Not Dead Yet: Options Trading Floors

LUCA GALATI, TERRENCE HENDERSHOTT, SAAD ALI KHAN, and RYAN RIORDAN*

May 31, 2026

ABSTRACT

Over 20% of U.S. options volume trades on physical floors, almost exclusively in S&P 500 index options. We exploit the COVID-19 closure of the Cboe floor to identify the impact of floor trading. The floor attracts complex trades, particularly the riskiest trades. During the closure, Cboe activated electronic auctions to execute complex orders. When electronic auctions are withdrawn, the cost of complex trades more than doubles, while costs for simple trades are mostly unchanged. During the closure, the riskiest trades become much less prevalent. The floor facilitates the most difficult trades, but raises the cost of less difficult ones.

Keywords: Floor trading, electronic trading, auction, liquidity, market microstructure
JEL codes: G20, G14, L10
Internet Appendix

*Luca Galati is with the LMU Munich School of Management at the Ludwig Maximilian University of Munich and with the Digital Finance Co-operative Research Centre. Terrence Hendershott is with the Haas School of Business at the University of California, Berkeley. Saad Ali Khan is with the Alberta School of Business at the University of Alberta. Ryan Riordan is with the LMU Munich School of Management at the Ludwig Maximilian University of Munich. Part of the research was carried out while Saad Ali Khan was at HEC Montreal. We are grateful to Citadel for helpful conversations and seminar participants at the University of Alberta and Ludwig Maximilian University of Munich for useful comments. This study should not be reported as representing the views of the Digital Finance Cooperative Research Centre (DFCRC). The views expressed are those of the authors and do not necessarily reflect those of the DFCRC. Any remaining errors or omissions are our own. This research did not receive any financial support. **Correspondence**: Luca Galati, LMU Munich School of Management at Ludwig Maximilian University of Munich, Schackstraße 4, 80539 DE Munich, Germany; e-mail: luca.galati@lmu.de.

Conflict-of-interest disclosure statement

Luca Galati
I have nothing to disclose.

Terrence Hendershott
I have received compensation exceeding $10,000 during the past three years for expert witness services provided to a variety of clients. Clients may or may not have an interest in the research in this paper. I have no other potential conflicts to disclose.

Saad Ali Khan
I have nothing to disclose.

Ryan Riordan
I have received compensation exceeding $10,000 during the past three years for expert witness services provided to a client. This client may or may not have an interest in the research in this paper. I have no other potential conflicts to disclose.

HUMAN INTERMEDIATION HAS LARGELY DISAPPEARED from modern financial markets. In equities, the transition is essentially complete (O'Hara, 2015). Brokers and designated market makers still stand on the New York Stock Exchange (NYSE), but floor trading accounts for roughly 3% of consolidated share volume that is concentrated in the opening and closing auctions. Nevertheless, in U.S. listed options the floor's footprint is an order of magnitude larger, with over 20% of dollar volume executing through open outcry, almost entirely in S&P 500 index options (SPX) on the Chicago Board Options Exchange (Cboe).[1] Why has open outcry persisted in this corner of the market when it disappeared elsewhere, and what would be lost if it disappeared?

This paper exploits the COVID-19 closure of the Cboe floor to ask what the floor contributes to execution in modern (options) markets, from the characteristics and costs of the trades it handles to how order flow adjusts when the floor is unavailable. The floor attracts complex trades, particularly the largest and most directional. When floor trading resumes on June 15, 2020, the cost of complex trades more than doubles, while costs for simple SPX trades and SPY complex trades are relatively unchanged. During the closure, the riskiest trades become much less prevalent, consistent with the floor facilitating the most difficult trades, but raising the cost of less difficult ones.

These results contribute to three literatures that are related to the value of physical trading floors. A literature on human intermediation in financial markets evaluates whether floor or electronic execution delivers better outcomes (Venkataraman, 2001; Barclay, Hendershott, and McCormick, 2003; Hendershott and Madhavan, 2015), with recent work studying the 2020 NYSE floor closure (Brogaard, Ringgenberg, and Roesch, 2025; Hu and Murphy, 2026).[2] A second literature studies options market microstructure and execution costs (e.g., Muravyev and Pearson, 2020; Kaeck, van Kervel, and Seeger, 2022; Hu, Kirilova, Park, and Ryu, 2024). Kaeck et al. (2022) document that effective spreads

[1]The trading floor has operated since Cboe first opened in 1973 and was the exchange's sole execution mechanism until 1984 when electronic trading for retail orders was first introduced. Cboe trades SPX options exclusively and invested in a new, larger trading floor in Chicago in 2022. Source: Cboe.

[2]In equities, however, the floor's footprint is small enough that disentangling its contribution from confounding variation is difficult. When the NYSE floor suspended operations in March 2020, listed stocks continued to trade simultaneously on more than a dozen alternative venues and more than half of U.S. equity volume executed off-exchange (Mackintosh, 2025), while Options Clearing Corporation rules require all listed options to trade on an exchange. Brogaard et al. (2025) find that the suspension widened spreads and increased pricing errors, and Hu and Murphy (2026) find that the floor reduces closing price efficiency for low-spread stocks.

in SPX options are an order of magnitude larger than price impact, leaving much of the spread unexplained by information asymmetry. A third literature studies the institutional mechanisms through which options orders execute. Bryzgalova, Pavlova, and Sikorskaya (2023) document an increase in retail options trading via wholesalers, Ernst and Spatt (2026) show how wholesalers internalize retail option order flow through designated market maker assignments and price improvement auctions, Anand and Muravyev (2025) show that the auctions facilitating internalization can harm quote competition, and Hendershott, Khan, and Riordan (2026) document how electronic auction mechanisms affect execution quality in options markets.

These literatures share a central methodological challenge. Orders are endogenously routed based on characteristics that also determine execution quality, so direct comparison of floor and electronic execution may conflate the mechanism with the selection of orders into it. The literature often addresses this endogeneity using endogenous switching models that impose strong distributional assumptions on the selection equation, making results sensitive to specification error (Madhavan and Cheng, 1997; Conrad, Johnson, and Wahal, 2003; Bessembinder and Venkataraman, 2004; Hendershott and Madhavan, 2015). The COVID-19 closure of the Cboe floor sidesteps this problem. The floor closed from mid-March through mid-June 2020, allowing us to observe execution costs behaves when the mechanism is unavailable.[3] The floor is used almost exclusively for complex trades involving multiple options, called legs, and accommodates over 70% of complex volume; floor-executed complex SPX trades alone account for 16% of OPRA dollar volume across all options. Because SPX trades only on Cboe, displaced orders that would have gone to the floor have no alternative venue to migrate to. During the closure Cboe activated the Automated Improvement Mechanism (AIM) for SPX, an electronic auction in which a broker exposes a pre-negotiated contra order to competing responses (Hendershott et al., 2026).[4] The changes were reversed at opening. The March 2020 closure coincided with the onset of COVID-19 and is not exogenous to market conditions; the June 2020 opening

[3]The floor had not previously closed while electronic trading continued. During prior exchange-wide shutdowns, such as the four-day closure following September 11, 2001, all trading venues ceased operations simultaneously.

[4]The permissible leg-ratio limit increased from 3:1 to 25:1. Orders with leg ratios above 25:1 account for 3.1% and 2.4% of dollar volume among the riskiest complex SPX trades during the pre-closure and opening periods, respectively. Therefore, these orders do not account for the decline in the riskiest trades documented below during the closure period.

less impacted by changes in market conditions, so we focus on the opening.[5]

When floor trading resumes, the effective spread on complex SPX trades rises from 15 to 27 cents, and total effective spreads nearly double from under \$4 million to almost \$7 million per day. Dollar volume falls from over \$3 billion to nearly \$2 billion, while total delta exposure traded remains unchanged. When the floor opens the same directional risk is transferred through fewer, costlier trades. A logit model of floor routing shows that trade size and absolute delta exposure alone account for 64% of the variation. The most floor-concentrated strategy class is Combo, synthetic futures that create large net directional exposure to the index. Combo makes up nearly 39% of floor complex dollar volume before the closure but only 1.3% of electronic volume. Combo migrates to electronic execution when the floor closes and returns almost entirely to the floor when it resumes.

Matched-sample comparisons control for observable changes in the composition of complex trades to quantify the floor's cost premium. We pair each floor trade following opening with its nearest electronic counterpart during closure on absolute delta, absolute vega, implied volatility, trade size, time to expiration, and number of legs. Floor trades execute at 19.08 cents versus 6.27 cents for matched electronic trades. The floor premium is approximately 7 cents, rising to 58 cents for high delta strategies (Combo). Market-maker revenues mirror this result, with a total Combo strategy floor premium of approximately 59 cents. To examine whether this reflects market conditions rather than the return of the floor, we look at trades largely unaffected by the Cboe floor opening, including simple SPX trades, which execute almost entirely electronically, and complex trades on the S&P 500 ETF (SPY), which execute on venues other than Cboe.[6] Neither of these shows cost increases around opening. The spread distributions in the full, unmatched sample show that floor trades have a much heavier right tail in effective spreads compared to electronic auction trades. Restricting to matched pairs compresses the right tail but does not eliminate the floor premium, confirming that it reflects a broad distributional shift rather than outliers.

[5] Cboe announced a June 8 opening on May 26 and postponed it to June 15 after civil unrest restricted physical access to the building (Cboe Global Markets, 2020a,b). The results are similar using floor closure as our event in Appendix A.

[6] SPX simple are options trades on SPX with a single-leg. We use SPX simple and SPX single-leg interchangeably in this paper. SPY is an ETF based on the S&P 500. SPX is based on the futures price and the SPY on the ETF price.

The floor charges a premium, yet floor trades show no signs of adverse selection. We regress short-horizon S&P 500 futures returns on the signed delta of complex floor-intensive trades (i.e., Combo strategies). Electronic trades generate price impact in the direction of their delta. Within 10 seconds of execution, a higher signed delta is associated with a 1.3 basis point futures return. Floor trades, with comparable signed delta have no price impact, possibly due to floor traders managing adverse selection through non-anonymous repeated relationships (Benveniste, Marcus, and Wilhelm, 1992). Determining whether the floor premium compensates intermediaries for taking large directional positions they cannot hedge immediately (Grossman and Miller, 1988) or from auction better encouraging competition is difficult without more detailed data identifying market participants in the trading process.

The cost advantage of electronic execution, however, applies only to the trades that electronic markets actually accommodate. When the floor closes, the volume of the largest directional trades drops sharply. The share of SPX complex dollar volume from trades simultaneously above the pre-closure floor median in absolute delta, absolute vega, and trade size falls from approximately 22% to 9%. The recovery at opening is sharp and immediate. Replicating the median floor trade's delta exposure electronically requires an average of 3.3 trades spread over 4.6 minutes. The floor intermediates positions that no single electronic counterparty is willing to absorb, because those positions are simultaneously large, carry substantial directional risk, and are difficult to hedge.

Why do the largest directional trades not execute electronically? Electronic auctions (i.e., AIM) require the initiating broker to arrive with a counterparty already lined up. The auction then tests whether competing bids can improve that pre-arranged price. If no single market maker is willing to take the other side of a large directional package on its own, the auction cannot run.[7] The floor works differently. A broker brings the order to the crowd without a pre-arranged counterparty and multiple market makers can split the position via a public negotiation/auction. This enables the crowd to more easily share risk that no individual market maker would assume alone. Therefore, when the floor closes, high delta trades are split into smaller trades or exit the market.

[7] If there is a tie in the auction, the execution can be split across multiple counterparties. Subsequent auction responders can bid for less than the full size, but the auction cannot start unless a single counterparty is first willing to commit to the entire trade.

These findings speak to market design. The floor accounts for 70% of complex SPX dollar volume but only 3.9% of trades. A small number of large, high delta positions generate most of its activity. The floor's cost reflects single execution immediacy for positions that are simultaneously large, directionally exposed, and uninformative. Electronic execution delivers lower costs for smaller, easier trades. Having both mechanisms simultaneously available could lower aggregate transaction costs. Whether the floor's economics survive when its smaller trades execute electronically is an open question.

We make three contributions. First, we identify a setting where trading exogenously switches between floor and electronic mechanisms within the same venue and option class to isolate the mechanism effect from possible selection. Second, we show that the unexplained portion of the SPX spread documented by Kaeck et al. (2022) is not explainable by adverse selection. Third, we extend Bryzgalova et al. (2023), Ernst and Spatt (2026), Anand and Muravyev (2025), and Hendershott et al. (2026) by showing that auction structure differences between the floor and electronic determine costs and which trades can execute electronically.

The paper proceeds as follows: Section I provides the relevant institutional details and data sources; Section II presents preliminary results on trading activity and strategies; Section III analyzes matched trades and compares execution quality across venues; Section IV studies differences in floor and electronic trading and costs; Section V concludes.

I. Data and Institutional Details

Cboe Options Exchange ("C1") operates a hybrid market structure in which electronic order handling and open outcry floor trading coexist (Cboe Global Markets, 2019, 2026).[8] On the electronic side, individual option series are matched through a limit order book, referred to as the Simple Book, where resting orders interact with incoming marketable orders in price-time priority. Multi-leg strategies have their own parallel facility, the Complex Order Book (COB), where an order specifying two or more legs at a guaranteed net price can rest and execute against other complex orders or leg into the individual series books when the combination of available single-leg liquidity permits. In addition to

[8] Cboe's primary options exchange, referred to throughout as C1, is the relevant venue for SPX. SPX trades exclusively on C1 and cannot be routed to any other options exchange.

the COB, Cboe operates a Complex Order Auction (COA) mechanism, which exposes an incoming marketable complex order to competing electronic responses for a brief interval of 100 milliseconds for most classes before filling at the best available price.[9]

In parallel, Cboe maintains a physical trading floor in Chicago where floor brokers represent institutional customer orders in the trading crowd and registered market makers provide liquidity through open outcry negotiation. Floor brokers receive orders from institutional clients, typically asset managers, hedge funds, or other large investors, and work them in the crowd by soliciting competing bids or offers from market makers present on the floor. Unlike electronic markets, where execution occurs through automated matching against a public order book, floor execution involves negotiation of both the net price and the individual leg prices, allowing the parties to reflect the full cost of hedging and the asymmetric nature of the risk transfer. Orders routed to the floor are directed to a workstation known as PAR (Public Automated Routing System), which serves as the interface between the electronic system and floor execution.

A. The Concentration of Floor Trading in SPX

Floor trading in the U.S. listed options market is concentrated almost entirely in a single product. Table I reports average daily trading volume across all option classes reported through OPRA, decomposed by order type and execution venue.

Panel A establishes the aggregate landscape. Complex orders account for roughly half of total OPRA dollar volume (50.67%) but only 28% of contract volume, reflecting the larger notional size of multi-leg packages relative to single-leg trades. Floor execution accounts for 22% of dollar volume and 8.5% of contract volume across all classes. The gap between these two shares confirms that floor trades are systematically larger than their electronic counterparts.

Panel B narrows the focus to SPX. The class accounts for $3.96 billion in average daily dollar volume, or about 26% of total OPRA dollar volume, despite representing only 4% of contract volume. This reflects the high notional value of index options relative to equity and ETF options. Within SPX, complex orders dominate, accounting for 86% of SPX dollar

[9]Under Cboe rules, a marketable complex order that does not opt out of the COA process will initiate an auction upon entry if its net limit price crosses the synthetic best bid or offer derived from the individual leg books. The COA is available for all classes during our sample period.

volume (\$3.39 of \$3.96 billion). Floor execution is similarly concentrated in complex trades. Floor-executed complex SPX orders represent \$2.38 billion per day, or roughly 70% of all SPX complex dollar volume and 16% of total OPRA dollar volume. Floor single-leg SPX volume is trivial by comparison (0.36% of OPRA dollar volume). Equity and ETF options, which represent the large majority of total listed options volume, are traded overwhelmingly through electronic mechanisms, with floor execution accounting for a negligible share.[10]

TABLE I HERE

The fact that SPX is a proprietary Cboe product has a further implication for empirical research. Because SPX cannot be listed or traded on any other exchange, observed differences in execution quality across mechanisms on Cboe cannot reflect differences in the venue or the liquidity pool available to the trader. A researcher comparing floor and electronic execution in equities, by contrast, must contend with the possibility that a trader who routes to the floor of one exchange could have routed electronically to another exchange with different liquidity conditions. That confound is absent here. All SPX volume, across all mechanisms, trades on Cboe.

B. Complex Options Strategies

A complex options order is a single instruction to execute two or more option legs simultaneously at a guaranteed net price. The net price is the sum of the leg prices, weighted by the leg ratios. A strategy that combines a purchased call at a premium of \$3.00 and a sold put at a premium of \$1.00 in a 1:1 ratio would be quoted at a net debit of \$2.00, regardless of where the individual legs trade within that constraint. The guarantee of simultaneous execution is the defining economic feature of a complex order. It eliminates execution risk, the possibility that one leg fills while the other does not, which would leave the trader with an unintended position. For strategies that combine legs with offsetting or partially offsetting exposures, this guarantee is essential because the hedging properties of the package exist only if both legs execute.

[10]These figures are computed over the pre-closure period of our sample, defined as January 2020 through March 15, 2020, and the opening period, including June 15 to October 2020. The calculation excludes the floor closure period of March 16 through June 14, 2020.

The strategies that make up the SPX complex market span a wide range of economic functions. Vertical spreads, in which a call or put is bought and sold at different strikes within the same expiration, provide exposure to a range of index levels while limiting both the maximum gain and the maximum loss. Calendar spreads combine positions at the same strike but different expirations and provide exposure to changes in the term structure of implied volatility. Straddles and strangles combine a call and a put in a way that profits from large moves in either direction. More elaborate structures such as butterflies, condors, and ratio spreads engineer specific payoff profiles across a range of index outcomes. At the high delta end of the spectrum are combos that pair a long (short) call with a short (long) put at the same strike and expiration to replicate a long (short) S&P 500 futures position, sometimes with additional legs. Because the call and put legs contribute deltas of the same sign, a combo's net directional exposure to the index is very large relative to the notional cost of the options. Combos thus carry by far the highest aggregate delta exposure per trade among SPX complex strategies, and we document that this characteristic largely determines which trades execute on the trading floor.

C. The COVID-19 Cboe Trading Floor Closure

On March 16, 2020, Cboe closed the C1 trading floor in response to the COVID-19 pandemic, effective immediately and until further notice (Cboe Global Markets, 2020d,e). All routing to the floor was disabled. Orders containing instructions to execute on the floor were rejected. Market participants could no longer access floor equipment, including the PAR workstations through which floor orders were processed, nor could floor brokers operate in the trading crowd.

To allow complex SPX options to continue trading during the closure, Cboe sought and obtained regulatory approval for two temporary rule changes. First, complex SPX orders with leg ratios up to 25:1, including strategies that had previously been restricted to floor execution, became eligible for electronic processing via the COB and the COA. Second, the Automated Improvement Mechanism (AIM), an electronic auction in which a firm with a pre-negotiated contra order can broadcast that order for competing responses before crossing it, was activated for SPX complex orders during regular trading hours, a function it had not previously performed for that class.[11] SAM, the solicitation auction mechanism,

[11] Cboe's regulatory notice specifies that both rule changes applied only during the electronic-only period

remained inactive for proprietary classes including SPX throughout the closure period.

Floor trading resumed on June 15, 2020. At that point, all temporary rule changes were reversed. The ratio restriction on electronic eligibility for non-conforming SPX complex orders was reinstated at 3:1, and the AIM mechanism for SPX during regular trading hours was deactivated. The market reverted to the hybrid configuration that had existed before the closure, with floor execution restored as the required channel for non-conforming complex SPX strategies. The opening, therefore, represents a second period transition, distinct from the closure, in which access to floor execution was restored while the electronic infrastructure available during the closure, expanded electronic eligibility and AIM, was simultaneously removed. These two transitions, the closure and the opening, together constitute the identifying variation we exploit.

D. Options Data and Types

Our primary data source is the Options Price Reporting Authority (OPRA), which disseminates transaction-level records for all U.S. listed options trades in real time. For each trade, OPRA provides the execution price, contract size, millisecond timestamp, exchange identifier, and a trade condition code. Two characteristics captured by the trade condition code are central to our analysis: whether a trade was executed on the floor or electronically, and whether it was part of a complex package. We focus exclusively on options written on the S&P 500 index (SPX). Because SPX options are a proprietary product of Cboe Global Markets and trade only on Cboe venues, all observations are subject to the same exchange rules, clearing arrangements, and market-maker obligations. Differences in execution outcomes, therefore, reflect differences in trading mechanism rather than differences in listing venue or regulatory environment.

Complex trades are reported in OPRA at the individual leg level, without an identifier linking legs of the same package. We reconstruct packages from leg-level prints through a multi-step procedure, summarized here and detailed in the Internet Appendix Section IA.II.[12] We adapt the time-based algorithm of Li (2020) and Li, Musto, and Pearson (2023), requiring each new leg to fall within both 3 milliseconds of the first leg and 2 milliseconds of the previous leg, rather than either condition alone. This imposes a hard

and would be reverted when open outcry trading resumed (Cboe Global Markets, 2020d,e).

[12]The Internet Appendix may be found in the online version of this article.

