Not Dead Yet: Options Trading Floors

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

November 22, 2026

ABSTRACT

Over 20% of U.S. options dollar volume trades on physical floors, mostly in S&P 500 index options. We study the COVID-19 closure of the Cboe floor, when Cboe activated SPX complex auctions, to identify the impact of floor trading. The floor executes complex trades, particularly the largest. Floor trades cost 36% more than matched electronic trades during the closure. Smaller trades are more expensive on the floor, while the largest are cheaper. Without the floor, the largest and most complex trades become half as prevalent. The floor facilitates the most difficult trades, but executes less difficult ones at higher costs.

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

---

*Luca Galati is with the LMU Munich School of Management at the Ludwig Maximilian University of Munich and with the Digital Finance Cooperative 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 Christina Atanasova (discussant), Darrell Duffie, Tom Ernst, Pankaj K. Jain, Marta Khomyn (discussant), Albert "Pete" Kyle, Albert Menkveld, Dmitriy Muravyev (discussant), Marios Panayides, Neil Pearson (discussant), and Citadel for helpful conversations and to conference and seminar participants at the EUROFIDAI-ESSEC Paris December Finance Meeting, the 39th Australasian Finance and Banking Conference, the FMA 2026 Asia/Pacific Conference, the FMA-Cboe 2026 Conference on Derivatives and Volatility, the Microstructure Exchange fall 2026 online seminar, the 15th CDI Conference on Derivatives, the UZH Rising Scholar Conference in Finance 2026, the University of Alberta, and the 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, Ludwig Maximilian University of Munich, Schackstraße 4, 80539 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). Although brokers and designated market makers still stand on the floor of the New York Stock Exchange (NYSE), floor trading accounts for roughly 3% of consolidated share volume, concentrated in the opening and closing auctions. In U.S. listed options, by contrast, over 20% of dollar volume executes through open outcry, about three quarters of it in S&P 500 index options (SPX) on the Chicago Board Options Exchange (Cboe).[1] Market participants disagree about what the floor does. Electronic market makers describe it as a venue for internalizing crosses and small orders. Exchanges that operate floors describe it as the venue for large, complicated orders that electronic systems handle poorly or not at all.[2] Why has open outcry persisted in this corner of the market when it disappeared elsewhere? What would be lost if it disappeared?

This paper exploits the COVID-19 closure of the Cboe floor to answer these questions. Cboe activated an electronic auction for complex SPX orders during the closure and withdrew it when floor trading resumed on June 15, 2020. Execution costs rise with trade size electronically and fall with it on the floor. Relative to electronic trades of the same size, floor trades pay 3.67 cents more in the smallest size quintile and 2.79 cents less in the largest. The quoted half-spread of a package is the cost of executing every leg at its quote. As a share of that half-spread, floor costs fall from 25% in the smallest quintile to 8% in the largest. Electronic trades pay about 15% at every size.[3] For the trades that

[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 invested in a new, larger trading floor in Chicago in 2022 (see Cboe) and partnered with CNBC to broadcast from the Chicago trading floor in 2026 (see Cboe). Floors are still being built. MIAX Sapphire opened an options trading floor in Miami in September 2025 (see MIAX).

[2] At the SEC's Roundtable on Options Market Structure on April 16, 2026 (Securities and Exchange Commission, 2026), John Fischer of Citadel Securities said, "We see internalization of small or retail-size orders on the floor as a major issue" (transcript, p. 87). Andrew Schultz of Susquehanna said that "the floors almost never price improve on an exposed block order price" and proposed that any trade under 500 contracts be exposed electronically (p. 85). Steve Crutchfield, formerly of Chicago Trading Company, said that "the only reason that orders go to floors is when someone is looking to internalize a big cross" (p. 90). He allowed for single-list products with liquidity concentrated on one floor, such as SPX (pp. 88–89). Kevin Tyrrell of NYSE said that "the floor is handling larger, more complicated orders" and that 75 to 80 percent of the activity on NYSE's options floors is multi-leg or stock-related (p. 82).

[3] The quoted half-spread is built from the leg NBBOs at the time the package price is fixed (Section I.D). With Cboe's complex order book quotes missing from the data, the benchmark is legging. Because the NBBO is for displayed size, it understates what legging a large package would cost and makes the 8% for the largest

both mechanisms execute, matched on option risk, size and complexity, floor trades cost 1.14 cents more, 36% of the electronic spread. Similar S&P 500 ETF (SPY) complex trades, which do not execute on the Cboe floor, show no change in cost.[4] Because most trades are small, the floor costs more in a trade-weighted average. In a contract-weighted average it costs less, saving about $120 million a year on the largest SPX complex trades against $17 million lost on the smaller ones. The share of complex SPX dollar volume from the largest and most complex trades falls by about half during the closure, from 24% to 13%, before it recovers to 21% when floor trading resumes. The floor executes the most difficult trades and costs more than electronic execution for the less difficult ones.

The economic role of the floor is to execute bundles of offsetting exposures at a single price. A package with a large gross position and a small net exposure to the index is cheap to absorb when its legs, the options it combines, trade together, because the market maker prices the net risk. Traded leg by leg, gross risk equals net risk with the added risk that the other legs do not fill. The same netting logic motivates proposals to let investors trade portfolios directly (Budish, Cramton, Kyle, Lee, and Malec, 2023) and to clear Treasury trades centrally so that offsetting obligations net (Duffie, 2023).[5] The floor adds two features. The residual risk of a package is divided among market makers who each choose their share, and no single firm has to commit to the whole position. Trade size is the main determinant of routing, but packages that net more of their delta go to the floor. Within size and strategy, the floor's cost relative to electronic execution declines as more of the delta nets. Packages that net vega rather than delta are more likely to trade electronically (Internet Appendix Section IA.IX). Our evidence shows what is lost when this mechanism disappears. The largest packages halve during the closure, and rebuilding one from electronic orders costs one and a half to two and a half times as much.

These results contribute to three literatures. Work on human intermediation asks whether human or electronic execution delivers better outcomes (Venkataraman, 2001; Barclay, Hendershott, and McCormick, 2003; Hendershott and Madhavan, 2015; Jain, 2005), most recently around the 2020 NYSE floor closure (Brogaard, Ringgenberg, and

floor trades, if anything, generous to the electronic alternative.

[4]SPY is an ETF that tracks the S&P 500. Unlike SPY options, which are American and settle into ETF shares, SPX options are European and cash-settled on the S&P 500 index.

[5]We thank Darrell Duffie and Pete Kyle for suggesting this connection.

Roesch, 2025; Hu and Murphy, 2026).[6] In SPX options, effective spreads are an order of magnitude larger than price impact (Kaeck, van Kervel, and Seeger, 2022). Other papers on how options orders execute study wholesaler internalization of retail flow (Bryzgalova, Pavlova, and Sikorskaya, 2023; Ernst and Spatt, 2026), auctions and quote competition (Anand and Muravyev, 2025) and the execution quality of electronic auctions (Hendershott, Khan, and Riordan, 2026). In the block trading literature, non-anonymous upstairs trading separates liquidity-motivated traders from informed traders and reaches liquidity that the downstairs book does not display (Seppi, 1990; Grossman, 1992; Madhavan and Cheng, 1997; Bessembinder and Venkataraman, 2004). The floor is also a market for packages. Budish et al. (2023) propose exchanges that accept orders for portfolios. Duffie (2023) argues that central clearing would net offsetting Treasury positions. In corporate bonds, investors now often sell a basket to one dealer as a single unit of risk, at lower cost than the same bonds traded one by one, though the saving shrinks as the basket grows and can vanish when markets falter (Meli and Todorova, 2026; Li, O'Hara, Rapp, and Zhou, 2025). The floor nets a package in the same way and, unlike a bond portfolio trade, divides it among several market makers. The closure shows what is lost when such a market is removed.

Orders route to a mechanism on characteristics that also determine execution quality. The endogenous switching models that address this selection (Madhavan and Cheng, 1997; Conrad, Johnson, and Wahal, 2003; Bessembinder and Venkataraman, 2004; Hendershott and Madhavan, 2015) are sensitive to specification. The closure of the Cboe floor from mid-March to mid-June 2020 lets us observe execution costs while the mechanism is unavailable.[7] Because SPX trades only on Cboe, the complex trades that the floor serves had no other exchange. During the closure Cboe activated the Automated Improvement Mechanism (AIM) for SPX, an auction in which a broker exposes a pre-negotiated contra order to competing responses (Hendershott et al., 2026). It also raised the maximum leg

[6] In equities, 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 on more than a dozen venues. Listed options, by contrast, must trade on an exchange under Options Clearing Corporation rules. Brogaard et al. (2025) find that the suspension widened spreads and increased pricing errors. Hu and Murphy (2026) find that the floor reduces closing price efficiency for low-spread stocks.

[7] The floor had not previously closed while electronic trading continued. In earlier exchange-wide shutdowns, such as the four-day closure after September 11, 2001, all venues closed together.

ratio of electronically eligible complex orders from 3:1 to 25:1. The opening of June 15 restored the floor, removed AIM and reinstated the 3:1 limit on the same day. Because it bundles the floor with electronic eligibility, we also estimate on the orders eligible under both rule sets, with a leg ratio of 3:1 or less and 12 or fewer distinct options. These orders include 63% of floor trades and give the same results (Internet Appendix Section IA.VIII).[8] We study the opening rather than the start of the closure because the VIX rose above 80 in March. Around the June opening, the VIX averages 29 before and 33 after and does not jump on the day the floor reopens.[9]

The closure does not by itself make floor and electronic trades comparable. We measure complexity by the number of legs counted with their ratios and check the results with the number of distinct options and the maximum leg ratio.[10] Floor trades in the two weeks after the opening average 784 contracts and 12.1 legs, against 36 contracts and 2.6 legs for electronic trades (Table VI). Their 3.1 distinct options and maximum leg ratio of 6.2 compare with 2.3 and 1.2 for electronic trades (Internet Appendix Table IA.XXIV). The largest and most complex floor trades have no electronic counterpart. In a logit of floor routing after the opening, trade size alone gives a pseudo-R^2 of 0.64, which rises to 0.70 with the number of legs (Table III) and to 0.71 with distinct options and the maximum leg ratio in its place (Internet Appendix Table IA.XXIII).

Across all trades, floor trades after the opening cost 1.27 cents more than electronic trades during the closure. The difference falls with trade size until trades of more than 1,000 contracts are cheaper on the floor.[11] The number of legs raises costs in both mecha-

[8]Cboe's rules also provide for compression forums, in which members cross offsetting SPX positions on set days (Cboe Global Markets, 2019, Rule 5.88). No 2020 trade in the Cboe execution file carries the compression identifier. The results hold for customer-initiated trades, which are unlikely to be compression trades (Internet Appendix Table IA.IV). The higher floor cost of small trades also appears in public Options Price Reporting Authority (OPRA) data, which lack trade signs and package identifiers. The large-trade comparison depends on how trades are signed and requires the Cboe data.

[9]Cboe announced a June 8 opening on May 26 and postponed it to June 15 after civil unrest restricted access to the building (Cboe Global Markets, 2020a,b). Around the closure, floor trades also cost more than their electronic matches (Internet Appendix Section IA.I).

[10]The ratio-weighted number of legs, the sum of the leg ratios, counts a 1:1:20 Index Combo as 22 legs. The maximum leg ratio is the number of contracts in the largest leg per contract in the smallest. The number of distinct options and the maximum leg ratio separate a spread with many different options from a spread hedged with a large Combo.

[11]The large-trade difference does not rest on a few trades. Dropping the largest 1% or 5% of floor trades gives −2.68 and −2.26 cents, each significant at the 5% level or better (Internet Appendix Table IA.IV). Every trading day after the opening contributes floor trades to the largest quintile (Internet Appendix

nisms and does not explain the decline (Table V). Matching each floor trade with its nearest electronic trade on option risk, size and the ratio-weighted number of legs gives 1,177 pairs, 36% of floor trades. A match on distinct options and the maximum leg ratio in place of the legs leaves 1,071 pairs with similar differences (Internet Appendix Section IA.VII). Coverage falls from 62% of the smallest quintile of floor trades to 9% of the largest. Within the pairs, the difference reverses with size as it does across all trades, from 2.51 cents in the smallest quintile to −2.08 cents in the largest, which has only 60 pairs (Internet Appendix Table IA.V). Pooled, with the full set of controls and strategy fixed effects, matched floor trades pay 1.14 cents more than their matches, with a similar difference in market maker revenue. Against AIM alone the difference doubles to 2.45 cents.

Unmatched floor trades are three times the size of matched ones and far more complex. Linear and machine learning models of the effective spread fitted to the electronic orders of the closure predict that, above the 80th percentile of floor trade size, these trades would have cost 1.9 to 4.8 cents more electronically, though the models extrapolate from smaller and simpler orders. Assembling a trade at the 90th percentile of floor size, 1,950 contracts, from consecutive electronic orders takes 65 orders over about a minute and costs about $6,200 in spreads and futures slippage. Floor trades of that size cost $2,400 to $4,200. Whether split or deferred, the large packages missing during the closure no longer executed as one. The replication prices the split.[12] We measure the costs of realized trades, not of trades desired but not executed (Perold, 1988). The trades that execute are the cheaper ones (Hendershott, Li, Livdan, and Schürhoff, 2024). Because small trades fill in either mechanism, selection does not explain why electronic auctions are cheaper for them. For large complex trades, which rarely execute electronically, selection understates the electronic cost and the floor's advantage.

Why do the largest trades go to the floor and cost less there? A simple explanation is a fixed cost per floor trade, since executing in the crowd uses people's time whatever the size of the order. A fixed cost of $500 per trade is $5.42 per contract, or 5.4 cents per unit of underlying, for a trade of 92 contracts, the mean of the smallest quintile. For a trade of

Section IA.II).

[12]Consistent with deferral, the share of complex SPX dollar volume from large, multi-leg packages reaches its low in the week of June 1, after the announcement of the opening. Direct tests for splitting are noisy. Only Complex Order Auction orders are more often followed within 60 seconds by an identical order during the closure than after the opening (Internet Appendix Section IA.X).

2,668 contracts, the mean of the largest, it is $0.19 per contract. Fitting a constant plus a fixed cost over size to the quintile means gives about $400 to $500 per floor trade and no fixed cost electronically. The fixed cost explains why the floor's extra cost fades with size. The rise of electronic costs with size flips the gap at the top. A fixed cost does not explain why electronic costs rise with size while floor costs per contract do not, why large packages halve when the floor closes or why the floor's extra cost falls with delta netting. Three differences between the mechanisms do. First, an AIM auction cannot start without contra interest that guarantees execution of its full size (Cboe Global Markets, 2019, Rules 5.37 and 5.38). The complex order book offers little committed liquidity because market makers need not quote complex strategies, and they initiate 94.5% of the packages that execute against it. On the floor, a broker represents the order to the crowd without first lining up a contra party. Without the floor, a large complex trade is certain to execute in full only if a member commits to the entire position before the auction starts.

Second, the floor can allocate an order more flexibly. Several in-crowd market makers can share an order (Cboe Global Markets, 2019, Rules 5.52(b) and 5.85). Allocation in AIM mostly follows a fixed rule that gives the initiating order 40% or 50% of the agency order (Cboe Global Markets, 2019, Rule 5.38). Within size quintiles, an additional fill per leg on the floor is associated with a spread more than 2 cents wider than in AIM for trades below 260 contracts and about 0.7 cents narrower above 1,000 contracts. A large trade shared across the crowd lets several market makers compete for pieces of it. Each takes the part that fits its inventory and risk limits, and sharing the position until it is offset lets the crowd offer a better price (Grossman and Miller, 1988). Sharing is worth most for packages that net. Relative to electronic trades, the floor's effective spread as a share of the quoted half-spread falls by 0.17 as the delta-netting share of the package rises from zero to one, conditional on trade size, the number of legs, their interactions with the floor indicator, the full set of controls and strategy fixed effects (Internet Appendix Table IA.XXIX). For small orders the comparison runs the other way. An electronic auction exposes the order to every market maker at once. Because exposure on the floor is the broker's effort, which a small order does not repay, the order often goes to one market maker, who prices it bilaterally rather than in competition.

The third difference is screening. A trader can forgo anonymity through a broker known in the crowd (Benveniste, Marcus, and Wilhelm, 1992; Grossman, 1992). Brokers

also know latent traders whose interest the electronic book does not display (Harris, 2003). The incentive to shop an order grows with its size. Revealing a large client's motive and size draws competing market makers into the crowd, and a liquidity-motivated trader who is not anonymous can credibly commit not to trade further (Seppi, 1990). Although the data do not record what brokers disclose, the costs fit this choice. The higher cost of small floor trades, which mostly go to one counterparty, is realized spread with no extra price impact. Across all trades, floor trades show no futures price impact. Above the 80th percentile, floor trades have an option price impact 2.68 cents lower than electronic trades of their size and move futures prices 0.49 basis points less per $10,000 of signed delta within 10 seconds.

These findings inform market design. The floor accounts for 70% of complex SPX dollar volume but only 1.6% of orders. A small number of large, netted positions generate most of its activity. For the largest trades the floor costs less and has lower price impact. The largest positions have no electronic match at all. With electronic execution cheaper for smaller, easier trades, having both mechanisms could lower aggregate transaction costs. The lesson is not specific to SPX. What the floor provides is a way to execute a netted package in which no single firm commits to the whole position and each liquidity supplier chooses its share. Portfolio trading in bond markets and the design of electronic auctions for complex orders face the same problem. Why Cboe does not offer an electronic auction with the flexibility of the floor, and whether the floor's economics survive when its smaller trades execute electronically, are questions for future research.

I. Complex Options Trading on the Floor and Electronically

SPX options trade only on Cboe, where a complex order can execute on the trading floor or electronically. The floor executes most complex SPX dollar volume, and its closure from March 16 to June 14, 2020, left the electronic mechanisms to execute that flow.

Cboe Options Exchange ("C1") operates a hybrid market in which electronic order handling and open outcry floor trading coexist (Cboe Global Markets, 2019, 2026). On the electronic side, individual option series trade in a limit order book (LOB), the Simple Book, where resting orders execute against incoming marketable orders in price-time priority. Multi-leg orders have a parallel facility, the complex limit order book (CLOB),

where an order for two or more legs at a guaranteed net price can rest and execute against other complex orders, or against the individual series books when their combined liquidity permits. Cboe also operates the Complex Order Auction (COA), which exposes a marketable complex order to competing responses for 100 milliseconds in most classes and then fills what it can against the responses and resting interest. Any unfilled balance rests in the CLOB.[13]

C1 also has a physical trading floor in Chicago. Floor brokers receive orders from clients, such as asset managers, hedge funds, and the proprietary desks of clearing members, and represent them in the trading crowd, where registered market makers respond with competing bids and offers in open outcry. Orders reach the floor through PAR (Public Automated Routing System), the workstation that connects the electronic system with floor execution.

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 call bought at $3.00 and a put sold at $1.00 in a 1:1 ratio trade at a net debit of $2.00, wherever the individual legs trade within that constraint). Simultaneous execution eliminates execution risk, the possibility that one leg fills while another does not, which would leave the trader with an unintended position. For strategies whose legs offset each other's exposures, the package hedges only if every leg executes.

SPX complex strategies include vertical and calendar spreads, straddles and strangles, butterflies, condors, and ratio spreads, which Table IA.XV of the Internet Appendix defines.[14] A Combo pairs a long (short) call with a short (long) put at the same strike and expiration and replicates a long (short) S&P 500 futures position. Packages that combine Combos with additional legs or other Combos are among the largest packages.

We combine trade records from the Options Price Reporting Authority (OPRA) and from the Cboe Options trade-by-trade execution file with option and futures quotes from LSEG Tick History. OPRA reports every U.S. listed options trade in real time with its price, contract size, millisecond timestamp, exchange identifier, and a condition code that records whether the trade executed on the floor or electronically and whether it was part of

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

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

a complex package. We use OPRA for total dollar volume across all U.S. options exchanges and for the SPY placebo samples, because SPY options trade on many exchanges.[15]

The Cboe data come from the Enhanced U.S. Options Trade-by-Trade Execution Detail file of Cboe DataShop. It reports every execution on C1 in 2020 for all underlyings, electronic and open outcry, single-leg and complex, and therefore contains every SPX execution. Each execution appears as two records, one for the buyer and one for the seller, linked by a common execution identifier. Each record reports the participant's side and capacity, which Cboe classifies as customer, professional customer, broker-dealer, firm, or market maker.[16] A trade-type field identifies the mechanism of each execution and, for some executions, which record belongs to the initiating order.

OPRA reports complex trades leg by leg, without an identifier linking the legs of a package. The Cboe file links them. For electronic trades, a complex execution identifier links all legs of a complex execution. For open outcry trades, the file records the time at which the trade was agreed in the crowd, and we define a floor package as all records sharing an agreement timestamp on a given day.[17] Because the file has no order identifier, an electronic order that executes against several counterparties can appear under several complex execution identifiers, and we combine complex executions with the same legs and sides, leg ratio, initiator capacity, mechanism, and microsecond timestamp into one electronic order. The Cboe identifiers link the legs of each SPX package directly, and we do not need a time-window rule (such as the 3-millisecond rule) of Li (2022), which would split many floor orders.[18] We classify each package into a standard strategy type (vertical spread, butterfly, condor, Combo, Combo paired with additional legs, and others) with the leg-configuration rules of Li (2022). About 95% of complex packages are classified. The remaining 4.9%, labeled non-standard, are used only for volume shares, such as the share of SPX volume that is complex, and in none of the spread analyses. Sections IA.IV

[15] Because OPRA neither links legs nor identifies initiators, we group SPY legs into packages with the time-window rule of Li (2022) and sign them with the quote rule.

[16] Cboe records the capacity of each order (Cboe Global Markets, 2019, Rule 1.1): customer (C), a person that is not a broker-dealer; professional customer (U), a non-broker-dealer that places more than 390 listed options orders per day on average; firm (F, J, and L), the proprietary accounts of clearing members, joint back office accounts, and accounts of affiliates; broker-dealer (B); and market maker (M and N).

[17] Cboe confirms that this agreement timestamp is common to all legs and fills of the same floor order.

[18] About two thirds of multi-leg SPX floor orders in 2020 span more than 3 milliseconds between their first and last reported leg.

and IA.V of the Internet Appendix detail the procedure.

All variables are constructed at the package level. Trade size is the total number of contracts across all legs. Number of legs is ratio-weighted rather than a simple count of distinct legs: each leg's ratio is its number of contracts divided by the number of contracts in the smallest leg, and the number of legs is the sum of these ratios. A 1:2:1 butterfly therefore has four legs, and a 1:1:20 Index Combo has 22. Dollar volume is the sum over legs of the leg price times the leg's contracts, multiplied by the SPX contract multiplier of $100; buy and sell legs are not netted against each other.

A. The Floor's Share of Complex Trading

Floor trading in U.S. listed options is concentrated in one product. Table I reports average daily volume across all option classes reported through OPRA, by order type and execution venue. In Panel A, complex orders account for about half of OPRA dollar volume (50.67%) and 28% of contract volume, and floor execution accounts for 22% of dollar volume and 8.5% of contract volume. A floor contract trades at about three times the dollar value of an electronic one, mostly because floor volume concentrates in SPX.

Panel B turns to SPX. The class accounts for $3.96 billion in average daily dollar volume, about 26% of OPRA dollar volume, and for 4% of contract volume. Complex orders make up 86% of SPX dollar volume ($3.39 of $3.96 billion). Floor-executed complex SPX orders account for $2.38 billion per day, about 70% of SPX complex dollar volume and 16% of OPRA dollar volume. Floor single-leg (simple) SPX volume is 0.36% of OPRA dollar volume. SPX accounts for about three quarters of all floor dollar volume.[19]

TABLE I HERE

Because SPX is a proprietary Cboe product, all SPX volume, floor and electronic, trades on one exchange under the same rule book and clearing arrangements. Differences between floor and electronic SPX trades therefore do not reflect a choice of listing venue, clearing, or regulation.

Figure 1 plots daily SPX option dollar volume as a share of total OPRA dollar volume. Panel A covers the full sample period, from January to October 2020. Complex SPX trades

[19]These figures cover the pre-closure period and the period after the opening, defined in the notes to Table I.

account for about 20 to 30% of OPRA dollar volume in January, with a dip to about 12% in early February, and single-leg SPX trades for roughly 3 to 5%. Both series rise from late February. Complex volume peaks above 50% of OPRA dollar volume in the first weeks of the closure and then reverts toward pre-closure levels. Panel B covers the four weeks around the opening. Neither series shows a discontinuity at June 15.

FIGURE 1 HERE

Figure 2 splits complex SPX volume by mechanism. Before the closure, the floor executes the majority of complex SPX dollar volume (Panel A). During the closure, floor volume drops to zero and electronic venues execute the flow. At the opening, floor trading resumes and electronic volume, now without the Automated Improvement Mechanism (AIM), falls back toward pre-closure levels. Panel B shows that the change at June 15 is immediate. Floor volume jumps from zero to about 20% of OPRA dollar volume, and electronic volume falls from about 29% to about 7%, a drop significant at the 1% level. The share of complex SPX dollar volume from the largest and most complex trades also falls during the closure and recovers after the opening (Section III.A).

FIGURE 2 HERE

B. The Closure as a Shock to Intermediation

The closure removed the floor brokers and the trading crowd, and Cboe activated an electronic auction for complex SPX orders while the floor was closed. Effective spreads on complex SPX trades rise during the closure and fall at the opening (Table II).

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, 2020c,d). All routing to the floor was disabled, and orders marked for floor execution were rejected. Floor brokers could no longer use the PAR workstations or operate in the trading crowd.

To keep complex SPX orders trading during the closure, Cboe made two temporary changes. First, complex SPX orders with leg ratios up to 25:1, including strategies previously restricted to floor execution, became eligible for electronic execution in the CLOB and the COA. Second, Cboe activated AIM for SPX complex orders during regular trading hours, a function it had not previously allowed for that class. An AIM auction can start

only after the initiating member pairs the agency order with contra-side interest that guarantees execution of the full order at a stop price (Cboe Global Markets, 2019, Rules 5.37 and 5.38). Other participants can then improve on that price and receive allocations.[20] The Solicitation Auction Mechanism (SAM) remained inactive for proprietary classes including SPX throughout the closure.

Floor trading resumed on June 15, 2020, and all temporary rule changes were reversed that day. The 3:1 ratio limit on electronic eligibility was reinstated, AIM for SPX during regular trading hours was deactivated, and the floor again became the required channel for SPX complex orders with leg ratios above 3:1. The closure and the opening provide the identifying variation. The opening restores the floor and removes AIM and the expanded electronic eligibility on the same day.

The sample runs from January 2 to October 21, 2020. It contains a pre-closure period in which floor and electronic execution are available, the floor closure from March 16 to June 14, 2020, and the period after the opening. The sample begins in January 2020 to avoid contamination from the rule change effective on October 21, 2019, and it ends in October 2020 to exclude the November 16, 2020, rule amendment. We exclude trades executed outside regular trading hours.

Table II reports daily means of trading activity and execution costs (defined in Section I.D) for complex SPX trades (Panel A) and complex SPY trades (Panel B) in the pre-closure period, the closure, and the period after the opening. Complex trades account for 86 to 88% of SPX dollar volume in every period. Before the closure, complex SPX trades average 53 contracts at a net price of $0.01 per unit of the underlying, because offsetting legs lower the net price of a package. Average trade size falls from 53 to 40 to 34 contracts across the three periods.

TABLE II HERE

Equally weighted effective spreads on complex SPX trades are 1.91, 2.33, and 1.80 cents in the three periods, and value-weighted effective spreads are 5.34, 7.58, and 3.83 cents. Spreads rise during the closure and fall at the opening, and market maker revenues

[20] Cboe's regulatory notice specifies that both changes applied only during the electronic-only period and would be reverted when open outcry trading resumed (Cboe Global Markets, 2020d).

follow the same path under each weighting. Hedge costs range from 0.34 to 0.39 cents equally weighted, about a seventh to a fifth of the average complex effective spread.

Panel B reports complex SPY trades, none of which executes on the Cboe floor (Section II.B). Their equally weighted effective spreads follow the same path as SPX spreads (1.09, 1.34, and 0.77 cents), and the decline from the closure to the period after the opening is significant at the 1% level. The regressions with controls in Section II control for these market-wide changes with the VIX and the daily SPY complex spread. We do not study single-leg SPX trades, of which only a small part trades on the floor. A single-leg trade executes against the quotes of its series, and those quotes are also the benchmark for its effective spread. In contrast, the benchmark of a complex trade is the synthetic quote built from the quotes of its legs, which the complex trade usually does not execute against. The benchmark is therefore typically independent of the trade, and the effective spread measures the cost of the complex trade relative to trading its legs in the single-leg books.

The June 2020 opening occurs in less extreme market conditions than the March closure. The closure in March 2020 coincided with the onset of the COVID-19 pandemic, a period of extreme volatility, volume surges, and shifting market participation that could confound any comparison through channels other than the mechanism.

Figure 3 shows the volatility environment. The VIX rises from about 15 to above 80 at the onset of the closure and declines through the spring. In June it moves between about 24 and 41, well below the March peak but above its January level (Panel A). In the four weeks around the opening, the VIX averages about 29 before the opening and 33 after it (Panel B). It jumps on June 11, two trading days before the opening, and shows no discontinuity at the opening date.

FIGURE 3 HERE

We use three sample windows. The full sample, from January 2 to October 21, 2020, covers the periods before, during, and after the closure. Table II uses it to compare descriptive statistics across these periods. The period after the opening, from June 15 to October 21, 2020, is the sample of the floor-routing logit (Section I.C), because routing to the floor is possible only when the floor is open. The opening window, from June 1 to 26, 2020, contains the electronic trades of June 1 to 12, the last two weeks of the closure, and the floor trades of June 15 to 26, the first two weeks after the opening. The comparisons of

floor and electronic trades in Sections II to IV use the opening window, which keeps the two sets of trades at most four weeks apart.

C. The Demand for the Floor: Size and Legs

Average costs mix trades of very different size and complexity, and the mix changes with the mechanisms available. To examine which orders route to the floor, we estimate a logit model of floor execution on complex SPX orders executed after the opening (June 15 to October 21, 2020). In this period, as before the closure, orders can execute on the floor or electronically, and AIM, which was available only during the closure, is no longer available. The matched floor trades of Section II.B are from the first two weeks of this period.

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

The dependent variable equals one if order i executes on the trading floor and zero if it executes electronically. The vector X_i includes trade size, the number of legs, absolute delta, days to expiration, absolute vega, gamma, implied volatility, and an SPXW indicator for PM-settled contracts (Section I.D defines the option characteristics). μ_s denotes strategy fixed effects and $\Lambda(\cdot)$ the logistic function. If the floor serves the trades hardest to execute electronically, the probability of floor execution rises with trade size and the number of legs, holding option characteristics fixed.

TABLE III HERE

Table III reports logit coefficients in Panel A and average marginal effects in Panel B. Most complex orders are small, and only 1.6% of all orders execute on the floor. Size alone yields a pseudo-R^2 of 0.64. Adding the number of legs raises it to 0.70, and adding all controls and strategy fixed effects increases it to 0.80. Size and legs are significant at the 1% level in every specification, including those with strategy fixed effects, so they predict floor execution within strategy types, not only across them.[21] Absolute delta is not statistically significant.

[21] With the number of distinct options and the maximum leg ratio in place of the number of legs, the pseudo-R^2 is 0.71 with trade size and 0.80 with all controls and strategy fixed effects, and the maximum leg ratio is significant at the 1% level in every specification (Internet Appendix Table IA.XXIII). Packages that net more of their delta are more likely to execute on the floor, and packages that net more of their vega less likely (Internet Appendix Table IA.XXVIII).

In the full specification, a doubling of trade size is associated with a 0.51 percentage point higher probability of floor execution, and a doubling of the number of legs with a 0.93 percentage point higher probability, against an unconditional probability of 1.6%. Holding size and legs fixed, floor execution is also more likely for packages with higher absolute vega and less likely for longer maturities, higher implied volatility, and PM-settled contracts. Many floor trades have no electronic match, and Section III.A estimates the cost of assembling a trade of their size from electronic orders.

D. Trade Initiators and End-User Costs

Floor trades are large and complex, and who initiates them matters for how execution costs are measured. Internet Appendix Table IA.XXI reports the capacity of the initiating party of complex SPX packages on each mechanism.

Effective spreads are conventionally measured from the side of the trade initiator, on the assumption that the initiator demands liquidity and pays the spread. In the CLOB, market makers rarely post resting orders. They monitor the complex limit orders that brokers post for their clients and execute against those priced to their advantage (Li, Musto, and Pearson, 2023). The initiator is then a market maker, and the investor who posted the resting order pays the spread. Our focus is the cost paid by end users, the traders other than market makers, such as customers and firms, as in Gârleanu, Pedersen, and Poteshman (2009). We therefore measure execution costs from the side of the end user: the initiator, or its counterparty when a market maker initiates the trade.[22] Market maker revenue is measured the same way. All SPX execution costs in the paper, including those in Panel A of Table II, are end-user measures.

The behavior of market makers in the CLOB is consistent with little standing liquidity for complex strategies. These strategies far outnumber individual series, and Cboe market makers are not required to quote in the CLOB (Cboe Global Markets, 2019, Rule 5.33,

[22]When a market maker initiates a trade against an end user, we measure the spread from the end user's side, so that it captures the end user's cost, which is the market maker's gain. Market makers initiate 1.2% of floor packages, 3% of AIM packages, and almost none of the COA packages over the sample period, so for these mechanisms the two conventions give similar average costs. We also measure the spread from the counterparty's side when both sides are market makers (0.3% of electronic orders and 2 floor trades in the opening window), although these trades have no end user. The main results are the same if we instead measure these trades from the initiator's side or drop them.

Interpretation .01). A large complex order with many legs therefore cannot expect resting interest of its size in the CLOB. It can go to the floor, where a broker represents it to the crowd, or to an electronic auction during the floor closure.

Measuring costs from the end user's side requires the initiating side of each trade. The Cboe data identify it for most trades, while OPRA does not. For electronic trades, the trade type identifies the initiator: the order that removes liquidity from the CLOB or starts a COA or AIM auction. On the floor, the initiator is the order represented in the crowd, which trades against the responding market makers. Fills that cannot be signed this way are assigned using the market-maker side or the order's other fills. Because package spreads require a direction on every leg, we exclude floor orders with any unsigned fills (14% of floor orders in the two weeks before the closure and 20% in the two weeks after the opening). Internet Appendix Section IA.V describes the full signing procedure.

We measure option spreads and implied volatilities against the last quote on each leg before the package price is fixed, which is the execution timestamp for electronic trades and the agreement timestamp for floor trades. The Cboe file reports a national best bid and offer (NBBO) with each record, taken when the trade is reported. Electronic trades are reported when they execute, and their effective spreads, quoted spreads, and market maker revenues use the NBBO at execution. A floor trade can be reported several minutes after its price is agreed in the crowd. For floor trades, we use the quotes prevailing at the agreement timestamp from LSEG Tick History (formerly Thomson Reuters Tick History).[23]

Absolute net delta, absolute net vega and net gamma are contract-weighted averages across legs of option sensitivities evaluated when the package price is fixed. Implied volatility comes from the quote midpoint on each leg. Days to expiration is the contract-weighted average of the remaining calendar days across legs. The regressions use the logs of trade size, the ratio-weighted number of legs and days to expiration. Gamma enters the regressions multiplied by 1,000. Following Li (2022), quoted and effective spreads are computed at the package level against a synthetic midpoint, the contract-weighted average of leg midpoints with each leg signed by the initiator's observed side on that leg, so the quoted spread is the quoted half-spread of the package. The hedge cost is the cost of

[23] With Cboe quotes for floor trades, taken when each leg is reported, the results do not change (Internet Appendix Table IA.IV).

crossing half the E-mini quoted spread on the package's absolute delta, and market maker revenue is the effective spread minus the hedge cost. Spreads are expressed in cents per unit of the underlying and winsorized at the 0.5% level in each tail.

Futures data are microsecond-stamped trades and quotes for E-mini S&P 500 futures on the CME Globex platform, also from LSEG Tick History. We use the front-month contract and roll to the next contract on the first day of the expiration month.[24] Each package is assigned the prevailing futures quote and the most recent futures trade at the time its price is fixed, the timestamp used for option quotes.

The segment of complex SPX order flow that concentrates on the floor consists of large, multi-leg packages initiated by customers and firms and filled by the trading crowd (Section I.C and Internet Appendix Table IA.XXI). Because most electronic trades are small and short-dated and have few legs, only the smaller and shorter-dated floor trades with fewer legs have electronic matches (Section II.B).

II. Execution Costs on the Floor and in the Electronic Market

Size and the number of legs predict which complex orders route to the floor (Section I.C), so the floor and the electronic mechanisms execute different trades. Across all complex SPX trades in the opening window, execution costs rise with trade size in the electronic mechanisms and fall with it on the floor (Section II.A). We then contrast the venues on matched trades, similar positions that both venues execute (Section II.B).

Unless noted otherwise, the analyses of Section II.A and of Sections III and IV use all trades in the opening window. The window contains 3,392 complex SPX floor trades and 205,725 electronic complex SPX orders. Regressions with trade-level controls use the 3,284 floor trades and 201,685 electronic orders with complete controls, unless noted otherwise.[25] Electronic executions are grouped into orders, and costs are end-user measures

[24] E-mini futures expire quarterly on the third Friday of March, June, September, and December.

[25] The two weeks after the opening contain 3,392 complex SPX floor trades. Implied volatility, and therefore the Greeks, cannot be computed for 108 of them. In 81 of these, at least one leg is deep in the money and its quote midpoint is below its intrinsic value, so no implied volatility exists for that leg. The excluded trades are concentrated among the largest, with 42 of them in the top quintile of floor trade size (1,041 contracts or more), 6.2% of that quintile. Effective spread regressions that keep the other trade-level controls but drop the Greeks and implied volatility include all 3,392 floor trades and give qualitatively the same results (not tabulated), so the missing observations do not drive our results.

