Nocturnal Trading*

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Abstract. Although still relatively new, nocturnal trading in U.S. equities, defined as trading between 8:00 p.m. and 4:00 a.m., has grown rapidly. It is largely retail-driven, concentrated in a small set of securities, and marked by substantial order imbalances. Using unique transaction-level data, we show that nocturnal execution costs exceed regular-hours benchmarks but are broadly consistent with elevated adverse selection faced by liquidity suppliers. Nocturnal returns generally do not reverse during the subsequent regular-hours session, except in a small subset of high-sentiment stocks. Overall, the nocturnal session appears to be an important source of price discovery and may create profit opportunities for retail liquidity demanders despite higher transaction costs.

Key words: Nocturnal Trading, Retail Investors, Execution Quality, Price Discovery

JEL: G20; G24; G28

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1 Introduction

Nocturnal trading of U.S. equities, defined as trading between 8:00 p.m. and 4:00 a.m. the following day, is a relatively recent phenomenon that is rapidly gaining momentum.[1] Such trading was virtually non-existent as recently as late 2022, before experiencing rapid growth throughout 2023 and 2024 (Figure 1). Trading volume during nocturnal hours is predominantly retail, and nocturnal activity often accounts for more than 10% of total daily retail volume for securities that actively trade overnight.

[Figure 1]

Whether nocturnal trading represents a valuable addition to the range of options available to retail investors is an open question. The absence of institutional competition during these hours may create an environment in which retail investors have greater opportunity to trade on price-relevant information such as global and firm-specific extended hours news.[2] However, the nocturnal market may also be susceptible to frictions commonly associated with retail trading, including attention-driven behavior and herding (Barber, Huang, Odean, and Schwarz, 2022, Eaton, Green, Roseman, and Wu, 2022). During regular trading hours, such retail behaviors are likely tempered by the presence of sophisticated institutional traders who contribute to price discovery and help maintain price efficiency. It is unknown whether similar mechanisms operate effectively during nocturnal hours.[3]

The relevance of these questions extends well beyond U.S. borders. Access to the 8 p.m.-4 a.m. session is expanding rapidly among retail-facing intermediaries globally. In Canada, for

[1] "Overnight Trading Gains Traction with the NYSE on Board," by I. Schmerken, Flextrade, November 21, 2024 (`https://bit.ly/4joe9UI`).

[2] "Momentum Is Building Toward Round-the-Clock Equity Trading," by J. Hintze, TabbFORUM, July 10, 2025 (`https://bit.ly/4rzJveT`).

[3] An additional concern is impaired decision-making due to reduced mental alertness documented by Han, Hirshleifer, Sheng, and Sun (2025). This is unlikely to be a first-order issue for our results, however, because a large share of nocturnal market participants in our sample are retail investors from the Asia-Pacific region, who trade during their daytime hours.

example, Wealthsimple began offering continuous 24/5 trading in select U.S.-listed stocks and ETFs in 2025, while Interactive Brokers Canada, Questrade, and Webull Canada now also offer overnight access to U.S. equities, routing order flow into the venues we study. Because Canadian and other non-U.S. investors hold large and rapidly growing positions in U.S. equities and ETFs – precisely the instruments that dominate nocturnal volume – our evidence on execution quality and price discovery speaks directly to a broad, international population of retail traders, as well as to the dealers and regulators that serve them.

Furthermore, it remains unclear whether the nocturnal market is capable of providing retail participants with liquidity that is competitively priced. A handful of proprietary trading firms (wholesalers), including Jane Street and Virtu, make markets during the nocturnal session over our sample period. The number of active wholesalers is larger during regular trading hours (Ernst, Malenko, Spatt, and Sun, 2025, Dyhrberg, Shkilko, and Werner, 2025), and whether their limited participation during the nocturnal session is sufficient to sustain a competitive liquidity environment is unclear. It is worth noting that during regular trading hours, wholesalers predominantly intermediate retail market and marketable limit orders off-exchange, while primarily routing non-marketable limit orders to exchanges (Battalio and Jennings, 2025, Anand, Samadi, Sokobin, and Venkataraman, 2025). During the nocturnal session, both marketable and non-marketable retail orders tend to be sent directly to the nocturnal venues.