3-millisecond cap on total package span. We then classify each group into a standard strategy type (vertical spread, butterfly, condor, combo, combo paired with additional legs, etc.) based on leg structure. Approximately 89% of complex trades are classified successfully; the remainder are labeled non-standard and excluded from the analysis sample. Finally, we assign per-leg trade direction either structurally (i.e., for strategies with deterministic leg roles, such as verticals, butterflies, and iron condors) or via the Lee and Ready (1991) algorithm following Moussawi, Xu, and Zhou (2022), for strategies where leg roles are ambiguous (straddles, strangles, and combos). Overall trade direction follows from the sign of the net package price relative to the midpoint.

All variables are constructed at the trade (complex package) level. Trade size is defined as the total number of contracts across all legs. Dollar volume is the product of the leg prices, total contracts, and the SPX contract multiplier ($100). The contract ratio is the ratio of the largest to the smallest leg size in contracts, capturing the degree of asymmetry across legs. Option characteristics, including absolute net delta, vega, and gamma, are computed as contract-weighted averages across legs using Black-Scholes sensitivities evaluated at the time of each trade, with implied volatility obtained from the prevailing NBBO midpoint on each leg. Days to expiration is the contract-weighted average of the remaining calendar days across legs. Following Li et al. (2023), quoted and effective spreads are computed at the package level using a synthetic midpoint, defined as the contract-weighted sum of leg-level NBBO midpoints with signs determined by each package leg's direction. Spreads are expressed in cents and winsorized at the 0.5% level in each tail.

The sample spans January 2^{nd} through October 21^{st}, 2020 and encompasses three distinct periods: a pre-closure period in which both floor and electronic execution are available, the floor-closure period from March 16 to June 14, 2020, and the floor opening period. The sample begins in January 2020 to exploit variation in the pre-closure period while avoiding any contamination from the institutional rule change effective on October 21, 2019; it ends in October 2020 to exclude the November 16, 2020 rule amendment. We exclude trades executed outside regular trading hours.

E. Futures Data

To examine the delta hedging activity associated with SPX options execution, we supplement the OPRA data with intraday tick-by-tick data on E-mini S&P 500 futures (ES) from LSEG Tick History (formerly Thomson Reuters Tick History, TRTH). This dataset provides millisecond-time-stamped records of trades and best bid-ask quotes for E-mini futures contracts traded on the Chicago Mercantile Exchange's Globex platform. For each observation, we record the trade price, volume, quoted bid and ask, and the timestamp.

We work with the front-month ES contract throughout, rolling to the next contract on the first day of the expiration month to avoid distortions near final settlement.[13] We align futures observations to the option package-level data using a common millisecond-level timestamp grid, matching each option package to the prevailing futures quote and the most recent futures trade price at the time of the package execution. This matching exploits the fact that the majority of delta hedging activity in response to an options execution occurs within seconds of the trade, and allows us to construct measures of contemporaneous futures market conditions for each options package in our sample.

II. Trading Activity and Strategies

The floor closure created a setting in which the same complex SPX order flow executes two ways: on the floor before the closure and at the opening, and electronically in between. Our data follow each trade across all three periods. This section uses that variation to establish who trades on the floor and how. We first describe trading activity and execution costs for single-leg and complex trades across the pre-closure, closure, and opening periods. We then estimate what determines whether a complex order routes to the floor or executes electronically. Finally, we characterize the complex strategies and the trade characteristics that distinguish floor from electronic execution.

A. Descriptive Statistics

Figure 1 plots daily SPX option dollar volume as a share of total OPRA volume. Panel A covers the full sample from January to October 2020. Complex trades account for 20 to 30% of total OPRA dollar volume during normal conditions, while single-leg trades remain stable at roughly 3% to 5%. Complex volume rises sharply in the weeks following the floor closure, peaking above 50% of OPRA dollar volume, before gradually reverting

[13] E-mini futures expire quarterly on the third Friday of March, June, September, and December. We confirm that our results are insensitive to alternative roll conventions.

toward pre-closure levels. Single-leg volume is mostly unaffected. Panel B zooms in on the four weeks surrounding the opening and confirms that neither series exhibits a discontinuity around June 15. Welch t-statistics for the difference in pre- and post-opening means are both statistically insignificant.

FIGURE 1 HERE

Figure 2 decomposes complex SPX volume by execution venue. Panel A shows that before the closure floor execution accounts for the majority of complex SPX dollar volume. During the closure, floor volume drops to zero, and electronic venues execute the flow.[14] At opening, floor trading resumes and electronic volume, without electronic auctions, falls back toward pre-closure levels. Panel B narrows the window to June 1 through June 26. The change at June 15 is immediate. Electronic volume, which consists of all complex SPX activity during the closure, drops sharply on the opening date as floor volume jumps from zero to roughly 20% of OPRA dollar volume. The Welch t-statistic for electronic volume is -14.92, significant at the 1% level, confirming a reallocation at the opening date.

FIGURE 2 HERE

Table II reports daily means of trading activity and execution cost measures for single-leg and complex SPX option trades across the pre-closure, closure, and opening periods. Panel A covers single-leg trades and Panel B covers complex trades. Complex trades dominate SPX volume, accounting for approximately 87% of total dollar volume in every period. They are substantially larger than single-leg trades in contract terms (41 versus 11 in the pre-closure period) with lower per-unit prices ($2.81 versus $25.27 per underlying), reflecting the offsetting structure of multi-leg packages. Trade size in contracts declines monotonically for both trade types across periods, falling from 41 to 27 contracts for complex trades and from 11 to 8 for single-leg trades. Dollar trade size for complex trades moves in the opposite direction during the closure, rising from $150,000 to $260,000, reflecting elevated index levels and volatility rather than a shift toward larger positions.

TABLE II HERE

[14] The near-complete absorption of floor volume by electronic venues suggests that any substitution from SPX options into OTC markets or other instruments was limited during the closure.

The execution costs of complex trades differ markedly between equally-weighted and value-weighted measures. Equally-weighted effective spreads are stable from pre-closure to closure (5.87 to 6.32 cents, not statistically significant) and then decline sharply after the floor resumes (to 3.83 cents). Value-weighted effective spreads move in the opposite direction, falling from 29.51 to 15.20 cents during the closure and recovering to 26.88 cents at opening. Market maker revenues follow the same trajectory in both weighting schemes. The EW/VW divergence arises because the floor intermediates the largest and most expensive complex trades. When the floor closes, these trades either execute electronically at lower spreads or do not execute at all, pulling the value-weighted average down. The equally-weighted measure weights each trade equally. Hedge costs for complex trades are small throughout (0.42 to 0.52 cents equally-weighted), suggesting that the spread premium earned by floor intermediaries is not explained by hedging costs.

Single-leg trades provide a useful benchmark because only a negligible part routes through the floor. Their equally-weighted effective spreads rise from 18.79 to 22.84 cents during the closure and fall to 10.10 cents at opening, and value-weighted spreads follow the same trajectory (39.40 to 57.15 to 27.57 cents). Both weighting schemes move together, in contrast to the different behavior in complex trades. The widening during the closure reflects elevated volatility rather than a venue effect, and the narrowing at opening tracks the return to calmer market conditions. Hedge costs for single-leg trades are stable at roughly 3.5 cents across all three periods.

These unconditional comparisons establish that complex trades dominate SPX volume and that their execution cost dynamics differ fundamentally from single-leg trades across the floor closure and opening. The floor does not expand the market. It intermediates a smaller set of trades at substantially higher per-trade cost. The divergence between equally-weighted and value-weighted measures for complex trades points to a composition effect tied to the floor's selective role in intermediating large, costly packages. To understand what drives these shifts, we next examine which trade characteristics predict floor routing.

B. Floor Routing and Strategy Composition

We begin by asking what determines whether a complex SPX order executes on the trading floor or through electronic channels. We estimate a logit model of the floor routing indicator on the full set of complex SPX transactions during the pre-closure period.

$$\Pr(\text{Floor}_i = 1) = \Lambda(\alpha + \beta' X_i + \mu_s) \tag{1}$$

The dependent variable equals one if trade i executes on the trading floor and zero if it executes electronically. The vector X_i for control variables includes log trade size, absolute delta, days to expiration, vega, gamma, implied volatility, and an SPXW indicator for PM-settled contracts. The term μ_s denotes strategy fixed effects and $\Lambda(\cdot)$ is the logistic function. We estimate eight specifications that progressively add trade characteristics and strategy fixed effects.

TABLE III HERE

Table III reports logit coefficients in Panel A and average marginal effects in Panel B. The unconditional probability of floor execution in the sample is 3.9%, reflecting the fact that most complex trades are small, delta-neutral structures that route electronically. Two variables dominate the routing decision. Trade size alone, in model (1), achieves a pseudo-R^2 of 0.52. Absolute delta alone, in model (2), achieves 0.19. Combining both variables without any additional controls or fixed effects, in model (3), raises the pseudo-R^2 to 0.64. This means that knowing only how large a trade is and how much directional exposure it carries is sufficient to correctly classify nearly two-thirds of routing outcomes. Adding the remaining controls in model (4) raises the pseudo-R^2 to 0.69, and including strategy fixed effects in models (5) through (8) brings it to 0.72 in the fully specified specification. The incremental gain from strategy fixed effects is modest relative to the explanatory power of size and delta alone, indicating that these two characteristics capture the routing decision not only across strategy types but also within them.

Panel B translates the coefficients into average marginal effects evaluated at observed values. In the fully specified specification, an increase in absolute delta of 0.1 raises the probability of floor execution by 0.89 percentage points, making it the strongest economic predictor. Doubling trade size raises floor probability by 1.3 percentage points.[15] Longer maturities, higher vega, and a greater number of legs all increase floor probability, while

[15] Average marginal effect of log trade size is 0.19, a doubling corresponds to $\ln 2 \approx 0.693$, so $0.019 \times 0.693 \approx$ 1.3 percentage points.

higher implied volatility and PM-settled contracts reduce it. The marginal effects remain stable across specifications, confirming that the routing decision is driven primarily by how large and how directionally exposed the trade is.

TABLE IV HERE

We next examine how strategy composition varies across venues and periods. Table IV reports the share of total complex SPX dollar volume by strategy type. Panel A pools floor and electronic trades within each period. Combos account for 25.33% of all complex SPX dollar volume before the closure and 23.07% after the opening, with a temporary rise to 38.61% during the closure as other floor-intensive strategies decline. At the other end of the spectrum, Vertical Put Spreads and Calendar Calls, which are near-delta-neutral and trade predominantly electronically, gain share during and after the closure as electronic execution trades a broader range of order flow.

Panel B disaggregates by venue. Before the closure, Combos account for 38.73% of floor dollar volume but only 1.33% of electronic volume. This concentration is consistent with the logit results. The strategies that carry the highest delta and trade in the largest sizes route almost exclusively to the floor. During the closure, when all order flow executes electronically, Combos account for 38.61% of electronic volume, close to their pre-closure share of floor volume. After the opening, the Combo share of electronic volume falls back to 5.28%, while Combos make up 35.70% of floor volume. The migration is nearly symmetric as the order flow that traded on the floor before the closure returns there once it becomes available again.

TABLE V HERE

Table V shows why Combos dominate floor trading and migrate to electronic venues during the closure. It reports average absolute delta, hedge cost, and trade size for each complex SPX strategy class, sorted by hedge cost. At the top, Combos carry the highest absolute delta (0.32 per underlying), the highest hedge cost ($464 per trade), and the largest average trade size (259 contracts, or $2.27 million). These are directional positions that pair long and short options at the same strike and expiration, and they generate substantial net delta exposure that the counterparty must hedge. Moving down the table, strategies become progressively more balanced. Ratio diagonal spreads carry moderate delta (0.09 to 0.11) and hedge costs between \$100 and \$200. Near the bottom, structures such as Butterflies, Calendar Spreads, and Vertical Spreads are near-delta-neutral with hedge costs below 10 cents and trade sizes one-fifth to one-tenth the size of Combos. The ordering from the top to the bottom of the table corresponds directly to the ordering from floor-intensive to electronically-intensive strategies identified by the logit model.

The logit, strategy characteristics, and volume composition results together identify the segment of complex SPX order flow that concentrates on the floor. This segment consists of large, directional positions with high hedge costs, and it is dominated by a single strategy class that accounts for more than one-third of all floor complex dollar volume. In the next section, we conduct a regression analysis and construct matched samples of floor and electronic trades around the opening and measure how costs differ across venues.

III. Execution Quality

Having established which trades route to the floor, we now ask how execution costs differ between floor and electronic venues for observably comparable trades. Because trades are not randomly assigned to venues, a direct comparison of floor and electronic execution would confound venue effects with differences in order flow characteristics. We address this selection problem through one-to-one nearest-neighbor matching.

A. Sample

We focus on the opening of the trading floor in June 2020 rather than the closure in March 2020. Results for the closure are reported in Appendix A.[16] The initial transition to electronic-only trading coincided with the onset of the COVID-19 pandemic, a period of extreme volatility, volume surges, and shifting market participation that could confound

[16] The results on the closure event are qualitatively similar. The closure may appear more exogenous because it was triggered by a public health emergency rather than a market design decision. The opening, however, provides a much cleaner setting for the reasons described in the introduction. It can also be considered comparably exogenous. On May 26, Cboe announced that the C1 trading floor would re-open on June 8 (Cboe Global Markets, 2020a). On June 3, Cboe postponed the opening to June 15 citing limited access to the area surrounding the Cboe building due to temporary closures in downtown Chicago (Cboe Global Markets, 2020c), a reason entirely unrelated to financial market conditions. No individual trader had the ability to influence or anticipate the exact opening date, and the one-week postponement was driven by circumstances external to the options market.

any comparison through channels unrelated to the venue. The opening occurs in a calmer environment and provides a cleaner test of how floor access affects execution costs.

FIGURE 3 HERE

Figure 3 illustrates the volatility environment across the two events. Panel A shows the VIX rising from roughly 15 to above 80 at the onset of the closure, then declining gradually through the spring. By June the VIX has stabilized between 25 and 35, well below the March peak but still elevated relative to January. Panel B narrows the window to the matching period (June 1 to June 26). The VIX fluctuates between 25 and 40 within this window. A simple difference-in-means test yields a t-statistic of 2.60, indicating that the pre- and post-opening averages differ statistically but the economic magnitude is modest (roughly 29 versus 33). The VIX shows no discontinuity at the opening date itself, supporting the interpretation that the execution quality shifts we document at the opening are not driven by a contemporaneous change in the volatility regime. In the baseline empirical test, we control for VIX directly.

B. Matching

For each floor trade executed in the two weeks after the opening (June 15 to June 26, 2020), we identify its nearest electronic counterpart from the two weeks before the opening (June 1 to June 14, 2020). Matching is one-to-one on six covariates without replacement. The matching covariates are absolute delta, absolute vega, implied volatility, trade size in contracts, days to expiration, and number of legs. We impose a per-variable caliper of 0.25 standard deviations to ensure that matched pairs are close on every dimension rather than merely on a composite distance metric.[17]

TABLE VI HERE

Table VI reports means for floor and electronic trades before and after matching. Panel A compares trade characteristics, and Panel B reports execution quality measures.

[17]Results are robust to full unmatched sample and alternative matching strategies. In addition to our baseline 1:1 nearest-neighbor covariate matching pooling all electronic trades, we obtain qualitatively similar results using: (i) one-to-many nearest-neighbor covariate matching, (ii) propensity score matching on the logit of the estimated propensity score, and (iii) matching floor trades against LOB and AIM electronic trades separately rather than pooling. All robustness tables are available upon request.

Before matching, floor trades differ sharply from electronic trades on every characteristic. Average absolute delta is 0.15 on the floor versus 0.03 electronically, and days to expiration is 68 versus 16. Trade size on the floor averages 372 contracts, compared with 32 electronically. These are the same characteristics the logit identifies as determinants of floor routing, and the differences confirm that the floor serves fundamentally different order flow than the electronic market.

After matching, the differences disappear. Absolute delta is 0.08 for both floor and matched electronic trades, trade size is 228 versus 224 contracts, and days to expiration is 19.1 versus 19.2 days. The rightmost column of Panel A reports means for unmatched floor trades. These trades are substantially more extreme than the matched sample, with average absolute delta of 0.19, trade size of 452 contracts, days to expiration of 96, and 10.2 legs per package. The matched sample of 1,827 pairs, therefore, represents the overlap region of the two distributions, and any cost differences we estimate apply to this shared support. The unmatched floor trades, which have no comparable electronic counterpart within the caliper, are the focus of the unmatched trades analysis in Section IV.B.

The execution quality measures in Panel B, which are not included in the matching algorithm, show a consistent result. Hedge costs are effectively equalized (1.05 cents on both sides), with a difference of 0.01 cents that is economically negligible. This balance arises by construction. The matching covariates include absolute delta, vega, and implied volatility, which together determine the cost of hedging a position in the underlying market. Because matched pairs share the same risk profile, they share the same hedging cost. Effective spreads, by contrast, differ substantially. Floor trades have an average effective spread of 19.08 cents versus 6.27 cents, a gap of 12.81 cents per underlying. Unmatched floor trades have an average effective spread of 47.10 cents, nearly four times the electronic mean. Market maker revenues are similar (18.02 versus 5.22 cents for matched trades, 44.77 cents for unmatched), consistent with the full spread difference accruing to intermediaries as revenue rather than being consumed by hedging costs.

C. Univariate Analysis

Figure 4 plots daily volume-weighted effective spreads for three series across the sample period: SPX complex trades, SPY complex trades, and SPX single-leg trades. Panel A covers January to October 2020. All three series co-move during the high-volatility period surrounding the floor closure in March, consistent with market-wide conditions driving spread dynamics. After the floor trading resumes in June, SPX complex spreads separate from the other two series. Panel B narrows the window to the two weeks before and after the opening. SPX complex effective spreads increase sharply once the floor becomes available, as the large, costly floor trades resume execution and pull the value-weighted average up. The Welch t-statistic for the difference in pre- and post-opening means is 11.51, significant at the 1% level. SPY complex options, which share the same equity exposure as SPX but trade on venues unaffected by the Cboe floor, and SPX single-leg options, which trade on the same exchange but route almost entirely electronically, show no comparable shift. The divergence between SPX complex and the two control series at the exact date of the opening supports the interpretation that the cost differential originates from floor intermediation rather than time-varying market conditions.

FIGURE 4 HERE

Figure 5 decomposes the spread into hedge costs and market maker revenues around the same opening window. The increase in SPX complex spreads is driven by higher market maker revenues ($t = 11.21$), while SPY complex revenues show no significant change. Hedge costs for SPX complex trades increase modestly ($t = 10.13$), but the magnitude is small relative to the revenue effect.

FIGURE 5 HERE

D. Regression Analysis

These unconditional comparisons, however, pool all strategy types. To isolate where the cost differential is concentrated, we estimate the following regression on the matched sample:

$$Y_i = \alpha + \beta_1 \,\text{Opening}_i + \beta_2 \,\text{Combo}_i \times \text{Opening}_i + \gamma' X_i + \mu_s + \varepsilon_i \tag{2}$$

The dependent variable Y_i is the execution cost for trade i, measured in cents per unit of underlying. We estimate two outcomes separately: the effective spread and market maker revenue. Opening_i equals one for floor trades executed after the opening and zero for matched electronic trades during the closure. Combo_i is an indicator for Combo strategies, which the previous section identifies as the most floor-intensive and directionally exposed strategy class. X_i includes trade-level controls (option Greeks and other characteristics), the VIX volatility index, and the average daily effective spreads for SPY complex options and SPX single-leg options, which absorb market-wide and product-specific variation in execution costs. μ_s denotes strategy fixed effects, which control for permanent cost differences across strategy types. The coefficient β_1 captures the average cost difference between floor and electronic execution across all matched strategies. β_2 captures the additional floor premium for Combos relative to the rest of the complex market. Standard errors are clustered by date.

TABLE VII HERE

Table VII reports estimates across two panels. The first four columns estimate the average floor premium across all complex strategies, and the last four add the Combo interaction to isolate the incremental premium for the most floor-intensive strategy class. Within each group, specifications progressively add controls: VIX alone, the SPY complex effective spread, the SPX single-leg effective spread, and the full set of trade-level controls with strategy fixed effects.

Panel A examines effective spreads. The coefficient on Opening in the baseline specification without the Combo interaction is 11.45 cents, indicating that matched floor trades execute at wider spreads than their electronic counterparts on average across all complex strategies. Adding the full set of trade-level controls with strategy fixed effects raises the estimate to 14.12 cents. These averages, however, mask substantial heterogeneity. Adding the Combo interaction, the Opening coefficient falls to 7.39 cents and the Combo interaction enters at 50.85 cents in the full specification, roughly seven times the baseline, indicating that the floor spread premium is concentrated in the most directionally exposed strategy class. For a matched Combo trade, the total floor premium is approximately 58 cents. Including strategy fixed effects absorbs the level effect of Combo but leaves the interaction unchanged, confirming that the premium reflects within-strategy cost differences between floor and electronic execution.

Panel B examines market maker revenues and mirrors the effective spread results. The Opening coefficient is 7.03 cents in the full specification and the Combo interaction is 52.43 cents, for a total Combo premium of approximately 59 cents. Because hedge costs are balanced by construction in the matched sample, the entire effective spread differential translates into market maker revenue. Intermediaries earn more per unit of underlying on floor trades than on observably comparable electronic trades, and the premium is largest for the strategies that carry the most directional exposure.