(Section I.D).

A. Opposite Size Gradients: Adverse Selection versus Dealer Competition

We sort trades into quintiles of the floor trade-size distribution, split at 130, 260, 483, and 1,040 contracts. All later regressions within size groups use these quintiles. Costs can rise with trade size or fall with it. Under adverse selection, as in Easley and O'Hara (1987), informed traders prefer to trade larger amounts, and market makers who cannot identify them in an anonymous market quote wider spreads for larger trades. Under dealer competition, as in over-the-counter corporate bonds, where investors ask dealers for quotes, costs instead fall with trade size (Schultz, 2001; Edwards, Harris, and Piwowar, 2007), as more dealers bid on larger trades (Hendershott and Madhavan, 2015).

Table IV reports mean effective spreads by size quintile within each mechanism. Electronic costs rise with size. Across electronic orders, the mean effective spread rises from 1.89 cents at or below the 20th percentile to 4.78 cents above the 80th percentile, and in AIM from 1.71 to 4.37 cents. Floor costs fall with size, from 7.84 to 2.26 cents. Above the 80th percentile, the mean total effective spread is $11,765 per electronic order, $13,116 per AIM order, and $3,745 per floor trade.

For electronic trades, adverse selection rises with trade size: price impact rises from −0.02 to 2.37 cents across electronic orders and from −0.06 to 3.13 cents in AIM. Floor trades in the same SPX options, negotiated in a crowd where brokers are known, show the pattern of corporate bonds, and their price impact falls with size, from 0.71 to 0.10 cents. Floor trades also have the most legs in every quintile, and their legs rise with size to 16.81 above the 80th percentile, against 8.11 across electronic orders and 10.91 in AIM.

TABLE IV HERE

Neither the quintile means nor the dollar totals hold the other characteristics of each trade or market conditions fixed. We estimate the cost difference between floor and electronic trades in the opening window, and how it varies with trade size and the number of legs, with the following regression:

$$Y_i = \alpha + \beta\,\text{Floor}_i + \gamma_1\,\text{Floor}_i \times \text{Trade Size}_i + \gamma_2\,\text{Floor}_i \times \text{Legs}_i + \delta' X_i + \mu_s + \varepsilon_i \qquad (2)$$

Y_i is the effective spread of trade i, in cents per unit of the underlying. Floor_i equals one for floor trades after the opening and zero for electronic trades during the closure. Trade Size_i is measured in contracts, and Legs_i is the ratio-weighted number of legs, the sum of the leg ratios. X_i contains the VIX, the average daily effective spread of SPY complex trades, and trade-level controls (quoted spread, absolute delta, days to expiration, absolute vega, gamma, implied volatility, trade size, the number of legs, and a PM-settled indicator). μ_s are strategy fixed effects, included with the full set of controls. Standard errors are clustered by date (20 days), and significance levels use conventional p-values.[26] The t-statistics in the tables use the clustered standard errors.

Floor trades cost more than electronic trades by 3.01 cents without controls and by 1.27 cents with the full set of controls and strategy fixed effects, significant at the 1% and 5% levels, respectively (Table V). The controls, including size and legs, do not explain all of this difference. The difference declines with trade size. The interaction of Floor with log trade size is −1.24 cents, significant at the 1% level, and the Floor coefficient of 8.54 cents is the difference at a size of one contract. The number of legs does not account for the decline. On its own, the interaction of Floor with the log number of legs is −0.62 cents, significant at the 5% level. Next to the size interaction, it is −0.27 cents and not statistically significant, and the size interaction is −1.20 cents, significant at the 1% level. The number of legs works against the decline in floor costs. With the full set of controls and strategy fixed effects, the coefficient on the number of legs is 0.88 to 1.19 cents, significant at the 1% level in each specification (Table V).

TABLE V HERE

Within-mechanism regressions with the VIX and the SPY complex spread as market-level controls give the same gradients as the means (Internet Appendix Table IA.VIII). Trades above the 80th percentile pay 2.90 cents more than the smallest trades across electronic orders and 5.54 cents less on the floor, each significant at the 1% level. With the full set of controls, the electronic difference is 2.32 cents, significant at the 1% level, and the floor difference keeps its negative sign but is not statistically significant. Within

[26] Given the 20 date clusters, we also compute wild cluster restricted (WCR) bootstrap p-values (999 replications, six-point weights, null imposed; MacKinnon and Webb, 2018) for every regression in the paper and the Internet Appendix. The untabulated results remain qualitatively the same.

AIM orders, trades above the 80th percentile also pay more than the smallest trades under both sets of controls, and market maker revenues follow the same patterns (Internet Appendix Table IA.IX). The difference between the two gradients is significant in the pooled regression, where the interaction of Floor with trade size is −1.24 cents (Table V).

The two gradients cross: with the full set of controls, floor trades at or below the 20th percentile pay 3.67 cents more than electronic trades in the same quintile, and floor trades above the 80th percentile, where the decline in total spreads is concentrated, pay 2.79 cents less, each significant at the 1% level (Internet Appendix Table IA.III).[27] Market maker revenues give similar differences. Harris (2003) predicts that options markets with small transaction sizes will automate and that floors will serve mainly large traders. The cost differences line up with that prediction, and the logit of Section I.C shows that the largest trades route to the floor.

B. The Price of Intermediation for Matched Trades

Trades are not randomly assigned to venues (Section I.C). A direct comparison of floor and electronic execution can confound mechanism effects with differences in order flow. During the closure, every complex SPX order executes electronically, including orders that would otherwise route to the floor. We therefore compare floor trades after the opening with matched electronic trades from the closure.[28]

Matched trades are similar in six characteristics of the option position: absolute delta, absolute vega, implied volatility, trade size in contracts, days to expiration, and ratio-weighted number of legs. Their cost difference therefore measures the price of

[27] The differences at the two ends have the same signs and are significant at the 1% level against AIM orders alone, with Cboe quotes, per fill, and relative to the quoted spread (Internet Appendix Table IA.IV). Per package, where spreads grow with the number of legs, the difference above the 80th percentile is significant only at the 10% level. The small-trade difference falls from 5.89 cents with market-level controls to 3.67 cents with the full set (Internet Appendix Table IA.III). Without the largest 1% or 5% of floor trades, the difference above the 80th percentile is −2.68 or −2.26 cents, significant at the 1% and 5% levels, and on orders eligible for electronic execution under both rule sets the differences at the two ends are 4.02 and −2.88 cents, each significant at the 1% level (Internet Appendix Table IA.IV). Applied to the floor contracts traded from June 15 to October 21, 2020, the differences amount to an additional cost of $4.17 million a year at or below the 20th percentile and a saving of $120.29 million a year above the 80th percentile (Internet Appendix Table IA.VII).

[28] Internet Appendix Section IA.I repeats the analysis of matched trades around the closure. Matched floor trades also cost more than their electronic matches, by 6.33 cents with all controls, amid much higher volatility.

intermediation on the floor against the electronic mechanisms of the closure. We pair floor and electronic trades by one-to-one nearest-neighbor matching without replacement. For each floor trade executed in the first two weeks after the opening (June 15–26, 2020), we take the nearest electronic trade from the last two weeks of the closure (June 1–12, 2020). We use a caliper of 0.25 standard deviations on each characteristic, the width Rosenbaum and Rubin (1985) recommend for the propensity score, which keeps each pair close on every characteristic.[29] We also select matched trades among AIM trades only, since in AIM, as on the floor, a broker exposes an order to competing responses.

The cost of matched SPX trades rises at the opening. Figure 4 plots daily mean effective spreads, market maker revenues, and hedge costs in the opening window. The SPX series follows the matched trades, with the electronic trades before the opening and the floor trades after it. The SPY series follows electronic SPY complex trades after the opening, matched to those before it. The mean daily effective spread of matched SPX trades rises from 2.88 cents before the opening to 4.30 cents after it (Panel A). The increase of 1.42 cents is significant at the 5% level. SPY complex effective spreads average about 1 cent both before and after the opening. A market-wide change in execution conditions would have moved the SPY series as well. Because the SPX trades are matched, the shift is unlikely to merely reflect differences in size, legs, or maturity.

FIGURE 4 HERE

Panels B and C decompose the effective spread into market maker revenue and hedge cost. Market maker revenues on matched SPX trades rise from 2.63 to 4.03 cents. The increase of 1.40 cents accounts for almost all of the increase in the effective spread. Hedge costs of matched SPX trades change by an insignificant 0.02 cents between the two periods. SPY complex market maker revenues stay at about 0.9 cents and hedge costs at 0.07 cents.

Table VI reports the balance of matched trades on the six characteristics. Across all trades in the opening window, floor trades are much larger and more complex than electronic trades (Panel A). Floor trades average 784 contracts and 12.1 legs, against 36 contracts and 2.6 legs electronically. They also have longer maturities (84 versus 22 days to expiration) and higher absolute vega (1.20 versus 0.20), with similar absolute delta (0.02 versus 0.03). Among matched trades, the differences almost disappear. Trade size is

[29] Our results are robust to calipers of 0.15, 0.20, 0.30, and 0.35 standard deviations (not tabulated).

342 versus 339 contracts, the number of legs is 3.08 versus 3.07, and days to expiration is 25.17 versus 25.16. Of the 3,284 floor trades with complete characteristics, 1,177 have an electronic match, a share of 35.8%.[30] These pairs cover the range of trades that both venues execute, and the cost differences we estimate apply to them. Floor trades without an electronic match, which we call unmatched, are larger, more complex, and longer-dated still (Section III.A).

TABLE VI HERE

Panel B reports execution quality measures, which do not define matched trades. Hedge costs are 0.28 cents on each side, because matched trades are close in absolute delta. Matched floor trades pay an average effective spread of 4.45 cents, against 3.15 cents for matched electronic trades. The difference of 1.30 cents per unit of underlying is about 40% of the electronic mean. Market maker revenue, the effective spread net of the hedge cost, shows the same gap (4.17 versus 2.87 cents). With equal hedge costs, the full spread difference accrues to intermediaries as revenue. Unmatched floor trades pay 5.46 cents in effective spread and 5.25 cents in market maker revenue. The gap between matched trades is not price impact. One minute after the trade, the price impact of matched floor trades is 1.36 cents lower than that of their electronic matches, so their realized spread is 2.65 cents higher, more than the whole gap (Section IV.B defines these measures). The 1,026 pairs of matched AIM trades cover 31.2% of floor trades. These floor trades pay an effective spread of 4.72 cents, against 2.18 cents for their AIM matches. The difference of 2.54 cents is about twice the difference against all electronic matches. One minute after the trade, their realized spread exceeds that of AIM trades by 2.68 cents.

The means do not control for market conditions or for the other characteristics of each trade. We estimate the cost difference trade by trade on matched trades:

$$Y_i = \alpha + \beta \,\mathrm{Floor}_i + \gamma' X_i + \mu_s + \varepsilon_i \tag{3}$$

The dependent variable Y_i is the effective spread or the market maker revenue of trade i, in cents per unit of underlying. Floor_i equals one for floor trades executed after the opening

[30] The share falls from 62.2% at or below the 20th percentile of floor trade size to 9.4% above the 80th percentile (Internet Appendix Table IA.V). Matching on the number of distinct options and the maximum leg ratio in place of the number of legs gives 1,071 pairs (Internet Appendix Section IA.VII).

and zero for matched electronic trades during the closure. X_i contains the controls of Equation (2). The market maker revenue regressions omit absolute delta, which determines the hedge cost. μ_s denotes strategy fixed effects. The electronic matches execute during the closure, when AIM is available for SPX complex orders. The coefficient β compares the floor with the electronic mechanisms available during the closure, including AIM.[31] With matched trades drawn only from AIM, β compares the floor with this auction alone. Standard errors are clustered by date, and significance levels use conventional p-values. If the floor executes matched trades at no higher cost than the electronic mechanisms of the closure, β is zero or negative. A positive β means that end users pay more on the floor for trades that these mechanisms also execute.

TABLE VII HERE

Matched floor trades execute at wider spreads than their electronic counterparts (Table VII). With the VIX and the daily SPY complex spread as controls, the Floor coefficient is 0.98 cents, significant at the 5% level. With the full set of controls, the estimate is 1.14 cents, significant at the 1% level, or 36% of the 3.15-cent mean effective spread of matched electronic trades. Market maker revenues mirror this result. The full-specification estimate is 1.15 cents, significant at the 1% level and 40% of the 2.87-cent mean market maker revenue of matched electronic trades. Across all trades, the effective spread difference with the full set of controls is 1.27 cents (Table V). Matched floor trades average 342 contracts, a size in the middle quintile, where the difference of 0.86 cents is close to the 1.14-cent estimate for matched trades but not statistically significant (Internet Appendix Table IA.III). Against matched AIM trades, the Floor coefficient for effective spreads is 2.45 cents in both specifications, significant at the 1% level. Floor trades pay more than twice the 2.18-cent mean effective spread of their AIM matches.[32]

The cost difference between matched trades could also pick up a market-wide change in option execution costs around June 15. SPY complex trades carry the same equity

[31] AIM trades account for 24.13% of the electronic matches. Internet Appendix Section IA.I reports the comparison with matched AIM trades around the closure.

[32] With matching on the number of distinct options and the maximum leg ratio, the estimates with the full set of controls are 1.27 cents against electronic matches and 2.60 cents against AIM matches, and on orders eligible for electronic execution under both rule sets they are 1.10 and 2.42 cents, each significant at the 1% level (Internet Appendix Tables IA.XXV and IA.XXVII).

exposure as SPX. SPY options are multi-listed, and we keep electronic executions on the fourteen exchanges other than Cboe Options and Cboe C2 Options (C2). No trade in the sample routes to the Cboe floor.[33] Table VII also estimates Equation (3) on these trades, without the SPY complex spread, the PM-settled indicator, and the number of legs. No SPY complex trade changes venue at the opening. We estimate the specification on all 428,627 electronic SPY complex trades in the opening window, with Floor_i equal to one after the opening.

The Floor coefficient for SPY complex effective spreads is −0.05 cents with the full set of controls and is not statistically significant. Market maker revenues give the same estimate. Matched SPX complex trades cost 1.14 cents more. This difference is not explained by a market-wide shift in execution costs around the opening.

III. The Floor's Advantage in Large Packages

The matched trades of Section II.B cover 35.8% of the floor trades with complete characteristics. Unmatched floor trades are larger, have more legs, and are longer dated. Execution costs rise with trade size in the electronic mechanisms and fall with it on the floor (Section II.A). For the largest floor trades, the electronic cost has to be predicted from smaller electronic orders or assembled from them.

A. Trades the Electronic Market Cannot Price

Many large floor trades have no electronic match. The 2,107 unmatched floor trades average 1,031 contracts, 17.2 legs, 117 days to expiration, and an absolute vega of 1.64, against 342 contracts, 3.1 legs, 25 days, and 0.41 for the 1,177 matched floor trades, with an absolute delta of 0.02 in each group (Table VI). Unmatched floor trades pay an average effective spread of 5.46 cents, and no electronic trade provides a cost comparison for them.

Unmatched floor trades are the large, multi-leg packages (Table VI), and trades of this kind become less prevalent when the floor closes. Figure 5 therefore takes the median

[33] We exclude Cboe Options and C2 because the return of floor activity may alter the composition of electronic order flow on these venues. NYSE American and Nasdaq PHLX operate trading floors, which account for a residual share of SPY activity and reopened before June 15, 2020. The other twelve exchanges are NYSE Arca, Nasdaq ISE, Nasdaq GEMX, Nasdaq MRX, Nasdaq BX Options, Nasdaq NOM, BOX, MIAX, MIAX Pearl, MIAX Emerald, Cboe BZX Options, and Cboe EDGX Options.

size and number of legs of unmatched floor trades as the threshold and plots the share of complex SPX dollar volume from trades above it in both size and number of legs. In Panel A, the weekly share averages about 24% before the closure, about 13% during the closure, and about 21% after the opening.[34] In the opening window (Panel B), the daily share rises from about 11.6% before the opening to about 19.6% after it. The difference of 8.04 percentage points is significant at the 1% level, and the VIX was higher after the opening than in early June (Figure 3). The recovery coincides with the return of the floor.

FIGURE 5 HERE

A model of electronic costs gives a benchmark for the cost of unmatched floor trades. We fit four models of the effective spread on the electronic orders of June 1 to 12, 2020, and predict the electronic cost of each unmatched floor trade from its characteristics. Two are linear and two are non-linear. The linear models are regressions on the controls of Equation (2), the share of calls, the time of day, and strategy and initiator capacity fixed effects, and the second adds squared log trade size. The third is a gradient boosting machine (GBM), a sum of regression trees fitted to the same variables that allows for non-linear effects and interactions. For these three models, the gap is the mean of the actual minus the predicted spread. Inference uses standard errors clustered by date for the linear models and, for the GBM, a standard error from 99 refits on bootstrap samples of trading days in both windows. The fourth model, double machine learning (DML), starts from the gap of a GBM that predicts each trade from the electronic orders of other trading days. It then subtracts the GBM's prediction errors on electronic orders, each weighted by its odds of floor execution from a gradient boosting classifier. Electronic orders that resemble floor trades receive the largest weights. The linear models and the GBM predict every floor trade from the fitted electronic cost function and need no such weights, whereas DML can only compare floor trades with electronic orders that resemble them: for a floor trade that no electronic order resembles, the probability of floor execution is close to one, and so is that of the few electronic orders nearest to it; their odds grow without bound, and they would determine the estimate. Following Crump, Hotz, Imbens,

[34] Its lowest weekly value, about 8.5%, falls in the week of June 1, after the May 26 announcement of the opening and in the week of the June 3 announcement of its delay. This low is consistent with traders deferring large trades until the floor returned.

and Mitnik (2009), DML drops all trades with a probability of floor execution above 0.90: 443 unmatched floor trades (136 of them above the 80th percentile) and the electronic orders above the same cut-off. Its standard errors are clustered by date. Out of sample, the models explain about 3% (linear) and 6% (GBM) of the variation in electronic effective spreads (Internet Appendix Section IA.III).

Table VIII reports the results. Across all unmatched floor trades, the differences between the actual and the predicted cost range from −0.07 to −2.59 cents, and none is statistically significant. Above the 80th percentile, unmatched floor trades pay 2.39 cents, 1.88 to 2.92 cents less than the linear and GBM predictions, significant at the 1% level. The DML estimate above the 80th percentile is −4.76 cents, significant at the 1% level.[35] At or below the 20th percentile, unmatched floor trades pay 1.94 to 3.16 cents more than the linear and GBM predictions, significant at the 5% level for the two linear models. Weighted by contracts, unmatched floor trades cost 2.03 to 3.06 cents less than the linear models predict, significant at the 1% level (not tabulated).[36]

TABLE VIII HERE

All execution costs in this paper are measured on trades that execute. On the floor, we do not observe orders that investors decide not to submit, or orders whose negotiated cost exceeds the investor's willingness to pay. An AIM auction never fails after it starts, but an investor may not find a member willing to guarantee the full size, and a COA fills only what responses and resting interest allow. In each mechanism, selection of which desired trades execute biases measured costs downward (Hendershott et al., 2024). The bias is smallest for small trades with few legs, which fill quickly. For the largest complex trades, selection removes many of them from the electronic sample during the closure, and the measured electronic cost of those that execute understates the cost of the trades that do not.

When a large complex trade cannot execute as one electronic package, the trader can

[35] Cut-offs of 0.95 and 0.99 and a logit model of the probability of floor execution also give negative gaps above the 80th percentile (not tabulated).

[36] In the placebo on the electronic orders of June 15–26, 2020, the linear models underpredict trades between the 20th and 80th percentiles by 0.50 to 1.34 cents. The largest electronic trades are predicted within 0.39 cents, except with squared trade size, which overpredicts them by 1.62 cents (Internet Appendix Table IA.XIV).

split it into smaller electronic trades.[37] We estimate the cost of doing so for a floor trade at the 90th percentile of size, 1,950 contracts.[38] If electronic orders supply large size as cheaply as the floor, the replication should cost about as much as floor trades of similar size. From the electronic orders of June 1 to 12, 2020, we chain consecutive orders within each trading day until their cumulative size reaches 1,950 contracts and pro-rate the last order in each chain, once from all electronic orders and once from AIM orders only.[39] A chain of trades can also accumulate delta, and the hedging of that delta can move futures prices against the trader. We compute this slippage as

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

where $\hat{\beta}_1$ is the electronic price impact coefficient of Equation (5) without strategy fixed effects, 0.43 basis points at 10 seconds and 0.42 at 15 seconds (Section IV.A), D is the absolute delta of the target in dollars per SPX point, and $S = 3{,}100$ is the average SPX level in June 2020. Equation (4) charges the futures price move on the full position.[40] We set $D = 2{,}549$ by scaling the mean absolute net delta of floor trades from June 15 to October 21, 2020, \$1,100 per SPX point at a mean size of 841 contracts, to 1,950 contracts.[41] Electronic total cost is the spread plus the smaller or larger slippage across the two horizons. Floor cost is the mean dollar effective spread of floor trades in bands of ±1%, ±2.5%, ±5%, and ±10% of percentile rank around the 90th percentile.

Table IX reports the replication. Assembling 1,950 contracts electronically takes 65.3 orders on average (median 64) over 1.3 minutes (median 1.0). The cumulative electronic spread is \$6,081, or 3.12 cents per unit of underlying. Slippage adds \$85 to \$87, for an electronic total cost of \$6,166 to \$6,168. Floor trades of similar size cost \$2,439 in the

[37] Across all electronic orders and on the CLOB, an order is not more likely to be followed within 60 seconds by an identical order during the closure than after the opening. COA orders are, with a Closure coefficient of 0.32 in a logit with the full set of controls, significant at the 1% level (Internet Appendix Table IA.XXXI).

[38] The target rounds the 90th percentile of floor trade size, 1,948.8 contracts, the median of the largest size quintile.

[39] The dollar effective spread of each order is its effective spread in cents times its number of contracts, because the cents-to-dollars conversion and the SPX multiplier of 100 cancel.

[40] With linear price impact (Kyle, 1985), the futures price move scales with D.

[41] With the coefficients for electronic trades above the 80th percentile, 0.28 and 0.25 basis points with strategy fixed effects (Section IV.A), slippage is about \$50 to \$56 and total electronic cost \$6,131 to \$6,137.

±1% band, $3,357 in the ±2.5% band, and $4,246 in the ±5% band. The floor advantage is $1,920 to $3,729, or 31% to 60% of the electronic total cost, and almost all of it comes from spreads. The electronic total is 1.5 to 2.5 times the floor cost of trades of similar size. The ±10% band spans the 80th to the 100th percentile, has a mean size of 2,668 contracts, and costs $3,745 on the floor. Chains built from AIM orders only need 36.2 orders (median 30) but take 4.1 minutes (median 3.3), because AIM orders are larger and arrive less often. Their spread is $6,166 and their total cost $6,251 to $6,253, so the floor advantage over AIM is $2,005 to $3,814, or 32% to 61% of their total cost.

TABLE IX HERE

The replication reproduces the size of a large floor trade and leaves out its composition. The chains combine consecutive orders of any strategy, and a trader who needs a specific multi-leg package (unmatched floor trades average 17.2 legs) cannot assemble it from unrelated small packages. Legging into the package piece by piece exposes the trader to execution risk on the legs still open.

B. Risk Sharing in the Crowd

Large multi-leg packages become much less prevalent without the floor (Figure 5), and the largest floor trades cost less than models of electronic costs predict (Table VIII). On the floor, no single member has to guarantee the full size of a package, and the crowd divides large packages among several market makers. The electronic mechanisms either require that guarantee before the trade or offer little committed liquidity. AIM, activated for SPX during the closure, can start only after the initiating member guarantees execution of the full size (Section I.B), and it tests whether a pre-paired trade can be price-improved.[42] Market makers have no quoting obligation on complex orders (Cboe Global Markets, 2019, Rule 5.33, Interpretation .01), and they initiate 94.5% of CLOB packages (Internet Appendix Table IA.XXI). The Complex Order Auction fills what it can within about 100

[42]The closure filing 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 prohibition on soliciting appointed market makers in single-leg AIM would otherwise leave such orders without electronic liquidity (Securities and Exchange Commission, 2020, at 15824–25). Complex AIM already allowed appointed market makers to be solicited as contras (Cboe Global Markets, 2020d). Internet Appendix Section IA.IV reports strategy composition in the CLOB, COA, and AIM separately.

milliseconds (Section I). On the floor, a broker represents the order to the crowd without first lining up a contra party. We call this difference pre-commitment.

A second difference, flexibility, concerns how an order can be divided among liquidity suppliers. Division of large trades among market makers in the crowd could lower the cost of large floor trades (Grossman and Miller, 1988).[43] On the floor, several in-crowd market makers can share an order at a common price, and an unfilled balance can keep working (Cboe Global Markets, 2019, Rules 5.52(b) and 5.85). In AIM, a fixed algorithm gives the initiating order either 50% or 40% of the agency order, depending on the number of other responses. On the floor, a Designated Primary Market-Maker (DPM) or Lead Market-Maker (LMM) quoting the best price can receive a participation entitlement ahead of the other in-crowd quotes (Internet Appendix Section IA.XI). Figure 6 plots the size of each fill as a share of the order leg it fills.

FIGURE 6 HERE

Pooled across trade sizes, floor fills are smaller relative to their order legs, and they come in many sizes. Across all electronic mechanisms, 52.2% of fills cover the whole order leg, against 14.3% of floor fills (Panel A). In AIM, 26.8% of fills cover the whole leg (Panel B).[44] Floor fills spread over intermediate shares, in particular below 30% of the leg. The average fill covers 37.5% of its order leg on the floor, against 48.1% in AIM and 66.9% across all electronic mechanisms (not tabulated). Several market makers can share a large position, each holding a part until it can offset it (Grossman and Miller, 1988).

The crowd sizes its own pieces. Conditional on execution, small floor trades more often go to a single counterparty (Table IV). At or below the 20th percentile, 50.9% of floor fills cover the whole leg, against 30.0% of AIM fills, and between the 20th and 40th percentiles 36.3% against 17.7%. Large floor trades are more often divided among several market makers. Between the 60th and 80th percentiles, 7.8% of floor fills cover the whole leg,

[43] The ratio of the effective spread to the quoted spread falls by 0.17 more for floor trades than for electronic orders as the share of delta that nets within a package rises from zero to one, with trade size, the number of legs, the full set of controls, and strategy fixed effects, significant at the 5% level (Internet Appendix Table IA.XXIX).

[44] AIM fills also cluster at half of the leg and at 40% of it, about 13% and 7% of AIM fills against about 11% and 4% of floor fills. These are the shares that the AIM allocation rule assigns to the initiating order, and the floor fills at half the leg are consistent with the DPM or LMM entitlement.

against 10.4% of AIM fills, and above the 80th percentile 1.9% against 4.3%.[45] Counted by order leg, the pattern is the same (Table IV). A single fill covers 70.8% of floor order legs at or below the 20th percentile, against 58.8% of AIM order legs, and 9.1% against 19.9% above the 80th percentile. The size pattern of floor fills fits the division of labor in block markets. A single dealer can fill a small block and trade out of it, and the largest blocks are assembled from many liquidity suppliers because dealers will not hold very large positions (Harris, 2003).

From the smallest to the largest size quintile, fills per leg rise from 1.39 to 4.83 on the floor and from 2.00 to 4.67 in AIM (Table IV).[46] On the floor, the effective spread rises with the number of fills per leg, and less so for larger trades. With the full set of controls, the interaction of fills with trade size is negative on the floor and positive across electronic orders and in AIM, each significant at the 5% level or better (Internet Appendix Table IA.X). The signs match the size gradients of Table IV, and the floor sign fits risk sharing in the crowd.

Table X regresses the effective spread on Floor, fills per leg, and their interaction, one regression per quintile of floor trade size, across all floor trades and AIM orders of the opening window with the full set of controls and strategy fixed effects. The floor-AIM difference in the cost of an additional fill per leg is 2.64 cents at or below the 20th percentile and 2.25 cents between the 20th and 40th percentiles, each significant at the 1% level. It is 0.28 cents between the 40th and 60th percentiles and 0.10 cents between the 60th and 80th percentiles, neither statistically significant, and −0.72 cents above the 80th percentile, significant at the 1% level. Within AIM, an additional fill per leg increases the effective spread by 0.20 to 0.89 cents, significant at the 5% level or better in each quintile except between the 20th and 40th percentiles. The decline of the difference with trade

[45] In linear probability regressions of a whole-leg indicator on the interactions of the Floor indicator with the size quintiles, the floor-minus-AIM differences in the two smallest quintiles are significant at the 1% level in every specification. In the two largest quintiles, they are significant at the 5% level or better with the VIX as the only control and with the SPY complex spread, and they are not statistically significant with the full set of controls and strategy fixed effects (not tabulated).

[46] Unweighted counts per order leg are close to these (Internet Appendix Table IA.XII). With the full set of controls and strategy fixed effects, floor trades have fewer fills per leg than AIM orders in each quintile below the 80th percentile, significant at the 1% level, and above it the difference of −0.02 is not statistically significant (Internet Appendix Table IA.XI, Panel A). Pooled across the floor, AIM, and the CLOB, the effective spread is 0.13 cents higher per fill with the full set of controls, significant at the 1% level (Panel B of the same table).

size matches the within-mechanism estimates of Internet Appendix Table IA.X. Above the 80th percentile, floor trades with three or more fills per leg pay 3.43 cents less than AIM orders of the same size quintile and fills group with the full set of controls, significant at the 1% level (Internet Appendix Table IA.XIII).

TABLE X HERE

IV. Are Floor Trades Informed?

Small and matched floor trades cost more than electronic trades, and the largest floor trades cost less (Section II). Market makers who cannot identify informed traders quote wider spreads for the trades those traders prefer (Easley and O'Hara, 1987). Two measures tell whether floor trades carry information. Futures returns after a trade measure its information about the index, and option quotes separate the price impact of a trade from the realized spread.

Risk sharing in the crowd could lower the cost of large floor trades (Section III.B), and so could screening of the orders that market makers fill (Seppi, 1990). Screening rests on non-anonymity. A trader can forgo anonymity through a floor broker, who builds a reputation for the trader (Grossman, 1992). Floor brokers know latent traders whose interest the electronic book does not display (Harris, 2003). A floor broker can credibly share the initiator's motive and remaining size with the crowd. Disclosure draws competing liquidity and divides the position among several suppliers. It also carries a leakage cost, and the broker decides how much of an order to disclose. In the upstairs market, liquidity suppliers rely on block brokers to determine whether an initiator is well informed and whether it has revealed the full size of its order (Harris, 2003).

A. Futures Price Impact of Floor and Electronic Trades

Screening implies that floor trades carry less information about the index than electronic trades with the same delta. If the higher floor cost of matched and small trades instead paid for information about the index, futures prices should move further in the direction of floor trades than in the direction of electronic trades with the same delta. They do not. We regress short-horizon E-mini S&P 500 futures returns on the signed delta of each

complex trade:

$$r^{f}_{t+h} = \alpha + \beta_1 \,\text{Signed Delta}_i + \beta_2 \,\text{Floor}_i \times \text{Signed Delta}_i + \gamma' X_i + \mu_t + \mu_s + \varepsilon_i \tag{5}$$

r^{f}_{t+h} is the log E-mini futures return, in basis points, from 100 milliseconds before the trade to h after it, for h equal to 10 and 15 seconds. Signed Delta is the trade's net delta exposure in units of $10,000 per one-point SPX move, signed by the side of the end user. X_i includes days to expiration, absolute vega, gamma, implied volatility, trade size, a PM-settled indicator, and the number of legs. μ_t and μ_s are date and strategy fixed effects. Floor and electronic trades occur on different dates, and the date fixed effects absorb the Floor main effect. The coefficient β_1 measures the futures price impact of electronic trades, and $\beta_1 + \beta_2$ the impact of floor trades. Standard errors are clustered by date, and significance levels use conventional p-values. The regressions use the 204,969 trades with complete controls.

TABLE XI HERE

Across all trades, electronic trades move futures prices in the direction of their delta (Panel A of Table XI). Without strategy fixed effects, each $10,000 of signed delta per SPX point is associated with a futures return of 0.43 basis points within 10 seconds and 0.42 basis points within 15 seconds, significant at the 1% level. The interaction of Floor with Signed Delta is −0.54 and −0.68 basis points, significant at the 5% and 1% levels. The implied impact of floor trades, $\beta_1 + \beta_2$, is −0.11 basis points at 10 seconds and −0.26 at 15 seconds. The two point estimates are negative, and a Wald test does not reject that $\beta_1 + \beta_2$ is zero (p-values of 0.64 at 10 seconds and 0.28 at 15 seconds, not tabulated). Across all trades, futures price impact does not account for the higher floor cost. This adds to the evidence in Kaeck et al. (2022) that much of the SPX spread is not explained by information asymmetry.

Figure 7 traces futures prices in transaction time, over the ten SPX complex trades before and after each complex trade, separately for trades in which the end user's net delta is positive and negative. Electronic trades execute after the index has moved against the end user's delta, by about 0.8 basis points over the ten preceding complex trades, and futures prices do not move further after the trade. Market makers initiate most CLOB

trades against resting complex orders and take those priced to their advantage (Li et al., 2023), and a move of the index against a resting order makes it advantageous to take. AIM trades, which the end user initiates, follow a smaller move, of about 0.2 to 0.35 basis points. Around floor trades, futures prices stay close to zero before and after the trade. Floor trades do not execute after the index has moved against the end user, and their direction carries no information about subsequent futures returns.

FIGURE 7 HERE

Screening should matter most for large trades, which a liquidity supplier must hold until it can unwind the position (Harris, 2003). With the two slopes of Equation (5) split by size quintile, futures prices move less after the largest floor trades than after electronic trades of their size with the same signed delta (Panel B of Table XI). Above the 80th percentile, electronic trades move futures prices by 0.28 and 0.25 basis points per $10,000 of signed delta at 10 and 15 seconds, significant at the 1% and 5% levels. The interaction of Floor with Signed Delta is −0.49 and −0.60 basis points, significant at the 5% and 10% levels. At or below the 20th percentile, electronic trades have no positive futures price impact, and the interaction of Floor with Signed Delta is not statistically significant.

B. Price Impact versus Realized Spread

Option quotes give a second measure. The price impact of a trade is the change in the synthetic midpoint of its package from the time the price is fixed to 1 minute later, signed by the side of the end user. The market maker loses this part of the effective spread and keeps the rest, the realized spread. Table XII regresses the 1-minute price impact on the Floor indicator, alone and interacted with the size quintiles, on the 201,201 trades with complete controls and a quote 1 minute after the trade. Without the quintile interactions, floor trades have a price impact 0.88 cents lower than electronic trades, significant at the 1% level. Between the 40th and 60th percentiles, where the average matched floor trade falls, the difference is −1.30 cents, significant at the 5% level and close to the 1.36-cent difference between pairs of matched trades (Section II.B). Above the 80th percentile, floor trades have a price impact 2.68 cents lower than electronic trades, significant at the 1% level and close to the 2.79-cent difference in effective spreads (Section II.A). At or below

the 20th percentile, the difference of −0.06 cents is not statistically significant. The higher floor cost of small trades is realized spread.

TABLE XII HERE

Price impact separates the two size gradients of Section II.A. In the unadjusted means of Table IV, large electronic orders have a price impact of 2.37 cents, against −0.02 cents for small orders, as adverse selection in Easley and O'Hara (1987) predicts. Figure 8, which splits the mean effective spread of trades at or below the 20th and above the 80th percentile into price impact and realized spread, shows that on the floor most of the decline is in the part the market maker keeps. In Table IV, the floor effective spread falls from 7.84 cents for small trades to 2.26 cents for large trades, and price impact from 0.71 to 0.10 cents. The largest floor trades move futures prices less than electronic trades (Panel B of Table XI), and the crowd divides them most often (Table IV). Screening of large trades fits these estimates. They are consistent with the separation of liquidity-motivated traders in Seppi (1990) and parallel the lower information content of upstairs block trades (Bessembinder and Venkataraman, 2004).[47]

FIGURE 8 HERE

V. Conclusion

Open outcry has disappeared from most financial markets, but it still executes a large share of U.S. options volume, about three quarters of it in complex SPX trades on the Cboe floor. We use the COVID-19 closure of that floor, and the electronic auction Cboe activated in its place, to ask what the floor contributes. The answer depends on the trade. For trades executed under both mechanisms, trading costs are higher on the floor, with the difference largely attributable to market-maker revenue rather than information costs. Comparable SPY trades, which are not executed on the Cboe floor, exhibit no change in trading costs when the floor opens. For the largest and most complex trades, the floor costs less and has

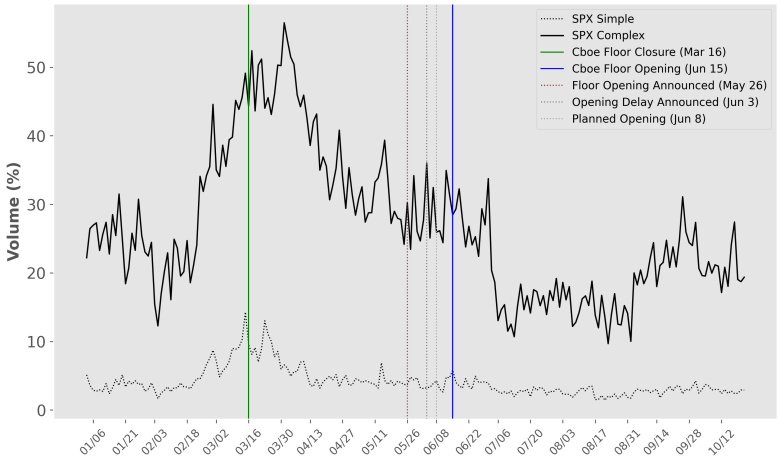
[47] On the NYSE, whose downstairs market is itself a floor, upstairs trades carry about as much information as downstairs trades (Madhavan and Cheng, 1997). Bessembinder and Venkataraman (2004) argue that the NYSE floor could replicate some benefits of upstairs trading, because floor brokers can work orders without fully revealing them.

lower price impact, and most of these trades have no electronic counterpart at all. When the floor closed, large and complex trade volumes fell, but they returned when the floor reopened. Assembling such a trade from the electronic orders that did execute costs more than the floor and leaves the trader exposed to execution risk, because those orders do not form the same multi-leg package.