Until very recently, nocturnal trading was confined to two Alternative Trading Systems (ATSs): Blue Ocean (BOATS) and Interactive Brokers' IBKR EOS (IBEOS). However, several additional venues are entering, or plan to enter, the overnight trading space, including major exchanges such as Nasdaq and the NYSE, along with other ATSs. During our sample period from January 2024 to January 2025, virtually all nocturnal trading volume occurs on BOATS. Trading activity is also highly concentrated cross-sectionally: roughly 50% of dollar volume is generated by just 10 stocks, and approximately 90% by the top 100. Virtually all BOATS volume originates from retail traders, with about 80% coming from the Asia-Pacific region in our sample period.

To study the nocturnal market and compare it with other parts of the 24-hour trading cycle, we construct a sample of frequently traded stocks that have activity in all three sessions: nocturnal, extended, and regular hours, on every day of the sample period, which spans January 2024 until January 2025.[4] Given the concentrated nature of overnight trading in a small set of actively traded names, this sample captures the vast majority of nocturnal volume. We find that quoted and effective spreads during the nocturnal session are comparable to those observed during extended hours. Compared to regular trading hours, nocturnal spreads are roughly twice as wide.

Realized spreads, which reflect trading costs net of adverse selection, offer a more nuanced view. While realized spreads during the nocturnal session are positive and exceed those observed during regular hours at very short horizons, they fall below regular-hours levels at longer horizons and even become slightly negative at the five-minute horizon. This suggests that, unless a nocturnal liquidity provider is able to exit their position relatively quickly, which is a challenge given the relatively low frequency of nocturnal order flow and the directional imbalances it often exhibits, they may not be adequately compensated for the risks and costs of liquidity provision. Given that wholesalers supply liquidity during the nocturnal session, it may appear puzzling that they would do so at a potential loss. The key to interpreting the realized spread result is that a substantial fraction of nocturnal liquidity is supplied by retail investors themselves; BOATS representatives estimate this share to be approximately 50% during our sample period. In such an environment, wholesalers can earn positive realized spreads while retail traders earn negative spreads, producing the negative average we observe at the five-minute horizon.

Why are nocturnal realized spreads lower than during other periods of the day? Trade price impacts during the nocturnal window are much larger than during regular trading hours. This flow is also persistent, generating order imbalances more than three times those observed during the day. In contrast, nocturnal quotes are considerably less informative. To assess their informational

[4]Extended hours include pre-open and post-close periods; respectively, 4:00 a.m. to 9:30 a.m. and 4:00 p.m. to 8:00 p.m. Regular hours include the main trading session from 9:30 a.m. to 4:00 p.m..

content, we follow Muravyev and Pearson (2020) and Hagströmer (2021) and compare depth-imbalance-weighted midquotes to unweighted midquotes. The results show that nocturnal limit orders are relatively uninformed, as weighted midquotes point in the direction opposite of actual future price movements.

This finding is noteworthy for two reasons. First, even if wholesalers tend to submit informed quotes during the nocturnal session, as one might expect from sophisticated liquidity providers with access to market indicators from around the globe, their information appears to be overwhelmed by the predominance of uninformed retail limit orders. Second, the structure of the nocturnal market is difficult to reconcile with modern models of dynamic limit order books (Goettler, Parlour, and Rajan, 2009, Roşu, 2020, Bhattacharya and Saar, 2021, Riccò, Rindi, and Seppi, 2024), which assume that informed traders submit both marketable and non-marketable orders and often prefer the latter. Instead, nocturnal trading more closely resembles the environment assumed in earlier models, where informed traders primarily rely on market orders (Glosten, 1994, Rock, 1996, Seppi, 1997).

Two events help shed additional light on the structure of the nocturnal market. The first is the restructuring of the trader clientele, driven partly by the exit of Korean retail traders following the August 2024 BOATS crash and partly by BOATS' continued addition of new clients. The second is the entry of a new market maker in November 2024. Taken together, these episodes provide useful evidence on the respective roles of retail and professional liquidity suppliers.