E. Placebo Tests

We probe the identification further with two placebo tests on trades largely unaffected by the floor opening. Table VIII estimates the same specification on SPY complex options and SPX single-leg options. SPY options track the same equity exposure as SPX but are multi-listed across sixteen exchanges with no dedicated Cboe floor.[18] We apply the same matching procedure used in the main analysis to SPY, yielding 147,863 matched pairs. SPX single-leg options trade on the same exchange as SPX complex options but route almost entirely through electronic channels; we estimate the specification on the full electronic sample of 631,129 trades without matching.

TABLE VIII HERE

Panel A reports effective spread results. The Opening coefficient for SPY complex is economically and statistically indistinguishable from zero across all four specifications (-0.01 cents, $t = -0.24$ in the preferred model). The Combo interaction is 0.11 cents and not significant. SPX single-leg effective spreads are 1.03 cents wider after the opening ($t = 4.80$), a small but statistically significant increase. Panel B reports market maker revenues. SPY complex again shows no effect (-0.00 cents, $t = -0.19$). SPX single-leg revenues increase by 1.65 cents ($t = 4.29$). The SPY results confirm that the SPX complex floor premium does not reflect a market-wide shift in execution costs around the opening date. The modest SPX single-leg effect is an order of magnitude smaller than the complex

[18] We exclude Cboe because the return of floor activity may alter the composition of electronic order flow on that venue. For NYSE American and Nasdaq PHLX, which also operate physical trading floors, we retain only electronic executions. Floor volume on NYSE American and Nasdaq PHLX accounts for a residual share of total SPY activity, and both venues re-opened their floors before the start of our sample window on June 1, 2020. Our results are unchanged if we further exclude these two exchanges entirely. The remaining thirteen exchanges are purely electronic throughout the sample: NYSE Arca, Nasdaq ISE, Nasdaq GEMX, Nasdaq MRX, Nasdaq BX Options, Nasdaq NOM, BOX, MIAX, MIAX Pearl, MIAX Emerald, Cboe C2, Cboe BZX Options, and Cboe EDGX Options.

floor premium (1.03 versus 58 cents for effective spreads) and may reflect limited spillovers from the return of floor activity to the broader SPX option class.

IV. Differences in Floor and Electronic Trading and Costs

The previous sections established what the floor charges and which orders and strategies route to it. This section turns to the orders the electronic market never sees: the large, directional floor positions that have no electronic counterpart. We first merge the complex SPX trade record with tick-level E-mini S&P 500 futures data to characterize how floor and electronic trades of comparable delta relate to short-horizon futures prices. We then ask what happens to these floor-only positions when the floor closes: how much directional exposure leaves the market, what it costs to assemble the median floor position electronically, and how much the floor saves relative to that replication.

A. The Price Impact of Electronic and Floor Trades

The cost results establish that the floor commands a premium for intermediating the most directionally exposed complex positions. We now ask whether this intermediation role affects how hedging demand transmits to the equity market. We merge the complex SPX trade record with tick-level E-mini S&P 500 futures data and compute the log futures return measured at 5 and 10 seconds after each options trade, relative to 100 milliseconds prior. We then regress these short-horizon futures returns on the signed delta exposure of complex Combo, the most floor-intensive option strategies, using the following specification:

$$r^f_{t+h} = \alpha + \beta_1 \,\text{Signed Delta}_i + \beta_2 \,\text{Floor/Period}_i \times \text{Signed Delta}_i + \gamma' X_i + \mu_t + \varepsilon_i \qquad (3)$$

The dependent variable r^f_{t+h} is the E-mini futures return at horizon $h \in \{5, 10\}$ seconds. Signed Delta is the trade's net delta exposure, normalized to \$10,000 per one-point SPX move. Floor$_i$ equals one if the trade executes on the Cboe trading floor and zero otherwise. Period$_i$ equals one if the trade executes during floor closure or opening and zero otherwise. X_i includes trade-level controls: days to expiration, vega, gamma, implied volatility, trade size, an SPXW indicator for PM-settled contracts, and the number of legs. μ_t denotes date fixed effects. The coefficient β_1 captures the futures price impact of electronic trades per unit of signed delta. The coefficient β_2 captures how much of this impact the floor absorbs, so that $\beta_1 + \beta_2$ gives the net futures price impact of a floor trade. Standard errors are clustered by date.

TABLE IX HERE

Table IX reports the results in two panels. Panel A estimates Equation (3) separately for the pre-closure and opening periods, distinguishing floor from electronic trades. In the pre-closure period, a one-unit increase in signed delta on an electronic trade is associated with a 1.31 basis point futures return within 10 seconds of execution, significant at the 1% level. The Floor interaction enters at −1.29 basis points, nearly fully offsetting the main effect. The net futures price impact of a floor trade is, therefore, close to zero ($1.31 - 1.29 = 0.02$ basis points), meaning that the floor executes directional trades without transmitting it to the equity market through immediate delta hedging. The 5-second returns tell the same story at a shorter horizon (0.57 versus −0.57 basis points). In the opening period, the same relationship holds at reduced magnitudes. Electronic trades generate a significant 0.21 basis point futures return at 5 seconds, and the Floor interaction offsets it almost exactly (−0.22 basis points). The smaller magnitudes reflect the lower volatility environment of the opening period rather than a change in the economic mechanism.

Floor trades generate no measurable futures price impact despite carrying comparable signed delta to electronic trades. This suggests that floor intermediaries manage their inventory differently from electronic market makers. Electronic counterparties who assume directional exposure appear to hedge promptly in the futures market, generating price impact in the direction of the trade's delta. Floor market makers, by contrast, either delay their hedging, offset positions internally across multiple clients, or add the exposure into their own inventory without immediately accessing the futures market. The same directional position, therefore, produces equity market transmission when it executes electronically but not when it executes on the floor.

Panel B isolates electronic trades only and examines how their informativeness changes across periods. In the pre-closure period, electronic Combo trades generate significant futures price impact (0.54 basis points at 5 seconds, 1.27 at 10 seconds), consistent with Panel A. When the floor closes, this informativeness vanishes. The Closure interaction nearly fully offsets the main effect (−0.53 at 5 seconds, −1.25 at 10 seconds), leaving a net impact of essentially zero. Electronic order flow becomes uninformative about short-horizon futures returns during the closure, consistent with the high delta positions that would generate equity market transmission exiting the market rather than migrating to electronic channels. We document this exit directly in the next section. When the floor resumes, electronic trades regain some informativeness. The Opening interaction is 0.21 basis points at 5 seconds, significant at the 5% level, indicating that electronic order flow partially recovers its predictive content for futures returns. The magnitude, however, is roughly one-third of the pre-closure level, consistent with the largest directional positions returning to the floor rather than continuing to route electronically.

These results connect with those of Benveniste et al. (1992) on the role of the specialist in trading uninformed but difficult-to-intermediate order flow. In their model, the specialist's advantage lies not in superior information but in the ability to credibly commit to providing liquidity for large positions that the anonymous market cannot. The SPX trading floor operates in the same manner. The high delta Combo positions it intermediates are not informationally motivated in the sense that they do not predict short-horizon equity returns. They are, however, costly to hedge and intermediate. The floor provides a venue where multiple market makers can negotiate the terms of assuming this exposure collectively, without immediately transmitting the hedging demand to the futures market. When the floor is unavailable, these positions do not migrate to electronic channels because no electronic counterparty is willing to pre-committ and assume exposures that are simultaneously large, difficult to hedge, and uninformative about future prices.

The floor, therefore, serves a dual function. It intermediates the most directionally exposed positions at higher per-trade cost, and in doing so it insulates the underlying market from the price impact that those positions would otherwise generate. We next ask whether these high delta positions indeed exit the market during the closure or migrate to electronic channels at different sizes.

B. Understanding Floor Trades that do not Execute Electronically

The matched regressions in Section III.D held the trade fixed and asked, conditional on a strategy existing in both venues, what floor execution costs. That comparison is silent on the trades that exist in only one venue. We now turn to them. The large, directional floor strategies that have no electronic counterpart when the floor closes. We ask three questions and report three findings. First, how much directional exposure leaves the market without the floor? The share of complex SPX dollar volume from trades that simultaneously exceed the pre-closure floor median on absolute delta, absolute vega, and trade size falls from roughly 22% to 9% during the closure and rebounds at the opening. Second, what does it cost to assemble the median floor position electronically? On average 3.3 trades over 4.6 minutes. Third, how much does the floor save relative to that electronic replication? Between 14 and 27% in dollar terms.

We begin by asking what distinguishes these trades. The floor trades that fail to match are the most extreme on every dimension. Table VI in Section III.B shows average trade size for unmatched floor trades is 452 contracts, against 228 for matched floor trades; days to expiration is 96, against 19; absolute delta is 0.19, against 0.08; and the average effective spread is 47 cents, against 19 cents for matched floor trades and 6 cents for matched electronic trades. These are the strategies for which no electronic counterpart exists within the matched sample.

Figure 6 plots daily aggregates for complex SPX trades. Panel A shows that the total dollar effective spread paid nearly doubles, rising from an average of roughly \$3.8 million to \$6.9 million per day (Welch $t = 3.33$).[19] Panel B shows that total complex dollar volume falls from approximately \$3.1 billion to \$2.2 billion ($t = -2.37$). Panel C shows that total absolute net delta exposure is statistically unchanged ($t = 0.39$). The floor's opening raises aggregate intermediation costs while decreasing volume while leaving total directional risk unchanged. Fewer trades with wider spreads, and the additional revenue accrues to floor intermediaries. This is consistent with the results reported in Table II and confirms that the composition shift, not a market-wide repricing, drives the cost increase.

FIGURE 6 HERE

Figure 7 shows where these trades sit in the cost distribution. Panel A uses the full, unmatched sample of 5,093 floor and 36,181 electronic trades executed during the opening period. Electronic spreads concentrate below 10 cents and rarely exceed 20. Floor spreads span the full range, with roughly 14% of trades in the highest bin above 117.50 cents. Panel

[19] In Appendix C, we adjust the total dollar effective spread by VIX and delta exposure to alleviate concerns on potential spreads anticipations of the floor opening.

B restricts the sample to the matched pairs from Table VI in Section III.B. Floor spreads remain higher than electronic spreads across the matched range, and only a small share still falls in the overflow bin. The contrast between the two panels isolates the segment of floor activity that the matched analysis cannot speak to, large directional positions that are costly to intermediate and that no electronic counterparty will absorb.

FIGURE 7 HERE

These positions may migrate to smaller electronic tickets when the floor closes or exit the market entirely. Figure 8 plots the weekly share of complex SPX dollar volume from trades that simultaneously exceed the pre-closure floor median on absolute delta, absolute vega, and trade size. Panel A shows the share holding near 22% before the closure, falling to roughly 9% during the closure, and recovering when the floor resumes. The 13-point drop is the directional exposure that mostly disappears from the trade record when the floor is unavailable, and that the right tail of Figure 7 Panel A represents. Panel B narrows to the two weeks around the opening; recovery is immediate.

FIGURE 8 HERE

How costly is it to reproduce a floor position without the floor? We focus on Combo trades, the most floor-intensive strategy class identified in Section II.B, and ask what it costs to assemble the median floor delta exposure electronically. The target is \$4,218 per SPX point, the median absolute delta exposure of floor Combo trades during the opening period. We construct electronic replication bundles by chaining consecutive electronic Combo trades within each trading day until cumulative absolute delta reaches the target, pro-rating the last trade in a bundle. Bundles are drawn from the closure window (June 1–14, 2020), when all Combo flow executed electronically. The dollar effective spread of each trade is its per-unit spread in cents times its contract count, since the cents-to-dollars conversion and the SPX multiplier cancel. To this spread cost, we add the cost of hedging the accumulated delta in the futures market. The dollar cost of this adverse movement is

$$\text{Slippage}_i = \frac{\hat{\beta}_1 \cdot D_i^2 \cdot S}{10^8} \tag{4}$$

where $\hat{\beta}_1$ is the opening-period electronic price impact coefficient from Panel A of Table IX, D_i is the absolute delta exposure in dollars per SPX point, S is the average SPX level (3,100 in June 2020), and the denominator combines the delta normalization with the basis point conversion. Position size and price movement both scale with D, so the dollar cost grows with D^2 (Kyle, 1985).[20] Total electronic cost is the sum of cumulative spread and slippage.

TABLE X HERE

Table X reports the results. Replicating the median floor delta exposure of $4,218 per SPX point takes an average of 3.3 electronic trades over 4.6 minutes (Panel A), as a single negotiated package is broken into smaller fills. The cumulative electronic cost is roughly $12,240, of which futures slippage is under 1% (Panels B and C). Floor execution of the same exposure costs $8,936 to $10,498, depending on the percentile band, leaving a floor advantage of $1,741 to $3,320 per trade, or 14 to 27%. The advantage widens in the wider bands, so it is not an artifact of subsample selection.

The results highlight a distinction between trade-level and market-level outcomes. For the largest positions the floor is cheaper: replicating the median floor Combo electronically costs 14 to 27% more once fragmentation and slippage are counted. At the market level, however, the electronic regime delivered the same aggregate directional exposure at lower total cost. During the closure, when all flow executed electronically, total absolute delta exposure was statistically unchanged while the total dollar effective spread paid was roughly $3.8 million per day, against $6.9 million once the floor reopened. The floor saves money only on the infrequent extreme positions that the electronic market cannot trade all at once. On the far more numerous orders that exist in both venues, the floor is the more expensive option. Summed across the order flow, this per-trade premium outweighs the savings on the tail.

A natural question is why an electronic mechanism cannot accommodate these trades in the first place. The temporary rule changes during the closure activated electronic auctions for SPX complex orders and raised the electronic leg-ratio limit from 3:1 to 25:1 (Securities and Exchange Commission, 2020, No. 34-88386). Neither change allows

[20] Price impact may be concave, scaling as $\sqrt{D}$ rather than D (Bouchaud, Farmer, and Lillo, 2009). Re-estimating Table IX with sign(Signed Delta) $\times \sqrt{|\text{Signed Delta}|}$ gives a slippage formula of $\hat{\beta}_1^{\surd} \cdot D_i^{3/2} \cdot S/10^6$ and lower costs at large exposures. Three features of the exercise all overstate slippage: the impact coefficient is held constant, the replication targets delta alone, and absolute delta sums exposure regardless of sign. The 3.3 trades over 4.6 minutes are therefore a lower bound. Appendix B repeats the exercise at the 75th percentile (Table BI).

electronic auctions to fully replicate the floor. AIM requires the Initiating Trading Permit Holder to submit an Initiating Order against the Agency Order, so the electronic auction tests whether a pre-paired trade can be price-improved (Hendershott et al., 2026; Cboe Global Markets, 2026, Rules 5.37 and 5.38).[21] The temporary rule expanded who could be a contra in AIM but kept the pairing requirement intact. Floor auctions operate differently. A floor broker brings an order to the crowd and solicits competing responses from multiple Market-Makers who can assume the exposure collectively (Cboe Global Markets, 2026, Rules 5.85 and 5.87). When no single electronic counterparty is willing to be the pre-paired contra on a large, high delta package, AIM cannot run. This asymmetry between paired and unpaired auctions, not the unavailability of an auction mechanism per se, helps explain why some trades exit the market during the closure rather than migrating to AIM.

The floor is not a cheaper version of electronic execution; it is a different service. The matched regressions in Section III.D priced one service, the cost per trade for packages that exist in both venues. The replication analysis prices the other, the cost per unit of directional exposure when the position must be assembled from scratch. Floor trades generate no measurable futures price impact, while electronic trades fragmented across minutes do. The floor sells single-shot immediacy on directional exposure; electronic markets offer a sequence of trades over several minutes at higher total cost and execution risk, when they accommodate the exposure at all.

V. Conclusion

The transition from human-intermediated to electronic trading is one of the defining structural shifts in modern financial markets. In equities, the process is largely complete. In options it is not. The largest complex strategies in S&P 500 index options continue to execute predominantly through open outcry, with a single strategy class (combos) accounting for nearly 39% of floor complex dollar volume. Whether the floor's persistence reflects a genuine intermediation advantage for the most directionally exposed order flow, or merely the absence of a competitive electronic alternative, is a question the prior

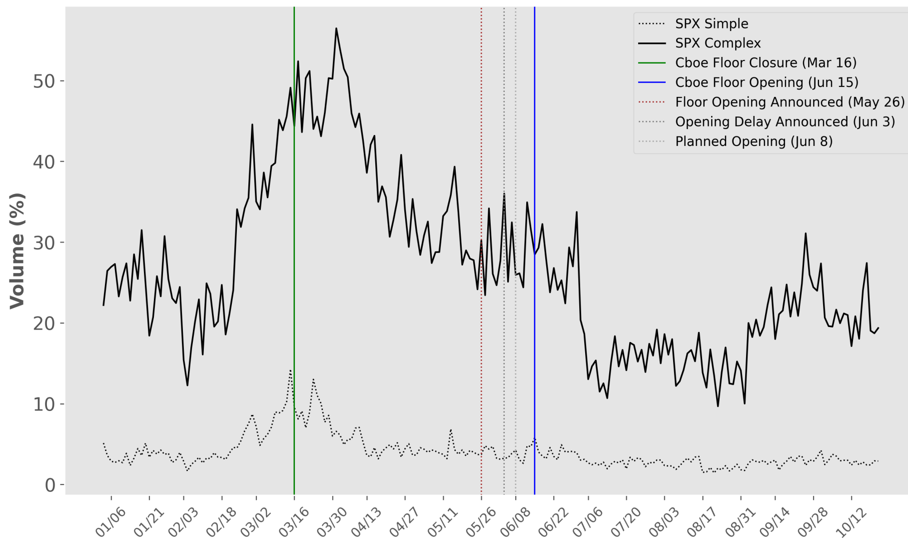
[21] The closure filing acknowledges this asymmetry. Cboe states that large customer orders on the floor are primarily filled by appointed Market-Makers solicited as contras, and that the temporary AIM rule change was needed because the standing AIM prohibition on soliciting appointed Market-Makers would otherwise leave such orders without electronic liquidity (Securities and Exchange Commission, 2020, at 15824–25).

literature has not addressed.

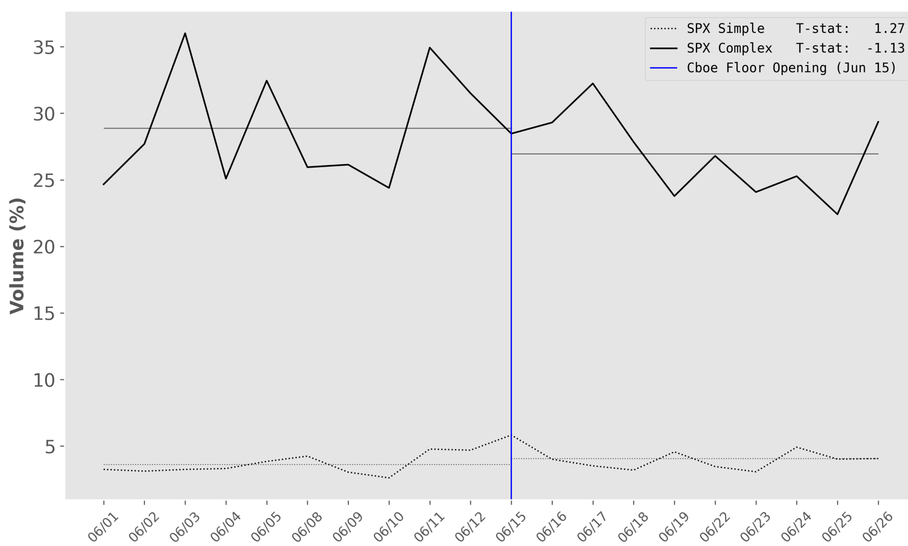
We address it by treating the June 15, 2020, opening of the Cboe trading floor after COVID-19, an event driven by causes external to the options market, as a shock to the availability of open outcry intermediation in SPX, options on the S&P 500 index that only trade on Cboe. We match each floor trade during the opening period to its nearest electronic counterpart during the preceding closure period on absolute delta, absolute vega, implied volatility, trade size, days to expiration, and number of legs. For the most floor-intensive, high delta strategy class, the effective-spread premium on the floor is approximately 58 cents, with a comparable market-maker revenue premium. Because the match holds option characteristics and trade size fixed, the differential reflects how each venue prices intermediation for economically equivalent positions. Placebos on SPY complex trades with the same underlying exposure on different venues, and on SPX single-leg options on Cboe show no comparable shift, ruling out time-varying market conditions as the main source.

The average cost advantage of electronic execution applies only to the trades electronic markets actually accommodate. The largest directional trades become much less prevalent during the closure when they can only be executed electronically, consistent with electronic liquidity providers being unwilling to absorb large exposures that carry substantial inventory and hedging risk. Floor trading appears to enable more efficient risk sharing amongst multiple market makers as compared to the electronic auction which requires at least one market maker to be willing to take the entire complex trade. Preserving floor access while extending electronic coverage to the broader market for complex option strategies should lower aggregate transaction costs without eliminating the execution service that some institutional investors rely on. However, the economic viability of the flow may be threatened if significant floor trading migrated to a coexisting electronic auction mechanism.