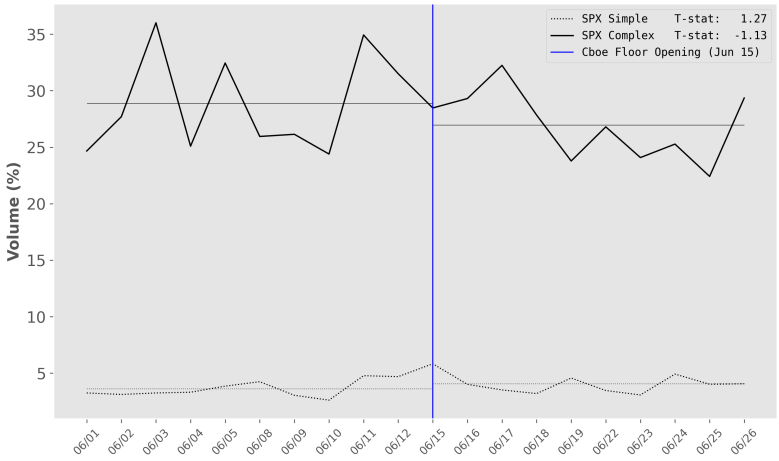
The floor differs from the auction in whether a trade needs a committed counterparty before it starts, in how the order is divided among market makers, and in what the broker chooses to disclose. The first decides whether the largest trades happen at all. The other two are one choice, how much effort the broker spends exposing an order to the crowd. In the crowd, a large order is shared among several market makers at one price and carries little information, and a small order often goes to one market maker and is priced in a mostly bilateral negotiation. In the auction, every order is exposed to every market maker at once, which serves small orders well but does not appear to accommodate the largest.

The cost advantage of electronic execution applies only to the trades electronic markets accommodate. The largest and most complex trades become half as prevalent during the closure, and models of electronic costs and a replication from electronic orders both put their electronic cost above what they pay on the floor. The electronic mechanisms either require a counterparty for the entire order before the trade or offer less committed liquidity. The floor instead divides a large position among several market makers, and the average execution cost falls with trade size. Preserving floor access while extending AIM to complex SPX orders could lower aggregate transaction costs. Whether the floor would remain viable if its smaller trades migrated to a coexisting electronic auction, and why Cboe does not offer an electronic auction with the flexibility of the in-person floor auctions, are open questions. The trading floor is not dead yet. The floor facilitates the most difficult trades, the largest and most complex, which Cboe's electronic mechanisms execute at higher cost or not at all.

Figures

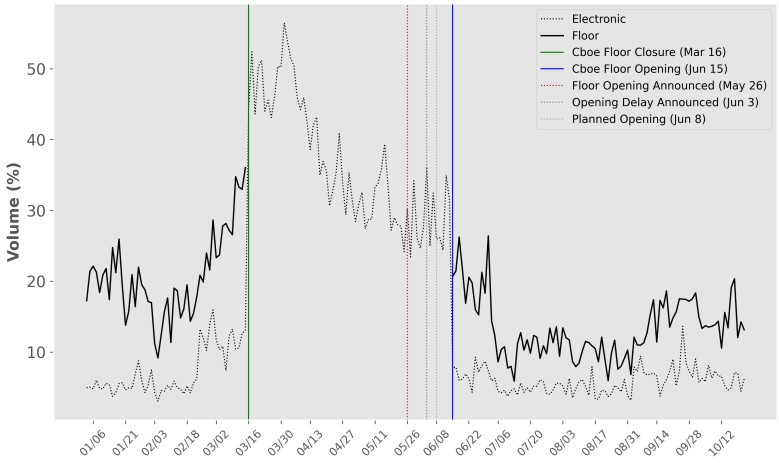


Panel A. Around the Closure and Opening

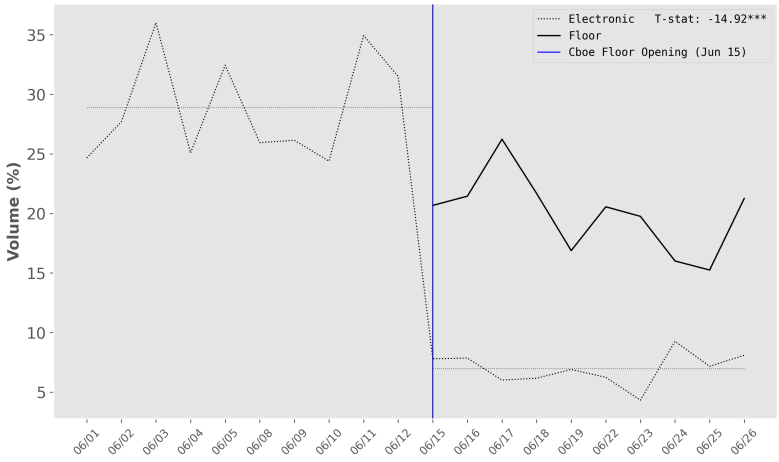


Panel B. Around the Opening (June 1–26)

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 period (January 2 to October 21, 2020) and separates complex trades (packages of two or more legs) from single-leg trades. Panel B covers the opening window (June 1–26, 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. In Panel B, horizontal lines show the means before and after the opening for each series, and the legend reports Welch t-statistics for their difference. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}\ p < 0.01$.



Panel A. Around the Closure and Opening



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

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 period (January 2 to October 21, 2020). Panel B covers the opening window, the two weeks before and the two weeks after the floor opening on June 15, 2020 (June 1–26, 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. In Panel B, horizontal lines show the means of electronic volume before and after the opening, and the legend reports the Welch t-statistic for their difference. *$p < 0.10$; **$p < 0.05$; *** $p < 0.01$.

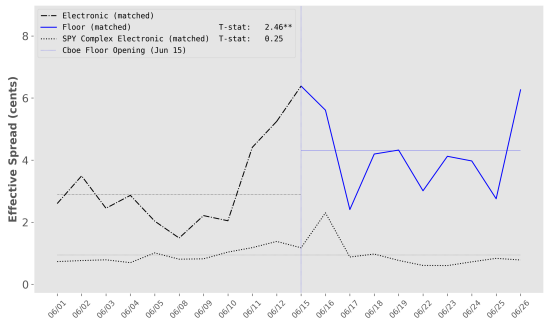


Panel A. Around the Closure and Opening

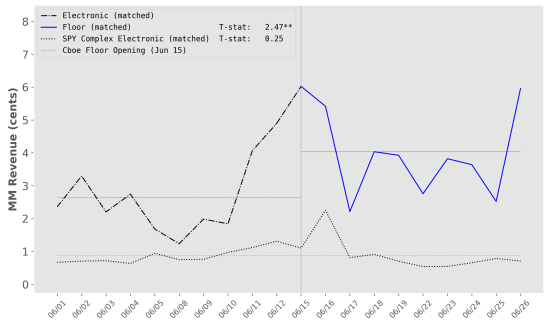


Panel B. Around the Opening (June 1–26)

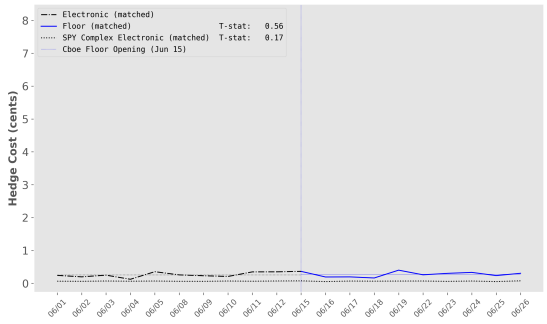
Figure 3. VIX Around the Closure and Opening
This figure plots the daily closing level of the Cboe Volatility Index (VIX). Panel A covers the full sample period (January 2 to October 21, 2020). The solid green line marks the Cboe floor closure on March 16, and the solid blue line marks the floor opening 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 covers the opening window, the two weeks before and after the opening (June 1 to June 26, 2020). In Panel B, horizontal lines show the means before and after the opening, and 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. Effective Spreads

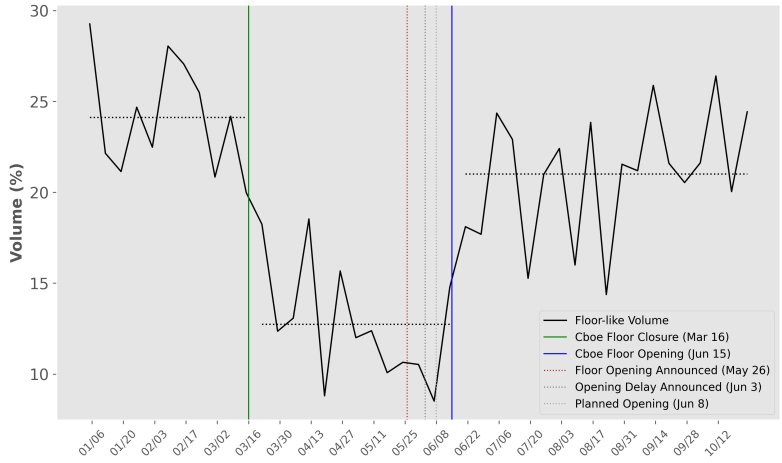


Panel B. Market Maker Revenues

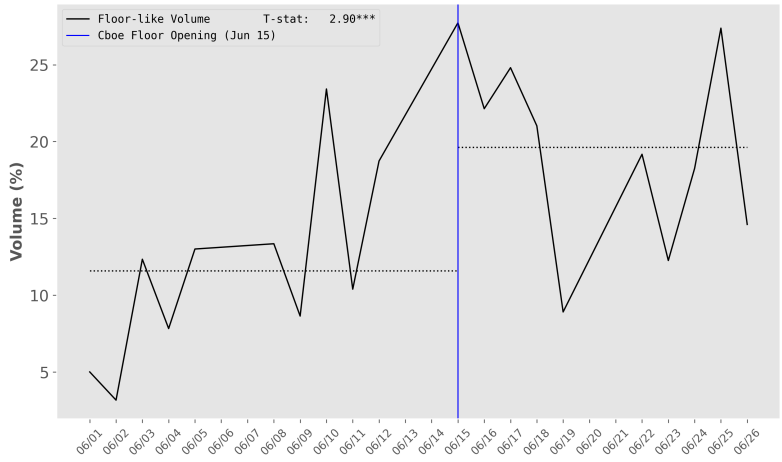


Panel C. Hedge Costs

Figure 4. Effective Spread, Market Maker Revenue, and Hedge Cost
This figure plots daily mean effective spreads (Panel A), market maker revenue (Panel B), and hedge costs (Panel C) in cents for matched SPX complex trades, with electronic trades before the opening (dash-dotted line) and floor trades after it (solid line), and for matched SPY complex trades, with trades after the opening matched to those before it (dotted line). All panels cover the opening window, the two weeks before and after the Cboe floor opening (June 1 to June 26, 2020). The dotted blue line marks the opening on June 15, 2020. Horizontal lines show the means before and after the opening for each series. The legend in each panel reports Welch t-statistics for the difference between these means for the SPX and SPY series. *$p < 0.10$; **$p < 0.05$; *** $p < 0.01$.



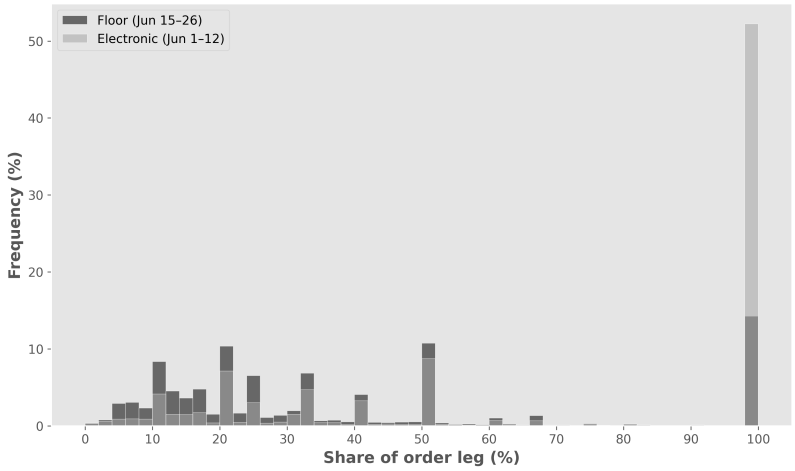
Panel A. Around the Closure and Opening (Weekly)



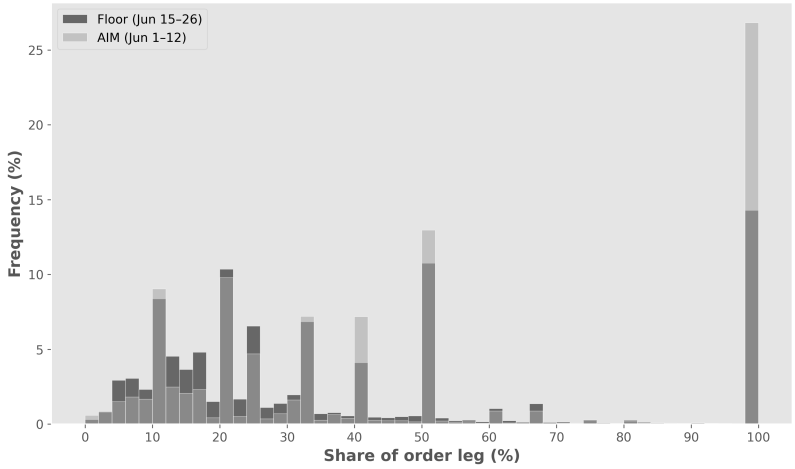
Panel B. Around the Opening (Daily, June 1–26)

Figure 5. Share of Volume from Trades Exceeding the Median Floor Trade without an Electronic Match (Trade Size, Number of Legs)

This figure plots the share of SPX complex dollar volume from trades whose trade size and number of legs each exceed the median of floor trades without an electronic match. Panel A reports weekly shares over the full sample period (January 2 to October 21, 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. The horizontal dotted lines show the means of the pre-closure period, the closure, and the period after the opening. Panel B reports daily shares in the opening window, the two weeks before and after the opening (June 1 to June 26, 2020). The horizontal dotted lines show the means before and after the opening, and the legend reports the Welch t-statistic for their difference. $^{*}p < 0.10$; $^{**}p < 0.05$; *** $p < 0.01$.

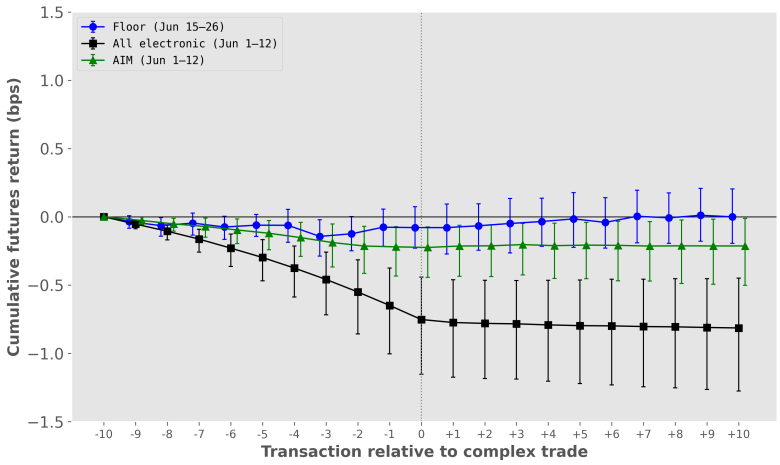


Panel A. Floor versus All Electronic Fills

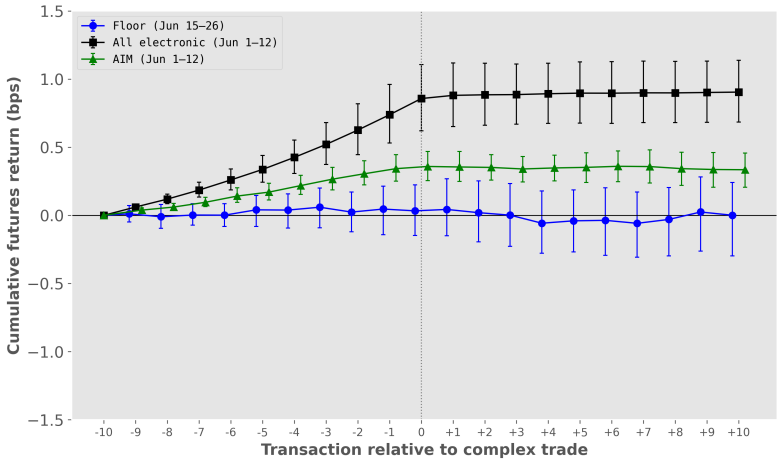


Panel B. Floor versus AIM Fills

Figure 6. Fill Size Relative to the Order Leg
This figure plots the distribution of fills by their size as a share of the order leg they fill, in percent of fills. A fill is a single execution in one leg of a package. Each panel compares fills in the opening window: floor fills in the first two weeks after the opening (June 15–26, 2020) and electronic fills in the last two weeks of the closure (June 1–12, 2020). Panel A uses all electronic fills and Panel B AIM (Automated Improvement Mechanism) fills. Electronic executions are grouped into orders. Bins are two percentage points wide, and the bin at 100% contains fills that cover the whole order leg.



Panel A. Positive Delta Trades



Panel B. Negative Delta Trades

Figure 7. Futures Returns around Complex SPX Trades
This figure plots mean cumulative E-mini S&P 500 futures returns, in basis points, around complex SPX trades in transaction time, from the tenth SPX complex trade before the complex trade to the tenth SPX complex trade after it. The clock counts all SPX complex trades of the same day, floor and electronic. At each trade, the futures price is the E-mini midpoint just before that trade. Returns are cumulated from the tenth trade before the complex trade, and the dotted vertical line marks the complex trade. Each complex trade has equal weight. Panel A uses trades in which the end user's net delta is positive and Panel B trades in which it is negative; returns are not signed. Each panel compares floor trades executed in the first two weeks after the opening (June 15–26, 2020) with all electronic trades and AIM (Automated Improvement Mechanism) trades executed in the last two weeks of the closure (June 1–12, 2020). Vertical bars are 95% confidence intervals from the wild cluster restricted (WCR) bootstrap with clustering by trading day (999 replications), obtained by inverting the bootstrap test: each interval contains the values not rejected at the 5% level.

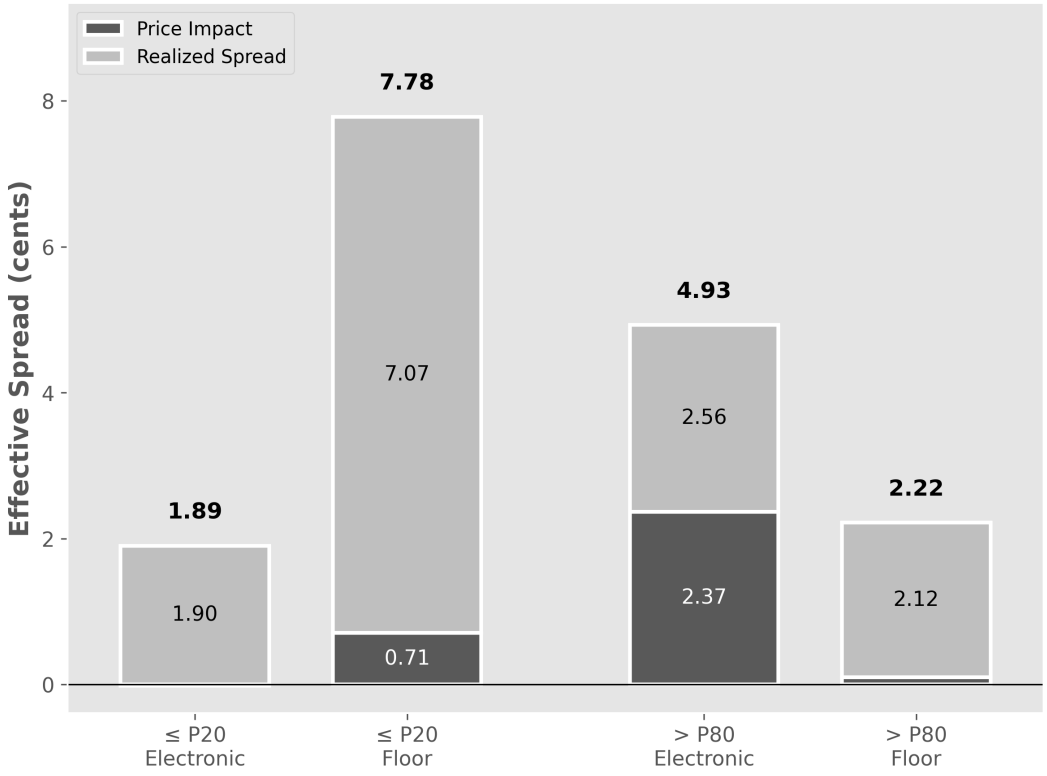


Figure 8. Price Impact and Realized Spread of Small and Large Trades
This figure splits the mean effective spread of complex SPX trades at or below the 20th percentile and above the 80th percentile of the floor trade-size distribution (130 contracts or fewer and 1,041 contracts or more) into price impact (dark) and realized spread (light), in cents per unit of the underlying. The figure uses all trades in the opening window: floor trades executed in the first two weeks after the opening (June 15–26, 2020) and electronic trades executed in the last two weeks of the closure (June 1–12, 2020). Electronic executions are grouped into orders. The price impact is the change in the synthetic midpoint of the package from the time the price is fixed to 1 minute later, signed by the side of the end user (the counterparty when a market maker initiates), and the realized spread is the effective spread minus the price impact. The sample contains the 3,373 floor trades and 201,668 electronic orders with a quote 1 minute after the trade. The bars at or below the 20th percentile contain 685 floor trades and 192,446 electronic orders, and those above the 80th percentile 676 floor trades and 831 electronic orders. Numbers above the bars are effective spreads. Means are not adjusted for controls.

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 full sample period (January 2 to October 21, 2020) excluding the floor closure: the pre-closure period (January 2 to March 13, 2020) and the period after the opening (June 15 to October 21, 2020). Dollar volume is reported in billions and contract volume in hundreds of thousands. The % OPRA columns report the average daily share of each category in 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 decomposes SPX volume by execution venue (floor versus electronic) and, within each venue, by order type.

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 complex (multi-leg) SPX options (Panel A) and complex SPY options (Panel B) over the full sample period: the pre-closure period (January 2 to March 13, 2020), the closure (March 16 to June 14, 2020), and the period after the opening (June 15 to October 21, 2020). In Panel A, floor and electronic trades are pooled before the closure and after the opening; the closure contains electronic trades only. Electronic fills are grouped into orders. Panel B covers electronic SPY complex trades executed on exchanges other than Cboe Options and C2. Volume is the share of SPX or SPY dollar volume executed in complex trades. Net Price is the execution price per unit of the underlying. Effective Spread is the trade direction times the difference between the execution price and the quote midpoint, measured from the side of the initiator, or, in Panel A, from the side of the counterparty when a market maker initiates the trade. Hedge Cost is the absolute delta exposure of the trade multiplied by half the quoted spread in E-mini S&P 500 futures at the time of the option trade. Market Maker (MM) Revenue is the effective spread minus the hedge cost. In Panel A, the three execution cost measures exclude the 1.4% of trades for which the implied volatility of a leg cannot be computed. Execution cost measures are reported as equally weighted (EW) and value-weighted (VW) daily means. Differences in means between adjacent periods in the last two columns are tested with a two-sample Welch t-test on the daily means. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}\ p < 0.01$.

Panel A: SPX Complex Trades						
Variables	Units	Pre-Closure	Closure	After Opening	Closure – Pre-Closure	After Opening – Closure
Volume	% of SPX Volume	86.43	87.86	87.49	1.43**	−0.37
Trade Size	Contracts	52.98	39.92	33.58	−13.06***	−6.34***
	$ Million	0.21	0.35	0.15	0.14***	−0.20***
Net Price	$	0.01	0.09	0.07	0.08	−0.02
Effective Spread (EW)	Cents	1.91	2.33	1.80	0.42**	−0.53***
Effective Spread (VW)	Cents	5.34	7.58	3.83	2.24**	−3.75***
Hedge Cost (EW)	Cents	0.39	0.34	0.37	−0.05***	0.03**
Hedge Cost (VW)	Cents	0.29	0.26	0.27	−0.03*	0.01
MM Revenue (EW)	Cents	1.52	1.98	1.43	0.46**	−0.55***
MM Revenue (VW)	Cents	5.05	7.33	3.56	2.28**	−3.77***
Panel B: SPY Complex Trades						
Variables	Units	Pre-Closure	Closure	After Opening	Closure – Pre-Closure	After Opening – Closure
Volume	% of SPY Volume	27.02	29.73	26.88	2.71*	−2.85**
Trade Size	Contracts	37.77	29.13	28.63	−8.64***	−0.50
	$ Million	0.01	0.02	0.01	0.01***	−0.01***
Net Price	$	0.80	1.33	0.63	0.53***	−0.70***
Effective Spread (EW)	Cents	1.09	1.34	0.77	0.25	−0.57***
Effective Spread (VW)	Cents	2.30	2.97	1.93	0.67**	−1.04***
Hedge Cost (EW)	Cents	0.08	0.08	0.07	0.00***	−0.01
Hedge Cost (VW)	Cents	0.12	0.16	0.13	0.04***	−0.03***
MM Revenue (EW)	Cents	1.01	1.27	0.69	0.26*	−0.58***
MM Revenue (VW)	Cents	2.18	2.81	1.80	0.63**	−1.01***

Table III. Determinants of Floor Trading After the Opening

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. Electronic executions are grouped into orders before estimation. The sample covers the period after the opening (June 15 to October 21, 2020) and contains up to 1,698,094 observations, of which 27,839 are floor trades; the number of observations in each specification is reported at the bottom of each panel. The estimated specification follows Equation (1):

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

where X_i includes trade size, the number of legs, days to expiration, absolute vega, gamma, implied volatility, absolute delta, and an SPXW indicator for PM-settled contracts. The number of legs is ratio-weighted, the sum of the leg ratios. Trade size, the number of legs, and days to expiration are in logs, and gamma is multiplied by 1,000. μ_s denotes strategy fixed effects, 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, the mean change in the predicted probability of floor execution from a one-unit increase in each variable evaluated at observed values, with z-statistics in parentheses. The unconditional floor probability is 1.64%. Significance stars use standard normal critical values. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}\ p < 0.01$.

Panel A: Estimated Coefficients

	(1)	(2)	(3)	(4)	(5)	(6)
Trade Size	2.01***	1.82***	1.80***	1.84***	1.84***	1.83***
	(152.81)	(132.73)	(115.65)	(122.71)	(120.99)	(111.37)
Number of Legs		2.13***	1.60***		3.42***	3.34***
		(51.25)	(38.12)		(8.52)	(8.05)
Days-to-Expiration			−0.06***			−0.09***
			(−3.81)			(−7.05)
|Vega|			0.34***			0.25***
			(30.46)			(20.19)
Gamma			0.03***			−0.00
			(10.04)			(−0.21)
IV			−1.05***			−0.66***
			(−5.69)			(−3.98)
|Delta|			−0.18			−0.01
			(−0.65)			(−0.02)
SPXW			−1.73***			−0.71***
			(−25.71)			(−11.94)
Intercept	−12.11***	−13.65***	−11.70***	−8.03***	−12.75***	−12.49***
	(−175.02)	(−140.38)	(−82.38)	(−9.86)	(−12.98)	(−12.75)
Strategy FE	No	No	No	Yes	Yes	Yes
Pseudo R-squared	0.64	0.70	0.75	0.79	0.79	0.80
Observations	1,698,094	1,698,094	1,678,134	1,698,060	1,698,060	1,678,104

continued on next page

Table III continued

Panel B: Average Marginal Effects

	(1)	(2)	(3)	(4)	(5)	(6)
Trade Size	0.0159***	0.0115***	0.0095***	0.0077***	0.0076***	0.0073***
	(95.72)	(79.24)	(53.33)	(60.33)	(59.48)	(51.36)
Number of Legs		0.0135***	0.0084***		0.0142***	0.0134***
		(59.64)	(46.33)		(8.63)	(8.10)
Days-to-Expiration			−0.0003***			−0.0004***
			(−3.71)			(−6.96)
|Vega|			0.0018***			0.0010***
			(28.99)			(18.97)
Gamma			0.0001***			−0.0000
			(10.72)			(−0.21)
IV			−0.0055***			−0.0026***
			(−5.81)			(−4.03)
|Delta|			−0.0009			−0.0000
			(−0.65)			(−0.02)
SPXW			−0.0128***			−0.0033***
			(−17.30)			(−10.40)
Strategy FE	No	No	No	Yes	Yes	Yes
Observations	1,698,094	1,698,094	1,678,134	1,698,060	1,698,060	1,678,104

Table IV. Characteristics of Trades by Size Quintile and Venue

This table reports means of trade characteristics for complex SPX trades by trade-size quintile and venue, across all trades. The sample is the opening window: floor trades executed in the two weeks after the opening (June 15–26, 2020) and electronic trades executed in the last two weeks of the closure (June 1–12, 2020). All Electronic contains all electronic orders, including AIM (Automated Improvement Mechanism) orders, and AIM contains the AIM orders only. Electronic executions are grouped into orders. The quintiles are those of the floor trade-size distribution, in contracts. Trades is the number of floor trades or electronic orders in each quintile. Trade size is the total number of contracts across all legs. The number of legs is ratio-weighted, the sum of the leg ratios. Effective spreads are in cents per unit of the underlying and are measured from the side of the end user. Total effective spread is the effective spread multiplied by trade size. Fills is the number of fills per leg, averaged over the legs of each trade with weights equal to the contracts in each leg. A fill is a single execution in one leg of a package, and it covers the whole order leg when its size equals the size of that leg of the order. An order leg is one option in one package. In the percentage of order legs filled whole by a single fill, each order leg counts once. The whole-leg measures use 715,502 electronic fills in 478,582 order legs, 175,051 AIM fills in 84,253 order legs, and 28,083 floor fills in 10,525 order legs. Price impact is the change in the synthetic midpoint of the package from the time the price is fixed to 1 minute later, signed by the side of the end user, for the trades with a quote 1 minute after the trade (201,668 electronic orders and 3,373 floor trades).

		Floor Trade-Size Quintile				
	All	≤ P20 (≤ 130)	P20–P40 (131–260)	P40–P60 (261–483)	P60–P80 (484–1,040)	> P80 (≥ 1,041)
Trades						
All Electronic	205,725	196,328	4,461	2,561	1,515	860
AIM	34,127	31,093	969	833	696	536
Floor	3,392	686	674	675	679	678
Trade Size (Contracts)						
All Electronic	36.89	13.96	186.19	356.85	715.10	2,349.43
AIM	79.66	11.60	190.62	359.28	739.59	2,535.61
Floor	807.23	92.33	192.40	366.27	720.59	2,667.52
Number of Legs						
All Electronic	2.58	2.44	4.46	5.69	6.87	8.11
AIM	3.23	2.57	8.75	10.20	10.53	10.91
Floor	11.98	5.46	10.26	10.94	16.47	16.81
Effective Spread (Cents)						
All Electronic	1.97	1.89	3.51	3.27	3.54	4.78
AIM	1.86	1.71	3.86	2.79	2.61	4.37
Floor	4.98	7.84	6.50	4.50	3.78	2.26
Total Effective Spread ($)						
All Electronic	126.79	31.55	659.75	1,172.78	2,524.89	11,765.30
AIM	314.00	23.57	764.03	1,016.41	1,962.40	13,115.73
Floor	1,982.84	717.87	1,237.09	1,642.10	2,580.45	3,744.85
Fills						
All Electronic	1.50	1.46	2.15	2.17	2.58	3.90
AIM	2.09	2.00	2.39	2.46	3.08	4.67
Floor	2.57	1.39	1.64	2.08	2.92	4.83
Fills That Cover the Whole Order Leg (% of Fills)						
All Electronic	52.2	55.1	28.4	26.1	18.9	8.1
AIM	26.8	30.0	17.7	15.7	10.4	4.3
Floor	14.3	50.9	36.3	20.6	7.8	1.9
Order Legs Filled Whole by a Single Fill (% of Order Legs)						
All Electronic	78.0	79.4	59.7	56.8	48.3	32.6
AIM	55.7	58.8	41.1	37.8	31.1	19.9
Floor	38.1	70.8	59.5	42.1	22.4	9.1
Price Impact, 1 Minute (Cents)						
All Electronic	0.05	−0.02	1.79	1.18	0.60	2.37
AIM	0.10	−0.06	2.47	1.02	0.56	3.13
Floor	0.37	0.71	0.99	−0.01	0.03	0.10

Table V. Floor and Electronic Execution Costs, Trade Size, and Number of Legs

This table reports OLS regressions of effective spread on all complex SPX trades. The sample is the opening window: floor trades executed in the two weeks after the opening (June 15–26, 2020) and electronic trades executed in the last two weeks of the closure (June 1–12, 2020). Electronic executions are grouped into orders. The estimated specification follows Equation (2):

$$Y_i = \alpha + \beta\, Floor_i + \gamma_1\, Floor_i \times Trade\ Size_i + \gamma_2\, Floor_i \times Legs_i + \delta' X_i + \mu_s + \varepsilon_i$$

where Y_i is the effective spread in cents per unit of underlying, measured from the side of the end user (the counterparty when a market maker initiates the trade). $Floor_i$ equals one for floor trades executed after the opening and zero for electronic trades executed during the closure. $Trade\ Size_i$ is measured in contracts and $Legs_i$ is the ratio-weighted number of legs, the sum of the leg ratios. Trade size, the number of legs, and days to expiration are in logs. Each specification is reported without and with controls: the Floor indicator alone, the interaction with trade size, the interaction with the number of legs, and both interactions. Trade size and the number of legs are included in every specification except the first. The controls X_i are the VIX, the average daily effective spread for SPY complex options, trade size, the number of legs, quoted spread, absolute delta, days to expiration, absolute vega, gamma, implied volatility, and a PM-settled indicator. Strategy fixed effects μ_s are included in every specification with controls. Specifications with controls use the trades with complete controls. t-statistics in parentheses are computed from standard errors clustered by date. Significance stars use these t-statistics with standard normal critical values. The intercept and the other controls are omitted for brevity. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$.

	Effective Spread							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Floor	3.01***	1.27**	13.95***	8.54***	2.84***	2.20***	13.99***	8.70***
	(8.05)	(2.40)	(9.29)	(5.11)	(6.07)	(3.73)	(9.34)	(5.13)
Number of Legs		0.88***	0.52***	1.01***	0.56***	1.19***	0.53***	1.14***
		(3.31)	(3.09)	(3.78)	(2.93)	(3.69)	(2.77)	(3.77)
Trade Size		0.15***	0.23***	0.16***	0.20***	0.14***	0.22***	0.16***
		(5.93)	(7.55)	(6.52)	(6.23)	(5.77)	(7.95)	(6.70)
Floor × Trade Size			−2.06***	−1.24***			−2.04***	−1.20***
			(−7.90)	(−4.46)			(−7.92)	(−4.41)
Floor × Number of Legs					−0.63*	−0.62**	−0.08	−0.27
					(−1.88)	(−2.03)	(−0.24)	(−0.99)
SPY Complex ES		0.77***		0.78***		0.77***		0.78***
		(3.20)		(3.24)		(3.23)		(3.26)
VIX		0.02		0.02		0.02		0.02
		(1.47)		(1.45)		(1.46)		(1.44)
Other Controls	No	Yes	No	Yes	No	Yes	No	Yes
Strategy FE	No	Yes	No	Yes	No	Yes	No	Yes
R-squared	0.00	0.03	0.00	0.04	0.00	0.03	0.00	0.04
Observations	209,117	204,969	209,117	204,969	209,117	204,969	209,117	204,969

Table VI. Summary Statistics of All, Matched, and Unmatched Trades

This table compares the means of floor and electronic complex SPX trades in the opening window, across all trades and among matched trades. The opening window contains floor trades executed in the two weeks after the opening (June 15–26, 2020) and electronic trades executed in the last two weeks of the closure (June 1–12, 2020). For each floor trade, the matched electronic trade is the nearest electronic trade on six characteristics: absolute delta (|Delta|), absolute vega (|Vega|), implied volatility, trade size in contracts, days to expiration, and ratio-weighted number of legs, each within 0.25 standard deviations. Each electronic trade is the match of at most one floor trade. Panel A reports the characteristics that define matched trades. Panel B reports execution quality measures that do not define matched trades: the effective spread, hedge cost, market maker (MM) revenue, price impact, and realized spread, all measured in cents per unit of underlying. When a market maker initiates the trade, the effective spread and market maker revenue are measured from the side of its counterparty, the end user. Price impact is the change in the synthetic midpoint from the time the price is fixed to 5 seconds or 1 minute later, signed by the side of the end user, and the realized spread is the effective spread minus the price impact over the same horizon. Price impact and realized spread use the trades with a quote at that horizon. Within each panel, the first three columns report means and differences across all trades, the next three among matched trades, and the following three among matched trades when the control pool is restricted to AIM (Automated Improvement Mechanism) trades ("Matched AIM"). Diff. is the floor mean minus the electronic or AIM mean. The 1,177 pairs of matched trades (2,354 trades) cover 35.8% of the 3,284 floor trades with complete characteristics; the 1,026 pairs of matched AIM trades (2,052 trades) cover 31.2%. The last column reports means for the 2,107 floor trades without an electronic match, which we call unmatched; the corresponding floor trades without an AIM match (2,258) are not reported.