In the period following the BOATS crash, trader composition changes noticeably and is associated with larger average trade size and greater order flow toxicity, consistent with the new mix of retail traders being more sophisticated on average. Although quoted spreads widen after the crash, the increase is not large enough to offset the rise in adverse selection, and realized spreads decline. This pattern suggests that a portion of nocturnal liquidity is supplied by relatively unsophisticated traders who do not respond efficiently when the trading environment changes.

The November event points in a different but complementary direction. The entry of a new

market maker is associated with greater quoting and trading activity, while average trade size and order flow toxicity remain largely unchanged. At the same time, quoted, effective, and realized spreads all decline, indicating that additional professional liquidity provision improves market quality. Thus, even in a market where retail traders play an important role in supplying liquidity, market quality still benefits from stronger competition among professional liquidity providers, suggesting that retail liquidity provision alone is not sufficient to discipline professional providers.

Finally, we document substantial price movements during the overnight session. When nocturnal liquidity demanders are net buyers, overnight prices increase, and they decline when nocturnal traders are net sellers but in this case the magnitude of the effect is dampened because of short-sale constraints. Nocturnal order imbalances generally predict the sign of returns during the remaining 24-hour period, but prices overreact significantly when nocturnal liquidity demanders are net buyers. To understand this pattern, we study nocturnal price movements for stocks compared to ETFs, and for stocks favored by retail investors compared to other stocks. Nocturnal order imbalances predict future ETF returns correctly, and ETF return overreactions are limited. The overreactions following nights with positive order imbalances are driven by stock trading, particularly in stocks favored by retail investors, often referred to as retail darlings. Once these stocks are removed, nocturnal price movements do not reverse after nocturnal net buying. We conclude that for ETFs and stocks that are not retail darlings, nocturnal traders contribute significantly to the 24-hour price discovery both when they are net buyers and net sellers. Our evidence suggests that while they overreact for some stocks, nocturnal investors are often better off trading overnight as opposed to waiting until subsequent sessions.

This study is related to the literature on quote and trade activity and price discovery during the pre-open and after-hours periods. Blonien and Ober (2024) provide analytical evidence that traders in active markets benefit from trading hours moving to near 24/7. Biais, Hillion, and Spatt (1999) examine price discovery during the pre-open on the Paris Bourse, whereas Cao, Ghy-

sels, and Hatheway (2000) investigate price discovery via quotes on Nasdaq during its pre-open. Barclay and Hendershott (2008) also analyze price discovery during the Nasdaq pre-open and find that increased pre-open trading volume enhances the efficiency of opening prices. Moreover, they document a shift in price discovery from the opening trade to the pre-open period, though this effect is concentrated among the highest-volume stocks. By the end of their sample period, pre-open trading reached 4% of share volume, exceeding after-hours trading volume.

McInish, Van Ness, and Van Ness (2002) document after-hours trading activity on regional exchanges for NYSE stocks. They find very little price discovery during after-hours trading, and that almost all of the trades take place at either the NYSE closing ask, bid, or the last trade price. Barclay and Hendershott (2003) study pre-open and after-hours trading activity and price discovery, while Barclay and Hendershott (2004) examine extended-hours trading costs and liquidity externalities, for Nasdaq stocks. The former study finds that about 10% of daily price discovery occurs between 8:00 a.m. and 9:30 a.m., while price discovery for the remaining extended hours periods is insignificant. These studies also find that trading outside of regular trading hours is sparse, focused on the most liquid stocks, and concentrated during select days. They document high volatility outside of regular trading hours, which they attribute to significant informed trading causing adverse selection for market makers. Perhaps as a result, they find trading costs that are three to four times as large as those during the regular trading hours.

We contribute to the literature on pre-open and after-hours trading by studying trading costs and price discovery during the nocturnal period, 8 p.m. to 4 a.m. To our knowledge, the first academic paper to document U.S. nocturnal trading is Barclay and Hendershott (2003), who report that in 2000, about one-third of trading days featured nocturnal trading for the top 250 Nasdaq stocks. Such trading often took place through late-night batch trading systems available to select institutions, with Instinet's midnight cross being the most prominent. We document that nocturnal trading activity for U.S. securities today is concentrated for select securities favored by retail investors, and that price discovery for these securities disproportionately occurs between

8 p.m. and 4 a.m. We also document wider effective and quoted spreads in the nocturnal period relative to regular hours, but unlike the evidence from pre-open and after-hours trading, we find that realized spreads, which are trading costs net of adverse selection, are about the same or even lower during the 8 p.m. to 4 a.m. window.