Figures

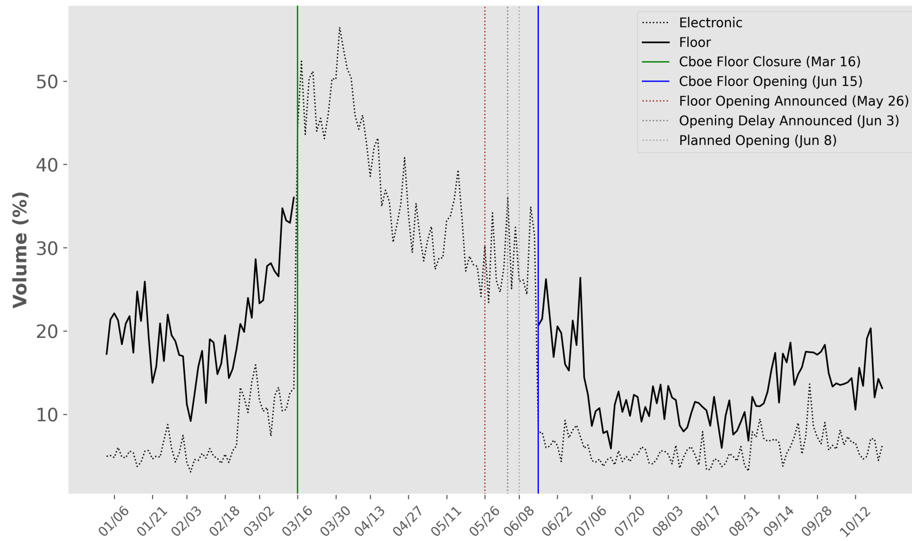


Panel A. Around the Closure and Opening

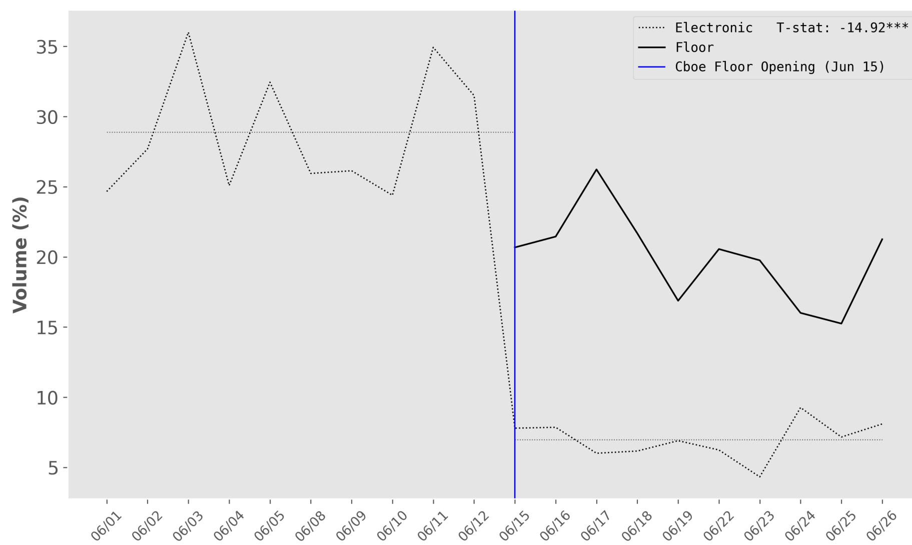


Panel B. Around the Opening (Jun 1 – Jun 26)

Figure 1. SPX Option Volume as Percentage of Total OPRA Volume: Complex versus Simple
This figure plots daily SPX option dollar volume as a percentage of total OPRA volume. Panel A covers the full sample from January to October 2020 and separates complex trades (packages of two or more legs) from single-leg trades. Panel B zooms in on the four weeks surrounding the floor opening on June 15, 2020. The solid green line marks the Cboe floor closure on March 16, 2020, and the solid blue line marks the floor opening on June 15, 2020. The dotted vertical lines mark the announcement of the planned opening on May 26, the announcement of the delay on June 3, and the originally planned opening date of June 8. Horizontal lines show closure and opening period means for each series. The legend in Panel B reports Welch t-statistics for the difference in means between the two sub-periods. *$p < 0.10$; **$p < 0.05$; *** $p < 0.01$.

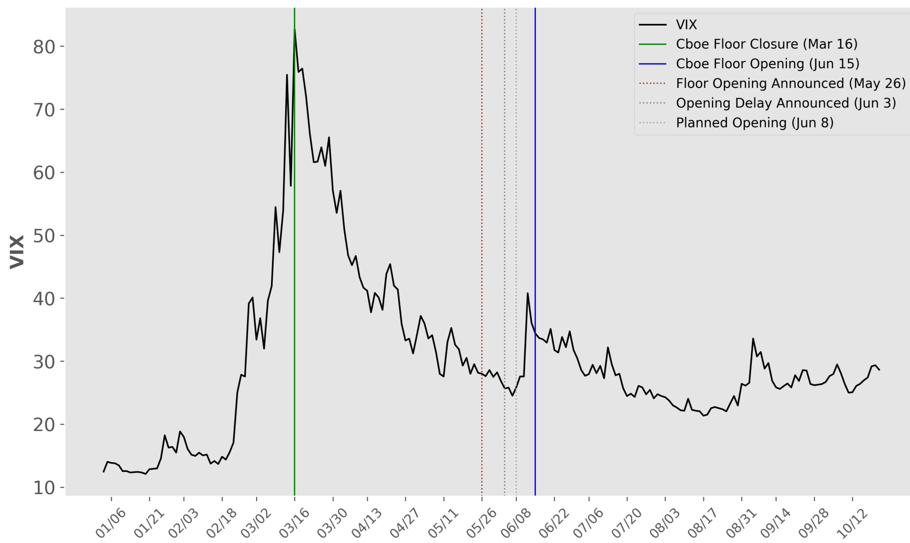


Panel A. Around the Closure and Opening



Panel B. Around the Opening (Jun 1 – Jun 26)

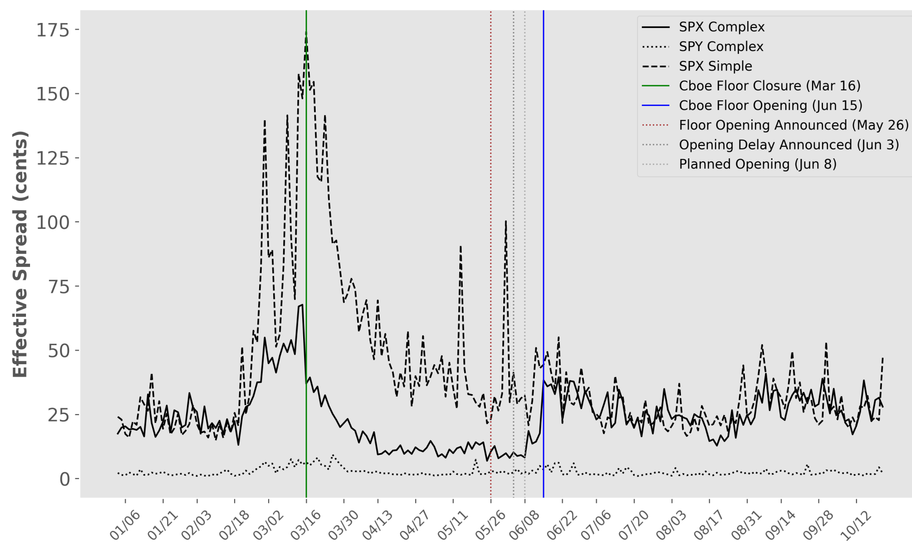
Figure 2. SPX Option Volume as Percentage of Total OPRA Volume: Floor versus Electronic
This figure plots daily floor and electronic complex SPX option dollar volume as a percentage of total OPRA volume. Panel A covers the full sample from January to October 2020. Panel B narrows the window to the four weeks surrounding the floor opening on June 15, 2020. The solid green line marks the Cboe floor closure on March 16, 2020, and the solid blue line marks the floor opening on June 15, 2020. The dotted vertical lines mark the announcement of the planned opening on May 26, the announcement of the delay on June 3, and the originally planned opening date of June 8. Horizontal lines show closure and opening period means for each series. The legend in Panel B reports Welch t-statistics for the difference in means between the two sub-periods. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}\ p < 0.01$.



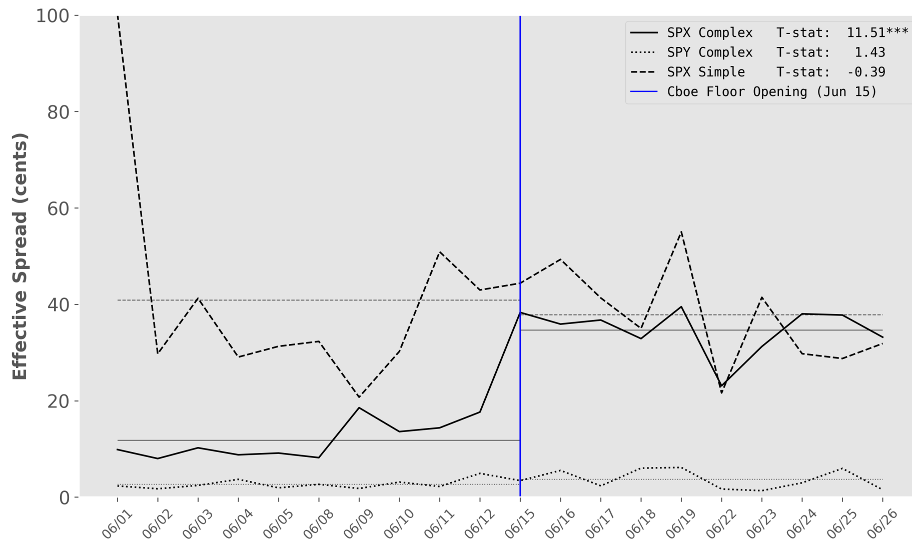
Panel A. Around the Closure and Opening

Panel B. Around the Opening (Jun 1 – Jun 26)

Figure 3. VIX Around the Closure and Opening
This figure plots the daily closing level of the Cboe Volatility Index (VIX). Panel A covers the full sample from January to October 2020. The solid green line marks the Cboe floor closure on March 16, and the solid blue line marks the floor opening on June 15. The dotted vertical lines mark the announcement of the planned opening on May 26, the announcement of the delay on June 3, and the originally planned opening date of June 8. Panel B narrows the window to the two weeks before and after the opening (June 1 to June 26, 2020). Horizontal lines show closure and opening period means for each series. The legend in Panel B reports Welch t-statistics for the difference in means between the two sub-periods. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}\ p < 0.01$.



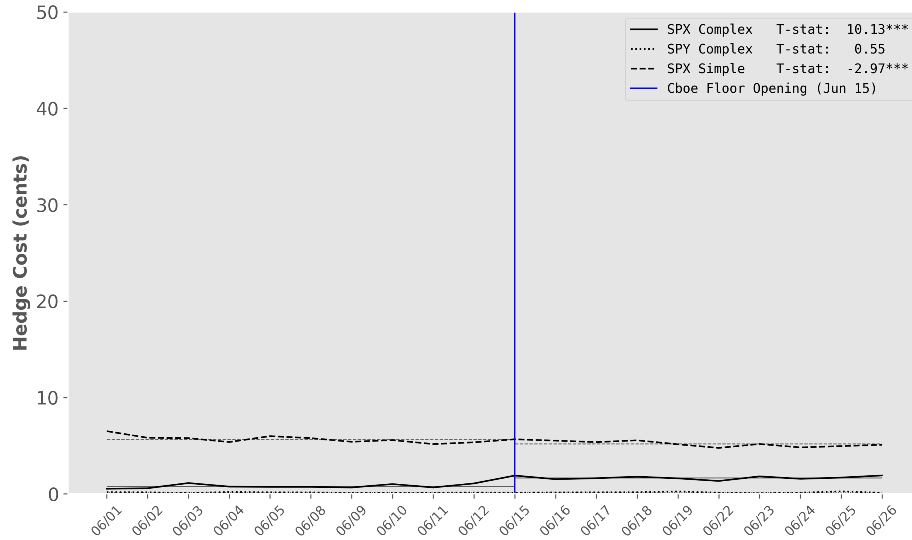
Panel A. Around the Closure and Opening



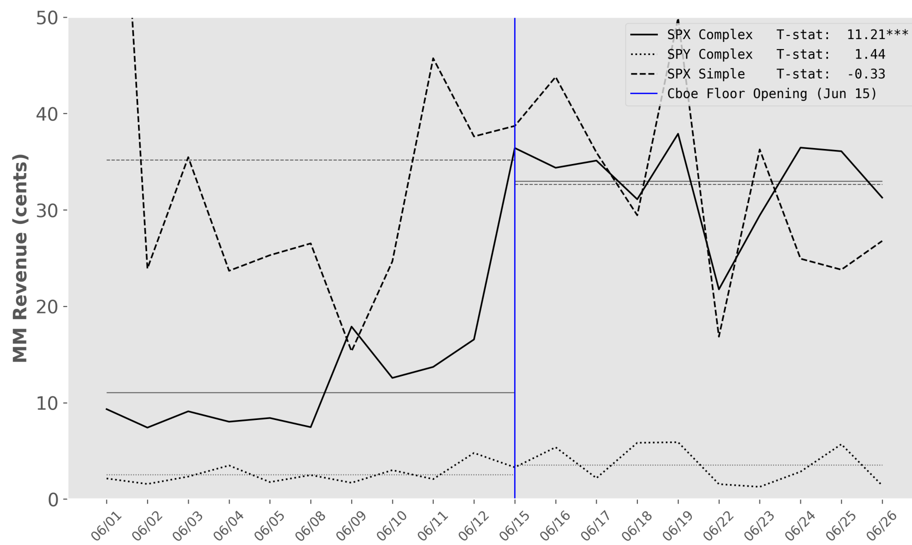
Panel B. Around the Opening (Jun 1 – Jun 26)

Figure 4. Volume-Weighted Effective Spreads

This figure plots daily volume-weighted effective spreads in cents for three series: SPX complex trades (solid line), SPY complex trades (dotted line), and SPX simple trades (dashed line). Panel A covers the full sample from January to October 2020. The solid green line marks the Cboe floor closure on March 16, and the solid blue line marks the floor opening on June 15. The dotted vertical lines mark the announcement of the planned opening on May 26, the announcement of the delay on June 3, and the originally planned opening date of June 8. Panel B narrows the window to the two weeks before and after the opening (June 1 to June 26, 2020). Horizontal lines show closure and opening period means for each series. The legend in Panel B reports Welch t-statistics for the difference in means between the two sub-periods. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}\ p < 0.01$.



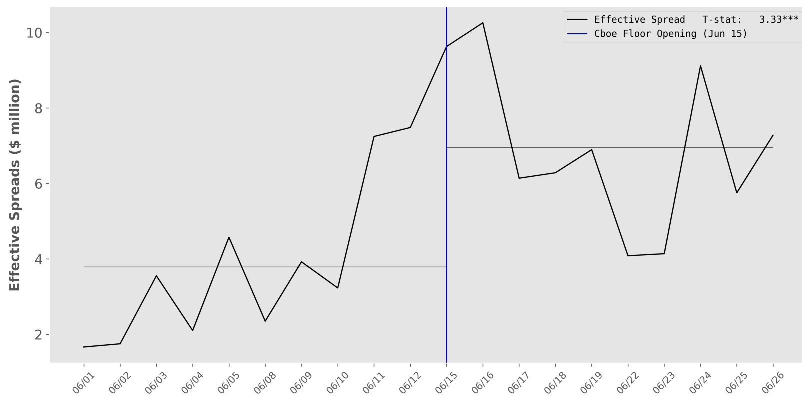
Panel A. Hedge Costs



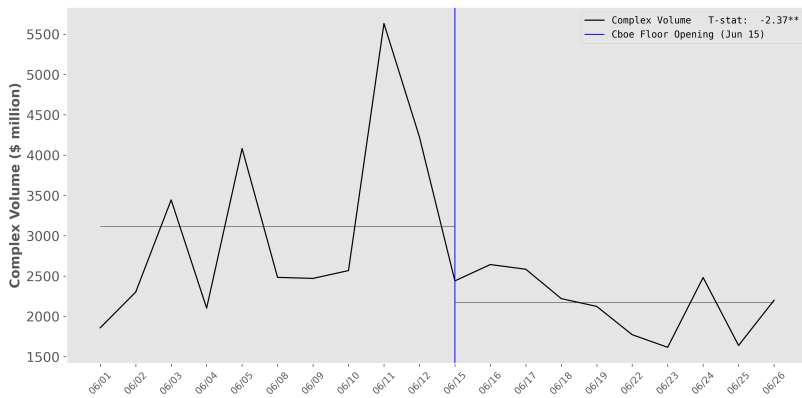
Panel B. Market Maker Revenues

Figure 5. Hedge Cost and Market Maker Revenue

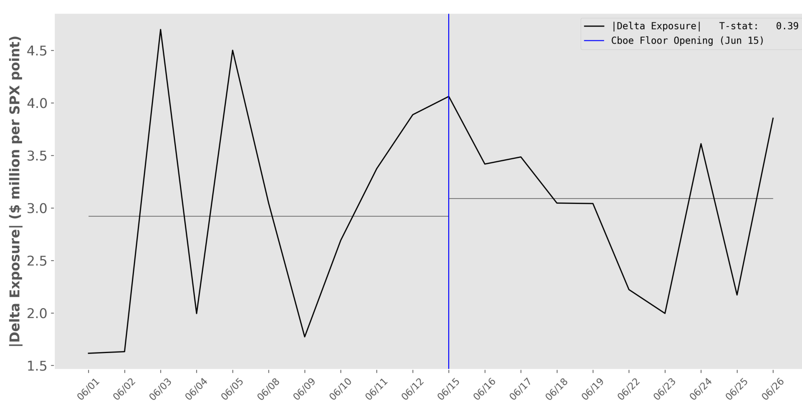
This figure plots daily volume-weighted hedge costs (Panel A) and market maker revenue (Panel B) in cents for three series: SPX complex trades (solid line), SPY complex trades (dotted line), and SPX simple trades (dashed line). Both panels cover the two weeks before and after the Cboe floor opening (June 1 to June 26, 2020). The solid blue line marks the opening on June 15, 2020. Horizontal lines show closure and opening period means for each series. The legend reports Welch t-statistics for the difference in means between the two sub-periods. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}\ p < 0.01$.



Panel A. Total Effective Spread Paid

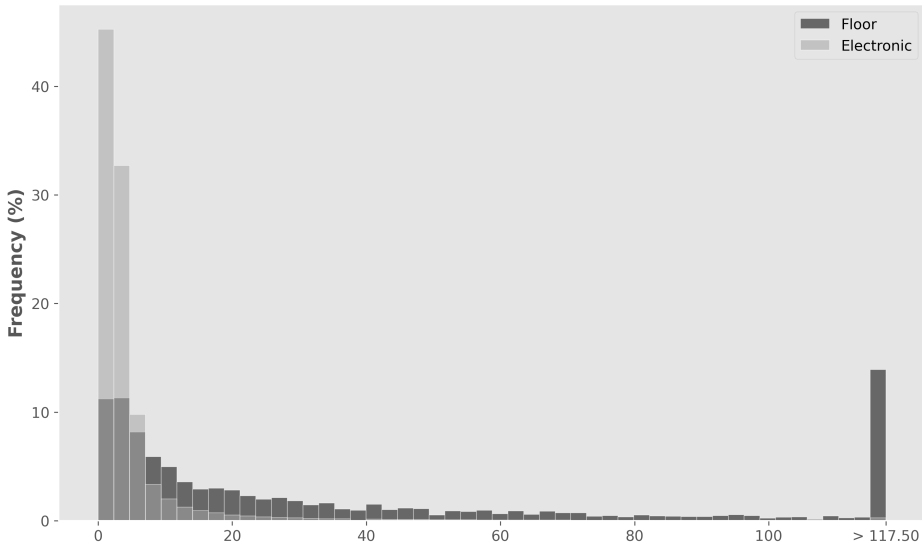


Panel B. Total Complex SPX Volume

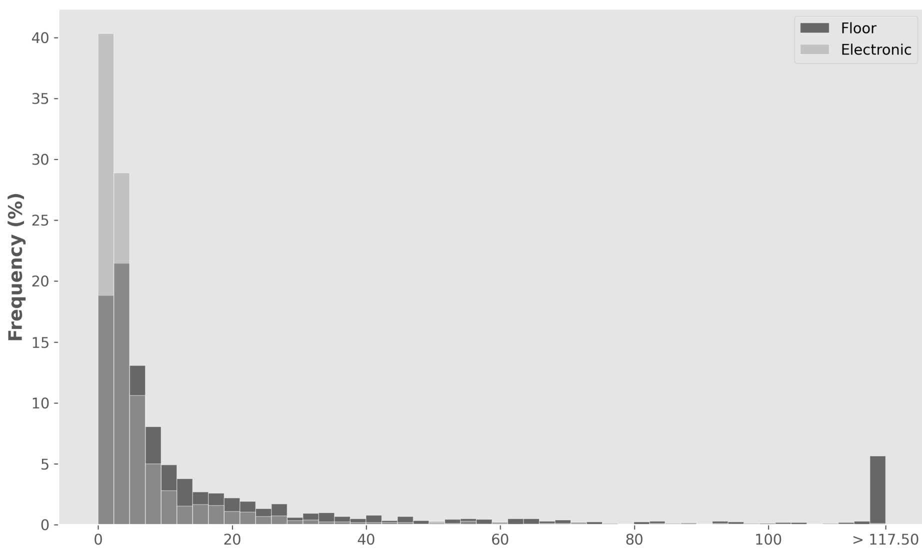


Panel C. Total Absolute Delta Exposure

Figure 6. Trading Activity Around the Opening
This figure plots daily aggregates for complex SPX trades during the two weeks before and after the floor opening (June 1 to June 26, 2020). Panel A reports the total dollar effective spread paid across all complex SPX trades in millions. Panel B reports total complex SPX dollar volume in millions. Panel C reports total absolute net delta exposure in millions. The solid blue vertical line marks the floor opening on June 15, 2020. The horizontal grey lines denote closure and opening period averages, and each panel reports the Welch t-statistic for the difference in means. *$p < 0.10$; **$p < 0.05$; *** $p < 0.01$.