Panel A: Options Trade Characteristics

	All Trades			Matched Trades			Matched AIM			Unmatched
	Floor	Elec.	Diff.	Floor	Elec.	Diff.	Floor	AIM	Diff.	Floor
|Delta|	0.02	0.03	−0.01	0.02	0.02	0.00	0.02	0.02	0.00	0.02
|Vega|	1.20	0.20	1.00	0.41	0.40	0.00	0.56	0.56	0.00	1.64
Implied Volatility	0.35	0.37	−0.02	0.39	0.38	0.00	0.38	0.37	0.00	0.34
Trade Size	783.62	36.17	747.44	341.51	339.41	2.10	295.11	269.79	25.32	1,030.58
Days-to-Expiration	84.18	21.77	62.41	25.17	25.16	0.01	33.13	33.12	0.01	117.15
Number of Legs	12.14	2.58	9.57	3.08	3.07	0.00	3.80	3.78	0.01	17.21

Panel B: Execution Quality

	All Trades			Matched Trades			Matched AIM			Unmatched
	Floor	Elec.	Diff.	Floor	Elec.	Diff.	Floor	AIM	Diff.	Floor
Effective Spread	5.10	1.97	3.13	4.45	3.15	1.30	4.72	2.18	2.54	5.46
Hedge Cost	0.24	0.36	−0.13	0.28	0.28	0.00	0.22	0.22	0.01	0.21
MM Revenue	4.86	1.60	3.26	4.17	2.87	1.30	4.50	1.97	2.53	5.25
Price Impact (5 s)	0.01	−0.01	0.01	−0.19	0.67	−0.86	−0.12	−0.14	0.02	0.12
Price Impact (1 min)	0.28	0.02	0.27	0.08	1.44	−1.36	−0.13	0.05	−0.18	0.40
Realized Spread (5 s)	5.10	1.98	3.13	4.64	2.50	2.14	4.84	2.33	2.52	5.36
Realized Spread (1 min)	4.83	1.95	2.87	4.38	1.72	2.65	4.84	2.15	2.68	5.08
Observations	3,284	201,685		1,177	1,177		1,026	1,026		2,107

Table VII. Execution Quality and Floor Opening

This table reports OLS regressions of effective spread and market maker revenue for matched SPX complex trades (columns (1)–(6)) and unaffected SPY complex trades (columns (7) and (8)), following Equation (3):

$$Y_i = \alpha + \beta\, Floor_i + \gamma' X_i + \mu_s + \varepsilon_i$$

where Y_i is in cents, $Floor_i$ equals one for trades executed after the opening and zero otherwise, and μ_s denotes strategy fixed effects. Columns (1)–(4) use the 1,177 pairs of matched trades of the opening window: floor trades executed in the two weeks after the opening (June 15–26, 2020) and their matched electronic trades from the last two weeks of the closure (June 1–12, 2020). Each matched electronic trade is the nearest electronic trade on |delta|, |vega|, implied volatility, trade size, days to expiration, and ratio-weighted number of legs, each within 0.25 standard deviations, and is the match of at most one floor trade. Electronic executions are grouped into orders before matched trades are selected. Columns (5) and (6) restrict the pool of electronic trades to those executed in AIM (Automated Improvement Mechanism) auctions, with the same matching, and use 1,026 pairs of matched trades. X_i includes the VIX in all specifications. In each pair of columns (1)–(6), the first specification adds the average daily effective spread for SPY complex options, and the second adds the trade-level controls (quoted spread, absolute delta, days to expiration, absolute vega, gamma, implied volatility, trade size, the number of legs, and a PM-settled indicator, with trade size, the number of legs, and days to expiration in logs). For SPX trades, when a market maker initiates the trade, both measures are taken from the side of its counterparty. Columns (7) and (8) use all electronic SPY complex trades executed in the opening window (June 1–26, 2020) on the fourteen exchanges other than Cboe Options and C2, and omit the SPY complex spread, the PM-settled indicator, and the number of legs. Absolute delta is omitted from the market maker revenue regressions because it mechanically determines the hedging cost component of the dependent variable. t-statistics in parentheses are computed from standard errors clustered by date, and significance stars use standard normal critical values. Intercept and some controls are omitted. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}\ p < 0.01$.

	Matched SPX Complex Trades						Unaffected SPY Complex Trades	
	Effective Spread		Market Maker Revenue		Effective Spread, AIM Only		Effective Spread	Market Maker Revenue
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Floor	0.98**	1.14***	1.00***	1.15***	2.45***	2.45***	−0.05	−0.05
	(2.43)	(2.99)	(2.60)	(2.94)	(4.93)	(6.05)	(−0.79)	(−0.79)
VIX	0.16***	0.11**	0.15***	0.12***	0.06*	0.01	0.02***	0.02***
	(4.44)	(2.56)	(4.26)	(2.78)	(1.73)	(0.19)	(3.67)	(3.71)
SPY Complex ES	0.96***	0.88***	0.97***	0.93***	0.78*	0.56		
	(2.94)	(3.08)	(3.15)	(3.21)	(1.94)	(1.22)		
|Delta|		51.80***				28.61**	1.32***	
		(3.84)				(1.98)	(5.71)	
Other Controls	No	Yes	No	Yes	No	Yes	Yes	Yes
Strategy FE	No	Yes	No	Yes	No	Yes	Yes	Yes
R-squared	0.01	0.11	0.01	0.09	0.02	0.05	0.46	0.46
Observations	2,354	2,354	2,354	2,354	2,052	2,052	428,627	428,627

Table VIII. Predicted Electronic Cost of Floor Trades without an Electronic Match

This table compares the effective spread of floor trades without an electronic match, which we call unmatched (Table VI), with the electronic effective spread predicted for them. The sample is the opening window. The models of the effective spread are fitted on electronic trades in the last two weeks of the closure (June 1–12, 2020) and predict the effective spread of the unmatched floor trades executed in the two weeks after the opening (June 15–26, 2020). Unmatched floor trades whose strategy or initiator capacity has no electronic order in June 1–12 are excluded. Electronic executions are grouped into orders. Effective spreads are in cents per unit of the underlying and are measured from the side of the end user. The linear model regresses the effective spread on the VIX, the average daily effective spread for SPY complex options, quoted spread, absolute delta, days to expiration, absolute vega, gamma, implied volatility, trade size, the number of legs, a PM-settled indicator, the share of calls, time of day, and strategy and initiator capacity fixed effects. Trade size, the number of legs, and days to expiration are in logs. The second linear model adds squared log trade size. The gradient boosting machine (GBM) is fitted on the same electronic trades and uses the variables of the linear model, with strategy and initiator capacity as categorical features. Double machine learning (DML) is an augmented inverse probability weighting estimate of the gap between the actual and the predicted spread, and its Predicted row is the actual spread minus that estimate. It drops the 443 unmatched floor trades with a propensity above 0.90, 136 of them above the 80th percentile. The table reports trade-weighted means for all unmatched floor trades and by the quintiles of the floor trade-size distribution (June 15–26, 2020). The first two rows report the actual floor effective spread and the number of trades for the linear models and the GBM. Panel A reports the two linear models, and Panel B the GBM and the DML estimate, with the actual effective spread and the number of trades that DML keeps. For the linear models, the gap tests use t-statistics computed from standard errors clustered by date, with the 20 trading days of the opening window (June 1–26, 2020) as clusters. For the GBM, stars use the standard error from 99 bootstrap draws that resample trading days within each window and refit the model. For DML, they use the influence-function standard error clustered by date. Stars appear only on the Actual − predicted rows and test whether the gap is zero; standard errors are not reported. All significance stars use standard normal critical values. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}\ p < 0.01$.

	All	≤ P20	P20–P40	P40–P60	P60–P80	> P80
Actual floor effective spread	5.47	10.77	7.62	5.50	4.78	2.39
Observations	2,103	256	345	412	518	572
Panel A: Linear Models						
Linear						
Predicted	5.54	7.90	6.70	5.76	4.83	4.27
Actual − predicted	−0.07	2.86**	0.93	−0.26	−0.06	−1.88***
Linear, squared trade size						
Predicted	5.81	7.61	6.54	5.78	5.15	5.19
Actual − predicted	−0.34	3.16**	1.08	−0.28	−0.37	−2.79***
Panel B: Non-Linear Models						
Gradient boosting machine (GBM)						
Predicted	6.39	8.83	7.77	6.52	5.37	5.31
Actual − predicted	−0.93	1.94	−0.15	−1.01	−0.59	−2.92***
Double machine learning (DML)						
Actual floor effective spread	6.00	11.58	7.98	5.77	5.53	2.37
Predicted	8.59	5.51	11.97	9.95	8.38	7.13
Actual − predicted	−2.59	6.07	−3.98	−4.18	−2.86	−4.76***
Observations	1,660	228	285	328	383	436

Table IX. Replication Costs of Floor Trades

This table reports the cost of replicating large floor trades through electronic execution. The sample is the opening window: floor trades executed in the two weeks after the opening (June 15–26, 2020) and electronic trades executed in the last two weeks of the closure (June 1–12, 2020). The target trade size is 1,950 contracts, the 90th percentile (P_{90}) of the floor trade-size distribution of the opening window. Floor costs are the mean dollar effective spread of floor trades whose trade-size rank in that distribution falls within the band's percentile range. Effective spreads are measured from the side of the initiator, or from the side of the counterparty when a market maker initiates the trade. Electronic replications chain consecutive electronic orders within each trading day until cumulative trade size reaches the target, pro-rated to deliver the exact target amount. The All Electronic columns chain all electronic orders, and the AIM columns chain only orders executed in AIM (Automated Improvement Mechanism) auctions. Electronic fills are grouped into orders. Slippage is computed as Slippage = $\beta_1 \cdot D^2 \cdot S/10^8$, where β_1 is the electronic price-impact coefficient on Signed Delta at the 10-second (10s) and 15-second (15s) horizons from the specifications without strategy fixed effects in Panel A of Table XI, 0.43 and 0.42 basis points per $10,000 of signed delta, D is the absolute delta exposure of the target in $/SPX point, and S = 3,100 is the June 2020 average SPX level. D scales the mean absolute net delta of floor trades after the opening, from June 15 to October 21, 2020 ($1,100 per SPX point at a mean trade size of 841 contracts) to the target trade size, which gives D = 2,549. Electronic total cost adds to the electronic spread the smallest (low estimate) and the largest (high estimate) slippage across horizons. The bands (±1% to ±10%) are ranges of percentile rank around the 90th percentile of the floor trade-size distribution (Panel D), and Observations (each side) counts the floor trades on each side of the 90th percentile within the band. Floor advantage is the electronic total cost minus the floor total cost, in dollars and as a percentage of the electronic total cost; the two ends of each range use the low and the high estimate of electronic total cost.

Panel A: Electronic Replication Mechanics (Jun 1–12, 2020)					
		All Electronic		AIM	
Orders Required	(mean)	65.3		36.2	
	(median)	64.0		30.0	
Elapsed Minutes	(mean)	1.3		4.1	
	(median)	1.0		3.3	
Trade Size	(target)	1,950			
Panel B: Electronic Execution Costs from Cumulative Futures Price Impact ($)					
Slippage	(10s)	87			
	(15s)	85			
Panel C: Total Execution Costs ($)					
		All Electronic		AIM	
Electronic Spread		6,081		6,166	
Electronic Total Cost	(low estimate)	6,166		6,251	
	(high estimate)	6,168		6,253	
		±1%	±2.5%	±5%	±10%
Floor Total Cost		2,439	3,357	4,246	3,745
Floor Advantage	($)	3,727–3,729	2,809–2,811	1,920–1,922	2,421–2,423
over All Electronic	(%)	60.4–60.5	45.6	31.1–31.2	39.3
Floor Advantage	($)	3,812–3,814	2,894–2,896	2,005–2,007	2,506–2,508
over AIM	(%)	61.0	46.3	32.1	40.1
Panel D: Floor Sample Composition					
Band Ranges		±1%	±2.5%	±5%	±10%
Percentile Ranges		P89–P91	P87.5–P92.5	P85–P95	P80–P100
Observations	(each side)	34	85	170	339
Mean Trade Size	(in band)	1,925	1,903	1,969	2,668

Table X. Effective Spread and Fills on the Floor and in AIM by Trade Size

This table reports OLS regressions of the effective spread, in cents per unit of the underlying, on the Floor indicator, the number of fills per leg, and their interaction, one regression per quintile of floor trade size:

$$Y_i = \alpha + \beta_1 Floor_i + \beta_2 Fills_i + \beta_3 Floor_i \times Fills_i + \gamma' X_i + \mu_s + \varepsilon_i$$

The sample is the opening window: floor trades executed in the two weeks after the opening (June 15–26, 2020) and AIM (Automated Improvement Mechanism) orders executed in the last two weeks of the closure (June 1–12, 2020), with complete controls. Electronic executions are grouped into orders. The quintiles are those of the floor trade-size distribution over June 15–26, 2020: 130 contracts or fewer (≤ P20), 131 to 260 contracts (P20–P40), 261 to 483 contracts (P40–P60), 484 to 1,040 contracts (P60–P80), and 1,041 contracts or more (> P80). *Fills* is the number of fills per leg of the trade, averaged over its legs with weights equal to the contracts in each leg, where a fill is one execution on a leg. X_i includes the quoted spread, absolute delta, days to expiration, absolute vega, gamma, implied volatility, trade size, a PM-settled indicator, the number of legs, the average daily effective spread for SPY complex options, and the VIX, and μ_s denotes strategy fixed effects. Trade size, the number of legs, and days to expiration are in logs. When a market maker initiates the trade, the effective spread is taken from the side of its counterparty. t-statistics in parentheses are computed from standard errors clustered by date. Significance stars use these t-statistics with standard normal critical values. Intercept and some controls are omitted for brevity. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$.

	≤ P20 (1)	P20–P40 (2)	P40–P60 (3)	P60–P80 (4)	> P80 (5)
Floor	1.90	−2.12	0.94	0.97	−0.36
	(1.30)	(−1.27)	(0.85)	(0.68)	(−0.22)
Fills	0.20**	0.27	0.66***	0.89***	0.68***
	(2.26)	(1.09)	(3.01)	(4.19)	(3.80)
Floor × Fills	2.64***	2.25***	0.28	0.10	−0.72***
	(2.69)	(3.15)	(0.73)	(0.29)	(−2.67)
VIX	0.02	0.21**	0.17**	0.06	0.17*
	(0.77)	(2.33)	(2.06)	(0.85)	(1.66)
SPY Complex ES	0.56***	0.81	−0.56	−1.48**	−0.66
	(4.13)	(0.81)	(−0.92)	(−2.13)	(−0.97)
Other Controls	Yes	Yes	Yes	Yes	Yes
Strategy FE	Yes	Yes	Yes	Yes	Yes
R-squared	0.05	0.09	0.06	0.10	0.15
Observations	31,408	1,615	1,459	1,305	1,124
Floor Trades	677	665	652	654	636
AIM Orders	30,731	950	807	651	488

Table XI. Price Impact of Options Trading on Futures Prices

This table reports OLS regressions of E-mini S&P 500 futures returns on the signed delta exposure of complex SPX trades. The dependent variable is the log futures return, in basis points, measured 10 seconds or 15 seconds after the options trade, relative to 100 milliseconds before it. Signed Delta is the trade's net delta exposure, normalized to $10,000 per one-point SPX move, and measured from the side of the end user: from the side of the initiator, or from the side of its counterparty when a market maker initiates the trade. The sample is the opening window: floor trades executed in the two weeks after the opening (June 15–26, 2020) and electronic trades executed in the last two weeks of the closure (June 1–12, 2020), with complete controls. Electronic executions are grouped into orders. Floor is an indicator that equals one if the trade executes on the Cboe trading floor and zero otherwise. The estimated specification follows Equation (5):

$$r^{f}_{t+h} = \alpha + \beta_1 \, Signed\ Delta_i + \beta_2 \, Floor_i \times Signed\ Delta_i + \gamma' X_i + \mu_t + \mu_s + \varepsilon_i$$

where r^{f}_{t+h} is the futures return at horizon h of 10 or 15 seconds, μ_t denotes date fixed effects, and μ_s denotes strategy fixed effects. The Floor indicator is absorbed by the date fixed effects. X_i includes the logs of days to expiration, trade size, and the number of legs, absolute vega, gamma, implied volatility, and a PM-settled indicator. t-statistics in parentheses are computed from standard errors clustered by date, and significance stars use standard normal critical values. Panel B interacts Signed Delta and Floor × Signed Delta with the five quintiles of floor trade size (≤ P20, 130 contracts or fewer; P20–P40, 131 to 260; P40–P60, 261 to 483; P60–P80, 484 to 1,040; > P80, 1,041 or more), one regression per horizon. Signed Delta × quintile is the electronic price impact in that quintile, and Floor × Signed Delta × quintile is the floor-minus-electronic difference. Intercepts and controls are omitted. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Panel A: All Trades				
	10 Seconds		15 Seconds	
	(1)	(2)	(3)	(4)
Signed Delta ($10K)	0.43***	0.44***	0.42***	0.43***
	(3.02)	(3.11)	(3.94)	(3.99)
Floor × Signed Delta	−0.54**	−0.57**	−0.68***	−0.71***
	(−2.03)	(−2.15)	(−2.59)	(−2.68)
Other Controls	Yes	Yes	Yes	Yes
Date FE	Yes	Yes	Yes	Yes
Strategy FE	No	Yes	No	Yes
R-squared	0.00	0.00	0.00	0.00
Observations	204,969	204,969	204,969	204,969
Panel B: By Trade-Size Quintile				
	Signed Delta × Quintile		Floor × Signed Delta × Quintile	
	10 Seconds	15 Seconds	10 Seconds	15 Seconds
≤ P20	−0.87	−1.10**	−1.37	−2.85
	(−1.27)	(−2.49)	(−0.69)	(−1.33)
P20–P40	2.40***	2.44***	−2.08**	−1.94**
	(3.86)	(6.66)	(−2.28)	(−2.14)
P40–P60	1.51***	1.73***	−1.48	−1.71*
	(2.65)	(3.47)	(−1.52)	(−1.69)
P60–P80	0.36	0.43	−0.20	−0.49
	(1.15)	(1.47)	(−0.33)	(−0.78)
> P80	0.28***	0.25**	−0.49**	−0.60*
	(4.30)	(2.22)	(−2.06)	(−1.84)
Other Controls	Yes	Yes	Yes	Yes
Date FE	Yes	Yes	Yes	Yes
Strategy FE	Yes	Yes	Yes	Yes
R-squared	0.00	0.00	0.00	0.00
Observations	204,969	204,969	204,969	204,969

Table XII. Option Price Impact by Trade Size

This table reports OLS regressions of the 1-minute price impact of all complex SPX trades. The sample is the opening window: floor trades executed in the two weeks after the opening (June 15–26, 2020) and electronic trades executed in the last two weeks of the closure (June 1–12, 2020). It contains the trades with complete controls and a quote 1 minute after the trade. Electronic executions are grouped into orders. The price impact is the change in the synthetic midpoint of the package from the time the price is fixed to 1 minute later, signed by the side of the end user (the counterparty when a market maker initiates the trade), in cents per unit of the underlying. $Floor_i$ equals one for floor trades and zero for electronic trades. The first specification includes the Floor indicator alone. The second interacts it with the quintiles of the floor trade-size distribution over June 15–26, 2020 (130 contracts or fewer, 131 to 260, 261 to 483, 484 to 1,040, and 1,041 or more) and adds the quintile indicators. Both specifications include the VIX, the average daily effective spread for SPY complex options, days to expiration, absolute vega, gamma, implied volatility, trade size, the number of legs, a PM-settled indicator, and strategy fixed effects. Trade size, the number of legs, and days to expiration are in logs. t-statistics in parentheses are computed from standard errors clustered by date. Significance stars use these t-statistics with standard normal critical values. The intercept, quintile indicators, and other controls are omitted for brevity. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}\ p < 0.01$.

	Price Impact (1 Minute)	
	(1)	(2)
Floor	-0.88^{***}	
	(-3.07)	
Floor × ≤ P20		-0.06
		(-0.15)
Floor × P20–P40		-0.85
		(-1.11)
Floor × P40–P60		-1.30^{**}
		(-2.25)
Floor × P60–P80		-0.51
		(-0.99)
Floor × > P80		-2.68^{***}
		(-2.74)
VIX	0.02^{*}	0.02
	(1.66)	(1.64)
SPY Complex ES	-0.02	-0.01
	(-0.11)	(-0.06)
Other Controls	Yes	Yes
Strategy FE	Yes	Yes
R-squared	0.01	0.01
Observations	201,201	201,201

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.

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.

Budish, E., P. Cramton, A. S. Kyle, J. Lee, and D. Malec (2023). Flow Trading. NBER Working Paper 31098, National Bureau of Economic Research.

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.

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

Cboe Global Markets (2020d). 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.

Crump, R. K., V. J. Hotz, G. W. Imbens, and O. A. Mitnik (2009). Dealing with limited overlap in

estimation of average treatment effects. *Biometrika 96*(1), 187–199.

Duffie, D. (2023). Resilience Redux in the US Treasury Market. In *Structural Shifts in the Global Economy, Jackson Hole Economic Policy Symposium*, pp. 77–119. Federal Reserve Bank of Kansas City.

Easley, D. and M. O'Hara (1987). Price, trade size, and information in securities markets. *Journal of Financial Economics 19*(1), 69–90.

Edwards, A. K., L. E. Harris, and M. S. Piwowar (2007). Corporate bond market transaction costs and transparency. *The Journal of Finance 62*(3), 1421–1451.

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

Gârleanu, N., L. H. Pedersen, and A. M. Poteshman (2009). Demand-Based Option Pricing. *The Review of Financial Studies 22*(10), 4259–4299.

Grossman, S. J. (1992). The Informational Role of Upstairs and Downstairs Trading. *The Journal of Business 65*(4), 509–528.

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

Harris, L. (2003). *Trading and Exchanges: Market Microstructure for Practitioners*. Oxford University Press.

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

Hendershott, T., D. Li, D. Livdan, and N. Schürhoff (2024). When failure is an option: Fragile liquidity in over-the-counter markets. *Journal of Financial Economics 157*, 103859.

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). Vestigial Tails? Floor Brokers at the Close in Modern Electronic Markets. *Management Science 72*(5), 3974–3996.

Jain, P. K. (2005). Financial Market Design and the Equity Premium: Electronic versus Floor Trading. *The Journal of Finance 60*(6), 2955–2985.

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.

Li, J. S., M. O'Hara, A. C. Rapp, and X. Zhou (2025). Bond Market Illiquidity: Is Portfolio Trading the Solution? SSRN Scholarly Paper. http://dx.doi.org/10.2139/ssrn.4495516.

Li, S. (2022). 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.

MacKinnon, J. G. and M. D. Webb (2018). The wild bootstrap for few (treated) clusters. *The Econometrics Journal 21*(2), 114–135.

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.

Meli, J. and Z. Todorova (2026). Portfolio Trading and Corporate Bond ETFs. *Financial Management*. Forthcoming.

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

Perold, A. F. (1988). The implementation shortfall: Paper versus reality. *Journal of Portfolio Management 14*(3), 4–9.

Rosenbaum, P. R. and D. B. Rubin (1985). Constructing a Control Group Using Multivariate Matched Sampling Methods That Incorporate the Propensity Score. *The American Statistician 39*(1), 33–38.

Schultz, P. (2001). Corporate bond trading costs: A peek behind the curtain. *The Journal of Finance 56*(2), 677–698.

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.

Securities and Exchange Commission (2026). Roundtable on Options Market Structure, Transcript. April 16, 2026. https://www.sec.gov/files/transcript-options-roundtable-041626.pdf.

Seppi, D. J. (1990). Equilibrium Block Trading and Asymmetric Information. *The Journal of Finance 45*(1), 73–94.

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

November 22, 2026

ABSTRACT

This Internet Appendix accompanies "Not Dead Yet: Options Trading Floors." Section IA.I repeats the analysis of matched trades around the March 2020 floor closure, against all electronic trades and against trades in the Automated Improvement Mechanism (AIM). Around the closure, matched floor trades pay 6.33 cents more than their electronic matches and 9.53 cents more than their AIM matches with the full set of controls. Section IA.II compares the effective spreads and market maker revenues of floor and electronic trades within quintiles of trade size, repeats the comparison with alternative samples, quotes, and cost measures, and, within each mechanism, relates effective spreads and market maker revenues to trade size and effective spreads to the number of fills and trade size. It also compares the number of fills per leg of floor and electronic trades within size quintiles, with and without weights, and relates effective spreads to fills. It further drops the largest floor trades, reports the share of floor trades with a match and the matched differences by size quintile, compares effective spreads relative to quoted spreads, and expresses the cost differences in dollars. Section IA.III describes the linear, gradient boosting, and double machine learning models that predict the electronic cost of floor trades without an electronic match. Section IA.IV defines the complex strategies and reports their volume shares, by mechanism and by electronic channel, and their characteristics, and Section IA.V describes how packages are reconstructed, classified, and signed from the Cboe trade-by-trade data. Section IA.VI reports the capacity of the initiating party of complex SPX packages on each mechanism. Section IA.VII measures package complexity by the

number of distinct options and the maximum leg ratio and repeats the routing logit and the matching with these measures. Section IA.VIII repeats the main regressions on orders eligible for electronic execution under both rule sets, Section IA.IX relates floor routing and costs to the shares of delta and vega that net within a package, and Section IA.X tests whether electronic orders were more often followed by identical orders during the closure. Section IA.XI documents the institutional details of floor trading and hybrid execution on Cboe.

IA.I: Floor Closure Results

The main analysis in Section II focuses on the opening of the Cboe trading floor in June 2020 because the 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 repeats the analysis of matched trades in the closure window, the two weeks before and the two weeks after the closure. 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 after it (March 16 to March 27, 2020), with the characteristics, selection rule, and caliper of Section II.B. Electronic executions are grouped into orders, and effective spreads and market maker revenues are measured from the side of the counterparty when a market maker initiates the trade. Of 5,941 floor trades, 1,443 have an electronic match, a share of 24.3%. As in Section II, we repeat the selection with the pool of electronic trades restricted to AIM trades, which were available for SPX complex orders during the closure. With this pool, 1,369 floor trades have an AIM match, a share of 23.0%.

Table IA.I reports means across all trades in the closure window and among matched trades. Across all trades, floor trades average 1,246 contracts and 13.0 legs, against 53 contracts and 2.7 legs for electronic trades, and they have longer maturities (83 against 42 days to expiration) and higher absolute vega (1.56 against 0.26). Among matched trades, the two groups are close, with 693 and 689 contracts, 3.8 legs each, and 45 and 47 days to expiration. The 4,498 floor trades without an electronic match have an average of 1,423 contracts and 15.9 legs. Matched floor trades pay an effective spread of 13.83 cents, against 9.73 cents for their electronic matches. The difference of 4.09 cents is 42% of the electronic mean. Market maker revenues show the same gap (13.51 against 9.40 cents), and hedge costs are similar at about 0.3 cents. The 1,369 floor trades with an AIM match average 662 contracts, 4.9 legs, and 57 days to expiration, against 635 contracts, 4.8 legs, and 59 days for their AIM matches. These floor trades pay an effective spread of 14.67 cents, against 6.52 cents for their AIM matches. The difference of 8.15 cents is about twice the difference against all electronic matches. Market maker revenues show the same gap (14.43 against 6.28 cents), and hedge costs are similar at about 0.25 cents. Spreads around the closure are about three times their level around the opening, when matched electronic trades pay

3.15 cents and matched AIM trades 2.18 cents (Table VI), which reflects the volatility of March 2020.

TABLE IA.I HERE

Table IA.II reports the regressions on matched trades. The Closure indicator equals one for electronic trades during the closure and zero for floor trades before it, so a negative coefficient means that floor execution costs more. With the VIX and the SPY complex spread as controls, matched floor trades pay 8.35 cents more than their electronic matches. The gap is larger than the raw difference because the VIX is much higher in the two weeks after the closure, and each VIX point raises effective spreads by 0.23 cents. With the full set of trade-level controls and strategy fixed effects, the difference is 6.33 cents, 65% of the mean electronic spread, and the VIX coefficient is no longer significant. Market maker revenues give nearly identical estimates, 8.36 and 6.56 cents. Against matched AIM trades, floor trades pay 12.40 cents more in effective spread with the VIX and the SPY complex spread as controls and 9.53 cents more with the full set of controls and strategy fixed effects. Every Closure estimate is significant at the 1% level.

TABLE IA.II HERE

The closure results have the same sign as the opening results. In both transitions, matched floor trades cost more than electronic trades of similar size and complexity, 1.14 cents (36%) around the opening and 6.33 cents (65%) around the closure with the full set of controls. Against matched AIM trades, the estimates are 2.45 cents around the opening (Table VII) and 9.53 cents around the closure. Relative to the mean spread of matched AIM trades, floor trades pay 112% more around the opening and 146% more around the closure. As in the main analysis, the electronic matches execute during the closure, when AIM is available for SPX complex orders. The larger gap in March coincides with extreme volatility, and we do not interpret the difference in magnitudes. The consistent sign across two transitions three months apart supports the interpretation that the cost difference reflects the presence or absence of floor intermediation rather than transient pandemic conditions.

Table IA.I. Summary Statistics of Matched Trades: Closure Window

This table compares the means of floor and electronic complex SPX trades in the closure window, across all trades and among matched trades. The closure window contains floor trades executed in the two weeks before the closure (March 2–13, 2020) and electronic trades executed in the two weeks after the closure (March 16–27, 2020). For each floor trade, the matched electronic trade is the nearest electronic trade on six characteristics: absolute delta (|Delta|), absolute vega (|Vega|), implied volatility, trade size in contracts, days to expiration, and ratio-weighted number of legs, each within 0.25 standard deviations. Each electronic trade is the match of at most one floor trade. Electronic executions are grouped into orders before matched trades are selected. Panel A reports the characteristics that define matched trades. Panel B reports execution quality measures that do not define matched trades: the effective spread, hedge cost, and market maker revenue, all measured in cents per unit of underlying. When a market maker initiates the trade, the effective spread and market maker revenue are measured from the side of its counterparty, the end user. Within each panel, the first three columns report means and differences across all trades, the next three among matched trades, and the following three among matched trades when the control pool is restricted to AIM trades ("Matched AIM"). The 1,443 pairs of matched trades (2,886 trades) cover 24.3% of the 5,941 floor trades; the 1,369 pairs of matched AIM trades (2,738 trades) cover 23.0%. The last column reports means for the 4,498 floor trades without an electronic match, which we call unmatched; the corresponding floor trades without an AIM match (4,572) are not reported.

Panel A: Options Trade Characteristics

	All Trades			Matched Trades			Matched AIM			Unmatched
	Floor	Elec.	Diff.	Floor	Elec.	Diff.	Floor	AIM	Diff.	Floor
|Delta|	0.02	0.02	0.00	0.02	0.02	0.00	0.02	0.02	0.00	0.02
|Vega|	1.56	0.26	1.29	0.59	0.58	0.01	0.79	0.77	0.02	1.87
Implied Vol.	0.52	1.14	−0.62	0.67	0.70	−0.03	0.64	0.66	−0.02	0.47
Trade Size	1,245.83	52.53	1,193.30	693.28	689.37	3.91	661.85	634.98	26.87	1,423.10
Days-to-Exp.	82.61	42.49	40.12	45.04	47.10	−2.06	57.45	59.35	−1.90	94.67
Number of Legs	12.96	2.69	10.27	3.82	3.82	0.00	4.89	4.84	0.05	15.89

Panel B: Execution Quality

	All Trades			Matched Trades			Matched AIM			Unmatched
	Floor	Elec.	Diff.	Floor	Elec.	Diff.	Floor	AIM	Diff.	Floor
Effective Spread	16.07	4.23	11.84	13.83	9.73	4.09	14.67	6.52	8.15	16.79
Hedge Cost	0.30	0.33	−0.02	0.31	0.33	−0.02	0.24	0.25	−0.01	0.30
MM Revenue	15.77	3.90	11.87	13.51	9.40	4.11	14.43	6.28	8.16	16.49
Observations	5,941	184,815		1,443	1,443		1,369	1,369		4,498

Table IA.II. Execution Quality and Floor Closure

This table reports OLS regressions of effective spread and market maker revenue for matched complex SPX trades in the closure window, following Equation (3):

$$Y_i = \alpha + \beta\, Closure_i + \gamma' X_i + \mu_s + \varepsilon_i$$

where Y_i is in cents, $Closure_i$ equals one for electronic trades executed during the closure and zero for floor trades executed before it, and μ_s denotes strategy fixed effects. Columns (1)–(4) use the 1,443 pairs of matched trades (2,886 trades) of the closure window: floor trades executed in the two weeks before the closure (March 2–13, 2020) and their matched electronic trades from the two weeks after the closure (March 16–27, 2020). Each matched electronic trade is the nearest electronic trade on |delta|, |vega|, implied volatility, trade size, days to expiration, and ratio-weighted number of legs, each within 0.25 standard deviations, and is the match of at most one floor trade. Electronic executions are grouped into orders before matched trades are selected. Columns (5) and (6) restrict the electronic trades to those executed in AIM auctions: the matching is the same, the pool of electronic trades contains only AIM trades, and the sample contains 1,369 pairs of matched trades (2,738 trades). Columns (5) and (6) report effective spread only. X_i includes the VIX in all specifications. In each pair of columns, the first specification adds the average daily effective spread for SPY complex options, and the second adds the trade-level controls (quoted spread, absolute delta, days to expiration, absolute vega, gamma, implied volatility, trade size, number of legs, and a PM-settled indicator) with strategy fixed effects. The controls use the logs of trade size, the number of legs, and days to expiration. When a market maker initiates the trade, both measures are taken from the side of its counterparty. Absolute delta is omitted from the market maker revenue regressions because it mechanically determines the hedging cost component of the dependent variable. t-statistics in parentheses are computed from standard errors clustered by date. Significance stars use these t-statistics with standard normal critical values. Intercept and some controls are omitted for brevity. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}\ p < 0.01$.

	Effective Spread		Market Maker Revenue		Effective Spread, AIM Only	
	(1)	(2)	(3)	(4)	(5)	(6)
Closure	−8.35***	−6.33***	−8.36***	−6.56***	−12.40***	−9.53***
	(−5.71)	(−5.84)	(−5.84)	(−5.65)	(−8.30)	(−6.92)
VIX	0.23***	0.08	0.23***	0.09	0.26***	0.11*
	(3.28)	(1.37)	(3.38)	(1.58)	(3.78)	(1.72)
SPY Complex ES	0.49	0.99	0.50	0.83	0.58	1.30
	(0.45)	(1.04)	(0.47)	(0.85)	(0.54)	(1.29)
|Delta|		68.93***				73.51***
		(3.52)				(2.72)
Other Controls	No	Yes	No	Yes	No	Yes
Strategy FE	No	Yes	No	Yes	No	Yes
R-squared	0.02	0.13	0.02	0.12	0.04	0.11
Observations	2,886	2,886	2,886	2,886	2,738	2,738

IA.II: Execution Costs by Trade Size

Table IA.III compares floor and electronic trades within the five quintiles of the floor trade-size distribution defined in Section II. It replaces the Floor indicator and its size and legs interactions in Equation (2) with interactions of the Floor indicator with the quintile indicators, and adds the quintile indicators. Each interaction measures the floor-electronic difference within a quintile. For effective spread and market maker revenue, one specification controls for the VIX and the daily SPY complex spread, and the other adds the trade-level controls and strategy fixed effects. The effective spread specification with trade-level controls and all market maker revenue regressions use the 3,284 floor trades and 201,685 electronic orders with complete controls. The effective spread specification with market-level controls uses all 3,392 floor trades and 205,725 electronic orders. Standard errors are clustered by date, and significance levels use conventional p-values, as in Section II.A.

TABLE IA.III HERE

At or below the 20th percentile, floor trades pay 5.89 cents more than electronic trades of the same size with market-level controls and 3.67 cents more with the full set of controls, each significant at the 1% level. Between the 20th and 40th percentiles, the difference is 2.92 and 1.79 cents, significant at the 1% and 5% levels. Between the 40th and 60th percentiles, where the average matched floor trade of 342 contracts falls, it is 1.10 and 0.86 cents and not statistically significant. No difference between the 60th and 80th percentiles is statistically significant. Above the 80th percentile, floor trades pay 2.62 and 2.79 cents less, significant at the 1% level. Market maker revenues give close estimates. With the full set of controls, they are 3.67 cents higher on the floor at or below the 20th percentile and 2.77 cents lower above the 80th percentile. Their significance levels match those of effective spreads in every quintile except between the 40th and 60th percentiles, where the market maker revenue difference with market-level controls is 1.48 cents, significant at the 10% level.

Table IA.IV repeats the specification of Table IA.III with the full set of controls under alternative designs, one regression per row. Against AIM orders alone, floor trades pay 4.20 cents more at or below the 20th percentile and 2.68 cents less above the 80th percentile. With Cboe quotes, the two differences are 3.55 and −2.77 cents, and with Cboe quotes against AIM orders they are 4.04 and −2.63 cents. Per fill, they are 3.26 and −1.44 cents. Each of these differences is significant at the 5% level or better. Relative to the quoted spread, floor trades pay more than AIM orders in each quintile below the 80th percentile, significant at the 1% level, and less above it, by 0.05 times the quoted spread, significant at the 1% level. Per package, floor trades pay 19.01 cents more at or below the 20th percentile, significant at the 1% level. Above the 80th percentile, the difference of −36.94 cents is significant at the 10% level.

