices change? A transaction-level analysis of NYSE stocks,” *The Review of Financial Studies*, vol. 10, pp. 1035–1064, 1997.

[16] A. C. Cameron, J. B. Gelbach, and D. L. Miller, “Robust inference with multiway clustering,” *Journal of Business & Economic Statistics*, vol. 29, pp. 238–249, 2011.

[17] G. W. Brier, “Verification of forecasts expressed in terms of probability,” *Monthly Weather Review*, vol. 78, pp. 1–3, 1950.

[18] C. R. Plott and S. Sunder, “Rational expectations and the aggregation of diverse information in laboratory security markets,” *Econometrica*, vol. 56, pp. 1085–1118, 1988.

[19] P. Handa, R. Schwartz, and A. Tiwari, “Quote setting and price formation in an order driven market,” *Journal of Financial Markets*, vol. 6, pp. 461–489, 2003.