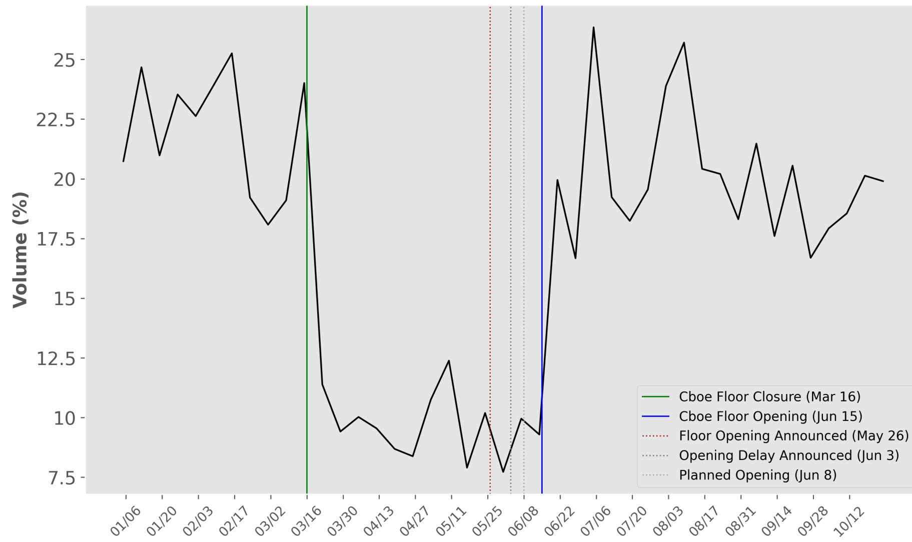
Panel A. Full Sample (Unmatched)



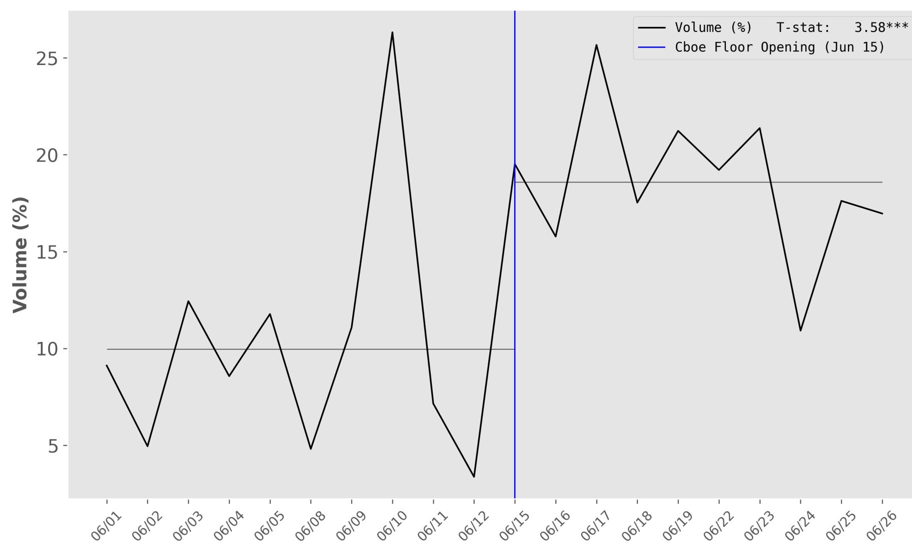
Panel B. Matched Sample

Figure 7. Effective Spreads by Venue

This figure plots the distribution of effective spreads (in cents) for floor and electronic complex SPX trades executed during the opening period. Panel A uses the full unmatched sample of 5,093 floor trades and 36,181 electronic trades. Panel B restricts the sample to the 1,827 matched pairs from Table VI. The horizontal axis measures effective spreads in cents. The vertical axis measures the percentage of trades in each bin.



Panel A. Around the Closure and Opening



Panel B. Around the Opening (Jun 1 – Jun 26)

Figure 8. Share of Trades Exceeding Floor Median (|Δ|, |ν|, Trade Size)
This figure plots the share of SPX complex dollar volume from trades whose absolute delta, absolute vega, and trade size each simultaneously exceed the corresponding pre-closure floor-sample median. Panel A reports weekly averages and covers the full sample from January to October 2020. The solid green line marks the Cboe floor closure on March 16, and the solid blue line marks the floor opening on June 15. The dotted vertical lines mark the announcement of the planned opening on May 26, the announcement of the delay on June 3, and the originally planned opening date of June 8. Panel B reports daily averages and narrows the window to the two weeks before and after the opening (June 1 to June 26, 2020). Horizontal lines show closure and opening period means. The legend in Panel B reports the Welch t-statistic for the difference in means between the two sub-periods. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}\ p < 0.01$.

Tables

Table I. Option Trading

This table reports average daily option trading volume in dollar terms and contract terms across all U.S. listed option classes reported through the Options Price Reporting Authority (OPRA). The sample covers the pre-closure (January 2 to March 13, 2020) and opening (June 16 to October 21, 2020) periods, excluding the floor closure period. Dollar volume is reported in billions and contract volume in hundreds of thousands. The % OPRA columns express each category as a share of total OPRA volume. Panel A reports volume for all option classes, decomposed by order type (complex versus single-leg) and execution venue (floor versus electronic). Panel B restricts attention to the S&P 500 index (SPX) option class and further decomposes SPX volume by order type and floor participation.

Panel A: All Option Classes

	$ Volume		Contract Volume	
	$ billions	% OPRA	100,000	% OPRA
Complex	7.39	50.67	74.53	28.22
Simple	6.90	49.33	189.85	71.78
Floor	3.25	22.00	22.37	8.54
Electronic	11.04	78.00	242.00	91.46

Panel B: SPX Option Class

	$ Volume		Contract Volume	
	$ billions	% OPRA	100,000	% OPRA
SPX	3.96	25.83	10.87	4.12
Complex	3.39	22.32	8.07	3.06
Simple	0.57	3.51	2.80	1.06
SPX Electronic	1.51	9.52	6.55	2.47
Complex	1.01	6.36	4.07	1.53
Simple	0.50	3.16	2.48	0.94
SPX Floor	2.45	16.31	4.33	1.65
Complex	2.38	15.95	4.01	1.53
Simple	0.07	0.36	0.32	0.12

Table II. Descriptive Statistics
This table reports daily means of trading activity and execution cost measures for SPX options across the pre-closure (January 2 to March 13, 2020), closure (March 16 to June 14, 2020), and post-closure (June 15 to October 21, 2020) periods. Panel A covers single-leg trades and Panel B covers complex trades, defined as packages of two or more option legs executed as a single transaction. Within the pre-closure and post-closure periods, floor and electronic trades are pooled; the closure period contains electronic trades only by construction. Volume is the share of total SPX dollar volume. Trade Size is measured in contracts and millions of dollars. Net Price (Panel B) and Price (Panel A) are the execution price in dollars per unit of the underlying index. Effective Spread is the absolute difference between the execution price and the midpoint of the quoted spread at the time of execution, in cents. Hedge Cost is defined as the absolute delta exposure of the trade multiplied by the quoted spread in E-mini S&P 500 futures prevailing at the time of the option trade, measured in cents. MM Revenue is the effective spread minus the hedge cost. All three execution cost measures are reported as equally-weighted (EW) and value-weighted (VW) daily means. The last two columns report differences in means between adjacent periods. Statistical significance is assessed using a two-sample Welch t-test with standard errors clustered by date. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Panel A: Simple Trades

Variables	Units	Pre-Closure	Closure	Opening	Closure – Pre-Closure	Opening – Closure
Volume	% of SPX Volume	12.09	11.50	12.37	−0.59	0.87**
Trade Size	Contracts	10.99	9.95	7.95	−1.04***	−2.00***
	$ Million	0.02	0.03	0.01	0.01***	−0.02***
Price	$	25.27	39.89	22.35	14.62***	−17.54***
Effective Spread (EW)	Cents	18.79	22.84	10.10	4.05	−12.74***
Effective Spread (VW)	Cents	39.40	57.15	27.57	17.75***	−29.58***
Hedge Cost (EW)	Cents	3.54	3.58	3.57	0.04	−0.01
Hedge Cost (VW)	Cents	5.55	5.81	5.50	0.26*	−0.31**
MM Revenue (EW)	Cents	15.25	19.26	6.53	4.01	−12.73***
MM Revenue (VW)	Cents	33.85	51.34	22.07	17.49***	−29.27***

Panel B: Complex Trades

Variables	Units	Pre-Closure	Closure	Opening	Closure – Pre-Closure	Opening – Closure
Volume	% of SPX Volume	86.01	87.77	86.84	1.76***	−0.93**
Trade Size	Contracts	41.18	35.30	26.87	−5.88***	−8.43***
	$ Million	0.15	0.26	0.09	0.11***	−0.17***
Net Price	$	2.81	3.94	2.67	1.13***	−1.27***
Effective Spread (EW)	Cents	5.87	6.32	3.83	0.45	−2.49***
Effective Spread (VW)	Cents	29.51	15.20	26.88	−14.31***	11.68***
Hedge Cost (EW)	Cents	0.52	0.42	0.46	−0.10***	0.04***
Hedge Cost (VW)	Cents	1.84	0.91	1.70	−0.93***	0.79***
MM Revenue (EW)	Cents	5.35	5.90	3.37	0.55	−2.53***
MM Revenue (VW)	Cents	27.68	14.28	25.19	−13.40***	10.91***

Table III. Determinants of Floor Trading
This table reports logistic regressions where the dependent variable equals one if a complex SPX option trade executes on the trading floor and zero if it executes electronically. The sample covers the pre-closure period (January 2 to March 13, 2020) and contains 913,270 observations. The estimated specification follows Equation (1):

$$\Pr(\text{Floor}_i = 1) = \Lambda(\alpha + \beta' X_i + \mu_s)$$

where X_i includes log trade size, absolute delta, days to expiration, vega, gamma, implied volatility, an SPXW indicator for PM-settled contracts, and log number of legs. μ_s denotes strategy fixed effects, which absorb the log legs variable, and $\Lambda(\cdot)$ is the logistic function. Panel A reports logit coefficients with z-statistics in parentheses, computed from standard errors clustered by date. Panel B reports average marginal effects, computed as the mean change in the predicted probability of floor execution from a one-unit increase in each variable evaluated at observed values. For log-transformed variables (trade size and legs), a one-unit increase corresponds to an approximate doubling. The unconditional floor probability is 0.039. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}\ p < 0.01$.

Panel A: Estimated Coefficients								
Log Trade Size	1.61***		1.67***	1.56***	1.58***		1.62***	1.57***
	(93.37)		(71.39)	(60.96)	(66.30)		(64.50)	(62.46)
|Delta|		10.48***	12.17***	10.75***		3.99***	7.27***	7.16***
		(43.28)	(49.20)	(45.56)		(13.05)	(23.53)	(24.21)
Days-to-Expiration				0.14***				0.05**
				(6.84)				(2.21)
Vega				0.24***				0.17***
				(18.02)				(9.44)
Gamma				−0.04***				−0.04***
				(−4.93)				(−4.87)
IV				−0.84***				−1.12***
				(−5.39)				(−8.24)
SPXW				−1.14***				−1.12***
				(−21.87)				(−19.15)
Log Legs				0.48***				
				(11.79)				
Intercept	−9.23***	−3.98***	−10.42***	−9.81***				
	(−109.94)	(−167.70)	(−96.50)	(−73.20)				
Strategy FE	No	No	No	No	Yes	Yes	Yes	Yes
Pseudo R-squared	0.52	0.19	0.64	0.69	0.68	0.37	0.70	0.72

Panel B: Average Marginal Effects								
Log Trade Size	0.035		0.027	0.021	0.022		0.022	0.019
|Delta|		0.325	0.194	0.144		0.099	0.098	0.089
Days-to-Expiration				0.002				0.001
Vega				0.003				0.002
Gamma				−0.001				−0.001
IV				−0.011				−0.014
SPXW				−0.018				−0.017
Log Legs				0.006				

Table IV. Complex Strategy Composition

This table reports the percentage of total SPX complex dollar volume attributable to each strategy type across the pre-closure (January 2 to March 13, 2020), closure (March 16 to June 14, 2020), and opening (June 15 to October 21, 2020) periods. Strategies are classified following Li et al. (2023) based on the configuration of option legs within each package. Panel A pools floor and electronic trades within each period; the closure period contains electronic trades only by construction. Panel B disaggregates by venue. For the pre-closure and opening periods, the Floor and Electronic columns report separate volume shares summing to 100% within each venue-period. The closure column reports electronic volume shares only. Combo denotes synthetic futures constructed by pairing a long call with a short put (or vice versa) at the same strike and expiration. All values are percentages.

Panel A: Volume by Strategy and Period

Strategy	Pre-Closure	Closure	Opening
Combo	25.33	38.61	23.07
Ratio Diagonal Put Spread	6.89	3.56	6.61
Ratio Diagonal Call Spread	3.37	2.02	4.39
Vertical Put Ratio	8.67	3.62	6.22
Vertical Call Ratio	2.77	1.62	4.77
Diagonal Put Spread	3.43	2.51	2.63
Vertical Call Spread	4.00	5.40	7.97
Vertical Put Spread	15.26	13.90	10.86
Butterfly	4.34	2.67	3.34
Calendar Put	5.35	6.86	4.46
Calendar Call	2.11	4.84	6.44
Others	18.49	14.42	19.22

Panel B: Volume by Strategy, Venue, and Period

Strategy	Electronic			Floor	
	Pre-Closure	Closure	Opening	Pre-Closure	Opening
Combo	1.33	38.61	5.28	38.73	35.70
Ratio Diagonal Put Spread	1.58	3.56	0.45	9.86	10.99
Ratio Diagonal Call Spread	0.98	2.02	0.42	4.71	7.21
Vertical Put Ratio	4.70	3.62	2.33	10.88	8.97
Vertical Call Ratio	1.75	1.62	1.88	3.34	6.82
Diagonal Put Spread	5.26	2.51	4.59	2.41	1.23
Vertical Call Spread	8.84	5.40	14.80	1.30	3.13
Vertical Put Spread	27.04	13.90	18.49	8.69	5.45
Butterfly	10.69	2.67	7.48	0.80	0.39
Calendar Put	11.97	6.86	8.59	1.66	1.53
Calendar Call	4.40	4.84	13.81	0.83	1.22
Others	21.48	14.42	21.91	16.80	17.36

Table V. Complex Strategy Characteristics

This table reports average trade characteristics for each complex SPX strategy type, excluding the floor closure period (March 16 to June 14, 2020). Floor and electronic trades are pooled. Strategies are classified following Li et al. (2023) based on the configuration of option legs within each package, and sorted by descending hedge cost. |Delta| is the absolute net delta of the package per unit of the underlying index. Hedge Cost is defined as the absolute net delta exposure of the trade multiplied by the half quoted spread in E-mini S&P 500 futures prevailing at the time of the option trade, reported in hundreds of dollars. Trade Size is reported in contracts and millions of dollars.

Strategy	|Delta| Per Underlying	Hedge Cost $ Hundreds Per Trade	Trade Size	
			Contracts	Million $
Combo	0.32	4.64	259.19	2.27
Ratio Diagonal Put Spread	0.09	1.91	236.48	1.33
Ratio Diagonal Call Spread	0.11	1.82	160.60	0.94
Vertical Put Ratio	0.04	0.49	105.83	0.34
Vertical Call Ratio	0.06	0.41	71.30	0.25
Diagonal Put Spread	0.05	0.16	32.52	0.14
Vertical Call Spread	0.05	0.10	18.07	0.03
Vertical Put Spread	0.03	0.09	24.23	0.05
Butterfly	0.01	0.06	44.31	0.11
Calendar Put	0.02	0.04	15.95	0.10
Calendar Call	0.02	0.03	11.81	0.06
Others	0.03	0.14	33.37	0.13

Table VI. Matched Sample Summary Statistics

This table compares pre-matching and post-matching means for floor and electronic complex SPX trades around the opening of the Cboe trading floor. For each floor trade executed in the two weeks after the opening (June 15–26, 2020), we identify the nearest electronic trade from the two weeks before the opening (June 1–14, 2020) using one-to-one nearest-neighbor matching without replacement. We match on six covariates: absolute delta (|Delta|), absolute vega (|Vega|), implied volatility, trade size in contracts, days to expiration, and number of legs, imposing a per-variable caliper of 0.25 standard deviations. Panel A reports the matching covariates before and after matching. Panel B reports execution quality measures that are not included in the matching algorithm: the effective spread, hedge cost, and market maker revenue, all measured in cents. Within each panel, the left columns report pre-matching means and differences, and the right columns report post-matching means and differences. The sample contains 3,654 trades (1,827 matched pairs) with a match rate of 35.9%.

Panel A: Options Trade Characteristics

	Before Matching			After Matching			
	Floor	Electronic	Difference	Floor	Electronic	Difference	Floor Unmatched
|Delta|	0.15	0.03	0.12	0.08	0.08	0.00	0.19
|Vega|	1.48	0.23	1.25	0.40	0.39	0.01	2.08
Implied Vol.	0.29	0.25	0.04	0.28	0.28	−0.00	0.30
Trade Size	371.57	31.88	339.70	228.36	224.33	4.03	451.68
Days-to-Exp.	68.20	16.07	52.14	19.05	19.22	−0.17	95.70
Legs	7.62	3.11	4.51	3.02	2.79	0.23	10.20

Panel B: Execution Quality

	Before Matching			After Matching			
	Floor	Electronic	Difference	Floor	Electronic	Difference	Floor Unmatched
Effective Spread	37.05	4.38	32.67	19.08	6.27	12.81	47.10
Hedge Cost	1.87	0.44	1.44	1.05	1.05	0.01	2.33
MM Revenue	35.18	3.95	31.23	18.02	5.22	12.81	44.77

Table VII. Execution Quality and Floor Opening

This table reports OLS regressions of effective spread and market maker revenue on matched samples of complex SPX trades. Each post-opening floor trade (June 15–26, 2020) is matched 1:1 without replacement to the nearest pre-opening electronic trade (June 1–14, 2020) on |delta|, |vega|, implied volatility, trade size, days to expiration, and number of legs. The estimated specification follows Equation (2):

$$Y_i = \alpha + \beta_1 \, Opening_i + \beta_2 \, Combo_i \times Opening_i + \gamma' X_i + \mu_s + \varepsilon_i$$

where Y_i is measured in cents. $Opening_i$ equals one for trades executed after the opening and zero otherwise. $Combo_i$ equals one if the traded strategy is a Combo and zero otherwise. X_i includes trade-level controls in all specifications: quoted spread, absolute delta, days to expiration, vega, gamma, implied volatility, log trade size, a PM-settled indicator, the average daily effective spread for SPY complex options and SPX single-leg, and the VIX volatility index. μ_s denotes strategy fixed effects. Absolute delta is omitted from the market maker revenue regressions because it mechanically determines the hedging cost component of the dependent variable. The sample contains 3,654 trades (1,827 matched pairs). t-statistics in parentheses are computed from standard errors clustered by date. Intercept and some controls are omitted for brevity. $^{*}p < 0.10$; $^{**}p < 0.05$; *** $p < 0.01$.