Table IA.IV also drops the 34 floor trades above 6,121 contracts and the 159 above 3,000 contracts, the largest 1% and 5% of floor trades, against all electronic orders and against AIM orders, and restricts floor trades and electronic orders to those eligible for electronic execution under both rule sets, a maximum leg ratio of 3:1 or less and 12 or fewer distinct options (Section IA.VIII). All ten trading days after the opening (June 15–26, 2020) contribute floor trades to every size quintile, with and without the trims, which reduce the quintile above the 80th percentile from 678 floor trades to 644 and 519. Without the largest 1% of floor trades, floor trades pay 3.67 cents more at or below the 20th percentile and 2.68 cents less above the 80th percentile, each significant at the 1% level. Without the largest 5%, the two differences are 3.67 and −2.26 cents, significant at the 1% and 5% levels. Against AIM orders, the trims give 4.19 cents at or below the 20th percentile, significant at the 1% level, and −2.62 and −2.23 cents above the 80th percentile, significant at the 1% and 5% levels. On the orders eligible under both rule sets, the two differences are 4.02 and −2.88 cents, each significant at the 1% level. Among customer-initiated trades, floor trades pay 3.36 cents more at or below the 20th percentile and 3.58 cents less above the 80th percentile, each significant at the 1% level. Relative to the quoted spread, floor trades pay more than all electronic orders in each quintile below the 60th percentile, by 0.13, 0.07, and 0.06 times the quoted spread, each significant at the 1% level, and less above the 80th percentile, by 0.07 times the quoted spread, significant at the 1% level. Between the 60th and 80th percentiles, the difference is not statistically significant.

TABLE IA.IV HERE

Table IA.V reports, within each quintile of the floor trade-size distribution, how many floor trades have a match and the mean effective spreads of the matched trades. The pairs are the matched trades of Section II.B of the paper, drawn from all electronic orders in Panel A and from AIM orders only in Panel B, and each pair is placed in the quintile of its floor trade. The base is the 3,284 floor trades of the opening window with complete matching characteristics. The difference is the mean effective spread of matched floor trades minus that of their matches, without controls. Its t-statistic comes from a regression of the effective spread on a floor indicator within the quintile, with standard errors clustered by date.

TABLE IA.V HERE

Of the 677 floor trades at or below the 20th percentile, 421 have an electronic match, 62.2%. The share falls to 48.1%, 36.8%, and 20.8% in the three middle quintiles and to 9.4% above the 80th percentile, where 60 of 636 floor trades have a match. Against AIM orders, the share falls from 62.9% at or below the 20th percentile to 6.4% above the 80th percentile, 41 floor trades. At or below the 20th percentile, matched floor trades pay an effective spread of 5.97 cents and their electronic matches 3.46 cents. The difference

of 2.51 cents is significant at the 5% level. Between the 40th and 60th percentiles, the difference is 1.71 cents, significant at the 5% level. The differences of 0.82 cents between the 20th and 40th percentiles and −0.54 cents between the 60th and 80th percentiles are not statistically significant. Above the 80th percentile, matched floor trades pay 0.58 cents and their electronic matches 2.66 cents, a difference of −2.08 cents, significant at the 10% level. Pooled across quintiles, the difference is 1.30 cents, significant at the 10% level. Against AIM matches, floor trades pay 4.29 cents more at or below the 20th percentile and 2.59 cents more between the 20th and 40th percentiles, each significant at the 1% level. The differences of 0.74, −0.57, and −0.74 cents in the three largest quintiles are not statistically significant. Pooled, the difference against AIM matches is 2.54 cents, significant at the 1% level.

Table IA.VI divides the effective spread of each trade by its quoted spread, the cost of executing every leg at its quote, and reports mean ratios by size quintile, without controls. For an electronic order, the ratio is its trade-size-weighted effective spread over its trade-size-weighted quoted spread. Panel A uses all 3,392 floor trades and 205,725 electronic orders of the opening window, 34,127 of them AIM orders, and places each trade in the quintile of its own size. Panel B uses the 1,177 pairs of matched trades and the 1,026 pairs of matched AIM trades and places both trades of a pair in the quintile of the floor trade. The significance of each difference comes from a regression of the ratio on a floor indicator within the quintile, with standard errors clustered by date.

TABLE IA.VI HERE

Without controls and across all trades, floor trades at or below the 20th percentile pay an effective spread of 0.248 times the quoted spread, and floor trades above the 80th percentile 0.081 times. Electronic orders pay between 0.138 and 0.172 times the quoted spread in every quintile. Floor trades pay 0.11 more than electronic orders at or below the 20th percentile, 0.04 less between the 60th and 80th percentiles, and 0.08 less above the 80th percentile, each significant at the 1% level. The differences of 0.02 and 0.01 between the 20th and 60th percentiles are not statistically significant. AIM orders pay between 0.057 and 0.112 times the quoted spread. Floor trades pay more than AIM orders in each quintile below the 80th percentile, by 0.14, 0.12, 0.10, and 0.06, each significant at the 1% level. Above the 80th percentile, the difference of −0.03 is not statistically significant. Pooled across sizes, floor trades pay 0.161, electronic orders 0.140, and AIM orders 0.106 times the quoted spread. The difference of 0.02 against electronic orders is not statistically significant, and the difference of 0.06 against AIM orders is significant at the 1% level.

Among matched trades, floor trades pay more than their electronic matches by 0.11, 0.09, and 0.10 times the quoted spread in the three smallest quintiles, each significant at the 1% level. Between the 60th and 80th percentiles, the difference of 0.01 is not statistically significant. Above the 80th percentile, the 60 matched floor trades pay 0.083

times the quoted spread and their electronic matches 0.208 times, a difference of −0.13, significant at the 5% level. Against AIM matches, the differences are 0.16, 0.14, and 0.12 in the three smallest quintiles, each significant at the 1% level, and 0.03 and −0.02 in the two largest, neither statistically significant. Pooled, the difference is 0.08 against electronic matches and 0.13 against AIM matches, each significant at the 1% level.

Table IA.VII expresses the cost differences in dollars over the period after the opening, June 15 to October 21, 2020, which has 91 trading days. Panel A multiplies the Floor × quintile coefficients of the effective spread in Table IA.III, with the full set of controls and strategy fixed effects, by the contracts of the floor trades in each quintile over the period. A coefficient in cents per unit of the underlying is a difference in dollars per contract. The coefficients are estimated in the opening window, and the 27,829 floor trades of the period comprise 23,466,015 contracts. A positive amount is an additional cost of floor execution, and a negative amount is a saving. Panel B reports price improvement, the quoted spread minus the effective spread, multiplied by the contracts of each trade and summed without controls over floor trades and over the electronic orders of the complex limit order book (CLOB) and the Complex Order Auction (COA). Annual amounts multiply the amount per trading day by 252.

TABLE IA.VII HERE

At or below the 20th percentile, the difference of 3.67 cents applied to the 410,365 floor contracts of the period is an additional cost of $1.51 million for floor trades, or $4.17 million a year. Between the 20th and 40th percentiles, the difference of 1.79 cents amounts to $5.30 million a year. Summed over the four quintiles at or below the 80th percentile, the additional cost is $16.83 million a year. Above the 80th percentile, the difference of −2.79 cents applied to 15,543,057 floor contracts is a saving of $43.44 million over the period, or $120.29 million a year. Summed over the five quintiles, floor trades cost $37.36 million less than electronic execution over the period, or $103.46 million a year. In Panel B, floor trades receive price improvement of $44.09 per contract, against $19.35 in the CLOB, $20.25 in the COA, and $19.64 across all electronic orders. Price improvement amounts to $2.87 billion a year on the floor, $1.74 billion across electronic orders, and $4.61 billion across all complex SPX trades.

Table IA.VIII compares each size quintile with the trades of 130 contracts or fewer in the same mechanism. With the VIX and the SPY complex spread as market-level controls, every larger quintile pays more than the smallest, across all electronic orders and in AIM, significant at the 1% level. Trades above the 80th percentile pay the most, 2.90 cents more across electronic orders and 2.72 cents more in AIM. With the full set of controls, which include trade size and strategy fixed effects, they pay 2.32 and 2.01 cents more, each significant at the 1% level. With market-level controls, the floor coefficients decline at every quintile to −5.54 cents above the 80th percentile, significant at the 1% level above

the 40th percentile. With the full set of controls, they decline from −0.52 to −2.43 cents, and none is statistically significant.

TABLE IA.VIII HERE

Table IA.IX repeats the within-mechanism regressions of Table IA.VIII for market maker revenue. With market-level controls, trades above the 80th percentile earn market makers 3.32 cents more than the smallest trades across electronic orders and 3.25 cents more in AIM, and 5.21 cents less on the floor, each significant at the 1% level. With the full set of controls, the electronic differences are 2.15 and 1.89 cents, each significant at the 1% level. The floor difference of −2.20 cents is not statistically significant.

TABLE IA.IX HERE

Table IA.X regresses the effective spread on the number of fills per leg, log trade size, and their interaction within each mechanism. With the full set of controls, the interaction is −0.47 cents on the floor, significant at the 1% level, 0.05 cents across electronic orders, significant at the 5% level, and 0.10 cents in AIM, significant at the 1% level. Because fills per leg and trade size interact, neither coefficient alone measures the size slope of a mechanism. When the number of fills and its Floor interaction replace those of the number of legs in Equation (2) of the paper, the interaction of Floor with trade size is −1.82 cents with the other controls but without strategy fixed effects, significant at the 1% level (not tabulated).

TABLE IA.X HERE

Table IA.XI relates the number of fills per leg to trade size and the effective spread to fills, across all trades in the opening window. In Panel A, each interaction of Floor with a size quintile is the floor-electronic difference in fills per leg within the quintile. Against AIM orders and with the VIX as the only control, floor trades have 0.51, 0.66, and 0.28 fewer fills per leg in the three smallest quintiles, each significant at the 1% level. With the full set of controls, they have fewer fills than AIM orders in each quintile below the 80th percentile, significant at the 1% level. Above the 80th percentile, the difference of −0.02 is not statistically significant. Against all electronic orders and with the full set of controls, floor trades have 0.89 and 0.48 fewer fills per leg below the 40th percentile and 0.39 and 0.87 more above the 60th percentile, each significant at the 1% level. Panel B pools floor trades with AIM and CLOB orders. The effective spread rises by 0.18 cents per fill with the VIX as the only control and by 0.13 cents with the full set of controls. The coefficients on log fills are 0.46 and 0.31 cents. Each is significant at the 1% level.

TABLE IA.XI HERE

Table IA.XII counts fills per order leg without weights. Each order leg counts once, and a fill is one execution. Pooled across sizes, a floor order leg receives 2.67 fills, against 2.08 for an AIM order leg. At or below the 20th percentile, a floor order leg receives 1.39 fills, against 1.96 for an AIM order leg. Between the 60th and 80th percentiles, it receives 2.87 fills, against 2.98, and above the 80th percentile 4.73, against 4.59.

TABLE IA.XII HERE

The lower floor cost of large trades appears among trades with many fills. Table IA.XIII compares floor trades with AIM orders of the same size quintile and fills group, across all floor trades and AIM orders of the opening window. The three fills groups are exactly one fill per leg, more than one and fewer than three, and three or more. Above the 80th percentile with three or more fills per leg, floor trades pay 3.54 cents less than AIM orders with the VIX and the SPY complex spread as controls and 3.43 cents less with the full set of controls, each significant at the 1% level. With the full set of controls, the differences of 1.19 cents with exactly one fill per leg and −1.83 cents with more than one and fewer than three are not statistically significant. In the three smallest quintiles and with the full set of controls, floor trades with exactly one fill per leg pay 3.50, 3.25, and 5.49 cents more than AIM orders, significant at the 5% level or better. With three or more fills per leg, they pay 9.78 and 9.71 cents more in the two smallest quintiles, significant at the 1% level.

TABLE IA.XIII HERE

Table IA.III. Floor and Electronic Execution Costs by Trade-Size Quintile

This table reports OLS regressions of effective spread and market maker revenue on all complex SPX trades by trade-size quintile. The sample is the opening window: floor trades executed in the two weeks after the opening (June 15–26, 2020) and electronic trades executed in the last two weeks of the closure (June 1–12, 2020). The estimated specification is $Y_i = \alpha + \sum_k \beta_k Floor_i \times Size_{k,i} + \sum_k \delta_k Size_{k,i} + \gamma' X_i + \mu_s + \varepsilon_i$, where Y_i is measured in cents per unit of the underlying. $Floor_i$ equals one for floor trades executed after the opening and zero for electronic trades executed during the closure. Electronic executions are grouped into orders. Option quotes are Cboe quotes for electronic trades and LSEG quotes for floor trades. $Size_{k,i}$ equals one if the trade falls in quintile k of the floor trade-size distribution over June 15–26, 2020: up to 130 contracts (≤ P20), 131 to 260 contracts (P20–P40), 261 to 483 contracts (P40–P60), 484 to 1,040 contracts (P60–P80), and 1,041 contracts or more (> P80). The first specification controls for the VIX and the average daily effective spread for SPY complex options. The second adds the trade-level controls (quoted spread, absolute delta, days to expiration, absolute vega, gamma, implied volatility, trade size, number of legs, and a PM-settled indicator) and strategy fixed effects μ_s. The controls use the logs of trade size, the number of legs, and days to expiration. The market maker revenue regressions omit absolute delta, which mechanically determines the hedging cost component of the dependent variable. Both measures are signed by the side of the end user, which is the counterparty when a market maker initiates the trade. Specifications with trade-level controls and all market maker revenue regressions use only the trades with complete controls. t-statistics in parentheses are computed from standard errors clustered by date. Significance stars use these t-statistics with standard normal critical values. The intercept, size-quintile indicators, and other controls are not reported. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$.

	Effective Spread		Market Maker Revenue	
	(1)	(2)	(3)	(4)
Floor × ≤ P20	5.89***	3.67***	5.75***	3.67***
	(10.36)	(4.87)	(9.91)	(4.97)
Floor × P20–P40	2.92***	1.79**	2.93***	1.83**
	(3.49)	(2.00)	(3.46)	(2.04)
Floor × P40–P60	1.10	0.86	1.48*	0.88
	(1.56)	(1.09)	(1.84)	(1.12)
Floor × P60–P80	0.13	0.21	0.50	0.22
	(0.15)	(0.26)	(0.59)	(0.28)
Floor × > P80	−2.62***	−2.79***	−2.87***	−2.77***
	(−3.12)	(−3.00)	(−3.14)	(−3.01)
VIX	0.03**	0.02	0.04**	0.02
	(2.02)	(1.43)	(2.16)	(1.31)
SPY Complex ES	0.85***	0.78***	0.73***	0.75***
	(4.66)	(3.29)	(3.60)	(3.00)
Other Controls	No	Yes	No	Yes
Strategy FE	No	Yes	No	Yes
R-squared	0.01	0.04	0.01	0.03
Observations	209,117	204,969	204,969	204,969

Table IA.IV. Floor and Electronic Execution Costs by Trade Size: Robustness

This table reports the Floor × trade-size quintile coefficients of Table IA.III under alternative designs, across all trades in the opening window. Each row is a separate regression with the full set of controls and strategy fixed effects. The controls use the logs of trade size, the number of legs, and days to expiration. Floor equals one for floor trades executed after the opening (June 15–26, 2020) and zero for electronic orders executed during the closure (June 1–12, 2020). Electronic executions are grouped into orders. The quintiles are those of the floor trade-size distribution over June 15–26, 2020: 130 contracts or fewer (≤ P20), 131 to 260 contracts (P20–P40), 261 to 483 contracts (P40–P60), 484 to 1,040 contracts (P60–P80), and 1,041 contracts or more (> P80). The dependent variable is the effective spread of the end user, in cents per unit of the underlying, unless the row says otherwise. Baseline uses all electronic orders, with Cboe quotes for electronic trades and LSEG quotes for floor trades. AIM only restricts the electronic sample to AIM orders. Cboe quotes measures the floor effective spread from Cboe quotes at the time each leg is reported and the electronic effective spread from Cboe quotes. Without the largest 1% and without the largest 5% drop the 34 and 159 floor trades above the 99th and 95th percentiles of floor trade size over June 15–26, 2020 (6,121.26 and 3,000.00 contracts) and keep the quintile cutoffs; the electronic sample is all electronic orders or, in the AIM only rows, AIM orders. Orders eligible under both rule sets restricts floor trades and electronic orders to packages with a maximum leg ratio, the number of contracts in the largest leg per contract in the smallest, of 3:1 or less and 12 or fewer distinct options, which include 2,142 of the 3,392 floor trades. Customer-initiated keeps only trades initiated by a customer. Effective spread per fill divides the effective spread of each leg by the number of fills in that leg. Effective spread over quoted spread divides the effective spread of each trade by its quoted spread, drops the quoted-spread control, and compares floor trades with all electronic orders or, in the row marked AIM only, with AIM orders. Effective spread per package measures the spread of the whole package. t-statistics in parentheses are computed from standard errors clustered by date. Significance stars use these t-statistics with standard normal critical values. The intercept, size-quintile indicators, and controls are not reported. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}\ p < 0.01$.

	Floor ×					
	≤ P20	P20–P40	P40–P60	P60–P80	> P80	Observations
Electronic sample and quotes						
Baseline	3.67***	1.79**	0.86	0.21	−2.79***	204,969
	(4.87)	(2.00)	(1.09)	(0.26)	(−3.00)	
AIM only	4.20***	2.49**	1.85**	1.11	−2.68***	36,911
	(5.85)	(2.52)	(2.31)	(1.37)	(−2.82)	
Cboe quotes	3.55***	1.77*	1.31	0.16	−2.77***	204,969
	(4.57)	(1.86)	(1.47)	(0.19)	(−2.68)	
Cboe quotes, AIM only	4.04***	2.55**	2.37***	1.11	−2.63**	36,911
	(5.62)	(2.45)	(2.64)	(1.28)	(−2.54)	
Sample						
Without the largest 1% of floor trades	3.67***	1.79**	0.86	0.21	−2.68***	204,939
	(4.87)	(2.00)	(1.09)	(0.26)	(−2.79)	
Without the largest 5% of floor trades	3.67***	1.79**	0.85	0.21	−2.26**	204,824
	(4.83)	(2.00)	(1.08)	(0.26)	(−2.37)	
AIM only, without the largest 1%	4.19***	2.50**	1.85**	1.11	−2.62***	36,881
	(5.83)	(2.53)	(2.31)	(1.37)	(−2.68)	
AIM only, without the largest 5%	4.19***	2.51**	1.85**	1.12	−2.23**	36,766
	(5.83)	(2.54)	(2.30)	(1.37)	(−2.30)	
Orders eligible under both rule sets	4.02***	2.01**	1.19	−0.03	−2.88***	201,997
	(4.28)	(2.52)	(1.47)	(−0.04)	(−3.90)	
Customer-initiated	3.36***	2.71***	2.05***	−1.15	−3.58***	85,718
	(3.56)	(2.83)	(2.81)	(−1.27)	(−2.87)	
Dependent variable						
Effective spread per fill	3.26***	0.91	0.08	−0.66	−1.44***	204,969
	(4.86)	(1.39)	(0.18)	(−1.39)	(−3.39)	
Effective spread over quoted spread	0.13***	0.07***	0.06***	0.00	−0.07***	204,969
	(6.87)	(3.45)	(2.99)	(0.06)	(−4.52)	
Effective spread over quoted spread, AIM only	0.14***	0.10***	0.09***	0.05***	−0.05***	36,911
	(8.92)	(4.77)	(4.61)	(5.48)	(−2.64)	
Effective spread per package	19.01***	35.14	21.12	9.29	−36.94*	204,969
	(4.09)	(1.28)	(1.30)	(0.66)	(−1.66)	
Other Controls	Yes	Yes	Yes	Yes	Yes	
Strategy FE	Yes	Yes	Yes	Yes	Yes	

Table IA.V. Match Coverage and Matched Effective Spreads by Trade Size

This table reports, by quintile of the floor trade-size distribution, the number of floor trades with a match and the mean effective spreads of matched floor and electronic trades in the opening window: floor trades executed in the two weeks after the opening (June 15–26, 2020) and electronic trades executed in the last two weeks of the closure (June 1–12, 2020). The pairs are the matched trades of Table VI: each floor trade is paired with the nearest electronic trade on absolute delta, absolute vega, implied volatility, trade size in contracts, days to expiration, and ratio-weighted number of legs, each within 0.25 standard deviations, and each electronic trade is the match of at most one floor trade. Panel A draws the matches from all electronic orders and Panel B from AIM (Automated Improvement Mechanism) orders only. Electronic executions are grouped into orders. Each pair is placed in the quintile of its floor trade. The quintiles are those of the floor trade-size distribution over June 15–26, 2020: 130 contracts or fewer (≤ P20), 131 to 260 contracts (P20–P40), 261 to 483 contracts (P40–P60), 484 to 1,040 contracts (P60–P80), and 1,041 contracts or more (> P80). Floor trades is the number of floor trades with complete matching characteristics, excluding FLEX options and non-standard packages. Share matched is the number of matched floor trades divided by the number of floor trades, in percent. Effective spreads are in cents per unit of the underlying and are measured from the side of the end user, which is the counterparty when a market maker initiates the trade. Difference is the mean effective spread of matched floor trades minus that of their electronic (Panel A) or AIM (Panel B) matches, without controls. t-statistics in parentheses are from an OLS regression of the effective spread on a floor indicator within the quintile, with standard errors clustered by date. Significance stars use these t-statistics with standard normal critical values. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}\ p < 0.01$.

	Floor Trade-Size Quintile					
	≤ P20 (≤ 130)	P20–P40 (131–260)	P40–P60 (261–483)	P60–P80 (484–1,040)	> P80 (≥ 1,041)	All
Panel A: Matches from All Electronic Orders						
Floor trades	677	665	652	654	636	3,284
Matched floor trades	421	320	240	136	60	1,177
Share matched (%)	62.2	48.1	36.8	20.8	9.4	35.8
Matched floor effective spread	5.97	5.22	3.45	1.46	0.58	4.45
Matched electronic effective spread	3.46	4.40	1.74	2.00	2.66	3.15
Difference	2.51**	0.82	1.71**	−0.54	−2.08*	1.30*
	(2.47)	(0.57)	(2.51)	(−0.61)	(−1.85)	(1.95)
Panel B: Matches from AIM Orders						
Floor trades	677	665	652	654	636	3,284
Matched floor trades	426	281	182	96	41	1,026
Share matched (%)	62.9	42.3	27.9	14.7	6.4	31.2
Matched floor effective spread	6.19	4.85	3.41	1.65	1.52	4.72
Matched AIM effective spread	1.90	2.26	2.68	2.22	2.26	2.18
Difference	4.29***	2.59***	0.74	−0.57	−0.74	2.54***
	(4.96)	(2.62)	(0.46)	(−0.56)	(−0.60)	(4.46)

Table IA.VI. Effective Spread over Quoted Spread by Trade Size

This table reports mean effective spreads over quoted spreads of floor and electronic complex SPX trades by quintile of the floor trade-size distribution in the opening window: floor trades executed in the two weeks after the opening (June 15–26, 2020) and electronic trades executed in the last two weeks of the closure (June 1–12, 2020). The ratio of each trade is its effective spread, measured from the side of the end user (the counterparty when a market maker initiates the trade), divided by its quoted spread. For an electronic order, the ratio is its trade-size-weighted effective spread divided by its trade-size-weighted quoted spread. Means are plain averages over trades, reported as ratios rounded to three decimals. Trades with a zero quoted spread have no ratio and are excluded. Electronic executions are grouped into orders. The sample excludes FLEX options, non-standard packages, and trades with initiators of more than one capacity. Panel A uses all trades, and each trade is placed in the quintile of its own size. All electronic contains all electronic orders, including AIM (Automated Improvement Mechanism) orders, and AIM contains the AIM orders only. Panel B uses the matched trades of Table VI, with matches drawn from all electronic orders or from AIM orders only, and both trades of a pair are placed in the quintile of the floor trade. The quintiles are those of the floor trade-size distribution over June 15–26, 2020: 130 contracts or fewer (≤ P20), 131 to 260 contracts (P20–P40), 261 to 483 contracts (P40–P60), 484 to 1,040 contracts (P60–P80), and 1,041 contracts or more (> P80). Each difference is the floor mean minus the electronic or AIM mean in the same row group. Significance stars are from an OLS regression of the ratio on a floor indicator within the quintile, with standard errors clustered by date. $^{*}p < 0.10$; $^{**}p < 0.05$; *** $p < 0.01$.

	Floor Trade-Size Quintile					
	≤ P20 (≤ 130)	P20–P40 (131–260)	P40–P60 (261–483)	P60–P80 (484–1,040)	> P80 (≥ 1,041)	All
Panel A: All Trades						
Effective Spread over Quoted Spread						
Floor	0.248	0.196	0.164	0.117	0.081	0.161
All electronic	0.138	0.172	0.158	0.154	0.163	0.140
Floor minus all electronic	0.11***	0.02	0.01	−0.04***	−0.08***	0.02
AIM	0.109	0.078	0.067	0.057	0.112	0.106
Floor minus AIM	0.14***	0.12***	0.10***	0.06***	−0.03	0.06***
Trades						
Floor	686	674	675	679	678	3,392
All electronic	196,328	4,461	2,561	1,515	860	205,725
AIM	31,093	969	833	696	536	34,127
Panel B: Matched Trades						
Matches from All Electronic Orders						
Floor	0.314	0.293	0.254	0.157	0.083	0.266
Matched electronic	0.207	0.204	0.159	0.145	0.208	0.189
Floor minus matched electronic	0.11***	0.09***	0.10***	0.01	−0.13**	0.08***
Pairs	421	320	240	136	60	1,177
Matches from AIM Orders						
Floor	0.322	0.264	0.187	0.084	0.070	0.250
Matched AIM	0.163	0.129	0.072	0.051	0.085	0.124
Floor minus matched AIM	0.16***	0.14***	0.12***	0.03	−0.02	0.13***
Pairs	426	281	182	96	41	1,026

Table IA.VII. Execution Costs and Price Improvement in Dollars

This table reports dollar amounts for complex SPX trades in the period after the opening, June 15 to October 21, 2020 (91 trading days). Total is the amount over the period, per day divides it by the 91 trading days, and annualized multiplies the amount per day by 252. Panel A multiplies the Floor × trade-size quintile coefficients of the effective spread from the specification with the full set of controls and strategy fixed effects in Table IA.III, in cents per unit of the underlying (equal to dollars per contract), by the contracts of the floor trades of the period in each quintile, summed over all legs. The coefficients are estimated in the opening window: floor trades executed in the two weeks after the opening (June 15–26, 2020) and electronic trades executed in the last two weeks of the closure (June 1–12, 2020). The quintiles of the floor trade-size distribution over June 15–26, 2020 are 130 contracts or fewer (≤ P20), 131 to 260 (P20–P40), 261 to 483 (P40–P60), 484 to 1,040 (P60–P80), and 1,041 or more (> P80). A positive amount means that floor execution costs more than electronic execution, and a negative amount that it costs less. The All row sums the quintiles. Panel B reports price improvement, the quoted spread minus the effective spread, for floor trades and for electronic orders in the complex limit order book (CLOB) and the Complex Order Auction (COA). All Electronic contains both, and All adds the floor trades. Price improvement in dollars per contract is multiplied by the contracts of each trade, summed over all legs, and summed without controls over the trades of each mechanism. A positive amount means that the packages executed at better prices than their legs at their quotes. Dollars per contract is the total divided by the contracts. Trades is the number of floor trades or electronic orders. Electronic executions are grouped into orders, and the effective spread and quoted spread of an order are averages over its executions weighted by trade size. Effective spreads are measured from the side of the end user, which is the counterparty when a market maker initiates the trade. Both panels exclude FLEX options, non-standard packages, and trades with initiators of more than one capacity. In Panel A, t-statistics in parentheses are computed from standard errors clustered by date, and significance stars use these t-statistics with standard normal critical values. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Panel A: Floor-Electronic Effective Spread Difference by Trade-Size Quintile

	Floor ×	Floor	Floor	Dollars		
	Quintile	Trades	Contracts	Total	Per Day	Annualized
≤ P20	3.67***	4,672	410,365	1,507,497	16,566	4,174,608
	(4.87)					
P20–P40	1.79**	5,560	1,072,871	1,915,403	21,048	5,304,193
	(2.00)					
P40–P60	0.86	5,517	2,017,942	1,725,995	18,967	4,779,677
	(1.09)					
P60–P80	0.21	6,062	4,421,780	927,987	10,198	2,569,810
	(0.26)					
> P80	−2.79***	6,018	15,543,057	−43,437,839	−477,339	−120,289,401
	(−3.00)					
All		27,829	23,466,015	−37,360,957	−410,560	−103,461,113

Panel B: Price Improvement by Mechanism

	Dollars per			Dollars		
	Contract	Trades	Contracts	Total	Per Day	Annualized
Floor	44.09	27,829	23,466,015	1,034,680,356	11,370,114	2,865,268,678
CLOB	19.35	1,099,217	21,919,063	424,219,076	4,661,748	1,174,760,519
COA	20.25	571,038	10,131,916	205,130,349	2,254,180	568,053,275
All Electronic	19.64	1,670,255	32,050,979	629,349,425	6,915,928	1,742,813,794
All	29.97	1,698,084	55,516,994	1,664,029,781	18,286,042	4,608,082,472

Table IA.VIII. Effective Spreads and Trade Size within Each Venue

This table reports OLS regressions of the effective spread on trade-size quintile indicators, estimated separately for each venue, across all trades in the opening window. The electronic samples contain all electronic orders and the AIM orders executed during the last two weeks of the floor closure (June 1–12, 2020). The floor sample contains the floor trades executed in the two weeks after the opening (June 15–26, 2020). Electronic executions are grouped into orders. The quintiles are those of the floor trade-size distribution over June 15–26, 2020: 131 to 260 contracts (P20–P40), 261 to 483 contracts (P40–P60), 484 to 1,040 contracts (P60–P80), and 1,041 contracts or more (> P80). The omitted group is trades of 130 contracts or fewer (≤ P20), so each coefficient is the difference in effective spread from the smallest trades of the same venue. The first specification for each venue controls for the VIX and the average daily effective spread for SPY complex options. The second adds the trade-level controls (quoted spread, absolute delta, days to expiration, absolute vega, gamma, implied volatility, trade size, number of legs, and a PM-settled indicator) and strategy fixed effects. The controls use the logs of trade size, the number of legs, and days to expiration. Effective spreads use Cboe quotes for electronic trades and LSEG quotes for floor trades, are in cents per unit of the underlying, and are measured from the side of the end user. t-statistics in parentheses are computed from standard errors clustered by date. Significance stars use these t-statistics with standard normal critical values. The intercept and other controls are omitted for brevity. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}\ p < 0.01$.

	All Electronic		AIM		Floor	
	(1)	(2)	(3)	(4)	(5)	(6)
P20–P40	1.64***	0.61***	2.18***	0.09	−1.27	−0.52
	(5.53)	(3.47)	(3.66)	(0.19)	(−1.20)	(−0.52)
P40–P60	1.42***	0.42	1.14***	−0.51	−3.22***	−1.03
	(8.74)	(1.51)	(2.66)	(−0.80)	(−3.16)	(−1.08)
P60–P80	1.68***	0.78***	0.93***	−0.19	−3.95***	−1.44
	(7.00)	(2.78)	(2.71)	(−0.37)	(−4.85)	(−1.61)
> P80	2.90***	2.32***	2.72***	2.01***	−5.54***	−2.43
	(7.42)	(4.75)	(4.57)	(3.24)	(−6.13)	(−1.64)
VIX	0.02	0.02	0.03	0.02	0.60***	0.66***
	(1.62)	(1.14)	(1.10)	(0.94)	(3.10)	(3.03)
SPY Complex ES	0.97***	0.92***	0.84**	0.65***	−0.85***	−0.96***
	(5.84)	(3.84)	(2.30)	(3.01)	(−5.44)	(−5.12)
Other Controls	No	Yes	No	Yes	No	Yes
Strategy FE	No	Yes	No	Yes	No	Yes
R-squared	0.00	0.03	0.01	0.03	0.02	0.08
Observations	205,725	201,685	34,127	33,627	3,392	3,284

Table IA.IX. Market Maker Revenue and Trade Size within Each Venue

This table reports OLS regressions of market maker revenue on trade-size quintile indicators, estimated separately for each venue, across all trades in the opening window. The electronic samples contain all electronic orders and the AIM orders executed during the last two weeks of the floor closure (June 1–12, 2020). The floor sample contains the floor trades executed in the two weeks after the opening (June 15–26, 2020). Electronic executions are grouped into orders. The quintiles are those of the floor trade-size distribution over June 15–26, 2020: 131 to 260 contracts (P20–P40), 261 to 483 contracts (P40–P60), 484 to 1,040 contracts (P60–P80), and 1,041 contracts or more (> P80). The omitted group is trades of 130 contracts or fewer (≤ P20), so each coefficient is the difference in market maker revenue from the smallest trades of the same venue. The first specification for each venue controls for the VIX and the average daily effective spread for SPY complex options. The second adds the trade-level controls (quoted spread, days to expiration, absolute vega, gamma, implied volatility, trade size, number of legs, and a PM-settled indicator) and strategy fixed effects. The controls use the logs of trade size, the number of legs, and days to expiration. The market maker revenue regressions omit absolute delta, which mechanically determines the hedging cost component of the dependent variable. Both specifications use only the trades with complete controls. Market maker revenue uses Cboe option quotes for electronic trades and LSEG option quotes for floor trades, is in cents per unit of the underlying, and is measured from the side of the end user. t-statistics in parentheses are computed from standard errors clustered by date. Significance stars use these t-statistics with standard normal critical values. The intercept and other controls are omitted for brevity. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$.

	All Electronic		AIM		Floor	
	(1)	(2)	(3)	(4)	(5)	(6)
P20–P40	1.65***	0.56***	2.29***	0.06	−1.10	−0.65
	(5.87)	(3.20)	(4.14)	(0.14)	(−0.98)	(−0.65)
P40–P60	1.43***	0.35	1.12**	−0.58	−2.68**	−1.10
	(8.65)	(1.33)	(2.43)	(−0.92)	(−2.26)	(−1.15)
P60–P80	1.77***	0.65**	1.11***	−0.30	−3.35***	−1.33
	(7.50)	(2.36)	(3.14)	(−0.60)	(−4.14)	(−1.41)
> P80	3.32***	2.15***	3.25***	1.89***	−5.21***	−2.20
	(6.51)	(4.39)	(4.75)	(3.09)	(−5.37)	(−1.42)
VIX	0.03*	0.02	0.03	0.02	0.60***	0.73***
	(1.84)	(1.03)	(1.18)	(0.91)	(2.73)	(3.49)
SPY Complex ES	0.83***	0.88***	0.78**	0.62***	−0.84***	−1.02***
	(4.25)	(3.43)	(2.05)	(2.77)	(−4.39)	(−5.97)
Other Controls	No	Yes	No	Yes	No	Yes
Strategy FE	No	Yes	No	Yes	No	Yes
R-squared	0.00	0.03	0.01	0.03	0.01	0.07
Observations	201,685	201,685	33,627	33,627	3,284	3,284

Table IA.X. Effective Spreads, Fills, and Trade Size within Each Venue

This table reports OLS regressions of the effective spread on the number of fills, trade size, and their interaction, estimated separately for each venue, across all trades in the opening window. The floor sample contains the floor trades executed in the two weeks after the opening (June 15–26, 2020). The electronic samples contain all electronic orders and the AIM orders executed during the last two weeks of the floor closure (June 1–12, 2020). Electronic executions are grouped into orders. Each observation is a floor package or an electronic order. Fills is the number of fills per leg of the trade. Trade size is the number of contracts summed over the legs. The first specification for each venue has no controls. The second adds the VIX, the average daily effective spread for SPY complex options, the trade-level controls (quoted spread, absolute delta, days to expiration, absolute vega, gamma, implied volatility, number of legs, and a PM-settled indicator), and strategy fixed effects. Trade size, the number of legs, and days to expiration are in logs. Effective spreads use Cboe quotes for electronic trades and LSEG quotes for floor trades, are in cents per unit of the underlying, and are measured from the side of the end user. t-statistics in parentheses are computed from standard errors clustered by date. Significance stars use these t-statistics with standard normal critical values. The intercept and other controls are omitted for brevity. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}\ p < 0.01$.