Panel A: Effective Spread								
	Overall				High Delta Strategy			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Opening	11.45***	13.51***	13.04***	14.12***	6.45***	7.88***	7.69***	7.39***
	(4.17)	(11.41)	(12.23)	(11.42)	(4.30)	(10.95)	(9.03)	(10.39)
Combo					15.73***	14.87***	14.68***	
					(3.91)	(3.96)	(3.90)	
Combo × Opening					50.63***	50.50***	50.56***	50.85***
					(7.62)	(8.00)	(8.06)	(12.02)
VIX	0.61***	0.20**	−0.15	−0.45**	0.41***	0.14**	0.01	−0.25**
	(2.78)	(2.08)	(−1.15)	(−2.57)	(3.47)	(2.55)	(0.06)	(−2.44)
SPY Complex ES		10.10***	1.78	3.51		7.08***	3.91	2.41
		(9.26)	(0.49)	(1.02)		(10.66)	(1.48)	(0.97)
SPX Simple ES			1.41***	0.29			0.54	0.42
			(2.63)	(0.51)			(1.34)	(1.10)
|Delta|				83.12***				77.16***
				(5.10)				(5.57)
Other Controls	No	No	No	Yes	No	No	No	Yes
Strategy FE	No	No	No	Yes	No	No	No	Yes
R-squared	0.08	0.11	0.11	0.51	0.46	0.48	0.48	0.61

Panel B: Market Maker Revenue								
	Overall				High Delta Strategy			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Opening	11.58***	13.56***	13.15***	13.95***	6.47***	7.89***	7.72***	7.03***
	(4.51)	(12.46)	(12.71)	(10.44)	(4.42)	(11.54)	(9.51)	(8.06)
Combo					11.11***	10.26***	10.08***	
					(2.97)	(2.95)	(2.89)	
Combo × Opening					50.38***	50.26***	50.31***	52.43***
					(7.99)	(8.43)	(8.50)	(9.30)
VIX	0.55***	0.16**	−0.15	−0.43**	0.40***	0.13**	0.00	−0.22*
	(2.84)	(1.97)	(−1.28)	(−2.38)	(3.45)	(2.39)	(0.04)	(−1.91)
SPY Complex ES		9.71***	2.35	2.17		7.04***	4.14	1.16
		(9.60)	(0.68)	(0.57)		(10.95)	(1.60)	(0.41)
SPX Simple ES			1.25**	0.52			0.49	0.63
			(2.39)	(0.84)			(1.25)	(1.47)
Other Controls	No	No	No	Yes	No	No	No	Yes
Strategy FE	No	No	No	Yes	No	No	No	Yes
R-squared	0.09	0.12	0.12	0.42	0.43	0.45	0.45	0.54

Table VIII. Execution Costs of Unaffected Trades

This table reports OLS regressions of effective spread and market maker revenue on electronic-only trades unaffected by the Cboe floor opening. The left panel examines SPY complex options (matched) and the right panel examines SPX simple options (unmatched). Floor trades are excluded from both samples. The estimated specification follows Equation (2):

$$Y_i = \alpha + \beta_1\, Opening_i + \beta_2\, Combo_i \times Opening_i + \gamma' X_i + \mu_s + \varepsilon_i$$

where Y_i is measured in cents. $Opening_i$ equals one for trades executed after the opening and zero otherwise. $Combo_i$ equals one if the traded strategy is a Combo and zero otherwise. X_i includes trade-level controls: quoted spread, absolute delta, days to expiration, vega, gamma, implied volatility, log trade size, and VIX. For SPY complex, we include the average daily effective spread for SPX simple trades. For SPX simple, we include a PM-settled indicator and the average daily effective spread for SPY complex options. μ_s denotes strategy fixed effects (SPY complex) or option type fixed effects (SPX simple). Absolute delta is omitted from the market maker revenue regressions because it mechanically determines the hedging cost component of the dependent variable. The SPY complex sample contains 295,726 trades (147,863 matched pairs) and the SPX simple sample contains 631,129 trades (full electronic sample without matching). t-statistics in parentheses are computed from standard errors clustered by date. Intercept and some controls are omitted for brevity. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}\ p < 0.01$.

Panel A: Effective Spread						
	SPY Complex				SPX Simple	
	(1)	(2)	(3)	(4)	(1)	(2)
Opening	0.00	−0.00	−0.00	−0.01	1.03***	1.03***
	(0.00)	(−0.10)	(−0.20)	(−0.24)	(4.80)	(4.77)
Combo		0.81***				
		(7.15)				
Combo × Opening		0.11		0.11		
		(0.40)		(0.38)		
VIX	−0.00	−0.00	−0.00	−0.00	0.07**	0.07**
	(−1.63)	(−1.51)	(−1.18)	(−1.18)	(2.16)	(2.22)
SPY Complex ES					1.66***	1.70***
					(6.47)	(6.58)
SPX Simple ES	0.03***	0.03***	0.03***	0.03***		
	(5.43)	(5.46)	(6.34)	(6.32)		
|Delta|	1.48***	0.90***	1.00***	1.00***	9.87***	9.92***
	(6.96)	(3.46)	(3.45)	(3.44)	(8.70)	(8.75)
Strategy FE	No	No	Yes	Yes		
Option Type FE					No	Yes
Other Controls	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.44	0.44	0.44	0.44	0.49	0.49

Panel B: Market Maker Revenue						
	SPY Complex				SPX Simple	
	(1)	(2)	(3)	(4)	(1)	(2)
Opening	−0.00	−0.00	−0.00	−0.00	1.65^{***}	1.65^{***}
	(−0.00)	(−0.04)	(−0.15)	(−0.19)	(4.29)	(4.30)
Combo		0.70^{***}				
		(6.41)				
Combo × Opening		0.11		0.11		
		(0.39)		(0.38)		
VIX	−0.00	−0.00	−0.00	−0.00	-0.12^{**}	-0.12^{**}
	(−1.63)	(−1.51)	(−1.18)	(−1.18)	(−2.22)	(−2.19)
SPY Complex ES					−0.47	−0.45
					(−0.77)	(−0.74)
SPX Simple ES	0.03^{***}	0.03^{***}	0.03^{***}	0.03^{***}		
	(5.43)	(5.46)	(6.34)	(6.32)		
Strategy FE	No	No	Yes	Yes		
Option Type FE					No	Yes
Other Controls	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.44	0.44	0.44	0.44	0.10	0.10

Table IX. Price Impact of Options Trading on Futures Price

This table reports OLS regressions of E-mini S&P 500 futures returns on signed delta exposure for complex SPX Combo trades. The dependent variable is the log futures return measured 5 or 10 seconds after the options trade, relative to 100 milliseconds prior. Signed Delta is the trade's net delta exposure, normalized to $10,000 per one-point SPX move. Panel A estimates the relationship separately for the pre-closure (January 2 to March 13, 2020) and opening (June 16 to October 10, 2020) periods. Floor is an indicator that equals one if the trade executes on the Cboe trading floor and zero otherwise. The estimated specification follows Equation (3):

$$r^f_{t+h} = \alpha + \beta_1 \, Signed\ Delta_i + \beta_2 \, Floor/Period_i \times Signed\ Delta_i + \gamma' X_i + \mu_t + \varepsilon_i$$

where r^f_{t+h} is the E-mini futures return at horizon $h \in \{5, 10\}$ seconds and μ_t denotes date fixed effects. Panel B restricts the sample to electronic trades only and interacts Signed Delta with period indicators. Closure equals one for dates from the floor closure (March 16, 2020) to the floor opening (June 15, 2020). Opening equals one for dates on or after the floor opening. X_i includes trade-level controls in all specifications: days to expiration, vega, gamma, implied volatility, trade size, a PM-settled indicator, and number of legs. Standard errors in parentheses are clustered by date. Intercepts and controls are omitted for brevity. * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

Panel A: Floor versus Electronic				
	Pre-Closure		Opening	
	5s returns	10s returns	5s returns	10s returns
Signed Delta ($10K)	0.57*	1.31***	0.21**	0.18*
	(1.82)	(2.73)	(2.28)	(1.70)
Floor × Signed Delta	−0.57*	−1.29***	−0.22**	−0.18*
	(−1.81)	(−2.64)	(−2.34)	(−1.67)
Day FE	Yes	Yes	Yes	Yes
R-squared	0.01	0.01	0.01	0.01
Observations	14,620	14,620	18,056	18,056
Panel B: Electronic Trading Across Periods				
	Pre-Closure vs Closure		Closure vs Opening	
	5s returns	10s returns	5s returns	10s returns
Signed Delta ($10K)	0.54*	1.27***	0.00	0.02
	(1.76)	(2.66)	(0.33)	(1.20)
Closure × Signed Delta	−0.53*	−1.25***		
	(−1.74)	(−2.61)		
Opening × Signed Delta			0.21**	0.17
			(2.28)	(1.54)
Day FE	Yes	Yes	Yes	Yes
R-squared	0.00	0.01	0.01	0.01
Observations	22,449	22,449	25,953	25,953

Table X. Replication Costs of Floor Trades

This table reports the cost of replicating floor Combo trades through electronic execution during the opening period. The absolute delta exposure threshold is measured from the full opening period (June 15 to October 16, 2020) and is normalized to $4,218 per SPX point, reflecting the median (P_{50}) floor opening-period trade. Floor costs are computed as the mean dollar effective spread (ES) of floor trades whose delta exposure rank falls within the band's percentile range (±1%, ±2.5%, ±5%, ±10%) relative to the opening distribution. Electronic replication targets are constructed by chaining consecutive trades within each trading day until cumulative |Delta| reaches the target, pro-rated to deliver exact target amounts, with execution costs estimated from the two-week closure window (June 1–14, 2020). Slippage is computed as Slippage = $\beta_1 \cdot D^2 \cdot S/10^8$, where β_1 is the opening-period five-second (5s) and ten-second (10s) electronic price-impact coefficient from cumulative futures price impact of Table IX Panel A (in basis points per unit signed delta), D is absolute delta exposure in \$/SPX point, and $S = 3,100$ is the June 2020 average SPX level. Electronic total execution costs count both futures price impact at the five- and ten-second horizons and bid–ask spreads on individual legs and delta risk borne over the execution window. Floor advantage (in both $ and %) reflects the cost difference between electronic replication and floor execution.

Panel A: Electronic Replication Mechanics (Jun 1–14, 2020)					
Trades Required	(mean)	3.3			
	(median)	2.0			
Elapsed Minutes	(mean)	4.6			
	(median)	1.6			
|Delta| Exposure	(target)	4,218			
Panel B: Electronic Execution Costs from Cumulative Futures Price Impact ($)					
Slippage	(5s)	116			
	(10s)	99			
Panel C: Total Execution Costs ($)					
Electronic Spread		12,140			
Electronic Total Cost	(low estimate)	12,239			
	(high estimate)	12,256			
		±1%	±2.5%	±5%	±10%
Floor Total Cost		10,498	10,154	9,311	8,936
Floor Advantage	($)	1,741–1,758	2,085–2,102	2,928–2,945	3,303–3,320
	(%)	14.2–14.3	17.0–17.2	23.9–24.0	27.0–27.1
Panel D: Floor sample composition					
Band Ranges		±1%	±2.5%	±5%	±10%
Percentile Ranges		P49–P51	P47.5–P52.5	P45–P55	P40–P60
Observations	(each side)	104	260	521	1,042
Total Observations		209	521	1,043	2,085
Mean |Delta|	(in band)	4,238	4,241	4,254	4,245

Appendix A: Floor Closure Results

The main analysis in Section III focuses on the opening of the Cboe trading floor in June 2020 because the initial closure in March 2020 coincided with the onset of the COVID-19 pandemic, a period of extreme volatility and shifts in market participation that could confound any comparison between floor and electronic execution. This appendix replicates the matched analysis around the closure event. For each floor trade executed in the two weeks before the closure (March 2 to March 13, 2020), we identify the nearest electronic trade from the two weeks following the closure (March 16 to March 27, 2020), using the same one-to-one nearest-neighbor matching algorithm, covariates, and caliper described in Section III.B. The matched sample contains 5,796 observations (2,898 matched pairs).

Table AI reports pre-matching and post-matching means. Before matching, floor trades differ substantially from electronic trades. Floor trades are an order of magnitude larger (372 contracts versus 32), carry higher absolute delta (0.15 versus 0.03), and involve more legs (7.6 versus 3.1). After matching, the algorithm achieves balance on all six covariates. The execution quality rows, which are not part of the matching algorithm, show that floor trades remain considerably more expensive than their electronic counterparts even after conditioning on observable trade characteristics. Post-matching effective spreads for floor trades are 19 cents compared with 6 cents for electronic trades, leaving a raw differential of 13 cents. Market maker revenues follow the same pattern (18 versus 5 cents). Hedge costs, by contrast, are effectively equalized across matched pairs at approximately 1 cent.

Table AII reports the matched regressions for effective spreads and market maker revenues across eight specifications that progressively add controls. Because the closure period coincides with elevated market volatility, we include the VIX level, the average daily effective spread for SPY complex options, and the average daily effective spread for SPX single-leg trades as additional controls to absorb market-wide variation in execution costs unrelated to the venue transition. In the baseline specification, effective spreads for matched floor trades are 46 cents higher than for electronic trades, and the gap narrows to 35 cents after adding the full set of controls and strategy fixed effects. For floor-intensive strategies, the full specification yields a coefficient of 47 cents. Market maker revenues mirror effective spreads almost exactly across all specifications, consistent with balanced hedge costs in the matched sample. The VIX coefficient is statistically significant in sparse specifications but loses significance once SPX single-leg spreads and the full control set are included, suggesting that market-wide volatility is absorbed by the other controls rather than driving the floor premium directly. The consistency of the closure and opening results across two independent period transitions, separated by three months, supports the interpretation that the cost differentials reflect the presence or absence of floor intermediation rather than transient pandemic conditions.

Table AI. Matched Sample Summary Statistics around Floor Closure
This table compares pre-matching and post-matching means for floor and electronic complex SPX trades around the closure of the Cboe trading floor. For each floor trade executed in the two weeks before the closure (March 2–13, 2020), we identify the nearest electronic trade from the two weeks after the closure (March 16–27, 2020) using one-to-one nearest-neighbor matching without replacement. We match on six covariates: absolute delta (|Delta|), absolute vega (|Vega|), implied volatility, trade size in contracts, days to expiration, and number of legs, imposing a per-variable caliper of 0.25 standard deviations. Within each panel, the left columns report pre-matching means and differences, and the right columns report post-matching means and differences. Panel A reports the matching covariates before and after matching. Panel B reports execution quality measures that are not included in the matching algorithm: the effective spread, hedge cost, and market maker revenue, all measured in cents per unit of underlying. The sample contains 5,796 trades (2,898 matched pairs) with a match rate of 30%.

Panel A: Options Trade Characteristics

	Before Matching			After Matching			
	Floor	Electronic	Difference	Floor	Electronic	Difference	Floor Unmatched
|Delta|	0.19	0.03	0.16	0.11	0.11	0.00	0.22
|Vega|	1.51	0.28	1.24	0.6	0.59	0.01	1.90
Implied Vol.	0.44	0.74	−0.29	0.54	0.55	−0.02	0.40
Trade Size	521.39	48.83	472.56	325.72	319.25	6.47	605.37
Days-to-Exp.	60.19	30.55	29.64	35.36	36.22	−0.87	70.85
Legs	9.09	3.71	5.38	3.63	3.21	0.42	11.44

Panel B: Execution Quality

	Before Matching			After Matching			
	Floor	Electronic	Difference	Floor	Electronic	Difference	Floor Unmatched
Effective Spread	69.09	13.38	55.71	51.84	20.70	31.14	76.49
Hedge Cost	2.45	0.44	2.02	1.52	1.55	−0.03	2.85
MM Revenue	66.64	12.94	53.70	50.33	19.16	31.17	73.64

Table AII. Execution Quality and Floor Closure

This table reports OLS regressions of the effective spread and market maker revenue on matched samples of complex SPX trades. Each pre-closure floor trade (March 2–13, 2020) is matched 1:1 without replacement to the nearest closure-period electronic trade (March 16–27, 2020) on |delta|, |vega|, implied volatility, trade size, days to expiration, and number of legs. The estimated specification follows Equation (2):

$$Y_i = \alpha + \beta_1 \, Closure_i + \beta_2 \, Combo_i \times Closure_i + \gamma' X_i + \mu_s + \varepsilon_i$$

where Y_i is measured in cents per unit of underlying. $Closure_i$ equals one for electronic trades executed during the closure and zero for floor trades executed before the closure. $Combo_i$ equals one if the traded strategy is a Combo and zero otherwise. X_i includes trade-level controls in all specifications: quoted spread, absolute delta, days to expiration, vega, gamma, implied volatility, log trade size, a PM-settled indicator, the average daily effective spread for SPY complex options and SPX single-leg, and the VIX volatility index. μ_s denotes strategy fixed effects. Absolute delta is omitted from the market maker revenue regressions because it mechanically determines the hedging cost component of the dependent variable. The sample contains 5,796 trades (2,898 matched pairs). t-statistics in parentheses are computed from standard errors clustered by date. Intercept and some controls are omitted for brevity. $^{*}p < 0.10$; $^{**}p < 0.05$; *** $p < 0.01$.

Panel A: Effective Spread								
	Overall				High Delta Strategies			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Closure	−46.12***	−43.88***	−37.09***	−34.67***	−34.86***	−32.78***	−27.94***	−23.70***
	(−9.55)	(−9.45)	(−11.33)	(−13.27)	(−10.69)	(−9.83)	(−11.22)	(−10.26)
Combo					50.49***	50.45***	49.81***	
					(26.48)	(27.51)	(31.22)	
Combo × Closure					−43.09***	−43.16***	−42.40***	−46.57***
					(−13.29)	(−13.35)	(−13.29)	(−12.05)
VIX	1.02***	0.80***	0.36	0.17	0.84***	0.64***	0.32*	0.18
	(7.28)	(3.40)	(1.43)	(1.19)	(8.87)	(3.43)	(1.77)	(1.44)
SPY Complex ES		3.76	−0.16	−1.15		3.42	0.55	−0.57
		(0.97)	(−0.06)	(−0.71)		(1.09)	(0.22)	(−0.37)
SPX Simple ES			0.44***	0.26***			0.32***	0.21***
			(2.96)	(2.74)			(3.71)	(2.64)
|Delta|				57.79***				54.01***
Other Controls	No	No	No	Yes	No	No	No	Yes
Strategy FE	No	No	No	Yes	No	No	No	Yes
R-squared	0.23	0.23	0.24	0.49	0.38	0.38	0.38	0.54

Panel B: Market Maker Revenues								
	Overall				High Delta Strategies			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Closure	-46.12^{***}	-43.88^{***}	-37.09^{***}	-34.67^{***}	-34.86^{***}	-32.78^{***}	-27.94^{***}	-23.70^{***}
	(−9.55)	(−9.45)	(−11.33)	(−13.27)	(−10.69)	(−9.83)	(−11.22)	(−10.26)
Combo					50.49^{***}	50.45^{***}	49.81^{***}	
					(26.48)	(27.51)	(31.22)	
Combo × Closure					-43.09^{***}	-43.16^{***}	-42.40^{***}	-46.57^{***}
					(−13.29)	(−13.35)	(−13.29)	(−12.05)
VIX	0.99^{***}	0.78^{***}	0.35	0.21	0.82^{***}	0.63^{***}	0.31^{*}	0.21
	(7.47)	(3.46)	(1.48)	(1.28)	(9.14)	(3.48)	(1.80)	(1.53)
SPY Complex ES		3.60	−0.21	−1.28		3.32	0.50	−0.68
		(0.97)	(−0.07)	(−0.74)		(1.09)	(0.21)	(−0.41)
SPX Simple ES			0.42^{***}	0.27^{***}			0.31^{***}	0.22^{**}
			(3.07)	(2.58)			(3.73)	(2.54)
Other Controls	No	No	No	Yes	No	No	No	Yes
Strategy FE	No	No	No	Yes	No	No	No	Yes
R-squared	0.09	0.12	0.12	0.42	0.43	0.45	0.45	0.54

Appendix B: Replication Cost Extension

The main analysis reports the cost of replicating the median floor trade electronically (Table X in Section IV.B). Table BI repeats the exercise at the 75th percentile of the floor delta exposure distribution, targeting \$9,853 per SPX point. Replicating this larger position requires approximately five electronic trades over eight minutes on average, compared with three trades over five minutes at the median. Dollar slippage from futures price impact rises substantially, from \$116 at the median to \$632 at the 75th percentile at the five-second horizon, reflecting the quadratic relationship between delta exposure and market impact. The floor cost advantage is larger and more robust across all band widths. At the tightest band (±1%), the floor saves approximately \$5,800–\$5,900 per trade (28%), and even at the widest band (±10%) the floor advantage remains \$2,200–\$2,300 (10–11%). The increasing floor advantage at higher delta exposure thresholds is consistent with electronic fragmentation costs growing faster than floor intermediation costs as position size rises.

Table BI. Replication Costs of Floor Trades: 75th Percentile

This table reports the cost of replicating floor Combo trades through electronic execution during the opening period. The absolute delta exposure threshold is measured from the full opening period (June 15 to October 16, 2020) and is normalized to \$9,853 per SPX point, reflecting the 75th percentile (P_{75}) floor opening-period trade. Floor costs are computed as the mean dollar effective spread (ES) of floor trades whose delta exposure rank falls within the band's percentile range (±1%, ±2.5%, ±5%, ±10%) relative to the opening distribution. Electronic replication targets are constructed by chaining consecutive trades within each trading day until cumulative |Delta| reaches the target, pro-rated to deliver exact target amounts, with execution costs estimated from the two-week closure window (June 1–14, 2020). Slippage is computed as Slippage = $\beta_1 \cdot D^2 \cdot S/10^8$, where β_1 is the opening-period five-second (5s) and ten-second (10s) electronic price-impact coefficient from cumulative futures price impact of Table IX Panel A (in basis points per unit signed delta), D is absolute delta exposure in \$/SPX point, and $S = 3,100$ is the June 2020 average SPX level. Electronic total execution costs count both futures price impact at the five- and ten-second horizons and bid–ask spreads on individual legs and delta risk borne over the execution window. Floor advantage (in both \$ and %) reflects the cost difference between electronic replication and floor execution.