	Floor		All Electronic		AIM	
	(1)	(2)	(3)	(4)	(5)	(6)
Fills	3.76***	4.20***	−0.23**	0.03	−0.28**	−0.05
	(3.94)	(5.10)	(−2.07)	(0.47)	(−2.45)	(−0.60)
Trade Size	−1.89***	−0.80*	0.10***	0.01	−0.04	−0.36***
	(−5.12)	(−1.82)	(2.59)	(0.44)	(−0.57)	(−4.01)
Fills × Trade Size	−0.39***	−0.47***	0.09***	0.05**	0.12***	0.10***
	(−3.07)	(−4.29)	(4.00)	(2.42)	(5.10)	(4.53)
VIX		0.60***		0.02		0.02
		(3.21)		(1.17)		(0.96)
SPY Complex ES		−0.85***		0.91***		0.68***
		(−5.50)		(3.73)		(3.05)
Other Controls	No	Yes	No	Yes	No	Yes
Strategy FE	No	Yes	No	Yes	No	Yes
R-squared	0.03	0.09	0.00	0.03	0.01	0.04
Observations	3,392	3,284	205,725	201,685	34,127	33,627

Table IA.XI. Fills by Trade Size and Effective Spreads on Fills

This table reports OLS regressions of fills on Floor × trade-size quintile indicators (Panel A) and of the effective spread on fills (Panel B), across all trades in the opening window. Fills is the trade's weighted average number of fills per leg, with each leg weighted by its ratio in the package. Log Fills is the natural log of Fills. Electronic executions are grouped into orders. Panel A compares floor trades executed after the opening (June 15–26, 2020) with all electronic orders or with AIM orders executed during the closure (June 1–12, 2020). Floor equals one for floor trades. The quintiles are those of the floor trade-size distribution over June 15–26, 2020: 130 contracts or fewer (≤ P20), 131 to 260 contracts (P20–P40), 261 to 483 contracts (P40–P60), 484 to 1,040 contracts (P60–P80), and 1,041 contracts or more (> P80). Each Floor × quintile coefficient is the floor-minus-electronic difference in fills within the quintile. The first specification controls for the VIX, the second adds the average daily effective spread for SPY complex options, and the third adds that for SPX single-leg options. The fourth adds the trade-level controls (quoted spread, absolute delta, days to expiration, absolute vega, gamma, implied volatility, trade size, and a PM-settled indicator) and strategy fixed effects. Panel B pools floor trades executed after the opening with AIM and complex limit order book (CLOB) orders executed during the closure. Its first specification controls for the VIX, the second adds the average daily effective spread for SPY complex options, and the third adds the trade-level controls of Panel A, the number of legs, and strategy fixed effects. The controls use the logs of trade size, the number of legs, and days to expiration. Quoted and effective spreads use Cboe quotes for electronic trades and LSEG quotes for floor trades. Effective spreads are in cents per unit of the underlying and are measured from the side of the end user. t-statistics in parentheses are computed from standard errors clustered by date. Significance stars use these t-statistics with standard normal critical values. The intercept, size-quintile indicators, and controls are not reported. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}\ p < 0.01$.

Panel A: Fills on Trade-Size Quintiles

	Floor vs. All Electronic				Floor vs. AIM			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Floor × ≤ P20	−0.01	−0.02	−0.02	−0.89***	−0.51***	−0.55***	−0.54***	−2.85***
	(−0.32)	(−0.53)	(−0.46)	(−13.18)	(−9.16)	(−9.97)	(−10.18)	(−14.16)
Floor × P20–P40	−0.47***	−0.47***	−0.47***	−0.48***	−0.66***	−0.69***	−0.68***	−0.86***
	(−9.37)	(−11.00)	(−10.63)	(−10.35)	(−7.63)	(−8.98)	(−8.59)	(−10.84)
Floor × P40–P60	−0.04	−0.05	−0.05	−0.05	−0.28***	−0.30***	−0.30***	−0.44***
	(−0.55)	(−0.66)	(−0.59)	(−0.71)	(−3.33)	(−3.63)	(−3.53)	(−4.34)
Floor × P60–P80	0.39***	0.38***	0.39***	0.39***	−0.06	−0.09	−0.09	−0.28***
	(3.86)	(3.99)	(3.98)	(4.05)	(−0.49)	(−0.80)	(−0.76)	(−2.75)
Floor × > P80	0.98***	0.98***	0.98***	0.87***	0.27	0.24	0.25	−0.02
	(5.98)	(6.10)	(6.10)	(5.11)	(1.41)	(1.26)	(1.28)	(−0.09)
Other Controls	No	No	No	Yes	No	No	No	Yes
Strategy FE	No	No	No	Yes	No	No	No	Yes
R-squared	0.06	0.06	0.06	0.17	0.10	0.10	0.10	0.42
Observations	209,117	209,117	209,117	204,969	37,519	37,519	37,519	36,911

Panel B: Effective Spread on Fills

	Fills			Log Fills		
	(1)	(2)	(3)	(4)	(5)	(6)
Fills	0.18***	0.19***	0.13***			
	(5.00)	(5.28)	(5.09)			
Log Fills				0.46***	0.47***	0.31***
				(4.42)	(4.68)	(5.16)
Other Controls	No	No	Yes	No	No	Yes
Strategy FE	No	No	Yes	No	No	Yes
R-squared	0.00	0.01	0.06	0.00	0.01	0.06
Observations	153,740	153,740	151,070	153,740	153,740	151,070

Table IA.XII. Fills per Order Leg by Trade Size

This table reports the mean number of fills per order leg in the opening window, for AIM orders executed during the last two weeks of the floor closure (June 1–12, 2020) and floor trades executed in the two weeks after the opening (June 15–26, 2020), for all trades and by trade-size quintile. An order leg is one option on one side of one order, where a floor package is one order, and a fill is a single execution on an order leg. Each order leg counts once, without weighting by contracts or by leg ratio, so a package with more legs contributes more order legs. Size groups are the quintiles of the floor trade-size distribution (June 15–26, 2020), in contracts. Electronic executions are grouped into orders. The last two columns report the number of order legs.

Size (Contracts)	AIM (Jun 1–12)	Floor (Jun 15–26)	Floor minus AIM	AIM Legs	Floor Legs
All Trades	2.08	2.67	0.59	84,253	10,525
≤ P20 (≤ 130)	1.96	1.39	−0.57	73,933	1,720
P20–P40 (131–260)	2.32	1.64	−0.68	3,072	1,945
P40–P60 (261–483)	2.41	2.04	−0.37	2,850	2,149
P60–P80 (484–1,040)	2.98	2.87	−0.11	2,435	2,244
> P80 (≥ 1,041)	4.59	4.73	0.14	1,963	2,467

Table IA.XIII. Floor and AIM Effective Spreads by Trade Size and Fills per Leg

This table reports OLS regressions of the effective spread on indicators for each combination of trade-size quintile and fills group and on their interactions with Floor, across all trades. The sample is the opening window: floor trades executed in the two weeks after the opening (June 15–26, 2020) and AIM orders executed in the last two weeks of the closure (June 1–12, 2020). Floor equals one for floor trades. Electronic executions are grouped into orders. Fills is the trade's weighted average number of fills per leg, with each leg weighted by its ratio in the package. Trades fall into three fills groups: exactly one fill per leg, more than one and fewer than three, and three or more. The quintiles are those of the floor trade-size distribution over June 15–26, 2020: 130 contracts or fewer (≤ P20), 131 to 260 contracts (P20–P40), 261 to 483 contracts (P40–P60), 484 to 1,040 contracts (P60–P80), and 1,041 contracts or more (> P80). Each entry is the coefficient on the interaction of Floor with a quintile and fills group, the floor-minus-AIM difference among trades of the same quintile and fills group. For each fills group, the first column controls for the VIX and the average daily effective spread for SPY complex options. The second adds the trade-level controls (quoted spread, absolute delta, days to expiration, absolute vega, gamma, implied volatility, trade size, number of legs, and a PM-settled indicator) and strategy fixed effects, and uses only the trades with complete controls. The controls use the logs of trade size, the number of legs, and days to expiration. All fills groups are estimated in the same regression, so the R-squared and the number of observations repeat across groups. Effective spreads use Cboe quotes for AIM orders and LSEG quotes for floor trades, are in cents per unit of the underlying, and are measured from the side of the end user. t-statistics in parentheses are computed from standard errors clustered by date. Significance stars use these t-statistics with standard normal critical values. The intercept, the quintile and fills group indicators, and the controls are not reported. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}\ p < 0.01$.

	Exactly One Fill per Leg		More than One, Fewer than Three		Three or More	
	(1)	(2)	(3)	(4)	(5)	(6)
Floor × ≤ P20	4.71***	3.50***	9.16***	7.57***	9.58***	9.78***
	(6.88)	(3.46)	(5.76)	(5.00)	(3.56)	(3.30)
Floor × P20–P40	2.74**	3.25**	0.89	1.07	10.96***	9.71***
	(2.12)	(2.41)	(0.61)	(0.73)	(4.60)	(3.96)
Floor × P40–P60	4.40***	5.49***	0.42	0.78	2.44*	2.06
	(3.45)	(3.92)	(0.30)	(0.48)	(1.68)	(1.25)
Floor × P60–P80	0.23	1.83	1.66	1.78	0.61	0.51
	(0.13)	(0.90)	(0.79)	(0.94)	(0.66)	(0.56)
Floor × > P80	1.05	1.19	−1.60	−1.83	−3.54***	−3.43***
	(0.55)	(0.59)	(−0.73)	(−0.79)	(−3.07)	(−3.02)
VIX and SPY Complex ES	Yes	Yes	Yes	Yes	Yes	Yes
Other Controls	No	Yes	No	Yes	No	Yes
Strategy FE	No	Yes	No	Yes	No	Yes
R-squared	0.03	0.06	0.03	0.06	0.03	0.06
Observations	37,519	36,911	37,519	36,911	37,519	36,911

IA.III: Models of the Electronic Effective Spread

Table VIII of the paper compares the effective spread of floor trades without an electronic match, which we call unmatched, with the electronic effective spread predicted for them. The models of the effective spread are fitted on the electronic orders executed in the last two weeks of the closure (June 1–12, 2020) and predict the effective spread of the floor trades executed in the two weeks after the opening (June 15–26, 2020). Electronic executions are grouped into orders. The effective spread is measured from the side of the end user, in cents per unit of the underlying, against the Cboe NBBO for electronic orders and against the last LSEG quote before the agreement time for floor trades (Section I.D of the paper). The sample excludes FLEX options, non-standard packages, trades with initiators of more than one capacity, and trades missing the effective spread or a variable of the model. Floor trades whose strategy or initiator capacity has no electronic order in June 1–12 are also dropped. This removes four of the 2,107 unmatched floor trades. The size quintiles are those of the floor trade-size distribution over June 15–26, 2020, split at 130, 260, 483, and 1,040 contracts.

Linear models. The two linear models are OLS regressions of the effective spread on trade size, the ratio-weighted number of legs, the quoted spread, absolute delta, days to expiration, absolute vega, gamma, implied volatility, a PM-settled (SPXW) indicator, the average daily effective spread of SPY complex trades, the VIX, the share of calls among the legs, the time of day in minutes after 9:30, and strategy and initiator capacity fixed effects. For floor trades, the time of day is the agreement time. The second linear model adds squared trade size. The two models are fitted on the 201,685 electronic orders with complete variables.

For a group of predicted trades, the gap is the mean of the actual minus the predicted effective spread. We estimate it as the coefficient of a floor indicator in a regression that pools the electronic training orders with the predicted trades. The indicator is interacted with every regressor, and each regressor is centered at its mean among the predicted trades. The interactions leave the fit to the training orders unchanged, and the coefficient of the indicator equals the mean prediction error of the predicted trades. The contract-weighted gap estimates the same regression by weighted least squares, with the predicted trades weighted by their contracts. Standard errors are clustered by trading day, with the ten training days and the ten days of the predicted trades as the 20 clusters. Significance stars use standard normal critical values. The placebo in Table IA.XIV applies the same test with the electronic orders of June 15–26, 2020, as the predicted trades.

Gradient boosting machine. The gradient boosting machine (GBM) predicts the effective spread with a sum of small regression trees. A regression tree splits the trades into groups by thresholds on the features and assigns one value to each group. The trees are added in sequence, each correcting the prediction of the trees before it, and their sum can capture nonlinear effects and interactions that the linear models leave out. We use

the HistGradientBoostingRegressor of scikit-learn with a learning rate of 0.1, at most 500 iterations, at most 15 leaves per tree, at least 400 observations per leaf, an L2 regularization of 1.0, and the random state 20200615. The features are the variables of the first linear model, with strategy and initiator capacity as native categorical features. The model is trained on the electronic orders of June 1–12, 2020, only. The gap is the mean of the actual minus the predicted effective spread, for all trades, by size quintile, and weighted by contracts. Its standard error comes from a bootstrap of trading days with 99 draws. Each draw resamples the training days and the days of the predicted trades with replacement within each window, refits the model, and recomputes the gap. The standard error is the standard deviation of the 99 gaps, the t-statistic is the gap divided by it, and the p-value uses the standard normal distribution. No standard errors are available for the placebo.

Double machine learning. Double machine learning (DML) estimates the gap with the augmented inverse probability weighting (AIPW) score for the average effect on the treated, with floor trades as the treated trades and the electronic orders of June 1–12, 2020, as controls. The estimate is the mean over floor trades of the actual minus the predicted effective spread, minus a correction from the prediction errors of the electronic orders weighted by $p/(1-p)$, where p is the propensity of floor execution. The weights give the most influence to the electronic orders that most resemble floor trades. The outcome model is the GBM above, cross-fitted on five folds of whole trading days. Each fold holds days from each of the two windows, and the prediction for a trade comes from the model fitted on the electronic orders of the other folds. The propensity model is a gradient boosting classifier, the HistGradientBoostingClassifier of scikit-learn with a learning rate of 0.05, at most 300 iterations, at most 31 leaves per tree, and at least 400 observations per leaf. Its features are those of the GBM without the two market variables, the VIX and the SPY complex spread. A logit (the LogisticRegression of scikit-learn with C equal to 1, with strategy and initiator capacity as standardized dummies) with the same features is the alternative propensity model. Trades with a propensity above 0.90 are dropped, with cut-offs of 0.95 and 0.99 as alternatives. With the classifier and the cut-off of 0.90, as in Table VIII, DML drops 443 unmatched floor trades, 136 of them above the 80th percentile. The DML predicted spread in that table is the actual spread minus the estimate. The standard error comes from the influence function of the AIPW score, clustered by trading day with the small-sample factor $G/(G-1)$, where G is the number of days. Significance stars use standard normal critical values.

Out of sample, the models explain about 3% (linear) and 6% (GBM) of the variation in electronic effective spreads. Unmatched floor trades lie outside the electronic sample, and their predictions are extrapolations.

TABLE IA.XIV HERE

Table IA.XIV. Predicted Electronic Cost: Placebo on Electronic Trades of June 15–26, 2020
This table applies the two linear models and the GBM of Table VIII of the paper to the electronic orders executed in the two weeks after the opening (June 15–26, 2020). It reports the mean of the actual minus the predicted effective spread, for all orders and by the quintiles of the floor trade-size distribution (June 15–26, 2020). The models are fitted on the electronic orders executed during the last two weeks of the floor closure (June 1–12, 2020). The linear models use the logs of trade size, the number of legs, and days to expiration, and the second adds squared log trade size. Electronic executions are grouped into orders. Effective spreads use Cboe quotes, are in cents per unit of the underlying, and are measured from the side of the end user. For the linear models, t-statistics are computed from standard errors clustered by date, with the 20 trading days of the opening window (June 1–26, 2020) as clusters. Significance stars use these t-statistics with standard normal critical values. †No standard errors are available for the GBM placebo. $^{*}p < 0.10$; $^{**}p < 0.05$; *** $p < 0.01$.

	All	≤ P20	P20–P40	P40–P60	P60–P80	> P80
Observations	180,357	177,078	2,071	768	326	114
Linear	0.21*	0.20*	0.96***	0.93***	1.34***	−0.34
Linear, squared trade size	0.22**	0.21*	0.74***	0.50**	0.65***	−1.62***
GBM†	0.10	0.08	0.68	0.88	1.27	−0.39

IA.IV: Complex Strategy Composition

This appendix describes the strategy composition of complex SPX trading across venues and periods and the characteristics of each strategy. We classify each complex package following Li (2022) based on the configuration of its option legs. Packages are formed from the Cboe complex execution identifiers and floor agreement timestamps described in Section IA.V. We group strategies by package structure. Combo-based packages comprise Combos, Index Combos, Combo Rolls, Box Spreads, and Multiple Combos. A Combo is a synthetic future that pairs a long call with a short put (or vice versa) at the same strike and expiration, and the other combo-based packages combine a Combo with additional legs or with other Combos. Table IA.XV defines each strategy, Table IA.XVI reports dollar volume shares by strategy group, and Table IA.XVIII reports average trade characteristics by strategy.

TABLE IA.XV HERE

TABLE IA.XVI HERE

Table IA.XVI reports the share of classified complex SPX dollar volume by strategy group, which excludes Non Standard packages. Panel A pools floor and electronic trades within each period. Combo-based packages account for 58.12% of classified complex SPX dollar volume before the closure and 62.38% after the opening, with a similar share of 57.05% during the closure. Within this group, the Index Combo share falls from 43.03% to 26.36% during the closure, while Box Spreads and Combo Rolls gain share. At the other end of the spectrum, Calendars and Diagonals, which average 12 to 47 contracts per trade (Table IA.XVIII) 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 mechanism. Before the closure, combo-based packages account for 76.71% of floor dollar volume but only 1.93% of electronic volume. During the closure, when all order flow executes electronically, combo-based packages account for 57.05% of electronic volume. After the opening, the combo-based share of electronic volume falls back to 11.04%, while combo-based packages make up 85.01% of floor volume. The migration largely reverses once the floor becomes available again. Index Combos show this pattern most clearly, with an electronic share of 0.27% before the closure, 26.36% during the closure, and 0.13% after the opening.

Table IA.XVII reports the share of complex SPX dollar volume by strategy group within the three electronic channels: the complex limit order book (CLOB), the Complex Order Auction (COA), and AIM. The three channels serve different segments of the complex market. Most CLOB and COA volume is in packages without a Combo. Before the closure, Vertical Spreads account for 29.58% of CLOB volume and 32.79% of COA volume, followed

by Butterflies and Condors (22.29% and 25.20%) and Calendars and Diagonals (16.93% and 17.19%). Combo-based packages (Combos, Index Combos, Combo Rolls, Box Spreads, and Multiple Combos) account for only 2.43% of CLOB volume and 1.08% of COA volume before the closure. During the closure, when all complex flow executes electronically, the combo-based share of CLOB volume rises to 31.94%, led by Index Combos (13.48%) and Box Spreads (9.58%), consistent with some displaced floor flow entering the book. In COA, the combo-based share rises only to 4.93%. In AIM, by contrast, combo-based packages account for 78.54% of closure-period dollar volume, and Index Combos alone account for 37.01%. This composition is close to that of the floor, where combo-based packages account for 76.71% of pre-closure volume (Table IA.XVI). After the opening, the combo-based share of CLOB volume falls back to 11.65%.

TABLE IA.XVII HERE

TABLE IA.XVIII HERE

Table IA.XVIII reports average delta exposure, hedge cost, and trade size for each complex SPX strategy outside the closure period, with floor and electronic trades pooled. Strategies are grouped by package structure and sorted by descending hedge cost within each group. At the top, Index Combos, Combo Rolls, and Box Spreads trade in by far the largest dollar sizes. Index Combos average 881 contracts ($5.77 million), Combo Rolls 838 contracts ($7.30 million), and Box Spreads 249 contracts ($13.93 million). Simple Combos carry the highest absolute delta (0.50 per underlying) and the highest hedge cost ($118 per trade). Simple Combos are much smaller than the other combo-based packages. They average 63 contracts ($0.92 million) and account for 0.26% of floor dollar volume before the closure and 0.08% after the opening (Table IA.XVI, Panel B). Index Combos pair a Combo with additional legs and carry an absolute delta of only 0.01 per underlying, but their size still produces the third-highest hedge cost ($60 per trade). Moving down the table, strategies become progressively smaller and more balanced. Ratio Spreads carry hedge costs between $10 and $32 per trade. Structures such as Butterflies, Calendars, and Vertical Spreads are near-delta-neutral with hedge costs roughly $10 or less per trade and trade sizes between 12 and 89 contracts on average, about one-tenth or less of the Index Combo average.

Table IA.XV. Complex Strategy Definitions

This table defines the complex strategies identified by the classification of SPX packages. Packages are classified following Li (2022) from the option type, strike, expiration, and contract ratio of each leg, and from the side of each leg in the Cboe trade-by-trade data. Strategies are grouped by package structure as in Tables IA.XVI, IA.XVIII, and IA.XVII. Names with (Put) or (Puts) in parentheses denote the put version of the call strategy. Leg sizes are in a 1:1 ratio unless the definition states otherwise. "Bought" and "sold" describe one side of the package; the counterparty holds the opposite position. Strategies marked with † have fewer than 100 packages in the full sample period outside the closure period and are not reported separately in Table IA.XVIII. The Legs column counts distinct option series. Elsewhere, the number of legs is ratio-weighted (Section I).

Strategy	Legs	Definition
Combos		
Combo	2	A call and a put with the same strike and expiration, one bought and one sold, in equal sizes (a synthetic future).
Index Combo	3+	One or more Combos executed together with one or more additional option legs that do not form further Combos, as a single package; the sizes of the additional legs need not equal those of the Combos.
Combo Roll	4	Two Combos with different expirations, in opposite directions, with the same or different strikes.
Box Spread	4	Two Combos with the same expiration and different strikes, in opposite directions.
2, 3, or 4 Combos†	4–8	Two to four Combos executed as one package that do not form a Box Spread or a Combo Roll (Multiple Combos in Table IA.XVI).
Ratio Spreads		
Vertical Call (Put) Ratio	2	Two calls (puts) with the same expiration and different strikes, one bought and one sold, in unequal sizes.
Ratio Calendar Call (Put)	2	Two calls (puts) with the same strike and different expirations, one bought and one sold, in unequal sizes.
Ratio Diagonal Call (Put) Spread	2	Two calls (puts) with different strikes and different expirations, one bought and one sold, in unequal sizes.
Straddle Ratio	2	A call and a put with the same strike and expiration, both bought or both sold, in unequal sizes.
Strangle Ratio	2	A call and a put with different strikes and the same expiration, both bought or both sold, in unequal sizes.
Straddles and Strangles		
Straddle	2	A call and a put with the same strike and expiration, both bought or both sold.
Strangle	2	A call and a put with different strikes and the same expiration, both bought or both sold.
Calendars and Diagonals		
Calendar Call (Put)	2	Two calls (puts) with the same strike and different expirations, one bought and one sold.
Diagonal Call (Put) Spread	2	Two calls (puts) with different strikes and different expirations, one bought and one sold.
Double Calendar Call (Put)	4	Two call (put) Calendars at different strikes over the same two expirations, both bought or both sold.

continued on next page

Table IA.XV continued

Strategy	Legs	Definition
Double Calendar	4	A call Calendar and a put Calendar at different strikes over the same two expirations, both bought or both sold.
Vertical Spreads		
Vertical Call (Put) Spread	2	Two calls (puts) with the same expiration and different strikes, one bought and one sold.
Vertical Rolls		
Vertical Call (Put) Roll	4	Two call (put) Vertical Spreads with different expirations, in opposite directions.
Butterflies and Condors		
Call (Put) Butterfly	3	Three calls (puts) with the same expiration and equally spaced strikes in a 1:2:1 ratio; the middle strike is traded in the opposite direction of the two outer strikes.
Call (Put) Broken Wing Butterfly	3	Three calls (puts) as in a Call (Put) Butterfly, but with unequally spaced strikes.
Call (Put) Ratio Butterfly†	3	Three calls (puts) as in a Call (Put) Butterfly, with two outer legs of equal size, but in an integer ratio other than 1:2:1, with leg sizes that are not all equal.
Call (Put) Butterfly (Custom)	3	Three calls (puts) with the same expiration and three strikes, the middle strike traded in the opposite direction of the two outer strikes, and either (i) outer legs of equal size, unequally spaced strikes, and an integer ratio other than 1:2:1, with leg sizes that are not all equal; or (ii) outer legs of different sizes, with the middle leg equal to the two outer legs combined (e.g., 2:3:1), and any strike spacing.
Iron Butterfly	4	A put and a call at a common middle strike, traded in one direction, and a lower-strike put and a higher-strike call traded in the other direction, all with the same expiration.
Condor Spread with Calls (Puts)	4	Four calls (puts) with the same expiration and four strikes; the two outer strikes are traded in one direction and the two inner strikes in the other.
Iron Condor	4	Two puts at the two lowest strikes and two calls at the two highest strikes, all with the same expiration; the two inner legs are traded in one direction and the two outer legs in the other.
Other Strategies		
Risk Reversal	2	A call and a put with different strikes and the same expiration, one bought and one sold; Li (2022) includes this structure in the Combo.
Call (Put) Ladder	3	Three calls (puts) with the same expiration and three strikes in a 1:1:1 ratio; the lowest-strike call (highest-strike put) is traded in one direction and the other two legs in the other.
Non Standard	–	Packages that match none of the configurations above. They account for 4.9% of complex trades. They count toward complex SPX volume but not toward the strategy shares in Tables IA.XVI and IA.XVII. Table IA.XVIII reports their size and delta. No spread analysis uses them.

Table IA.XVI. Complex Strategy Composition

This table reports the percentage of classified SPX complex dollar volume attributable to each strategy group in the pre-closure period (January 2 to March 13, 2020), the closure period (March 16 to June 14, 2020), and the period after the opening (June 15 to October 21, 2020), which together form the full sample period. Strategies are classified following Li (2022) based on the configuration of option legs within each package and grouped by package structure; Table IA.XV defines the strategies in each group. Panel A pools floor and electronic trades within each period; the closure period contains electronic trades only. Panel B disaggregates by venue. For the pre-closure period and the period after the opening, the Floor and Electronic columns report separate volume shares summing to 100% within each venue-period. The closure column reports electronic volume shares only.

Panel A: Volume by Strategy and Period

Strategy	Pre-Closure	Closure	After Opening
Combo	0.27	0.24	1.00
Index Combo	43.03	26.36	37.42
Combo Roll	6.87	11.32	6.20
Box Spread	7.36	17.05	17.11
Multiple Combos	0.59	2.08	0.65
Ratio Spreads	5.19	4.39	3.07
Straddles and Strangles	3.20	3.71	3.17
Calendars and Diagonals	7.14	10.24	10.87
Vertical Spreads	13.29	12.75	10.87
Vertical Rolls	4.53	4.68	2.55
Butterflies and Condors	8.08	6.93	6.59
Other Strategies	0.44	0.25	0.47

Panel B: Volume by Strategy, Venue, and Period

Strategy	Electronic			Floor	
	Pre-Closure	Closure	After Opening	Pre-Closure	After Opening
Combo	0.30	0.24	3.09	0.26	0.08
Index Combo	0.27	26.36	0.13	57.18	53.86
Combo Roll	0.60	11.32	1.05	8.95	8.47
Box Spread	0.76	17.05	6.77	9.54	21.67
Multiple Combos	0.00	2.08	0.00	0.78	0.93
Ratio Spreads	7.17	4.39	4.60	4.54	2.40
Straddles and Strangles	6.05	3.71	6.48	2.26	1.71
Calendars and Diagonals	17.04	10.24	25.80	3.86	4.29
Vertical Spreads	30.78	12.75	26.08	7.51	4.17
Vertical Rolls	12.64	4.68	7.22	1.85	0.49
Butterflies and Condors	23.36	6.93	18.33	3.03	1.42
Other Strategies	1.03	0.25	0.43	0.24	0.49

Table IA.XVII. Complex Strategy Composition in CLOB, COA, and AIM

This table reports the percentage of classified SPX complex dollar volume attributable to each strategy group in the complex limit order book (CLOB), the Complex Order Auction (COA), and the Automated Improvement Mechanism (AIM). Strategies are classified following Li (2022) based on the configuration of option legs within each package and grouped by package structure; Table IA.XV defines the strategies in each group. The first three columns report strategy shares within CLOB volume and the next three columns report strategy shares within COA volume in the pre-closure period (January 2 to March 13, 2020), the closure period (March 16 to June 14, 2020), and the period after the opening (June 15 to October 21, 2020), which together form the full sample period. The final column reports strategy shares within AIM volume during the closure period. Each column sums to 100%. All values are percentages.

Strategy	CLOB			COA			AIM
	Pre-Closure	Closure	After Opening	Pre-Closure	Closure	After Opening	Closure
Combo	0.39	0.55	3.65	0.14	0.67	2.04	0.01
Index Combo	0.31	13.48	0.11	0.21	1.56	0.16	37.01
Combo Roll	0.83	7.37	1.37	0.20	1.62	0.44	14.99
Box Spread	0.90	9.58	6.52	0.53	1.08	7.26	23.54
Multiple Combos	0.00	0.96	0.00	0.00	0.00	0.00	2.99
Ratio Spreads	6.69	6.98	4.98	8.00	8.01	3.84	2.49
Straddles and Strangles	8.28	7.19	8.22	2.31	2.41	3.19	2.37
Calendars and Diagonals	16.93	15.93	26.19	17.19	28.35	25.04	4.14
Vertical Spreads	29.58	20.29	24.68	32.79	30.72	28.75	5.85
Vertical Rolls	12.68	8.09	6.20	12.58	12.60	9.15	1.59
Butterflies and Condors	22.29	9.11	17.67	25.20	12.47	19.59	4.87
Other Strategies	1.14	0.48	0.39	0.86	0.50	0.55	0.10

Table IA.XVIII. Complex Strategy Characteristics

This table reports average trade characteristics for each complex SPX strategy type in the full sample period (January 2 to October 21, 2020), excluding the floor closure period (March 16 to June 14, 2020). Floor and electronic trades are pooled. Strategies are defined in Table IA.XV, grouped by package structure, and sorted by descending hedge cost within each group. |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. |Net Delta| Per Trade is the absolute net delta exposure of the trade in units of 10,000 delta shares. Hedge Cost is winsorized like the other execution cost measures, and |Net Delta| is not winsorized. Non Standard groups all packages that the classifier cannot assign to a named strategy; its hedge cost is not reported. Strategies with fewer than 100 packages outside the closure period (marked with † in Table IA.XV; 194 packages in total) are not reported.

			Trade Size		
Strategy	|Delta| Per Underlying	Hedge Cost $ Hundreds Per Trade	Contracts	Million $	|Net Delta| Per Trade 10,000 Shares
Combos					
Combo	0.50	1.18	63.05	0.92	0.32
Index Combo	0.01	0.60	880.91	5.77	0.07
Combo Roll	0.00	0.17	838.26	7.30	0.02
Box Spread	0.01	0.06	248.86	13.93	0.01
Ratio Spreads					
Strangle Ratio	0.04	0.32	292.55	0.62	0.04
Ratio Calendar Call	0.07	0.24	71.68	0.28	0.02
Ratio Calendar Put	0.04	0.22	228.20	0.37	0.03
Ratio Diagonal Put Spread	0.03	0.21	209.16	0.54	0.04
Ratio Diagonal Call Spread	0.04	0.19	105.60	0.45	0.05
Straddle Ratio	0.03	0.15	47.80	0.38	0.01
Vertical Call Ratio	0.03	0.11	60.13	0.14	0.01
Vertical Put Ratio	0.02	0.10	85.57	0.19	0.01
Straddles and Strangles					
Straddle	0.05	0.15	36.40	0.34	0.01
Strangle	0.04	0.10	30.49	0.11	0.01
Calendars and Diagonals					
Diagonal Put Spread	0.05	0.13	46.55	0.18	0.02
Diagonal Call Spread	0.05	0.12	30.29	0.17	0.02
Double Calendar Call	0.01	0.03	24.11	0.08	0.00
Calendar Put	0.01	0.03	16.08	0.10	0.00
Calendar Call	0.01	0.02	11.74	0.08	0.00
Double Calendar Put	0.01	0.02	21.50	0.11	0.00
Double Calendar	0.01	0.02	30.09	0.10	0.00
Vertical Spreads					
Vertical Call Spread	0.04	0.08	19.76	0.03	0.01
Vertical Put Spread	0.03	0.07	25.44	0.04	0.01
Vertical Rolls					
Vertical Call Roll	0.02	0.07	36.68	0.21	0.01
Vertical Put Roll	0.01	0.06	63.59	0.42	0.01
Butterflies and Condors					
Put Butterfly (Custom)	0.01	0.09	89.32	0.37	0.01
Put Butterfly	0.01	0.07	65.40	0.17	0.01
Iron Butterfly	0.03	0.06	17.35	0.04	0.01
Call Butterfly (Custom)	0.02	0.05	26.65	0.04	0.00
Condor Spread with Puts	0.01	0.04	48.99	0.14	0.00
Call Butterfly	0.02	0.04	23.19	0.04	0.00
Iron Condor	0.01	0.03	25.40	0.02	0.00
Condor Spread with Calls	0.01	0.03	36.47	0.06	0.00
Call Broken Wing Butterfly	0.02	0.03	23.59	0.04	0.00
Put Broken Wing Butterfly	0.01	0.02	25.13	0.11	0.00
Other Strategies					
Risk Reversal	0.27	0.66	53.19	0.21	0.11
Put Ladder	0.02	0.16	98.82	0.56	0.02
Call Ladder	0.03	0.14	54.83	0.15	0.01
Non Standard	0.04	–	109.34	0.46	0.04

IA.V: Complex Order Reconstruction and Strategy Classification

We construct SPX complex packages from the Cboe Trade-by-Trade (TBT) data. Each TBT record reports one side of an execution in a single option series, with that side's capacity (customer, professional customer, firm, broker-dealer, or market maker), direction, and trade type. The two sides of an execution share an execution identifier (*exec_id*). We merge the two records of each execution into one fill and identify the initiating side from the pair of trade types.[1] The legs of a complex trade are separate executions; we link them into packages using the complex execution identifier (*complex_exec_id*) for electronic trades and the floor agreement time (*floor_action_ts*) for floor trades, as described below.

A. Electronic Complex

Each leg of an electronic complex trade is a separate execution, and the legs of the same trade share a *complex_exec_id*. Table IA.XIX shows an example: a vertical call spread on SPXW options expiring the same day, executed on the complex limit order book (CLOB) on September 4, 2020. The trade has two legs, the 3480 and 3490 calls, and each leg is one execution, identified by its *exec_id*. Each execution appears twice, once for each side. In each execution, the customer side with trade type *Complex Remove* is the initiator: its incoming order executes against the resting order on the other side, which has trade type *Complex Add*. The initiating customer sells the 3480 call at 0.90 and buys the 3490 call at 0.65 for 10 contracts each, that is, it sells 10 call spreads for a net credit of 0.25 per spread. Because both executions carry the same *complex_exec_id*, we link them into one package, and we classify the package as a vertical call spread from its legs: two calls with the same expiration and different strikes, one bought and one sold, in equal sizes (a 1:1 ratio).

An electronic order can execute against several counterparties, for example when it trades against more than one resting order on the CLOB or is split among several responders in an auction. Cboe records each of these fills as a separate complex execution with its own *complex_exec_id* and reports no order identifier. We therefore reconstruct orders by combining packages that have (i) the same legs (the same option series, each traded on the same side), (ii) the same ratio of leg sizes, (iii) the same initiator capacity, (iv) the same execution mechanism, and (v) the same timestamp, which Cboe reports to the microsecond. These are identical complex packages, initiated by the same type of trader (e.g., a customer), executing in the same microsecond; each package adds at least one fill on each leg of the order.

[1] The trade types also identify the mechanism of each execution: the trading floor or, electronically, the complex limit order book (CLOB), the Complex Order Auction (COA), or the Automated Improvement Mechanism (AIM). For instance, if one side has trade type AIM Agency - Complex and capacity customer, and the other side has AIM Contra - Complex and capacity market maker, the customer's agency order is the initiator and the market maker is the contra party paired with it in the AIM auction.

TABLE IA.XIX HERE

B. Floor Complex

Unlike electronic trades, floor complex trades cannot be grouped using *complex_exec_id*, which can differ across fills. Instead, all records of a floor trade carry the time at which the trade was agreed upon on the trading floor (*floor_action_ts*), recorded to the millisecond. Because floor trades are agreed upon by open outcry, two separate trades are unlikely to share the same timestamp to the millisecond.[2] We therefore group floor records into packages on *floor_action_ts*. Table IA.XX shows an example: a customer buys 375 vertical put spreads, buying the 2625 put and selling the 1925 put. The order is filled in two executions per leg, of 275 and 100 contracts, each with a market maker. The two fills have different execution identifiers and are reported at different times (*transact_time*), but all eight records share the same *floor_action_ts*, which groups them into one package.

We identify the initiator of each floor execution in three steps. First, where the trade types (*trade_type*) distinguish the two sides, we use them. From September 28, 2020, the record of a market maker responding in the crowd can carry *MM In-crowd - Complex*, which Cboe defines as a market maker order executed in the crowd, while the record of the order represented in the crowd carries *Floor Legged In - Complex*, a complex order executed by legging in. Before that date, the record of the order represented in the crowd carries *Floor Unqualified Type - Complex*, and a market maker's record usually carries *MM In-crowd - Simple*; for these fills, we use the second step rather than the trade types. Second, where the trade types do not distinguish the two sides, we treat the side that is not a market maker as the initiator, since floor brokers typically bring customer and firm orders to the trading crowd, where in-crowd market makers fill them by open outcry. In Table IA.XX, both sides carry the same trade type (*Floor Order on PAR - Complex*), so the customer is the initiator as the side that is not a market maker. Third, where both or neither side are market makers, we assign the direction of the other signed executions on the same option in the same package. If there are none, or they disagree, we cannot sign the execution and drop the whole package; this applies to 14% of floor orders in the two weeks before the closure and 20% in the two weeks after the opening.

The NBBO in the TBT data is recorded at *transact_time*, when the trade is reported. For floor trades, however, reporting may occur several minutes after the trade is agreed, so the corresponding TBT quotes can reflect market conditions after the agreement.[3] We therefore use LSEG quote data for floor trades, assigning each leg the most recent quote prevailing before *floor_action_ts*, the timestamp at which the trade was agreed, and

[2] A single order has one initiator, so all its legs have the same initiator capacity. Only 21 floor packages from January 2 to October 21, 2020 have legs with initiators of different capacities, and none falls in March 2–13 or June 15–26, 2020. We drop these 21 packages from our analysis.

[3] The median time between *floor_action_ts* and the *transact_time* of the last leg is 78 seconds.

construct the package-level synthetic quote from these leg-level quotes.[4] For 30.4% of floor legs, the LSEG quote differs from the TBT quote. For electronic trades, which are reported contemporaneously with execution, we use the NBBO recorded in the TBT data.

TABLE IA.XX HERE

[4]The median age of the assigned quote is 2 seconds.

Table IA.XIX. An Electronic Complex Trade in the Cboe TBT Data
This table shows the Cboe Trade-by-Trade (TBT) records of one SPX complex trade executed electronically on the complex limit order book (CLOB) on September 4, 2020: a vertical call spread on SPXW options expiring the same day. A customer sells 10 spreads, selling the 3480 call at 0.90 and buying the 3490 call at 0.65. Each leg is one execution (*exec_id*) with two records, one for each side; the side with trade type Complex Remove initiates against the resting Complex Add order. Both legs share one complex execution identifier (*complex_exec_id*), which links them into one package. Execution identifiers have been randomized.

Time	Strike	Type	Side	Size	Price	Capacity	Trade Type	exec_id	complex_exec_id
10:41:10.113946	3480	C	Buy	10	0.90	Customer	Complex Add	Y1D0180LM	YF801L01M
10:41:10.113946	3480	C	Sell	10	0.90	Customer	Complex Remove	Y1D0180LM	YF801L01M
10:41:10.113946	3490	C	Sell	10	0.65	Customer	Complex Add	81YML100E	YF801L01M
10:41:10.113946	3490	C	Buy	10	0.65	Customer	Complex Remove	81YML100E	YF801L01M

Table IA.XX. A Floor Complex Trade in the Cboe TBT Data
This table shows the Cboe Trade-by-Trade (TBT) records of one SPX complex trade executed on the trading floor on September 28, 2020: a vertical put spread on SPX options expiring October 16, 2020. A customer buys 375 spreads, buying the 2625 put at 1.50 and selling the 1925 put at 0.15. Each leg is filled in two executions (*exec_id*) of 275 and 100 contracts with market makers, and each execution has two records, one for each side. All records share the time at which the trade was agreed on the floor (*floor_action_ts*), which links them into one package; *transact_time* is the time at which each execution is reported (shown to the millisecond). Trade type: PAR-C = Floor Order on PAR - Complex. Both sides of each execution have the same trade type; the customer is the initiator. Times and execution identifiers have been randomized.

floor_action_ts	transact_time	Strike	Type	Side	Size	Price	Capacity	Trade Type	exec_id
14:01:02.822	14:02:57.762	2625	Put	Buy	275	1.50	Customer	PAR-C	51X4L000E
14:01:02.822	14:02:57.762	2625	Put	Sell	275	1.50	Market Maker	PAR-C	51X4L000E
14:01:02.822	14:02:57.930	2625	Put	Buy	100	1.50	Customer	PAR-C	X0L1H0054
14:01:02.822	14:02:57.930	2625	Put	Sell	100	1.50	Market Maker	PAR-C	X0L1H0054
14:01:02.822	14:02:57.762	1925	Put	Sell	275	0.15	Customer	PAR-C	XF501L004
14:01:02.822	14:02:57.762	1925	Put	Buy	275	0.15	Market Maker	PAR-C	XF501L004
14:01:02.822	14:02:57.930	1925	Put	Sell	100	0.15	Customer	PAR-C	X1I0050L4
14:01:02.822	14:02:57.930	1925	Put	Buy	100	0.15	Market Maker	PAR-C	X1I0050L4

IA.VI: Trade Initiators by Mechanism

Table IA.XXI reports the composition of complex SPX packages by the capacity of the initiating party on the trading floor, the CLOB, AIM, and the COA. On the floor, customers initiate 42.0% of packages and firms 49.9%. Market makers initiate only 1.2%, consistent with their role on the floor of responding to the orders that brokers bring to the crowd. Market makers initiate 94.5% of CLOB packages, and customers 4.8%. The two electronic auctions serve customers, who initiate 89.4% of AIM packages and 89.1% of COA packages.

TABLE IA.XXI HERE

Table IA.XXI. Trade Initiators by Venue

This table reports the composition of complex SPX packages by the capacity of the initiating party on each venue: the trading floor, the complex limit order book (CLOB), the Automated Improvement Mechanism (AIM), and the Complex Order Auction (COA). The sample is the full sample period (January 2 to October 21, 2020), which covers the pre-closure period, the closure, and the period after the opening. The table reports the percentage of packages initiated by market makers, customers, firms, broker-dealers, and professional customers, together with the number of packages. Electronic executions are grouped into orders (Section IA.V), so electronic counts are orders and floor counts are packages.

	Packages by Initiator Capacity (%)					
Venue	Market Maker	Customer	Firm	Broker-Dealer	Professional Customer	Packages
Floor	1.2	42.0	49.9	4.6	2.3	51,577
CLOB	94.5	4.8	0.1	0.0	0.5	2,272,717
AIM	2.6	89.4	6.6	1.0	0.3	161,536
COA	0.0	89.1	0.0	0.0	10.9	1,294,196

IA.VII: Distinct Options and Leg Ratios

The number of legs in the paper is ratio-weighted: it is the sum of the leg ratios of a package. This section measures package complexity in two other ways, by the number of distinct options in a package and by its maximum leg ratio. Table IA.XXII reports three measures of package complexity by mechanism and floor trade-size quintile, across all trades in the opening window: the ratio-weighted number of legs of Table IV of the paper, the number of distinct options in a package, and the maximum leg ratio, the number of contracts in the largest leg per contract in the smallest. The sample contains the 3,392 floor trades executed after the opening (June 15–26, 2020) and the 205,725 electronic orders executed during the closure (June 1–12, 2020), of which 34,127 are AIM orders. The quintiles are those of Section II.

TABLE IA.XXII HERE

Floor trades combine 3.10 distinct options on average, against 2.33 for all electronic orders and 2.47 for AIM orders, and their maximum leg ratio is 6.06, against 1.19 and 1.48. At or below the 20th percentile, floor trades have 2.51 distinct options and a maximum leg ratio of 2.84, against 2.30 and 1.12 across electronic orders and 2.38 and 1.16 in AIM. Above the 80th percentile, floor trades have 3.64 distinct options, against 3.30 across electronic orders and 3.66 in AIM, and a maximum leg ratio of 8.12, against 3.48 and 4.63. The number of distinct options rises with size in each mechanism. Across electronic orders, the maximum leg ratio rises in every quintile, from 1.12 to 3.48. In AIM, it is 4.43 between the 20th and 40th percentiles and between 4.63 and 4.98 in the larger quintiles. On the floor, it rises from 2.84 at or below the 20th percentile to 8.14 between the 60th and 80th percentiles. The ratio-weighted number of legs rises with size in each mechanism, from 5.46 to 16.81 on the floor, from 2.44 to 8.11 across electronic orders, and from 2.57 to 10.91 in AIM.

Table IA.XXIII repeats the floor-routing logit of Table III in the paper with the logs of the number of distinct options and the maximum leg ratio in place of the ratio-weighted number of legs. The sample contains the complex SPX orders executed after the opening (June 15 to October 21, 2020), with electronic executions grouped into orders. The specifications include the two complexity measures alone, add trade size, and add days to expiration, absolute vega, gamma, implied volatility, absolute delta, and the SPXW indicator. Each specification is estimated without and with strategy fixed effects. Panel A reports logit coefficients and Panel B average marginal effects, with z-statistics computed from standard errors clustered by date.

TABLE IA.XXIII HERE

Without strategy fixed effects, the two complexity measures alone yield a pseudo-R^2 of 0.34, and adding trade size raises it to 0.71. With trade size, the coefficient on the number of distinct options is 0.49 and that on the maximum leg ratio is 2.14. With the other controls, they are 0.52 and 1.49. Each is significant at the 1% level. With strategy fixed effects, the pseudo-R^2 is 0.56 with the two complexity measures alone, 0.79 with trade size, and 0.80 with the other controls. In these three specifications, the coefficient on the maximum leg ratio is 3.32, 2.27, and 2.15, and that on the number of distinct options is 0.86, −3.48, and −2.60. Each is significant at the 1% level. With the full set of controls and strategy fixed effects, the average marginal effect of the maximum leg ratio is 0.0086 and that of the number of distinct options is −0.0104. Trade size has a coefficient between 1.80 and 1.83 in every specification that includes it, significant at the 1% level.

Within strategies, the number of distinct options varies only among Index Combos. In the strategy fixed-effects sample, the 16,668 Index Combo trades, 15,957 of them on the floor, contain between 3 and 12 distinct options, and every other strategy always has the same number of distinct options. The maximum leg ratio varies among Index Combos, from 1 to 540. It also varies within ten other strategies: Vertical Put and Call Ratios, custom Put and Call Butterflies, Ratio Diagonal Put and Call Spreads, Strangle Ratios, Straddle Ratios, and Ratio Calendar Puts and Calls (not tabulated).

We also estimate the logit with each complexity measure on its own (not tabulated). With the maximum leg ratio as the only complexity measure, its coefficient is 3.43 alone, 2.23 with trade size, and 1.58 with the other controls. In the same specifications with strategy fixed effects, it is 3.29, 2.37, and 2.20. With the number of distinct options as the only complexity measure, its coefficient is 3.23, 1.93, and 1.53 without strategy fixed effects and 1.09, −2.94, and −2.38 with them. Each of these coefficients is significant at the 1% level. On its own and without strategy fixed effects, the maximum leg ratio yields a pseudo-R^2 of 0.33, and the number of distinct options yields 0.10.

Section II.B matches trades on the ratio-weighted number of legs. This section repeats the matching with the number of distinct options and the maximum leg ratio in its place. The other five characteristics, the caliper of 0.25 standard deviations, and the one-to-one selection are those of Section II.B, and electronic executions are grouped into orders. Of the 3,284 floor trades, 1,071 have an electronic match and 878 have an AIM match. Table IA.XXIV reports means across all trades in the opening window and among matched trades.

TABLE IA.XXIV HERE

Across the 3,284 floor trades with complete matching characteristics, floor trades average 3.08 distinct options and a maximum leg ratio of 6.16, against 2.32 and 1.19 for electronic trades. Floor trades and their electronic matches both average 2.42 distinct options and a maximum leg ratio of 1.33, with 331.56 and 329.45 contracts and 21.40 and

21.55 days to expiration. The 2,213 unmatched floor trades average 1,002.39 contracts, 3.41 distinct options, and a maximum leg ratio of 8.49. Matched floor trades pay an effective spread of 4.51 cents, against 3.04 cents for their electronic matches, a difference of 1.48 cents. Market maker revenues show the same difference of 1.48 cents (4.21 against 2.74 cents), and hedge costs are 0.30 cents on each side. One minute after the trade, the price impact of matched floor trades is 0.99 cents lower than that of their electronic matches, and their realized spread is 2.44 cents higher. Floor trades with an AIM match and their AIM matches average 2.55 distinct options and maximum leg ratios of 1.64 and 1.63. These floor trades pay an effective spread of 4.50 cents, against 1.88 cents for their AIM matches, a difference of 2.62 cents. One minute after the trade, their realized spread exceeds that of their AIM matches by 2.84 cents. With matching on the number of legs, the effective spread differences are 1.30 cents against electronic matches and 2.54 cents against AIM matches (Table VI).

Table IA.XXV estimates Equation (3) on these matched trades with the specifications of Table VII, except that the number of distinct options and the maximum leg ratio replace the number of legs among the trade-level controls. Standard errors are clustered by date, and significance levels use conventional p-values.

TABLE IA.XXV HERE

With the VIX and the SPY complex spread as controls, matched floor trades pay 1.17 cents more in effective spread than their electronic matches. With the full set of controls and strategy fixed effects, the difference is 1.27 cents. Market maker revenues give 1.20 and 1.29 cents. Against matched AIM trades, floor trades pay 2.58 cents more in effective spread with the VIX and the SPY complex spread as controls and 2.60 cents more with the full set of controls and strategy fixed effects. Every Floor estimate is significant at the 1% level. With matching on the number of legs, the corresponding estimates in Table VII are 0.98 and 1.14 cents for the effective spread, 1.00 and 1.15 cents for market maker revenue, and 2.45 cents in both specifications against AIM matches. Each of these is significant at the 1% level, except the effective spread estimate with the VIX and the SPY complex spread as controls, which is significant at the 5% level. Neither the number of distinct options nor the maximum leg ratio has a statistically significant coefficient in any specification.

Table IA.XXII. Complexity of Trades by Size Quintile and Venue

This table reports means of three measures of package complexity for complex SPX trades by trade-size quintile and venue, across all trades. The sample is the opening window: floor trades executed in the two weeks after the opening (June 15–26, 2020) and electronic trades executed in the last two weeks of the closure (June 1–12, 2020). All Electronic contains all electronic orders, including AIM (Automated Improvement Mechanism) orders, and AIM contains the AIM orders only. Electronic executions are grouped into orders. The quintiles are those of the floor trade-size distribution, in contracts. Trades is the number of floor trades or electronic orders in each quintile. The number of legs is ratio-weighted, the sum of the leg ratios, as in Table IV. Distinct options is the number of distinct option series in a package. The maximum leg ratio is the number of contracts in the largest leg divided by the number of contracts in the smallest leg.

		Floor Trade-Size Quintile				
	All	≤ P20 (≤ 130)	P20–P40 (131–260)	P40–P60 (261–483)	P60–P80 (484–1,040)	> P80 (≥ 1,041)
Trades						
All Electronic	205,725	196,328	4,461	2,561	1,515	860
AIM	34,127	31,093	969	833	696	536
Floor	3,392	686	674	675	679	678
Number of Legs						
All Electronic	2.58	2.44	4.46	5.69	6.87	8.11
AIM	3.23	2.57	8.75	10.20	10.53	10.91
Floor	11.98	5.46	10.26	10.94	16.47	16.81
Distinct Options						
All Electronic	2.33	2.30	2.69	2.89	3.00	3.30
AIM	2.47	2.38	3.17	3.42	3.49	3.66
Floor	3.10	2.51	2.89	3.18	3.30	3.64
Maximum Leg Ratio						
All Electronic	1.19	1.12	2.11	2.68	3.15	3.48
AIM	1.48	1.16	4.43	4.98	4.88	4.63
Floor	6.06	2.84	5.45	5.77	8.14	8.12

Table IA.XXIII. Determinants of Floor Trading: Distinct Options and Maximum Leg Ratio
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. Electronic executions are grouped into orders before estimation. The sample covers the period after the opening (June 15 to October 21, 2020) and contains up to 1,698,094 observations; the number of observations in each specification is reported at the bottom of each panel. The estimated specification follows Equation (1) of the paper:

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

where the number of distinct option series in a package (distinct options) and the number of contracts in its largest leg divided by the number in its smallest leg (maximum leg ratio) replace the number of legs of Table III. The specifications include the two complexity measures alone, add trade size, and add days to expiration, absolute vega, gamma, implied volatility, absolute delta, and an SPXW indicator for PM-settled contracts, each without and with strategy fixed effects μ_s. Distinct options, the maximum leg ratio, trade size, and days to expiration are in logs, and gamma is multiplied by 1,000. $\Lambda(\cdot)$ 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, the mean change in the predicted probability of floor execution from a one-unit increase in each variable evaluated at observed values, with z-statistics in parentheses. Significance stars use standard normal critical values. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Panel A: Estimated Coefficients

	(1)	(2)	(3)	(4)	(5)	(6)
Trade Size		1.81***	1.80***		1.83***	1.83***
		(130.82)	(115.03)		(120.69)	(111.43)
Distinct Options	1.69***	0.49***	0.52***	0.86***	−3.48***	−2.60***
	(27.78)	(6.52)	(6.08)	(3.25)	(−7.45)	(−4.91)
Maximum Leg Ratio	3.06***	2.14***	1.49***	3.32***	2.27***	2.15***
	(102.40)	(60.32)	(43.97)	(24.43)	(10.62)	(9.38)
Days-to-Expiration			−0.08***			−0.09***
			(−5.28)			(−7.21)
|Vega|			0.33***			0.24***
			(30.71)			(19.79)
Gamma			0.03***			−0.00
			(10.01)			(−0.68)
IV			−1.25***			−0.65***
			(−6.34)			(−3.99)
|Delta|			−0.49*			0.13
			(−1.68)			(0.31)
SPXW			−1.64***			−0.71***
			(−25.52)			(−11.91)
Intercept	−6.70***	−12.36***	−10.85***	1.07	−3.16***	−4.23***
	(−108.63)	(−115.09)	(−68.14)	(1.22)	(−3.12)	(−3.92)
Strategy FE	No	No	No	Yes	Yes	Yes
Pseudo R-squared	0.34	0.71	0.75	0.56	0.79	0.80
Observations	1,698,094	1,698,094	1,678,134	1,698,060	1,698,060	1,678,104

continued on next page

Table IA.XXIII continued

Panel B: Average Marginal Effects						
	(1)	(2)	(3)	(4)	(5)	(6)
Trade Size		0.0110***	0.0094***		0.0075***	0.0073***
		(79.46)	(54.30)		(58.98)	(51.26)
Distinct Options	0.0196***	0.0030***	0.0027***	0.0058***	−0.0143***	−0.0104***
	(24.29)	(6.66)	(6.39)	(3.31)	(−7.26)	(−4.84)
Maximum Leg Ratio	0.0354***	0.0130***	0.0078***	0.0222***	0.0093***	0.0086***
	(60.93)	(61.83)	(36.01)	(25.57)	(10.78)	(9.43)
Days-to-Expiration			−0.0004***			−0.0004***
			(−5.11)			(−7.12)
|Vega|			0.0017***			0.0010***
			(29.57)			(18.63)
Gamma			0.0001***			−0.0000
			(10.68)			(−0.68)
IV			−0.0065***			−0.0026***
			(−6.50)			(−4.04)
|Delta|			−0.0026*			0.0005
			(−1.69)			(0.31)
SPXW			−0.0118***			−0.0033***
			(−17.83)			(−10.38)
Strategy FE	No	No	No	Yes	Yes	Yes
Observations	1,698,094	1,698,094	1,678,134	1,698,060	1,698,060	1,678,104

Table IA.XXIV. Summary Statistics of All, Matched, and Unmatched Trades: Matching on Distinct Options and Maximum Leg Ratio

This table compares the means of floor and electronic complex SPX trades in the opening window, across all trades and among matched trades, when matched trades are selected on the number of distinct options and the maximum leg ratio instead of the number of legs. The opening window contains floor trades executed in the two weeks after the opening (June 15–26, 2020) and electronic trades executed in the last two weeks of the closure (June 1–12, 2020). For each floor trade, the matched electronic trade is the nearest electronic trade on seven characteristics: absolute delta (|Delta|), absolute vega (|Vega|), implied volatility, trade size in contracts, days to expiration, the number of distinct options (option series) in the package, and the maximum leg ratio, the number of contracts in the largest leg per contract in the smallest leg, each within 0.25 standard deviations. Each electronic trade is the match of at most one floor trade. Electronic executions are grouped into orders before matched trades are selected. Panel A reports the characteristics that define matched trades. Panel B reports execution quality measures that do not define matched trades: the effective spread, hedge cost, market maker (MM) revenue, price impact, and realized spread, all measured in cents per unit of underlying. When a market maker initiates the trade, the effective spread and market maker revenue are measured from the side of its counterparty, the end user. Price impact is the change in the synthetic midpoint from the time the price is fixed to 5 seconds or 1 minute later, signed by the side of the end user, and the realized spread is the effective spread minus the price impact over the same horizon. Price impact and realized spread use the trades with a quote at that horizon. Within each panel, All Trades reports means and differences across all trades, Matched Trades among matched trades, and Matched AIM among matched trades when the control pool is restricted to AIM (Automated Improvement Mechanism) trades. Diff. is the floor mean minus the electronic or AIM mean. The 1,071 pairs of matched trades (2,142 trades) and the 878 pairs of matched AIM trades (1,756 trades) are drawn from the 3,284 floor trades of the All Trades columns. Unmatched reports means for the 2,213 floor trades without an electronic match, which we call unmatched; the floor trades without an AIM match are not reported.

Panel A: Options Trade Characteristics

	All Trades			Matched Trades			Matched AIM			Unmatched
	Floor	Elec.	Diff.	Floor	Elec.	Diff.	Floor	AIM	Diff.	Floor
|Delta|	0.02	0.03	−0.01	0.03	0.03	0.00	0.02	0.02	0.00	0.02
|Vega|	1.20	0.20	1.00	0.33	0.33	0.00	0.49	0.49	0.00	1.62
Implied Vol.	0.35	0.37	−0.02	0.39	0.39	0.00	0.38	0.38	0.00	0.34
Trade Size	783.62	36.17	747.44	331.56	329.45	2.11	278.75	249.79	28.96	1,002.39
Days-to-Exp.	84.18	21.77	62.41	21.40	21.55	−0.15	28.88	28.96	−0.08	114.57
Distinct Options	3.08	2.32	0.76	2.42	2.42	0.00	2.55	2.55	0.00	3.41
Maximum Leg Ratio	6.16	1.19	4.97	1.33	1.33	0.00	1.64	1.63	0.00	8.49

Panel B: Execution Quality

	All Trades			Matched Trades			Matched AIM			Unmatched
	Floor	Elec.	Diff.	Floor	Elec.	Diff.	Floor	AIM	Diff.	Floor
Effective Spread	5.10	1.97	3.13	4.51	3.04	1.48	4.50	1.88	2.62	5.38
Hedge Cost	0.24	0.36	−0.13	0.30	0.30	0.00	0.23	0.23	0.01	0.21
MM Revenue	4.86	1.60	3.26	4.21	2.74	1.48	4.27	1.65	2.61	5.17
Price Impact (5 s)	0.01	−0.01	0.01	−0.08	0.63	−0.71	−0.29	−0.19	−0.10	0.05
Price Impact (1 min)	0.28	0.02	0.27	0.24	1.23	−0.99	−0.28	−0.03	−0.26	0.30
Realized Spread (5 s)	5.10	1.98	3.13	4.60	2.43	2.16	4.79	2.08	2.72	5.35
Realized Spread (1 min)	4.83	1.95	2.87	4.26	1.82	2.44	4.78	1.93	2.84	5.10
Observations	3,284	201,689		1,071	1,071		878	878		2,213

Table IA.XXV. Execution Quality and Floor Opening: Matching on Distinct Options and Maximum Leg Ratio

This table reports OLS regressions of effective spread and market maker revenue for matched complex SPX trades in the opening window, following Equation (3):

$$Y_i = \alpha + \beta\, Floor_i + \gamma' X_i + \mu_s + \varepsilon_i$$

where Y_i is in cents, $Floor_i$ equals one for trades executed after the opening and zero otherwise, and μ_s denotes strategy fixed effects. Matched trades are selected on the number of distinct options and the maximum leg ratio instead of the number of legs, as in Table IA.XXIV. The effective spread and market maker revenue regressions against all electronic trades use the 1,071 pairs of matched trades (2,142 trades) of the opening window: floor trades executed in the two weeks after the opening (June 15–26, 2020) and their matched electronic trades from the last two weeks of the closure (June 1–12, 2020). Each matched electronic trade is the nearest electronic trade on |delta|, |vega|, implied volatility, trade size, days to expiration, number of distinct options (option series) in the package, and maximum leg ratio, the number of contracts in the largest leg per contract in the smallest leg, each within 0.25 standard deviations, and is the match of at most one floor trade. Electronic executions are grouped into orders before matched trades are selected. The AIM Only regressions restrict the pool of electronic trades to those executed in AIM (Automated Improvement Mechanism) auctions, with the same matching, report effective spread only, and use 878 pairs of matched trades (1,756 trades). X_i includes the VIX in all specifications. For each dependent variable, one specification adds the average daily effective spread for SPY complex options, and the other also adds the trade-level controls (quoted spread, absolute delta, days to expiration, absolute vega, gamma, implied volatility, trade size, number of distinct options, maximum leg ratio, and a PM-settled indicator) with strategy fixed effects. Trade size, days to expiration, the number of distinct options, and the maximum leg ratio are in logs. When a market maker initiates the trade, both measures are taken from the side of its counterparty. Absolute delta is omitted from the market maker revenue regressions. t-statistics in parentheses are computed from standard errors clustered by date, and significance stars use standard normal critical values. Intercept and some controls are omitted. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}\ p < 0.01$.

	Effective Spread		Market Maker Revenue		Effective Spread, AIM Only	
	(1)	(2)	(3)	(4)	(5)	(6)
Floor	1.17***	1.27***	1.20***	1.29***	2.58***	2.60***
	(2.99)	(3.74)	(3.20)	(3.77)	(6.40)	(6.49)
VIX	0.16***	0.12**	0.15***	0.14**	0.05**	0.01
	(3.79)	(2.31)	(3.61)	(2.55)	(2.03)	(0.45)
SPY Complex ES	0.87***	0.79***	0.88***	0.84***	0.69**	0.55*
	(2.94)	(2.59)	(3.18)	(2.92)	(2.57)	(1.67)
|Delta|		51.08***				36.93**
		(4.01)				(2.38)
Distinct Options		0.48		1.34		2.14
		(0.08)		(0.22)		(0.32)
Maximum Leg Ratio		−0.20		−0.30		1.11
		(−0.18)		(−0.27)		(1.02)
Other Controls	No	Yes	No	Yes	No	Yes
Strategy FE	No	Yes	No	Yes	No	Yes
R-squared	0.02	0.12	0.02	0.10	0.02	0.05
Observations	2,142	2,142	2,142	2,142	1,756	1,756

IA.VIII: Orders Eligible for Electronic Execution under Both Rule Sets

The opening on June 15, 2020 restored the floor and, on the same day, reinstated the 3:1 limit on the leg ratio of complex orders eligible for electronic execution (Section I.B of the paper). We re-estimate the main regressions on the trades eligible for electronic execution under both rule sets: a maximum leg ratio, the number of contracts in the largest leg per contract in the smallest, of 3:1 or less, and 12 or fewer distinct options. These trades include 2,142 of the 3,392 floor trades of the opening window. Cboe's rules also provide for compression forums, in which members cross offsetting SPX positions on set days (Cboe Global Markets, 2019, Rule 5.88). No 2020 trade in the Cboe trade file carries the compression trade type. Table IA.XXVI repeats the regressions of Table V on the eligible trades. Each specification is estimated without controls and with the full set of controls and strategy fixed effects: the Floor indicator alone, its interaction with trade size, its interaction with the number of legs, and both interactions. The specifications with controls use the 201,997 eligible trades with complete controls. Standard errors are clustered by date, and significance levels use conventional p-values.

TABLE IA.XXVI HERE

Eligible floor trades cost 2.90 cents more than eligible electronic orders without controls and 1.65 cents more with the full set of controls and strategy fixed effects, each significant at the 1% level. Across all trades, the two estimates are 3.01 and 1.27 cents (Table V). The difference declines with trade size. The interaction of Floor with log trade size is −2.14 cents without controls and −1.34 cents with the full set of controls, each significant at the 1% level. On its own and with the full set of controls, the interaction of Floor with the log number of legs is −2.83 cents, significant at the 1% level. Next to the size interaction, it is −1.89 cents, significant at the 10% level, and the size interaction is −1.18 cents, significant at the 1% level. With the full set of controls and strategy fixed effects, the coefficient on the number of legs is −2.57 to −2.01 cents, significant at the 5% level in each specification.

Within the size quintiles of Table IA.III, with the quintile cutoffs of all floor trades, the eligible floor trades number 531, 445, 394, 395, and 377. With the full set of controls and strategy fixed effects, eligible floor trades pay 4.02 cents more than eligible electronic orders at or below the 20th percentile and 2.01 cents more between the 20th and 40th percentiles, significant at the 1% and 5% levels. Between the 40th and 60th percentiles the difference is 1.19 cents, and between the 60th and 80th percentiles −0.03 cents, neither statistically significant. Above the 80th percentile, eligible floor trades pay 2.88 cents less, significant at the 1% level (Table IA.IV).

Table IA.XXVII selects matched trades again among the eligible trades, with the matching of Table VII, and repeats its regressions of effective spread and market maker revenue. The matching gives 1,015 pairs of matched trades out of the 2,056 eligible

floor trades with complete characteristics, and 673 pairs against AIM orders. For each dependent variable, one specification controls for the VIX and the daily SPY complex spread, and the other adds the trade-level controls and strategy fixed effects. Standard errors are clustered by date, and significance levels use conventional p-values.

TABLE IA.XXVII HERE

Matched eligible floor trades pay 0.99 cents more than their electronic matches with the VIX and the SPY complex spread as controls and 1.10 cents more with the full set of controls, each significant at the 1% level. Their market maker revenue is 1.03 and 1.12 cents higher, each significant at the 1% level. Against matched AIM trades, the Floor coefficient for effective spreads is 2.42 cents in both specifications, significant at the 1% level. On all matched trades, the corresponding estimates with the full set of controls are 1.14, 1.15, and 2.45 cents (Table VII).

Table IA.XXVI. Floor and Electronic Execution Costs, Trade Size, and Number of Legs: Trades Eligible under Both Rule Sets

This table repeats the OLS regressions of effective spread of Table V on the complex SPX trades eligible for electronic execution both during the closure and after the opening: trades with a maximum leg ratio, the number of contracts in the largest leg per contract in the smallest, of 3:1 or less and with 12 or fewer distinct options. The sample is the opening window: floor trades executed in the two weeks after the opening (June 15–26, 2020) and electronic trades executed in the last two weeks of the closure (June 1–12, 2020). The eligible sample contains 2,142 floor trades. Electronic executions are grouped into orders. The estimated specification follows Equation (2):

$$Y_i = \alpha + \beta\, Floor_i + \gamma_1\, Floor_i \times Trade\ Size_i + \gamma_2\, Floor_i \times Legs_i + \delta' X_i + \mu_s + \varepsilon_i$$

where Y_i is the effective spread in cents per unit of underlying, measured from the side of the end user (the counterparty when a market maker initiates the trade). $Floor_i$ equals one for floor trades executed after the opening and zero for electronic trades executed during the closure. $Trade\ Size_i$ is measured in contracts and $Legs_i$ is the ratio-weighted number of legs, the sum of the leg ratios. Trade size, the number of legs, and days to expiration are in logs. Each specification is reported without and with controls: the Floor indicator alone, the interaction with trade size, the interaction with the number of legs, and both interactions. Trade size and the number of legs are included in every specification except the one with the Floor indicator alone and no controls. The controls X_i are the VIX, the average daily effective spread for SPY complex options, trade size, the number of legs, quoted spread, absolute delta, days to expiration, absolute vega, gamma, implied volatility, and a PM-settled indicator. Strategy fixed effects μ_s are included in every specification with controls. Specifications with controls use the trades with complete controls. t-statistics in parentheses are computed from standard errors clustered by date. Significance stars use these t-statistics with standard normal critical values. The intercept and the other controls are omitted for brevity. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$.

	Effective Spread							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Floor	2.90***	1.65***	14.59***	9.36***	5.64***	4.44***	15.45***	10.31***
	(8.24)	(3.52)	(6.74)	(3.85)	(5.87)	(3.86)	(7.25)	(4.15)
Number of Legs		−2.57**	0.31	−2.33**	0.36	−2.05**	0.35	−2.01**
		(−2.55)	(1.30)	(−2.35)	(1.52)	(−2.00)	(1.45)	(−1.97)
Trade Size		0.14***	0.21***	0.14***	0.19***	0.13***	0.21***	0.14***
		(5.47)	(6.74)	(6.04)	(5.87)	(5.23)	(6.70)	(5.94)
Floor × Trade Size			−2.14***	−1.34***			−1.96***	−1.18***
			(−5.96)	(−3.28)			(−5.30)	(−2.90)
Floor × Number of Legs					−3.34***	−2.83***	−1.81**	−1.89*
					(−3.81)	(−2.69)	(−1.98)	(−1.84)
SPY Complex ES		0.85***		0.85***		0.85***		0.85***
		(3.90)		(3.91)		(3.92)		(3.92)
VIX		0.02		0.02		0.02		0.02
		(1.35)		(1.33)		(1.33)		(1.32)
Other Controls	No	Yes	No	Yes	No	Yes	No	Yes
Strategy FE	No	Yes	No	Yes	No	Yes	No	Yes
R-squared	0.00	0.03	0.00	0.03	0.00	0.03	0.00	0.03
Observations	206,081	201,997	206,081	201,997	206,081	201,997	206,081	201,997

Table IA.XXVII. Execution Quality and Floor Opening: Trades Eligible under Both Rule Sets
This table repeats the OLS regressions of effective spread and market maker revenue of Table VII for matched SPX complex trades eligible for electronic execution both during the closure and after the opening: trades with a maximum leg ratio, the number of contracts in the largest leg per contract in the smallest, of 3:1 or less and with 12 or fewer distinct options. The specification follows Equation (3):

$$Y_i = \alpha + \beta\, Floor_i + \gamma' X_i + \mu_s + \varepsilon_i$$

where Y_i is in cents, $Floor_i$ equals one for trades executed after the opening and zero otherwise, and μ_s denotes strategy fixed effects. The sample is the opening window: eligible floor trades executed in the two weeks after the opening (June 15–26, 2020) and their matched eligible electronic trades from the last two weeks of the closure (June 1–12, 2020). Matched trades are selected again within the eligible sample. Each matched electronic trade is the nearest electronic trade on |delta|, |vega|, implied volatility, trade size, days to expiration, and ratio-weighted number of legs, each within 0.25 standard deviations, and is the match of at most one floor trade. Electronic executions are grouped into orders before matched trades are selected. The effective spread and market maker revenue regressions use 1,015 pairs of matched trades. The AIM-only regressions restrict the pool of electronic trades to those executed in AIM (Automated Improvement Mechanism) auctions, with the same matching, and use 673 pairs of matched trades. X_i includes the VIX in all specifications. For each dependent variable, one specification adds the average daily effective spread for SPY complex options, and the other also adds the trade-level controls (quoted spread, absolute delta, days to expiration, absolute vega, gamma, implied volatility, trade size, number of legs, and a PM-settled indicator) with strategy fixed effects. Trade size, the number of legs, and days to expiration are in logs. When a market maker initiates the trade, both measures are taken from the side of its counterparty. Absolute delta is omitted from the market maker revenue regressions. t-statistics in parentheses are computed from standard errors clustered by date, and significance stars use standard normal critical values. Intercept and some controls are omitted. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}\ p < 0.01$.

	Matched Eligible SPX Complex Trades					
	Effective Spread		Market Maker Revenue		Effective Spread, AIM Only	
	(1)	(2)	(3)	(4)	(5)	(6)
Floor	0.99***	1.10***	1.03***	1.12***	2.42***	2.42***
	(2.65)	(4.00)	(2.93)	(3.71)	(4.99)	(6.53)
VIX	0.18***	0.16***	0.17***	0.18***	0.07**	0.06*
	(6.73)	(4.54)	(6.48)	(5.12)	(2.10)	(1.95)
SPY Complex ES	1.20***	1.30***	1.22***	1.36***	0.57	0.70**
	(4.21)	(6.39)	(4.60)	(5.86)	(1.41)	(2.24)
|Delta|		58.48***				39.15**
		(4.54)				(2.55)
Other Controls	No	Yes	No	Yes	No	Yes
Strategy FE	No	Yes	No	Yes	No	Yes
R-squared	0.03	0.15	0.03	0.12	0.03	0.09
Observations	2,030	2,030	2,030	2,030	1,346	1,346

IA.IX: Netting of Delta and Vega

Table IA.XXVIII adds two netting measures to the logit of floor routing in Table III of the paper. The delta netting share of a package is one minus the absolute value of its net delta exposure divided by its gross delta exposure. The net exposure sums the delta of each leg times its contracts, signed by the side of the initiator in that leg, and the gross exposure sums the absolute values of the same terms. The vega netting share is defined in the same way from vega. A share of zero means that the legs do not offset, and a share of one that they offset fully. For an electronic order, net and gross exposures are summed over its packages. The sample is the period after the opening (June 15 to October 21, 2020) without the 19,960 trades that have no Greeks, and it contains 1,678,134 observations, of which 27,134 are floor trades. The specifications include the two netting shares alone, add trade size and the number of legs without and with strategy fixed effects, and add the full set of controls of Table III without and with strategy fixed effects. Standard errors are clustered by date.

TABLE IA.XXVIII HERE

Packages that net more of their delta are more likely to execute on the floor, and packages that net more of their vega are less likely to. With the two netting shares alone, the coefficient on the delta netting share is 4.52 and that on the vega netting share −2.16, and the pseudo-R^2 is 0.07. With trade size and the number of legs, the coefficients are 1.84 and −2.56, and the pseudo-R^2 is 0.72. With the full set of controls and strategy fixed effects, they are 1.29 and −0.48, and the pseudo-R^2 is 0.80. Both coefficients are significant at the 1% level in every specification, including those with strategy fixed effects. In the full specification, the average marginal effect of the delta netting share is 0.0052 and that of the vega netting share −0.0019, each significant at the 1% level. Trade size and the number of legs are significant at the 1% level in every specification that includes them.

Table IA.XXIX relates the floor-electronic difference in the effective spread over the quoted spread to the two netting shares, across all trades in the opening window. The dependent variable is the effective spread of the end user divided by the quoted spread of the package. The base specification includes the Floor indicator, the two netting shares, and their interactions with Floor. Another specification adds the VIX, the average daily effective spread for SPY complex options, absolute delta, days to expiration, absolute vega, gamma, implied volatility, a PM-settled indicator, and strategy fixed effects. Both specifications are also estimated with trade size, the number of legs, and their interactions with Floor. The sample contains the 204,969 trades with a netting share, without the 108 floor trades and 4,040 electronic orders that have no Greeks. Standard errors are clustered by date.