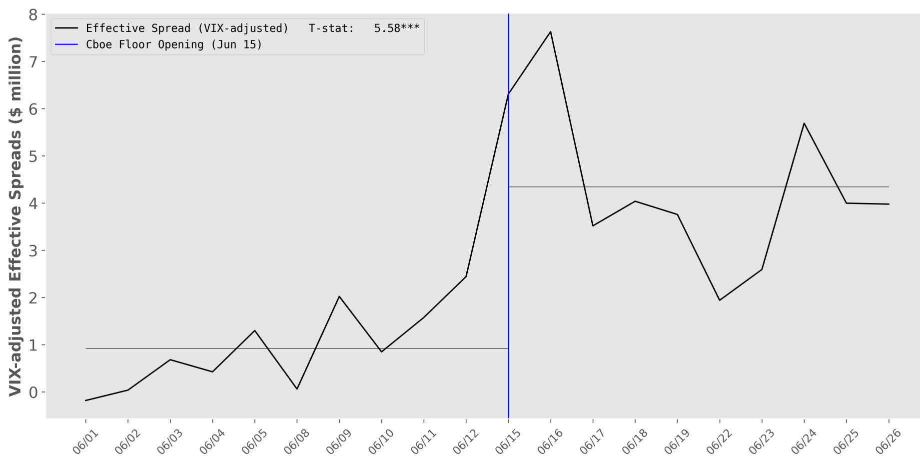
Panel A: Electronic Replication Mechanics (Jun 1–14, 2020)					
Trades Required	(mean)	4.9			
	(median)	4.0			
Elapsed Minutes	(mean)	8.1			
	(median)	4.4			
|Delta| Exposure	(target)	9,853			
Panel B: Electronic Execution Costs from Cumulative Futures Price Impact (\$)					
Slippage	(5s)	632			
	(10s)	542			
Panel C: Total Execution Costs (\$)					
Electronic Spread		20,707			
Electronic Total Cost	(low estimate)	21,249			
	(high estimate)	21,339			
		±1%	±2.5%	±5%	±10%
Floor Total Cost		15,412	15,716	17,927	19,046
Floor Advantage	(\$)	5,837–5,927	5,533–5,623	3,322–3,412	2,203–2,293
	(%)	27.5–27.8	26.0–26.4	15.6–16.0	10.4–10.7
Panel D: Floor sample composition					
Band Ranges		±1%	±2.5%	±5%	±10%
Percentile Ranges		P74–P76	P72.5–P77.5	P70–P80	P65–P85
Observations	(each side)	104	261	521	1,042
Total Observations		209	523	1,043	2,085
Mean |Delta|	(in band)	9,804	9,698	9,673	9,917

Appendix C: VIX-Adjusted Aggregate Spreads

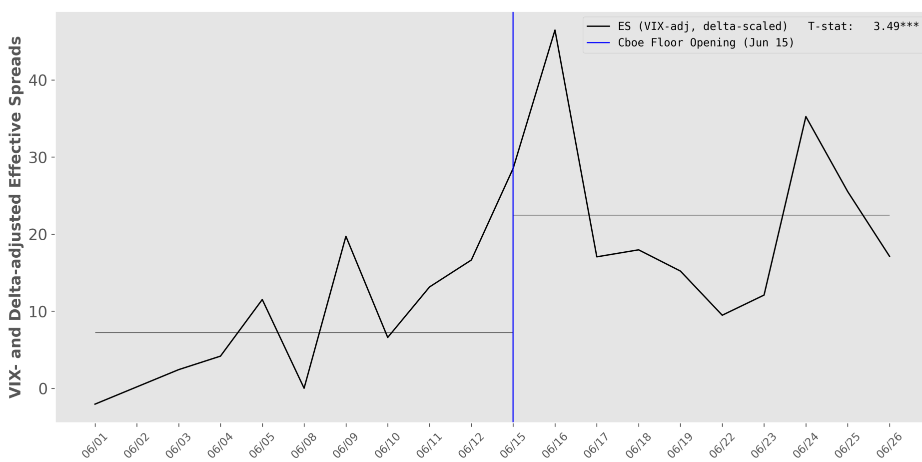
Figure 6 in Section IV.B documents a sharp increase in total dollar effective spreads a few days before the floor opening. This spike does not appear in the volume-weighted average spread in Panel B of Figure 4 in Section III, suggesting it is driven by elevated volume as shown in Panel B of Figure 6 rather than wider per-trade spreads. June 11 and 12 coincide with a sharp rise in the VIX evident in Figure 3 in Section III.A, which increases both trading volume and mechanical spread levels. Because total dollar effective spreads are the product of per-unit spreads and trade size summed across all trades, a VIX-driven volume surge can generate a spike in the aggregate even if per-trade execution costs are unchanged.

To isolate the floor effect from volatility-driven variation, we residualize each trade's effective spread on the daily VIX level and then aggregate the residuals to daily totals in the same manner as Figure 6. Figure C1 Panel A plots the resulting VIX-adjusted series. The pre-opening spikes disappear. The series fluctuates near \$1 million per day during the closure window and jumps sharply on June 15, averaging approximately \$4.3 million per day after the opening. The Welch t-statistic for the difference in pre- and post-opening means is 5.58, significant at the 1% level. The increase in aggregate intermediation costs survives the VIX adjustment, confirming that the pre-opening peaks reflect volatility rather than anticipation of the floor's return.

Panel B further adjusts for the directional content of each trade by dividing the VIX-adjusted residual by $\max(0.1, |\text{Delta}|)$ before aggregating, following the delta-adjusted spread measure in Götz, Riordan, Schuster, and Uhrig-Homburg (2025). This normalization expresses execution costs per unit of directional exposure, so that the aggregate reflects the total cost of transferring directional risk rather than the total cost of transacting. The series again jumps discretely at the opening date, from roughly \$7 million to \$22 million per day (Welch $t = 3.49$, significant at the 1% level). The floor opening raises aggregate intermediation costs even after accounting for both the volatility environment and the directional content of the trades.



Panel A. VIX-Adjusted Total Dollar Effective Spreads



Panel B. VIX- and Delta-Adjusted Total Dollar Effective Spreads

Figure C1. VIX-Adjusted Aggregate Effective Spreads around the Floor Opening
This figure plots daily aggregate effective spreads for complex SPX trades during the two weeks before and after the floor opening (June 1 to June 26, 2020). Panel A reports total dollar effective spreads residualized on the daily VIX level, in millions. Panel B divides each trade's VIX-adjusted effective spread by max(0.1,|Delta|) before aggregating, following the delta-adjusted spread measure in Götz et al. (2025), in millions. The solid blue vertical line marks the floor opening on June 15, 2020. The horizontal grey lines denote closure and opening period averages, and each panel reports the Welch t-statistic for the difference in means. *$p < 0.10$; **$p < 0.05$; *** $p < 0.01$.

REFERENCES

Anand, A. and D. Muravyev (2025). Does Internalization Impact Quote Competition? SSRN Scholarly Paper. http://dx.doi.org/10.2139/ssrn.4891227.

Barclay, M. J., T. Hendershott, and D. T. McCormick (2003). Competition among Trading Venues: Information and Trading on Electronic Communications Networks. *The Journal of Finance 58*(6), 2637–2665.

Benveniste, L. M., A. J. Marcus, and W. J. Wilhelm (1992). What's Special about the Specialist? *Journal of Financial Economics 32*(1), 61–86.

Bessembinder, H. and K. Venkataraman (2004). Does an Electronic Stock Exchange Need an Upstairs Market? *Journal of Financial Economics 73*(1), 3–36.

Bouchaud, J.-P., J. D. Farmer, and F. Lillo (2009). How Markets Slowly Digest Changes in Supply and Demand. In *Handbook of Financial Markets: Dynamics and Evolution*, pp. 57–160. North-Holland.

Brogaard, J., M. C. Ringgenberg, and D. Roesch (2025). Does Floor Trading Matter? *The Journal of Finance 80*(1), 375–414.

Bryzgalova, S., A. Pavlova, and T. Sikorskaya (2023). Retail Trading in Options and the Rise of the Big Three Wholesalers. *The Journal of Finance 78*(6), 3465–3514.

Cboe Global Markets (2019). Rules of Cboe Exchange, Inc. https://cdn.cboe.com/resources/regulation/rule_book/C1_Exchange_Rule_Book-Effective-October-7-2019.pdf.

Cboe Global Markets (2020a). Cboe Global Markets Plans to Reopen Chicago Trading Floor on Monday, June 8, 2020. Press Release.

Cboe Global Markets (2020b). Cboe Global Markets Postpones Reopening of Chicago Trading Floor to June 15, 2020. Press Release. Reopening postponed from June 8 due to closures in downtown Chicago and restricted access to the Cboe building.

Cboe Global Markets (2020c). Cboe Options Exchange (C1) Floor Reopening Update. Regulatory Circular. https://x.com/CBOE/status/1268173348128854019?ref_src=twsrc%5Etfw.

Cboe Global Markets (2020d). Cboe Options Trading Floor Closure Update. https://cdn.cboe.com/resources/release_notes/2020/Cboe-Options-Trading-Floor-Closure-Update.pdf.

Cboe Global Markets (2020e). Novel Coronavirus Update, Trading Floor Closure. https://cdn.cboe.com/resources/release_notes/2020/Novel-Coronavirus-Update-Trading-Floor-Closure.pdf.

Cboe Global Markets (2026). Rules of Cboe Exchange, Inc. https://cdn.cboe.com/resources/regulation/rule_book/C1_Exchange_Rule_Book.pdf.

Conrad, J., K. M. Johnson, and S. Wahal (2003). Institutional Trading and Alternative Trading Systems. *Journal of Financial Economics 70*(1), 99–134.

Ernst, T. and C. Spatt (2026). Payment for Order Flow and Option Internalization. *The Review of*

Financial Studies 0(0), 0.

Götz, A., R. Riordan, P. Schuster, and M. Uhrig-Homburg (2025). Measuring Option Liquidity. SSRN Scholarly Paper. http://dx.doi.org/10.2139/ssrn.5239635.

Grossman, S. J. and M. H. Miller (1988). Liquidity and Market Structure. *The Journal of Finance 43*(3), 617–633.

Hendershott, T., S. A. Khan, and R. Riordan (2026). Option Auctions. *The Review of Financial Studies 39*(3), 783–834.

Hendershott, T. and A. Madhavan (2015). Click or Call? Auction versus Search in the Over-the-Counter Market. *The Journal of Finance 70*(1), 419–447.

Hu, E. and D. Murphy (2026, May). Vestigial Tails? Floor Brokers at the Close in Modern Electronic Markets. *Management Science 72*(5), 3974–3996.

Hu, J., A. Kirilova, S. G. Park, and D. Ryu (2024). Who Profits from Trading Options? *Management Science 70*(7), 4742–4761.

Kaeck, A., V. van Kervel, and N. J. Seeger (2022). Price Impact versus Bid–Ask Spreads in the Index Option Market. *Journal of Financial Markets 59*(Part A), 100675.

Kyle, A. S. (1985). Continuous Auctions and Insider Trading. *Econometrica 53*(6), 1315–1335.

Lee, C. M. C. and M. J. Ready (1991). Inferring Trade Direction from Intraday Data. *The Journal of Finance 46*(2), 733–746.

Li, S. (2020). Inferring Complex Strategies from Intraday Multi-Leg Options Trades. SSRN Scholarly Paper. http://dx.doi.org/10.2139/ssrn.4128457.

Li, S., D. K. Musto, and N. D. Pearson (2023). Costs of Executing Complex Options Trades. The Wharton School Research Paper. http://dx.doi.org/10.2139/ssrn.4389665.

Mackintosh, P. (2025). Off-Exchange Trading Increases Across All Types of Stocks. Nasdaq Economic Research. https://www.nasdaq.com/articles/exchange-trading-increases-across-all-types-stocks.

Madhavan, A. and M. Cheng (1997). In Search of Liquidity: Block Trades in the Upstairs and Downstairs Markets. *The Review of Financial Studies 10*(1), 175–203.

Moussawi, R., L. Xu, and Z. C. Zhou (2022). A Market Maker of Two Markets: The Role of Options in ETF Arbitrage. SSRN Scholarly Paper. http://dx.doi.org/10.2139/ssrn.4395938.

Muravyev, D. and N. D. Pearson (2020). Options Trading Costs are Lower than You Think. *The Review of Financial Studies 33*(11), 4973–5014.

O'Hara, M. (2015). High Frequency Market Microstructure. *Journal of Financial Economics 116*(2), 257–270.

Securities and Exchange Commission (2020). Self-regulatory organizations; Cboe exchange, inc.; notice of filing and immediate effectiveness of a proposed rule change to amend rule 5.24. https://www.sec.gov/files/rules/sro/cboe/2020/34-88386.pdf.

Venkataraman, K. (2001). Automated Versus Floor Trading: An Analysis of Execution Costs on the Paris and New York Exchanges. *The Journal of Finance 56*(4), 1445–1485.

Internet Appendix

Not Dead Yet: Options Trading Floors

— not for publication —

LUCA GALATI, TERRENCE HENDERSHOTT, SAAD ALI KHAN, and RYAN RIORDAN

May 31, 2026

ABSTRACT

This Internet Appendix provides supplementary institutional details related to the paper "Not Dead Yet: Options Trading Floors." The Appendix documents the hybrid market structure of the Cboe Options Exchange, the interaction between electronic and open outcry execution, the operation of PAR routing and complex-order handling, and the institutional changes surrounding the COVID-19 floor closure in March 2020. It also provides additional detail on the reconstruction, classification, and signing of complex option strategies from millisecond-level transaction data.

IA.I: Institutional Details of Cboe Floor Trading and Hybrid Execution

A. Scope and sources

This Appendix documents the institutional details of open outcry floor trading at Cboe Options Exchange ("C1") and its interaction with electronic execution mechanisms in the hybrid market design. Our primary institutional sources are (i) the C1 Exchange Rule Book effective October 7, 2019 and contemporaneous rule filings, (ii) Cboe circulars and operational updates surrounding the March 2020 COVID-19 floor closure and subsequent opening, and (iii) Cboe's published technical and market-structure documents describing complex-order handling and the boundary between electronic and floor-eligible trading.[1]

B. Hybrid market architecture and trading sessions

Hybrid model. Cboe operates a hybrid options market in which the same option classes may be executed electronically (through an automated matching engine and displayed order books) and, for designated classes, through in-person open outcry on the Chicago trading floor. The hybrid design dates back to Cboe's "Hybrid Trading System" transition in the early 2000s, which integrated electronic executions and quoting with an open outcry floor auction.[2]

Trading sessions. C1 distinguishes between Regular Trading Hours (RTH) and Global Trading Hours (GTH). Open outcry is an RTH functionality: during GTH, C1 operates in an electronic-only mode for the relevant products, and orders that would otherwise route to the floor (via PAR) are not accepted for floor handling.[3] Within RTH, open outcry trading in a given series begins only after the series has opened for electronic trading.[4]

The trading floor as a price-discovery venue for selected products. In modern U.S. listed options, most volume is electronic, but Cboe continues to operate a floor that is

[1]For readability, we refer to the exchange as "Cboe" and the venue as "C1" when quoting specific rulebook mechanisms that apply to Cboe Options Exchange. Rules and functionalities change over time; the institutional description here is anchored to the rule set applicable to the 2019–2020 period and to the temporary amendments adopted during the COVID-related inoperability of the physical floor.

[2]See, for example, SEC approval orders and related rule filings for Cboe's Hybrid system evolution, including the original Hybrid approval and later enhancements. In the current C1 rulebook structure, open outcry trading is governed primarily by Chapter 5, Section G, and routing/eligibility for floor handling is governed by the PAR rules and complex-order rules (discussed below).

[3]Operationally, the floor-based PAR routing and open outcry mechanisms are inactive in GTH; by rule, C1 may return orders that route to PAR during GTH.

[4]This sequencing matters empirically: the opening process is electronic, and floor trading begins only after the electronic opening rotation for the series/class has completed.

materially relevant in index products. Cboe market-structure publications emphasize that open outcry remains commonly used for (i) certain products, (ii) certain complex strategies, and (iii) large orders, particularly during volatile periods.[5]

C. *Participants, roles, and floor governance*

open outcry trading is organized around a *trading crowd* for each class (often described colloquially as a “pit” or “post”). The main participant types are:

- **Floor Brokers (agency intermediaries).** Floor brokers are representatives of member firms who handle customer agency orders on the floor. They are obligated to use due diligence to execute orders at the best available prices under the rules, including requesting quotes from the crowd and continuously representing certain marketable orders.[6]

- **Market Makers (liquidity suppliers).** Market makers are exchange-registered liquidity providers that may trade for their own accounts and are subject to quoting and market-quality obligations in their appointed classes.[7]

- **Designated liquidity providers (DPM/LMM).** In some classes, C1 appoints a Designated Primary Market-Maker (DPM) and/or a Lead Market-Maker (LMM) and may grant these participants a *participation entitlement* in allocations at a given price when they are quoting at the best price.[8]

- **PAR Officials (exchange-appointed order handlers).** PAR Officials are exchange personnel (or contractors) designated to operate a PAR workstation and effect proper executions of orders in their custody. They have explicit display and due-diligence obligations, are not affiliated with market-making firms, and are compensated exclusively by the Exchange.[9]

[5] Cboe and industry market-structure publications also report that open outcry constitutes a meaningful share of SPX and VIX volume in recent data, illustrating that the floor is not purely residual even after broad electronification.

[6] See Rule 5.91 for the detailed due-diligence obligations, representation requirements, and constraints on discretion.

[7] See, for example, Rules 5.51–5.52 for market-maker obligations and quoting.

[8] These entitlements exist both in electronic allocation and in open outcry allocation, subject to class-by-class application. In open outcry, the entitlement is applied after Priority Customer orders in the Book at the execution price are satisfied, as described below.

[9] See Rule 5.90.

Floor access, clerks, and supervision. The rulebook restricts authority to transact on the trading floor to approved Trading Permit Holders performing floor functions (e.g., Floor Brokers and Market Makers). Clerks have badge and booth requirements and are limited in how and where they may stand relative to trading crowds. The floor is overseen by Floor Officials, who can interpret certain rules in real time and may nullify or adjust transactions that violate key trading rules.[10]

D. Order entry, systematization, and the PAR routing channel

Systematization and audit trail ("enter it before you trade it"). A central institutional feature of floor trading on C1 is that orders handled on the floor must be captured in a systematized format to satisfy audit-trail requirements. The rulebook requires that orders transmitted to the floor be recorded on approved order forms (or electronic media), including time-of-receipt information, and that cancellations/changes be similarly recorded. If the Exchange's systems are disrupted, participants must maintain written records and subsequently input the information into Exchange systems by prescribed deadlines.[11]

PAR as the operational bridge between electronic and floor handling. C1's *Public Automated Routing system (PAR)* is the operational channel by which eligible orders are routed to the trading floor for manual handling and potential open outcry execution. A PAR workstation is an exchange-provided order management tool used on the trading floor by Trading Permit Holders and PAR Officials.[12] Orders may route to PAR in two primary ways: (i) the user explicitly designates the order as *Direct to PAR*, or (ii) the order is designated as *Default* and cannot be electronically processed under the system rules, in which case it routes to PAR subject to user instructions.[13]

What can be done with an order on PAR. Once an order is on PAR, the floor broker/PAR Official can, subject to rules and user instructions: (i) submit the order (or a portion) back into the System for electronic processing if eligible, including participation in a complex order auction (COA); (ii) execute the order (or a portion) in open outcry on the floor (including executions against Priority Customer orders and other interest resting in the electronic Book at the best price); (iii) route to an away exchange (if eligible for routing);

[10]See Rule 5.80 for floor admission and conduct; and the Floor Officials' authority to adjust/nullify trades that violate, among others, the open outcry allocation rules.

[11]See Rule 5.7 for systematization requirements, contingency procedures during malfunctions, and audit-trail/COATS-related interpretations. The rulebook explicitly recognizes that hand-signal communications may initiate or modify orders on the floor, but such actions must still be systematized.

[12]See Rule 5.82.

[13]See Rule 5.82(b).

(iv) route to another PAR workstation; or (v) cancel the order.[14] This flexibility matters: PAR is not merely an "execution venue" but an order-handling interface that permits hybrid "work" of an order across electronic and floor mechanisms.

Direct-routing and order marking. After Cboe's migration of C1 onto a Bats-technology platform, Cboe issued operational guidance that orders intended for manual open outcry handling must be properly marked and routed with exchange-specified directives and PAR workstation identifiers.[15]

E. What is floor-only (or effectively floor-only) in the C1 rule set?

The C1 rulebook and technical specifications create explicit *eligibility boundaries* between electronic processing and floor/manual handling. These boundaries are important for understanding why certain strategy types concentrate on the floor and why the floor closure in March 2020 required rule adjustments.