TABLE IA.XXIX HERE

Without controls, the interaction of Floor with the delta netting share is −0.33 and the interaction with the vega netting share 0.14, each significant at the 1% level. With the controls and strategy fixed effects, they are −0.25 and 0.09, each significant at the 1% level. With trade size, the number of legs, and their Floor interactions, the delta interaction is −0.26, significant at the 1% level, and with the full set of controls and strategy fixed effects it is −0.17, significant at the 5% level. In this specification, the effective spread over the quoted spread of floor trades falls by 0.17 relative to that of electronic orders as the delta netting share rises from zero to one. The vega interaction is 0.16 and 0.10 in the same two specifications, each significant at the 1% level. With the full set of controls and strategy fixed effects, the interaction of Floor with log trade size is −0.04, significant at the 1% level, and the interaction with log number of legs is −0.01, significant at the 10% level. The coefficient on the delta netting share itself is between −0.19 and −0.29 and significant at the 1% level in every specification.

Table IA.XXX compares floor and electronic trades within quintiles of the netting share. It repeats the specification of Table IA.III with the full set of controls and strategy fixed effects, with the interactions of Floor with the quintiles of the floor distribution of the delta or vega netting share over June 15–26, 2020, and the netting-quintile indicators, in place of the trade-size quintile interactions and indicators. The upper bounds of the four lowest quintiles are 0.8461, 0.9444, 0.9774, and 0.9926 for the delta netting share and 0.4576, 0.7469, 0.8926, and 0.9649 for the vega netting share. Each row is a separate regression, against all electronic orders (204,969 observations) or against AIM orders only (36,911 observations). Standard errors are clustered by date.

TABLE IA.XXX HERE

Against all electronic orders, floor trades pay 2.80 cents more at or below the 20th percentile of the delta netting share and 2.05 cents more between the 20th and 40th percentiles, each significant at the 1% level. Above the 40th percentile, the differences of 0.45, 0.23, and 0.11 cents are not statistically significant. Against AIM orders, floor trades pay 3.54 and 2.58 cents more in the two lowest quintiles, each significant at the 1% level, and 0.90, 0.88, and 0.91 cents more in the three highest, none statistically significant. By the vega netting share and against all electronic orders, the differences of 0.57 and −0.45 cents in the two lowest quintiles are not statistically significant, floor trades pay 2.66 and 2.64 cents more between the 40th and 80th percentiles, each significant at the 1% level, and the difference of 0.71 cents above the 80th percentile is not statistically significant. Against AIM orders, floor trades pay 2.29 cents more at or below the 20th percentile, significant at the 5% level, 2.85 and 2.43 cents more between the 40th and 80th percentiles, each significant at the 1% level, and 1.29 cents more above the 80th percentile, significant at the 5% level. Between the 20th and 40th percentiles, the difference of 0.12 cents is not statistically significant.

Without controls, the floor-electronic differences in mean 1-minute price impact and realized spread show which component carries the cost difference in each netting quintile (not tabulated). The comparison uses the 3,273 floor trades and 197,928 electronic orders with a quote 1 minute after the trade, and significance comes from regressions of each measure on a floor indicator within the quintile, with standard errors clustered by date. By delta netting quintile, the difference is in the realized spread. Pooled, the price impact difference is 0.27 cents and not statistically significant, and the realized spread difference is 2.87 cents, significant at the 1% level. Within quintiles, the price impact differences range from −0.68 to 1.10 cents, and none is statistically significant. The realized spread differences are 3.05, 3.88, 3.62, and 3.12 cents in the four lowest quintiles, each significant at the 1% level, and 1.73 cents above the 80th percentile, significant at the 5% level. By vega netting quintile, no price impact difference is statistically significant either. The realized spread differences are 5.61 cents at or below the 20th percentile, 2.83 and 2.89 cents between the 40th and 80th percentiles, and 1.67 cents above the 80th percentile, each significant at the 5% level or better, and 0.54 cents between the 20th and 40th percentiles, which is not statistically significant.

Table IA.XXVIII. Netting Shares and Floor Trading After the Opening

This table reports logistic regressions where the dependent variable equals one if a complex SPX trade executes on the trading floor and zero if it executes electronically, after the opening (June 15 to October 21, 2020). Electronic executions are grouped into orders, and the 19,960 trades without Greeks are excluded. The estimated specification is

$$\Pr(\text{Floor}_i = 1) = \Lambda(\alpha + \theta_1 \, \textit{Delta Netting}_i + \theta_2 \, \textit{Vega Netting}_i + \beta' X_i + \mu_s)$$

The delta netting share of a package is one minus the absolute value of its net delta divided by its gross delta. The net delta sums over the legs the delta times the number of contracts, signed by the side of the initiator in each leg, and the gross delta sums the absolute values of the same terms. The vega netting share is defined in the same way from vega. For an electronic order, net and gross exposures are summed over its packages. The specifications include the two netting shares alone, add trade size and the ratio-weighted number of legs without and with strategy fixed effects μ_s, and add the controls of Table III (trade size, number of legs, days to expiration, absolute vega, gamma, implied volatility, absolute delta, and an SPXW indicator for PM-settled contracts) without and with strategy fixed effects. Trade size, the number of legs, and days to expiration are in logs, and gamma is multiplied by 1,000. $\Lambda(\cdot)$ is the logistic function. Panel A reports logit coefficients and Panel B average marginal effects, with z-statistics in parentheses computed from standard errors clustered by date. Significance stars use standard normal critical values. The intercept is not reported in the specifications with strategy fixed effects. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}\ p < 0.01$.

Panel A: Estimated Coefficients

	(1)	(2)	(3)	(4)	(5)
Delta Netting Share	4.52***	1.84***	1.24***	0.65***	1.29***
	(37.48)	(19.72)	(8.39)	(5.29)	(7.92)
Vega Netting Share	−2.16***	−2.56***	−0.76***	−1.06***	−0.48***
	(−48.56)	(−34.80)	(−4.85)	(−13.39)	(−2.93)
Trade Size		1.88***	1.84***	1.81***	1.85***
		(125.64)	(119.94)	(116.03)	(111.96)
Number of Legs		2.00***	3.35***	1.62***	3.38***
		(43.54)	(7.84)	(35.96)	(7.98)
Days-to-Expiration				−0.05***	−0.10***
				(−3.12)	(−7.70)
|Vega|				0.23***	0.24***
				(18.62)	(20.30)
Gamma				0.01***	0.00
				(3.63)	(0.04)
IV				−0.93***	−0.49***
				(−4.96)	(−2.92)
|Delta|				1.08***	1.99***
				(2.65)	(4.19)
SPXW				−1.70***	−0.71***
				(−26.07)	(−11.89)
Intercept	−6.36***	−13.50***		−11.55***	
	(−65.01)	(−112.84)		(−64.32)	
Strategy FE	No	No	Yes	No	Yes
Pseudo R-squared	0.07	0.72	0.79	0.75	0.80
Observations	1,678,134	1,678,134	1,678,104	1,678,134	1,678,104
Floor Trades	27,134	27,134	27,130	27,134	27,130

continued on next page

Table IA.XXVIII continued

Panel B: Average Marginal Effects					
	(1)	(2)	(3)	(4)	(5)
Delta Netting Share	0.0706***	0.0109***	0.0051***	0.0034***	0.0052***
	(31.02)	(19.75)	(8.08)	(5.16)	(7.50)
Vega Netting Share	−0.0337***	−0.0152***	−0.0031***	−0.0056***	−0.0019***
	(−35.45)	(−39.75)	(−4.83)	(−14.31)	(−2.92)
Trade Size		0.0111***	0.0075***	0.0095***	0.0074***
		(78.85)	(57.98)	(53.56)	(51.03)
Number of Legs		0.0118***	0.0137***	0.0085***	0.0135***
		(51.48)	(7.90)	(48.46)	(8.01)
Days-to-Expiration				−0.0003***	−0.0004***
				(−3.04)	(−7.56)
|Vega|				0.0012***	0.0010***
				(17.17)	(18.98)
Gamma				0.0001***	0.0000
				(3.70)	(0.04)
IV				−0.0049***	−0.0020***
				(−5.07)	(−2.95)
|Delta|				0.0057***	0.0079***
				(2.61)	(4.09)
SPXW				−0.0125***	−0.0033***
				(−17.45)	(−10.38)
Strategy FE	No	No	Yes	No	Yes
Observations	1,678,134	1,678,134	1,678,104	1,678,134	1,678,104

Table IA.XXIX. Netting Shares and Effective Spread over Quoted Spread

This table reports OLS regressions of the effective spread over the quoted spread on all complex SPX trades. The sample is the opening window: floor trades executed in the two weeks after the opening (June 15–26, 2020) and electronic trades executed in the last two weeks of the closure (June 1–12, 2020). Electronic executions are grouped into orders. Trades without Greeks have no netting share and are excluded (108 floor trades and 4,040 electronic orders). The estimated specification is

$$Y_i = \alpha + \beta\, Floor_i + \theta' Netting_i + \lambda' Floor_i \times Netting_i + \delta' X_i + \mu_s + \varepsilon_i$$

where Y_i is the effective spread divided by the quoted spread of the package. The effective spread is measured from the side of the end user (the counterparty when a market maker initiates the trade). $Floor_i$ equals one for floor trades executed after the opening and zero for electronic trades executed during the closure. $Netting_i$ contains the delta and vega netting shares defined in Table IA.XXVIII. The base specification includes Floor, the two netting shares, and their interactions with Floor, and another specification adds the controls and strategy fixed effects μ_s. Both are also estimated with trade size, the number of legs, and their interactions with Floor, where the number of legs is the ratio-weighted number of legs, the sum of the leg ratios. The controls X_i are the VIX, the average daily effective spread for SPY complex options, absolute delta, days to expiration, absolute vega, gamma, implied volatility, and a PM-settled indicator. The controls do not include the quoted spread. Trade size, the number of legs, and days to expiration are in logs. t-statistics in parentheses are computed from standard errors clustered by date. Significance stars use these t-statistics with standard normal critical values. The intercept and the other controls are omitted for brevity. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}\ p < 0.01$.

	Effective Spread over Quoted Spread			
	(1)	(2)	(3)	(4)
Floor	0.23***	0.23***	0.38***	0.39***
	(3.50)	(4.41)	(4.88)	(6.12)
Delta Netting Share	−0.20***	−0.29***	−0.19***	−0.29***
	(−15.08)	(−16.23)	(−15.58)	(−16.11)
Vega Netting Share	−0.10***	−0.02	−0.09***	−0.02
	(−7.16)	(−1.28)	(−6.71)	(−1.20)
Trade Size			0.01***	0.01***
			(25.94)	(10.84)
Number of Legs			−0.02***	0.02**
			(−2.68)	(2.22)
Floor × Delta Netting Share	−0.33***	−0.25***	−0.26***	−0.17**
	(−4.05)	(−3.85)	(−2.89)	(−2.44)
Floor × Vega Netting Share	0.14***	0.09***	0.16***	0.10***
	(4.74)	(2.88)	(4.99)	(2.85)
Floor × Trade Size			−0.04***	−0.04***
			(−6.60)	(−6.11)
Floor × Number of Legs			−0.00	−0.01*
			(−0.36)	(−1.69)
SPY Complex ES		−0.03***		−0.03***
		(−4.98)		(−5.04)
VIX		−0.00***		−0.00***
		(−7.39)		(−7.47)
Other Controls	No	Yes	No	Yes
Strategy FE	No	Yes	No	Yes
R-squared	0.06	0.12	0.06	0.12
Observations	204,969	204,969	204,969	204,969

Table IA.XXX. Floor and Electronic Execution Costs by Netting-Share Quintile

This table reports OLS regressions of effective spread on all complex SPX trades in the opening window by quintile of the delta or vega netting share. Each row is a separate regression with the full set of controls and strategy fixed effects, as in Table IA.III, with the interactions of Floor with the netting-share quintile indicators and the netting-share quintile indicators in place of the trade-size quintile interactions and indicators. Floor equals one for floor trades executed after the opening (June 15–26, 2020) and zero for electronic orders executed during the closure (June 1–12, 2020). Electronic executions are grouped into orders. The delta and vega netting shares are defined in Table IA.XXVIII. The quintiles are those of the floor distribution of each netting share over June 15–26, 2020, and each quintile includes its upper bound. The upper bounds of the four lowest quintiles are 0.8461, 0.9444, 0.9774, and 0.9926 for the delta netting share, and 0.4576, 0.7469, 0.8926, and 0.9649 for the vega netting share. The dependent variable is the effective spread of the end user (the counterparty when a market maker initiates the trade), in cents per unit of the underlying. All electronic orders compares floor trades with every electronic order, and AIM only restricts the electronic sample to AIM orders. Trades without Greeks have no netting share and are excluded (108 floor trades, and 4,040 electronic orders or 500 AIM orders). The controls are the VIX, the average daily effective spread for SPY complex options, quoted spread, absolute delta, days to expiration, absolute vega, gamma, implied volatility, trade size, number of legs, and a PM-settled indicator. Trade size, the number of legs, and days to expiration are in logs. t-statistics in parentheses are computed from standard errors clustered by date. Significance stars use these t-statistics with standard normal critical values. The intercept, netting-quintile indicators, and controls are not reported. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}\ p < 0.01$.

	Floor × Netting-Share Quintile					
	≤ P20	P20–P40	P40–P60	P60–P80	> P80	Observations
Delta netting share						
All electronic orders	2.80***	2.05***	0.45	0.23	0.11	204,969
	(4.58)	(2.75)	(0.52)	(0.21)	(0.14)	
AIM only	3.54***	2.58***	0.90	0.88	0.91	36,911
	(6.47)	(4.02)	(1.04)	(0.87)	(1.26)	
Vega netting share						
All electronic orders	0.57	−0.45	2.66***	2.64***	0.71	204,969
	(0.47)	(−0.43)	(4.67)	(4.42)	(1.09)	
AIM only	2.29**	0.12	2.85***	2.43***	1.29**	36,911
	(2.29)	(0.11)	(5.37)	(3.81)	(2.02)	
Other Controls	Yes	Yes	Yes	Yes	Yes	
Strategy FE	Yes	Yes	Yes	Yes	Yes	

IA.X: Splitting of Orders during the Closure

Table IA.XXXI tests whether electronic orders are more likely to be followed by an identical order during the closure than after the opening, as they would be if traders split packages into several electronic orders. The sample contains the electronic orders of the last two weeks of the closure (June 1–12, 2020) and of the first two weeks after the opening (June 15–26, 2020). Electronic executions are grouped into orders. The dependent variable of the logit equals one if a later order on the same trading day, at most 60 seconds later, has the same options, the same leg ratios, the same end-user side on every leg, and the same end-user capacity. The Closure indicator equals one for orders executed during the closure. End users are customers, firms, and market makers, and orders whose end user is a broker-dealer or a professional customer are dropped. The logit is estimated on all electronic orders, which pool CLOB, COA, and AIM orders, on CLOB orders, and on COA orders. One specification includes the Closure indicator and recent activity, the log of one plus the number of orders of the same strategy in the previous 60 seconds. The other adds the number of legs, days to expiration, absolute vega, gamma, implied volatility, absolute delta, the SPXW indicator, and the VIX. Trade size is not a control, because splitting a large trade makes its orders smaller. Every specification includes strategy fixed effects, and standard errors are clustered by date (20 trading days).

TABLE IA.XXXI HERE

Across all electronic orders, the Closure coefficient is −0.03 with recent activity as the only control and −0.05 with the full set of controls, and the average marginal effects are −0.0051 and −0.0075. On the CLOB, the coefficients are 0.01 and −0.01, and the average marginal effects 0.0017 and −0.0016. None of these is statistically significant. For COA orders, the Closure coefficient is 0.35 with recent activity as the only control and 0.32 with the full set of controls, and the average marginal effects are 0.0424 and 0.0385, each significant at the 1% level. In the samples of the specifications with recent activity as the only control, 18.11% of COA orders are followed by an identical order during the closure and 14.75% after the opening, against 22.78% and 22.49% of all electronic orders. The coefficient on recent activity is positive and significant at the 1% level in every specification.

Daily counts of similar later orders give no statistically significant difference between the closure and after the opening for all electronic orders, the CLOB, or the COA (not tabulated). For each electronic order, these tests count the later orders within 60 seconds on the same trading day with the same strategy, with at least one, two, or three identical options, or with all options identical, with and without requiring the same direction of net delta, and compare the daily means of the two periods with Welch t-statistics. Across all electronic orders, an order is followed within 60 seconds by 0.75 orders with all options

identical during the closure and 0.78 after the opening, a difference of −0.03 (t-statistic of −0.34). On the CLOB, the corresponding numbers are 0.56 and 0.61, a difference of −0.05 (t-statistic of −0.40).

Table IA.XXXI. Identical Electronic Orders within 60 Seconds: Closure and After the Opening
This table reports logistic regressions where the dependent variable equals one if an electronic complex SPX order is followed, at most 60 seconds later on the same trading day, by an order of the same sample with the same options, the same leg ratios, the same end-user side on every leg, and the same end-user capacity, and zero otherwise. Electronic executions are grouped into orders. The sample contains the electronic orders of June 1 to 26, 2020: those of the last two weeks of the closure (June 1–12, 2020) and those of the first two weeks after the opening (June 15–26, 2020). The logit is estimated separately on all electronic orders, which pool CLOB, COA, and AIM orders, on CLOB orders, and on COA orders. End users are customers, firms, and market makers. Orders whose end user is a broker-dealer or a professional customer, FLEX and non-standard orders, orders with more than one initiator capacity, and market-maker-initiated orders with more than one capacity on the other side are excluded. The estimated specification is

$$\Pr(\text{Identical}_i = 1) = \Lambda(\alpha + \beta\,\text{Closure}_i + \gamma N_i + \delta' X_i + \mu_s)$$

where Closure_i equals one for orders executed during the closure (June 1–12, 2020) and zero for orders executed after the opening (June 15–26, 2020), and N_i is the log of one plus the number of orders of the same strategy in the previous 60 seconds, in the same sample. For each sample, one specification omits X_i, and the other includes it. X_i includes the number of legs, days to expiration, absolute vega, gamma, implied volatility, absolute delta, an SPXW indicator for PM-settled contracts, and the VIX. The number of legs and days to expiration are in logs, and gamma is multiplied by 1,000. μ_s denotes strategy fixed effects, and $\Lambda(\cdot)$ is the logistic function. Panel A reports logit coefficients and Panel B average marginal effects. z-statistics in parentheses are computed from standard errors clustered by date (20 trading days). Significance stars use standard normal critical values. The bottom of Panel B reports the percentage of orders followed by an identical order during the closure and after the opening. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Panel A: Estimated Coefficients

	All Electronic		CLOB		COA	
	(1)	(2)	(3)	(4)	(5)	(6)
Closure	−0.03	−0.05	0.01	−0.01	0.35***	0.32***
	(−0.54)	(−1.42)	(0.21)	(−0.32)	(5.05)	(4.55)
Same-Strategy Orders	0.68***	0.66***	0.52***	0.51***	1.07***	1.06***
Previous 60 Seconds	(26.24)	(31.25)	(16.57)	(20.58)	(27.97)	(24.59)
Number of Legs		0.24***		0.24*		0.03
		(2.95)		(1.87)		(0.11)
Days-to-Expiration		−0.21***		−0.18***		−0.15***
		(−9.78)		(−6.65)		(−7.77)
|Vega|		0.19***		0.17***		0.21***
		(7.28)		(5.96)		(4.32)
Gamma		0.00		0.00		0.00
		(0.55)		(1.57)		(0.56)
IV		−0.40***		−0.03		−0.94***
		(−2.70)		(−0.16)		(−4.74)
|Delta|		−2.18***		−2.07***		0.13
		(−4.42)		(−3.52)		(0.18)
SPXW		−0.53***		−0.65***		−0.33***
		(−5.29)		(−5.56)		(−3.16)
VIX		−0.01***		−0.01***		0.00
		(−2.82)		(−2.78)		(0.29)
Intercept	−1.23***	−1.06***	−0.82***	−0.76***	−3.10***	−2.39***
	(−233.98)	(−6.79)	(−104.95)	(−3.48)	(−5.76)	(−2.65)
Strategy FE	Yes	Yes	Yes	Yes	Yes	Yes
Pseudo R-squared	0.06	0.08	0.05	0.07	0.11	0.12
Observations	367,676	362,149	224,540	221,369	109,347	107,474

continued on next page

Table IA.XXXI continued

Panel B: Average Marginal Effects						
	All Electronic		CLOB		COA	
	(1)	(2)	(3)	(4)	(5)	(6)
Closure	−0.0051	−0.0075	0.0017	−0.0016	0.0424***	0.0385***
	(−0.54)	(−1.41)	(0.21)	(−0.31)	(5.12)	(4.69)
Same-Strategy Orders	0.1109***	0.1062***	0.0790***	0.0755***	0.1283***	0.1262***
Previous 60 Seconds	(32.10)	(28.20)	(19.82)	(19.78)	(22.96)	(20.54)
Number of Legs		0.0380***		0.0359*		0.0041
		(2.96)		(1.87)		(0.11)
Days-to-Expiration		−0.0343***		−0.0273***		−0.0177***
		(−10.22)		(−6.76)		(−8.56)
|Vega|		0.0298***		0.0253***		0.0254***
		(7.44)		(6.11)		(4.39)
Gamma		0.0003		0.0007		0.0002
		(0.55)		(1.57)		(0.55)
IV		−0.0640***		−0.0040		−0.1123***
		(−2.72)		(−0.16)		(−4.70)
|Delta|		−0.3492***		−0.3085***		0.0150
		(−4.44)		(−3.57)		(0.18)
SPXW		−0.0927***		−0.1108***		−0.0426***
		(−4.98)		(−5.01)		(−3.02)
VIX		−0.0019***		−0.0018***		0.0003
		(−2.80)		(−2.75)		(0.29)
Strategy FE	Yes	Yes	Yes	Yes	Yes	Yes
Followed by an Identical Order,						
Closure (%)	22.78	22.76	20.18	20.20	18.11	17.95
After the Opening (%)	22.49	22.56	19.94	19.99	14.75	14.82
Observations	367,676	362,149	224,540	221,369	109,347	107,474

IA.XI: 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 (Cboe Global Markets, 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.[5] The provisions we cite on floor participants and their obligations, open outcry priority and allocation, crossing, PAR routing and trade reporting read the same in the current rule book (Cboe Global Markets, 2026). The ratio limit for electronic complex orders and the maximum number of legs per order ticket have changed since 2020. We describe both as they stood in 2020.

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.[6]

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.[7] Within RTH, open outcry

[5] 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.

[6] 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 rule book in force in 2020, as in the current one, open outcry trading is governed primarily by Chapter 5, Section G (Cboe Global Markets, 2019, 2026), and routing/eligibility for floor handling is governed by the PAR rules and complex-order rules (discussed below).

[7] 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.

trading in a given series begins only after the series has opened for electronic trading.[8]

The trading floor as a price-discovery mechanism for selected products. In modern U.S. listed options, most volume is electronic, but Cboe continues to operate a floor that is 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.[9]

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.[10]
- **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.[11]
- **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.[12]
- **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

[8] 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.

[9] 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.

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

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

[12] 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.

obligations, are not affiliated with market-making firms, and are compensated exclusively by the Exchange.[13]

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.[14]

D. Order Capacity, Agency and Proprietary Orders, and Trade Initiators

Every order on C1 carries a capacity code for the account behind it. This subsection sets out who may trade on the floor and in which role, separates agency from proprietary orders, and explains what the initiator labels in the paper reveal. Rule numbers refer to the rule book in force in 2020 (Cboe Global Markets, 2019). Table IA.XXXII summarizes.

Capacity codes and account definitions. Trading on the Exchange requires a Trading Permit, and its holder is a Trading Permit Holder (TPH) (Rule 3.1(a)). Rule 1.1 defines the eight capacity codes listed in Table IA.XXXII. A Public Customer is any person that is not a broker-dealer, and every TPH counts as a broker-dealer. A Professional is a person that is not a broker-dealer and places more than 390 listed options orders per day, on average over a calendar month, for its own beneficial accounts. A Priority Customer is a Public Customer that is not a Professional, and Priority Customer orders resting in the Book have first priority at a price (Rule 5.85(a)(2)(A)).

Capacity in the data and the labels in the paper. The Cboe trade-by-trade file reports five buckets: Customer (C), ProCustomer (U), BrokerDealer (B), Firm (F, J, and L), and MarketMaker (M and N). The eight codes cannot be recovered from it. "Customer" in the paper means capacity C, the Priority Customers. The label is legal and can include institutions, such as asset managers or pension funds, that are not broker-dealers and stay below the Professional threshold. "Firm" in the paper means the Firm bucket: proprietary accounts of clearing members, joint back office accounts, and accounts of affiliates that are not TPHs. A TPH that does not know the capacity of an order may report B and correct it later (Rule 6.1(h)).

[13] See Rule 5.90.

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

Who trades on the floor and in which role. Only TPHs approved for a floor function trade on the floor (Section IA.XI.C). The in-crowd market participants are in-crowd market makers, on-floor DPMs or LMMs, and Floor Brokers or PAR Officials representing orders in the crowd (Rule 1.1).

- **Floor Brokers act as agents.** A Floor Broker accepts orders from TPHs and registered broker-dealers, and from public customers only as the nominee of a TPH organization approved to do business with the public (Rules 3.35 and 3.50(a)). It can represent an order of any capacity, including a market maker's own order, whose owner it must name on request (Rule 5.91(b)).
- **PAR Officials act as agents.** They are Exchange employees or contractors who execute the orders placed with them (Rule 5.90).
- **In-crowd market makers trade as principals.** They must be physically present in the crowd (Rule 5.50(e)) and must give a two-sided quote when a Floor Broker or PAR Official asks for one (Rule 5.52(e)). An on-floor DPM or LMM quoting the best price can also receive the participation entitlement of Section IA.XI.G (Rule 5.85(a)(2)(B)).

No TPH may initiate a trade on the floor for an account in which it has an interest unless it is a registered market maker, error positions excepted (Rule 8.22). Market makers are therefore the only principals in the crowd. Any other order, including a firm's proprietary order, reaches the crowd only through a Floor Broker or a PAR Official. Priority Customer and broker-dealer orders resting in the Book can also trade with a represented order (Rule 5.85(a)(2)).

Agency and proprietary orders. Agency and proprietary describe the account behind an order, not the person who represents it. An order is proprietary when it is for a TPH's own account, the account of an associated person, or an account over which either exercises investment discretion (Rule 5.87(b)(3)). The rule book calls a TPH that represents customer orders as agent, or that trades for its own account without being a market maker, an Order Entry Firm (Rule 3.51). One firm can act in both ways on the same trade: a clearing firm can bring a customer order (C) and take the other side for its own account (F). Rule 5.9(a) allows it to trade as principal against an order it represents as agent only after the order, or its own quote, has been exposed on the System for one second, or by crossing the two orders under Rule 5.87 on the floor or in an AIM auction. Proprietary orders on the floor also need an exemption from Section 11(a)(1) of the Exchange Act. Under the "G" exemption, they yield priority to Priority Customer and broker-dealer orders resting in the Book at the same price (Rules 5.85(a)(2)(E) and 5.87(b)).

Original orders and contra orders in floor crosses. The crossing mechanisms of Section IA.XI.H assign each order a role. In a facilitation cross, a Floor Broker holds a Public Customer order of a TPH organization and a facilitation order of the originating firm. The Floor Broker requests a market, bids or offers on the customer's behalf at a better price, and crosses the remainder with the facilitation order only after the other in-crowd participants have had the chance to trade (Rule 5.87(d)). The customer order, of capacity C or U, is the original order, and the firm's order is the contra. In a solicited transaction, the TPH representing an original order, which the rule book calls the TPH "initiating" it (Rule 5.86(d)), solicits a TPH, a public customer, a broker-dealer, or a market maker to trade against it, and the solicited order is the contra (Rule 5.86 and Interpretation .01).

The crossing entitlement applies to original orders of at least the eligible size, which the Exchange sets at no less than 50 contracts. The Floor Broker may cross part of such an order with another order it holds, with the originating firm's facilitation order, or, where the Exchange allows, with a solicited order (Rule 5.87(f)). A DPM or LMM that is also the originating firm receives no participation entitlement on that cross (Rule 5.87(f)(3)). When a Floor Broker crosses two orders it holds under Rule 5.87(c), the rule treats them alike and names no original order. In classes the Exchange designates, a TPH holding an option order of at least the designated size, never below 500 contracts, may also hedge it in stock or futures before announcing it, if it then offers the whole hedge to the in-crowd participants who trade the order (Rule 5.87, Interpretation .07).

Initiators in the paper. On the floor, the paper's initiator is the order represented in the crowd, and the in-crowd market makers who respond to it are its counterparties. Section IA.V describes the three signing steps: the trade types, then the side that is not a market maker, then the direction of other fills on the same leg. The fills that remain unsigned are crosses of two represented orders, mostly between two market makers and in some cases between two firms, and the paper excludes the orders that contain them. A market maker initiates when its record is that of an order represented in the crowd, such as an order that a Floor Broker holds for it (Rule 5.91(b)). This is the case in 1.2% of floor packages. Execution costs are end-user measures, taken from the initiator, or from its counterparty when a market maker initiates (Section I.D).

An initiator capacity gives the account type of the original order. A customer-initiated order is an agency order for a Priority Customer. A firm-initiated order is an order for a clearing member's proprietary account, a joint back office account, or an affiliate's account, which a Floor Broker or PAR Official represents as agent. The capacity names neither the customer nor the firm. A firm counterparty in a customer-initiated order can be the originating firm's facilitation order, a solicited order of another firm, or a firm order that another Floor Broker represents in the crowd. A market maker counterparty can be an in-crowd responder or a market maker solicited as a contra. The closure filing describes

large customer orders on the floor as filled primarily by appointed market makers solicited as contras (Section III.B). The file has no participant identifiers, so these cases cannot be told apart.

Electronic counterparts. Market makers have no quoting obligation for complex strategies (Rule 5.33, Interpretation .01). The Exchange can also bar market makers' complex orders from the COB, the paper's CLOB, and admit them only in narrow cases, such as opposite resting Priority Customer complex orders (Rule 5.33(b)(2)). Market makers initiate 94.5% of CLOB packages by taking resting orders, and the end user is the resting side. In AIM, the Initiating TPH pairs an order it represents as agent, the Agency Order, with an Initiating Order that is its own principal interest or a solicited order (Rules 5.37 and 5.38). After Priority Customer orders, the Initiating Order receives up to 50% of the Agency Order when one other participant responds at the final price and 40% when two or more respond (Rule 5.38(e)). In single-leg AIM, the Initiating Order may not be for a market maker appointed in the class, and complex AIM has no such restriction. The rule book's Initiating Order is thus the contra, and the paper's initiator is the Agency Order, a customer order in 89.4% of AIM packages. AIM is the electronic route for facilitation and solicitation, with a timed auction in place of the request for a market (Rule 5.9(a)). In the COA, the incoming complex order starts the auction and is exposed to responses (Rule 5.33(d)). Customer orders initiate 89.1% of COA packages.

Table IA.XXXII. Order Capacity and Roles on the Cboe Floor
This table lists the capacity codes of Rule 1.1 of the Cboe rule book in force in 2020 (Cboe Global Markets, 2019), the account each code designates, the bucket that the Cboe trade-by-trade file reports for the code, with the label used in the paper in parentheses, and how an order of that capacity can trade in open outcry. The file reports the five buckets, not the eight codes.

Code	Account	Data bucket (paper label)	How it trades on the floor
C	Public Customer; Professionals are coded U, so C is a Priority Customer	Customer (customer)	Agency order represented by a Floor Broker. Original order in a facilitation cross (Rule 5.87(d)). First priority when resting in the Book (Rule 5.85(a)(2)(A)).
U	Professional: not a broker-dealer, more than 390 orders per day on average	ProCustomer (professional customer)	Agency order represented by a Floor Broker. A Public Customer for facilitation crosses, handled like a broker-dealer order in the Book (Rule 1.1).
B	Broker or dealer, including a foreign broker-dealer	BrokerDealer (broker-dealer)	Order represented by a Floor Broker. Can be an original or a solicited order. Fourth priority when resting in the Book (Rule 5.85(a)(2)(D)). Default code when the capacity is unknown (Rule 6.1(h)).

continued on next page

Table IA.XXXII continued

Code	Account	Data bucket (paper label)	How it trades on the floor
F	Proprietary account of a clearing member of the Options Clearing Corporation	Firm (firm)	Proprietary order represented by a Floor Broker. Cannot trade in person (Rule 8.22). Original order when the firm initiates, or the facilitation or solicited contra to a customer order. Needs an exemption from Section 11(a)(1) (Rule 5.87(b)).
J	Joint back office account; participants are registered broker-dealers (Rule 11.4)	Firm (firm)	Order represented by a Floor Broker. Cannot trade in person (Rule 8.22). Can be an original or a solicited order.
L	Account of an affiliate that is not a TPH	Firm (firm)	Order represented by a Floor Broker. Can be an original or a solicited order.
M	Account of a Cboe market maker	MarketMaker (market maker)	Trades in person in the crowd and must quote on request (Rules 5.50(e) and 5.52(e)). DPM or LMM entitlement if appointed. Can be solicited as a contra (Rule 5.86). Its own order can be represented by a Floor Broker (Rule 5.91(b)).
N	Account of a market maker on another options exchange	MarketMaker (market maker)	Order represented by a Floor Broker. Not an in-crowd participant.

E. 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.[15]

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.[16] Orders may route to PAR in two

[15] 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.

[16] See Rule 5.82.

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.[17]

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); (iv) route to another PAR workstation; or (v) cancel the order.[18] PAR is 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.[19]

F. 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 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.[20]

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, 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

[17] See Rule 5.82(b).

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

[19] 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.

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

trading.[21] C1 may make additional complex-order instructions available for PAR routing, including (among others) Complex Only, Multi-Class Spread, and SPX Combo.[22]

Additional technical/operational constraints that create floor concentration. Beyond the 3:1 ratio boundary, Cboe technical specifications for the U.S. options complex book process document several restrictions that are directly relevant for substitution and "strategy splitting":

- **Maximum number of legs.** The Exchange sets the maximum number of legs of an electronic complex order class by class (Rule 1.1). On the floor, a complex order of 12 legs or fewer must be entered on a single order ticket. If the Exchange permits, an order of more than 12 legs may be split across several tickets that the Trading Permit Holder representing it identifies as one complex order.[23]
- **Legging restrictions.** Even for electronically eligible ratios, the system may permit a complex order to "leg" into the simple book 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.[24]
- **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.[25]
- **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.[26]

These eligibility constraints generate a natural substitution margin between floor and electronic 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

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

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

[23] Rule 5.7(f)(4).

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

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

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

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.

G. 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).[27]

Execution price priority. For an order represented in open outcry, bids/offers at the best price have priority.[28]

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).[29] 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 in-crowd quote,

[27] See Cboe Regulatory Circulars on open outcry trading requirements and prohibited practices. Similar requirements appear in older Cboe circulars from the 1990s.

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

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

40% if two, and 30% if three or more), and it is capped by the size of the DPM/LMM quote.[30]

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.[31] Contracts that one market maker declines go to the others (Rule 5.85(a)(2)(C)(iv)).

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.[32]

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).[33]
- **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.[34]

[30] 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.

[31] Rule 5.85(a)(2)(C).

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

[33] Rule 5.91.

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

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.[35]

H. 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 originating firm's proprietary interest (i.e., the broker/firm "facilitates" the customer order). A solicited transaction is an agency order crossed with pre-arranged contra interest ("solicited" liquidity). On the floor, these transactions are permitted only if executed under open outcry exposure and allocation rules.[36]

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 the crowd's market and the protection of priority interest (including Priority Customer orders in the Book).[37]

Crossing entitlement. If the relevant conditions are met, the broker (facilitator/solicitor) may receive 20% or 40% of the contracts remaining after Public Customer orders in the Book and then in the crowd are satisfied. 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).[38]

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 packages.

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

[36] See Rule 5.86 for the detailed mechanics and conditions.

[37] 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.

[38] Rule 5.87(f)(2) sets out the 20% or 40% crossing entitlement, and Rule 5.87(b)(2) caps the combined DPM/LMM participation and crossing entitlements at 40%.

I. 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 in Cboe's rules, the CLOB in this paper) 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.[39]

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 competing responses; and (iii) other auction/crossing mechanisms (e.g., complex variants of the Automated Improvement Mechanism (AIM) and the Solicitation Auction Mechanism (SAM), where available).[40]

Key eligibility constraints that differentiate electronic vs floor execution. The ratio boundary, the leg-count and legging restrictions, and the special price types and trade-condition codes described in Section IA.XI.F define the boundary between electronic and floor execution for complex strategies.

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.[41]

[39] 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.

[40] 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.

[41] 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.

J. 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.[42]

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).[43]

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.[44] This is the institutional channel through which the 2020 floor closure changes the feasible set of complex strategy executions.

Temporary activation of AIM for SPX. During the floor closure, Cboe also activated AIM for SPX/SPXW complex orders during RTH, a function AIM had not previously performed for that class, and deactivated it when floor trading resumed on June 15, 2020 (Section I.B). The CLOB and COA remained available after the opening, with the 3:1 ratio limit on electronic complex orders reinstated.[45]

K. Why Does the Floor Still Exist?

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:

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

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

[44] 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.

[45] See Cboe Global Markets (2020d) and Cboe Global Markets (2020c). The March 12, 2020 notice states that the AIM activation applied only during all-electronic trading and would be reverted when open outcry trading resumed.

1. **Feasible-set differences (what the floor can do that the electronic workflow restricts).** The eligibility constraints of Section IA.XI.F make some strategies effectively floor-only, and replicating their exposure electronically requires splitting them into several orders.

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.[46]

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 executing large packages and for market makers supplying liquidity in stressed conditions.[47]

Implication for empirical interpretation. These institutional features imply that the floor is a complementary execution channel that (i) expands the feasible set of package executions, (ii) changes the exposure/information environment of execution, and (iii) can concentrate liquidity for large multi-leg index packages. The closure of the floor on March 16, 2020, its opening on June 15, 2020, and the temporary changes to electronic complex-order eligibility and AIM between those dates provide variation for studying execution outcomes across mechanisms.

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

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