Simple orders. On a class-by-class basis, C1 may permit certain simple order types, instructions, and times-in-force to be routed to PAR for manual handling and open outcry.[16]

Complex orders: the ratio boundary as a central segmentation device. For complex orders, C1 imposes a ratio-based boundary that (in normal operation) determines whether a multi-leg order may be processed electronically or must be handled manually on the floor. Specifically, *other than Index Combo orders*, a complex order with a ratio less than one-to-three (0.333) or greater than three-to-one (3.00) may only be submitted for manual handling and open outcry trading.[17] C1 may make additional complex-order instructions available for PAR routing, including (among others) Complex Only, Compression/PCC, Multi-Class Spread, RFC, and SPX Combo.[18]

Additional technical/operational constraints that create floor concentration. Beyond the 3:1 ratio boundary, Cboe technical specifications for the U.S. options complex book pro-

[14] See Rule 5.82(c) for the menu of permitted PAR actions.

[15] See Cboe Exchange Notice on direct routing to PAR and related order-marking requirements; such notices specify how default vs. direct-to-PAR directives determine whether an order reaches the floor or is processed electronically.

[16] Rule 5.83(a) enumerates available simple order types and instructions that the Exchange may make available for PAR routing.

[17] See Rule 5.83(b). This ratio boundary is a key institutional feature for empirical work that compares electronic and floor execution.

[18] See Rule 5.83(b)(2) for the list of complex-order instructions made available for PAR routing.

cess document several restrictions that are directly relevant for substitution and "strategy splitting":

- **Maximum number of legs differs by electronic vs floor routing.** Electronic complex orders have a maximum number of legs (set by the exchange and generally far below "everything you could write down"), while floor-routed orders may support creation/handling of complex instruments with substantially more legs (including up to very high leg counts for floor-routed non-FLEX complex orders).[19]

- **Cash-priced complex orders and other special price types.** Cash-spread (PriceType=C) complex orders may be rejected by the electronic complex book and instead require floor routing to PAR.[20]

- **Certain trade-condition codes require floor routing.** For example, "CMBO" (combo) trade-condition handling for SPX/SPXW may require the order to be directed to PAR and is not accepted for electronic processing.[21]

These restrictions imply that a trader seeking to execute an economically meaningful but "electronically non-eligible" package must either (i) route the package to the floor (when the floor is operational), or (ii) decompose the desired package into multiple electronically eligible orders (or into a sequence of electronically eligible complex and simple orders), which may introduce legging risk, exposure to interim price changes, and additional information leakage.

F. Open outcry price formation and allocation

Open outcry as a competitive auction with explicit priority rules. Open outcry is a verbal/visible auction mechanism in which floor brokers (and PAR officials) represent orders to the trading crowd and in-crowd liquidity providers respond with bids/offers. Cboe regulatory guidance emphasizes that trades executed on the floor must be executed in open outcry and may not be executed as private "cross-only" transactions; bids and offers must be requested and exposed in the crowd (with narrowly defined exceptions such as certain electronic crossing mechanisms).[22]

[19]See Cboe's US Options Complex Book Process documentation for the maximum-leg rules and the distinction between electronic and floor-routed complex instrument creation.

[20]See the Complex Book Process specification section on Cash Spreads and the routing requirements for such orders.

[21]See the Complex Book Process specification on Combo trade-condition handling and floor-routing requirements.

[22]See Cboe Regulatory Circulars on open outcry trading requirements and prohibited practices. Historically, similar requirements appear in older Cboe circulars from the 1990s, underscoring continuity in the "public auction" requirement.

Execution price priority. For an order represented in open outcry, bids/offers at the best price have priority.[23]

Priority at the same price: interaction with the electronic book. A distinctive feature of C1's hybrid design is that open outcry executions are not insulated from the electronic Book. At a given execution price, Priority Customer orders resting in the electronic Book have first priority. If multiple Priority Customer orders are at the same price, the System allocates them in time priority (order of receipt by the System).[24] After Priority Customer orders, the rulebook specifies additional priority layers, including potential DPM/LMM participation entitlements and then in-crowd responses.

Participation entitlement (DPM/LMM). If the Exchange applies a participation entitlement to a class, and the DPM/LMM is quoting at the best price, the DPM/LMM receives the greater of: (i) the amount it would receive under the general in-crowd allocation rules, and (ii) a percentage entitlement of the remaining non-Priority Customer contracts after Priority Customer orders in the Book are satisfied. The entitlement percentage depends on the number of other in-crowd quotes at that price (e.g., 50% if one other ICMP quote, 40% if two, and 30% if three or more), and it is capped by the size of the DPM/LMM quote.[25]

In-crowd market participant responses. In-crowd market participant (ICMP) bids/offers made at the time the market is established have priority after Priority Customer orders (and any applied entitlement). The floor broker/PAR official (or DPM/LMM/Market-Maker, depending on who is controlling the execution) determines which participants responded at the time the market was established and the sequence in which responses were made. If two or more bids/offers are simultaneously made and the sequence cannot be determined, the remaining contracts are allocated equally among the ICMPs at that price.[26]

Then, non-customer book interest. After Priority Customer orders and in-crowd responses, remaining contracts may execute against non-customer order interest and quotes resting in the electronic Book, with allocation governed by the electronic allocation rules applicable to that class.[27]

---

[23] Rule 5.85(a)(1).

[24] Rule 5.85(a)(2)(A).

[25] Rule 5.85(a)(2)(B). The rulebook also distinguishes "on-floor" vs "off-floor" DPM/LMM entitlements when both are appointed, with on-floor entitlements applying to orders represented in open outcry.

[26] Rule 5.85(a)(2)(C) and (D).

[27] Rule 5.85(a)(2)(E) references application of the allocation algorithm in Rule 5.32 for Book interest at the execution price.

Floor broker and PAR official obligations: prompt representation and time-stamping. The rulebook codifies detailed obligations intended to preserve auction integrity and auditability:

- **Floor Brokers:** must use due diligence in handling orders (including requesting quotes and ensuring compliance with firm-quote obligations), must continuously represent market and marketable limit orders at the trading station, and must electronically record the time of initial representation via PAR (subject to systematization requirements).[28]

- **PAR Officials:** must display promptly certain customer limit orders that improve the best disseminated quote (subject to exemptions), must keep "Autobook" active, and must electronically record representation times.[29]

Trade reporting and "late" flags. open outcry executions must be reported within a short time window; transactions not reported within the required window are marked late, and patterns of late reporting can be treated as rule violations.[30]

G. Crossing, facilitation, and solicitation on the floor

A second distinctive institutional feature of floor trading is that open outcry supports brokered crossing activity (facilitation and solicitation) subject to exposure rules, and that the rulebook provides explicit *crossing entitlements* that can be interpreted as incentives to bring order flow to the floor.

Facilitated and solicited transactions. A facilitated transaction is an agency order crossed with the floor broker's proprietary interest (i.e., the broker/firms "facilitates" the customer order). A solicited transaction is an agency order crossed with pre-arranged contra interest ("solicited" liquidity). These transactions are permitted only if executed under open outcry exposure and allocation rules.[31]

Exposure and competition. Even when a broker intends to cross or facilitate, the order must be exposed to the crowd so that other in-crowd liquidity providers can compete. In practice, the broker requests quotes, and the cross may only occur at a price consistent with

[28] Rule 5.91.

[29] Rule 5.90, including the "30-second standard" for display under normal conditions and the enumerated exemptions.

[30] See Rule 6.1 on trade reporting (including the 90-second requirement and outage procedures).

[31] See Rule 5.86 for the detailed mechanics and conditions; Cboe Regulatory Circulars also emphasize that floor trades must not be executed as non-exposed private crosses.

the crowd's market and the protection of priority interest (including Priority Customer orders in the Book).[32]

Crossing entitlement. If the relevant conditions are met, the broker (facilitator/solicitor) may receive a specified share of the remaining non-customer contracts (after Priority Customer Book interest is satisfied and after other priority rules apply). In the C1 framework, the entitlement depends on the circumstances and the type of cross (and may also be limited by combined entitlements when a DPM/LMM also has a participation entitlement).[33]

Why this matters empirically. Crossing entitlements and the ability to solicit contra interest provide a clear microstructure channel through which floor execution can differ from purely anonymous, time-priority electronic execution. These features may affect execution costs and the distribution of who supplies liquidity, especially for large and/or complex institutional packages.

H. Complex orders: electronic mechanisms, constraints, and the floor boundary

Definition and representation. A complex order is a multi-leg package (two or more legs) executed at a net debit/credit price (and, in some cases, may include an underlying stock or security future leg). C1 maintains a complex order book (COB) where eligible complex orders may rest and interact with other complex orders and, subject to restrictions, with liquidity implied from the individual-leg (simple) books.[34]

Electronic complex execution pathways. For eligible complex orders, electronic execution may occur through: (i) the continuous complex order book (resting complex liquidity interacting under price-time rules); (ii) complex order auctions (COA), which expose a complex order to solicited/competitive responses; and (iii) other auction/crossing mechanisms (e.g., complex variants of AIM or SAM, where available).[35]

Key eligibility constraints that differentiate electronic vs floor execution. Cboe's rulebook and technical specifications impose multiple constraints that define the boundary

[32]See Rule 5.86 and Rule 5.87 (Crossing Orders) for the request-for-market and price constraints; see also floor-trading circulars on the open outcry and exposure requirements.

[33]Rule 5.86 sets out the percentage entitlements and caps (including limits on the combined DPM/LMM participation entitlement and the crossing entitlement).

[34]See Rule 5.33 for the definition of complex orders, COB handling, and the synthetic best bid/offer concepts used for complex order evaluation and price protections.

[35]Rule 5.33 describes complex order auction handling and interaction with COB; Cboe also publishes technical specifications describing these mechanisms and their eligibility constraints by class and session.

between electronic and floor execution for complex strategies. Three are particularly relevant:

1. **Contract ratio constraint (the "3:1 boundary").** Under normal (pre-COVID) rules, other than Index Combo orders, complex orders with contract ratios outside the range [1/3, 3] are not eligible for electronic processing and must be submitted for manual handling and open outcry.[36]

2. **Leg-count and legging restrictions.** Even for electronically eligible ratios, complex orders face restrictions on (i) the maximum number of legs permitted for a given electronic pathway and (ii) whether the complex order may "leg" into the simple book. The system may permit legging only for strategies with a small number of legs (e.g., two, three, or four), and may prohibit legging for certain sign patterns (e.g., all-buy or all-sell three/four leg strategies) and for stock-option orders.[37]

3. **Special price types and strategy codes.** Cash-priced complex orders (cash spreads) and certain strategy/trade-condition codes (e.g., specific combo handling for SPX/SPXW) may be rejected in the electronic workflow and require floor routing.[38]

Complex order priority protections in open outcry. C1 also specifies when a complex order executed in open outcry may execute at a net price without "giving priority" to equivalent bids/offers in the individual-leg markets. The rulebook distinguishes between (i) complex orders with ratios within the standard electronic range and (ii) high-ratio complex orders that are floor-only in normal times. For example, for certain standard-ratio complex orders, open outcry execution without giving priority to resting leg interest is permitted only if at least one leg improves the corresponding best bid/offer of a Priority Customer order in the Book by at least one minimum increment. For high-ratio complex orders (outside [1/3, 3]), the rulebook requires more stringent improvement conditions across legs.[39]

Substitution and "strategy splitting" when electronic constraints bind. These eligibility constraints generate a natural substitution margin between floor and electronic

[36] Rule 5.83(b).

[37] See Rule 5.33(g) on legging restrictions and the exchange-determined maximum number of legs for legging eligibility.

[38] See the Cboe US Options Complex Book Process specification for Cash Spreads and trade-condition-code handling, including PAR routing requirements.

[39] See Rule 5.85(b) for the detailed conditions for open outcry complex execution without giving priority to equivalent bids/offers in the individual series. These conditions are central to how the hybrid market protects Priority Customer interest when floor-negotiated net prices do not map one-for-one onto the displayed leg markets.

execution. When the desired strategy falls outside the electronically supported set—e.g., a ratio backspread with ratio > 3:1, a package with many legs beyond the electronic maximum, a cash-price spread, or a strategy requiring a trade-condition code not accepted electronically—a trader must either: (i) execute the package via PAR/open outcry (when available), or (ii) approximate the same economic exposure through multiple electronically eligible orders (for example, splitting a high-ratio strategy into two or more lower-ratio complex orders, or combining one complex order with one or more single-leg orders). The second approach can introduce *legging risk* (interim exposure to market moves between component executions), can worsen information leakage (multiple prints and/or multiple exposures), and can alter priority/exposure mechanics relative to a single negotiated net-price package.

I. COVID-19 floor closure: operational shift and confirmatory rule changes

On March 16, 2020, Cboe temporarily closed its Chicago options trading floor due to the COVID-19 pandemic. During the closure period, open outcry trading ceased, and C1 operated in a screen-based only configuration.[40]

Operational consequences. Cboe announcements emphasized that, with the floor closed: (i) orders with instructions to route to the trading floor would be rejected/returned, and (ii) floor brokers and market makers could continue to participate electronically from remote locations using approved order-entry tools (e.g., institutional front ends and exchange-connected interfaces).[41]

Temporary expansion of electronic complex-order eligibility. Because the floor previously served as the execution channel for high-ratio complex strategies, Cboe implemented confirmatory/temporary rule changes to accommodate that order flow in the electronic environment. In particular, for exclusively listed index option classes, Cboe temporarily expanded the definition/eligibility of complex orders for electronic processing to include ratios up to 25-to-1 (and down to 1-to-25), and set corresponding minimum increment rules for these complex orders.[42] This is the institutional channel through which the 2020 floor closure changes the feasible set of complex strategy executions.

Temporary activation/expansion of electronic auctions for SPX. During the floor closure, Cboe also activated or expanded certain electronic auction mechanisms for SPX/SPXW

[40]See Cboe operational updates and circulars regarding the March 2020 closure and the opening date.

[41]See Cboe floor-closure updates describing how floor participants could continue to trade electronically and how floor-directed orders were handled.

[42]See the screen-based-only environment provisions regarding loss/inoperability of the floor and Cboe's COVID-related rule change filings and circulars that expanded complex-order ratio eligibility.

complex orders (including AIM/C-AIM functionality) that were otherwise limited, and it later reinstated RTH constraints (including size caps) as the floor resumed.[43]

J. Why the floor still exists?

Although the listed options market is predominantly electronic, the Cboe floor persists in part because it supports *package-level negotiation and execution* for certain large and/or complex orders whose economics are not always well served by standardized electronic constraints. Three institutional reasons stand out:

1. **Feasible-set differences (what the floor can do that the electronic workflow restricts).** Ratio constraints (e.g., the 3:1 boundary in normal times), leg-count limits, cash-spread handling, and special trade-condition codes can make some strategies effectively floor-only. Even when an economic exposure is replicable electronically, it may require splitting into multiple orders, increasing execution risk and complexity.

2. **Liquidity formation for certain complex instruments.** Cboe has acknowledged that some complex instruments (e.g., box spreads, box swaps, and jelly rolls) have historically traded predominantly in open outcry and that electronic liquidity formation for these packages can be constrained in important index products.[44]

3. **Hybrid incentives and governance.** Floor-specific participation entitlements and crossing mechanics (facilitation/solicitation), coupled with exposure rules and customer-priority protections, create a distinct trading protocol that can be valuable for institutional package execution and for market makers supplying liquidity in stressed conditions.[45]

Implication for empirical interpretation. These institutional features imply that the floor is not merely a "legacy" execution channel, but a complementary mechanism that (i) expands the feasible set of package executions, (ii) changes the exposure/information environment of execution, and (iii) can concentrate liquidity for certain classes of multi-leg index strategies. This is precisely why the temporary removal of the floor and the contemporaneous expansion of electronic complex-order eligibility during March–June 2020 provide informative variation for studying execution outcomes across mechanisms.

[43] See SEC releases and Cboe rule filings around March–October 2020 regarding SPX AIM/C-AIM activation, response interval settings, and maximum eligible order size in RTH. These filings explicitly discuss balancing electronic functionality with the role of the floor for larger and more complex institutional orders.

[44] See Cboe documentation on the Quoted Spread Book (QSB) initiative and related statements about why certain spreads historically concentrated on the floor.

[45] See Rules 5.85–5.87 and related Regulatory Circulars for the incentive/protection design embedded in open outcry allocations and crossing.

IA.II: Complex Order Reconstruction and Strategy Classification

We follow Li (2020) and Li et al. (2023) and group legs into packages based on the proximity of their timestamps. More specifically, we require that each new leg arrive within 3 ms of the first leg in the candidate group and within 2 ms of the immediately preceding leg.[46,47]

Table IA.I presents an example of how the grouping works in practice. The first three legs share an identical timestamp and carry TradeConditionID 119, indicating an electronic execution on the complex order book (MultLegAutoEx). Their sizes follow a 1:2:1 ratio across three distinct strikes of the same option type and expiration, and the algorithm, therefore, identifies them as a Butterfly. The next two legs are reported twelve milliseconds later with TradeConditionID 120, indicating an execution in an electronic auction (MultLegAuct). They share the same strike and expiration but have opposite option types (one Call, one Put) in a 1:1 ratio, with opposite trade directions, and the algorithm identifies them as a Combo. Although the prints all fall within a twelve-millisecond window, the gap between the Butterfly and the Combo (twelve milliseconds) exceeds the 3 ms first-to-last threshold that any candidate package must satisfy, and the algorithm, therefore, classifies them as two separate complex trades. The differing TradeConditionIDs (119 versus 120) and the structural mismatch between the two groups (single option type with three strikes for the Butterfly versus opposite option types at the same strike for the Combo) are consistent with this classification.

As in Li et al. (2023), we sign strategies based on comparing the net price of the complex trade to its synthetic midpoint. For instance, the Butterfly in Table IA.I executed at a net price of \$2.25 per share,[48] while its synthetic midpoint, computed as the ratio-weighted sum of leg midpoints across the three legs, is \$2.35 per share.[49] Because the net price is \$0.10 below the midpoint, the trade is signed as seller-initiated. Combo trades, however, cannot be identified and signed solely based on their structure, as this requires inferring the trade direction of the put and call legs. We follow Moussawi et al. (2022) and sign

[46] We adopt the two-threshold time-window rule of Li (2020) but replace the disjunctive (OR) condition with a conjunctive (AND) one: rather than requiring a leg to arrive within 3 ms of the first leg in the group *or* within 2 ms of the previous leg, we require *both*. This imposes a hard 3 ms ceiling on the first-to-last leg span of any package, preventing time-chaining in which many small consecutive 2 ms gaps accumulate into a much larger total span, and reducing false-positive groupings.

[47] Cboe also permits a Combo to be packaged with additional legs (e.g., a Combo plus a Vertical). Cboe refers to these structures as Index Combos and describes them as Combos paired with additional legs to offset or take on additional risk; we, therefore, treat them as Combos in our analysis. We apply a stricter 0 ms tolerance to avoid false positives in which an unrelated nearby strategy would be paired with a Combo and misclassified as an Index Combo.

[48] Net price = wing 1 + wing 2 - 2 × body = 40.86 + 24.03 - 2(31.32) = \$2.25.

[49] The synthetic midpoint is $(synth\_ask + synth\_bid)/2$, where $synth\_ask$ sums the asks of long legs minus the bids of short legs (ratio-weighted) and $synth\_bid$ does the reverse. For the Butterfly, $synth\_ask = 41.1 + 24.2 - 2(31.1) = \$3.10$ and $synth\_bid = 40.7 + 23.9 - 2(31.5) = \$1.60$, giving a midpoint of $(\$3.10 + \$1.60)/2 = \$2.35$.

Combo trades using the Lee and Ready (1991) algorithm applied to each leg. Using this procedure, we successfully group 89% of complex trades in our sample into one of 33 standard strategy categories.

As shown above, the net price and synthetic midpoint are computed on a per-leg basis, with each leg weighted by its ratio (1:2:1 in the Butterfly example). The effective spread is defined as the inferred trade direction times the difference between the net price and the synthetic midpoint, which is $0.10 (or 10 cents) per share for the Butterfly. All Greeks are ratio-weighted across legs in the same way. This normalization makes effective spreads, Greeks, and all quantities comparable across strategies with different numbers of legs, all expressed on a per-underlying-share basis.

Table IA.I. OPRA Print Grouping

This table shows an example of how OPRA prints are grouped into distinct complex trades. The first three rows are identified as the legs of a 1:2:1 Butterfly; the last two are the legs of a 1:1 Combo. All five prints were reported on May 26, 2020.

Symbol	Time	TradeCondID	Size	Price	Ask	Bid	Expiration	Strike	Type
SPX	2020-05-26 11:49:39.377	119	40	40.86	41.10	40.70	2020-06-19	2900.0	P
SPX	2020-05-26 11:49:39.377	119	80	31.32	31.50	31.10	2020-06-19	2850.0	P
SPX	2020-05-26 11:49:39.377	119	40	24.03	24.20	23.90	2020-06-19	2800.0	P
SPX	2020-05-26 11:49:39.389	120	200	158.88	159.20	158.50	2020-09-18	3000.0	C
SPX	2020-05-26 11:49:39.389	120	200	168.88	169.30	168.50	2020-09-18	3000.0	P