Our paper is also related to the recent literature on the divergence between overnight and intraday market returns, first reported by French and Roll (1986). This literature does not study overnight trading activity per se, but some of the proposed explanations for why overnight returns are positive, while day-time returns are zero or even negative, are related to our work. Several authors find that overnight returns are generally information-driven and specifically related to earnings announcements (Barardehi, Bernhardt, Ruchti, and Weidenmier, 2021, Wong and Yang, 2023). There is also evidence that overnight returns have higher beta risk than returns during the day (Hendershott, Livdan, and Rosch, 2020). Others discuss a "tug-of-war" between different investor clienteles (Akbas, Boehmer, Jiang, and Koch, 2022, Lou, Polk, and Skouras, 2019, Lu, Malliaris, and Qin, 2023) or frictions affecting liquidity providers, such as margin requirements and shorting constraints (Bogousslavsky, 2021).

More recently, Bondarenko and Muravyev (2023) and Boyarchenko, Larsen, and Whelan (2023) study the e-mini S&P 500 futures contract which trades 24 hours to show that the positive overnight return comes from the European open, when European traders process overnight information, as opposed to from the preceding Asian trading. We contribute to this literature by studying how nocturnal trading and information releases affects prices for stocks and ETFs trading 24 hours. While we also find large positive nocturnal returns on average for stocks and ETFs that trade 24 hours, we find no discernible effect on returns of the European open for stocks favored by nocturnal traders.

2 Background

This section provides an overview of the nocturnal trading market. The Internet Appendix provides a more detailed discussion of the institutional details.

Nocturnal trading in U.S. equities dates back at least to 2018 when broker-dealer PRO Securites (tZERO Group) started accepting and executing orders overnight. They started an alternative trading system that operated as a continuous nocturnal order book (MMID: PROS) in 2019, and subsequently formed the Blue Ocean ATS. BOATS went live for trading U.S. NMS securities in June of 2021 (MMID: BLUE). Since its inception, BOATS has been the primary platform executing trades from 8 p.m. to 4 a.m. in the U.S. (see Figure 1). Conversations with Blue Ocean suggest that during our sample period, 80% of their volume is from retail brokers in the Asia-Pacific region, with most of the rest coming from U.S. retail brokers. Blue Ocean also states that institutional investors do not currently have a very large presence on their platform. BOATS operates as a limit order market, accepting both marketable and non-marketable limit orders. All order sizes are fully displayed, and the platform does not permit hidden or reserve orders during our sample period.

Although BOATS handles most of the nocturnal volume, it is not the only ATS executing trades from 8 p.m. to 4 a.m. Interactive Brokers, via their platform IBKR EOS ATS (IBEOS), announced that they were offering nocturnal trading in November 2022. In addition to their own volume, Interactive Brokers has affiliates all over the world, including the Asia-Pacific region, that were given access to IBEOS during the nocturnal period. In July of 2023, Interactive Brokers announced that they were increasing the number of symbols available for nocturnal trading to 10,000, and that they had entered into a partnership with BOATS to access supplemental liquidity. In addition to BOATS and IBEOS, other platforms, such as MOON ATS (MOON) and Bruce ATS (BOSS), have very recently launched overnight trading platforms. All of these alternative platforms execute a relatively small share of nocturnal volume. The four platforms are not di-

rectly connected, and there is no consolidated data feed that captures their activity for centralized reporting. Data feeds are instead available at the individual platform level, either directly from the platforms or through data vendors.

After a gradual ramp-up, many major U.S. retail brokers such as E*Trade, Interactive Brokers, Robinhood, and Schwab now offer nocturnal trading for a broad cross-section of securities. Many foreign brokers also allow their clients to trade U.S. NMS securities between 8 p.m. and 4 a.m. U.S. Eastern time, which overlaps with the Asia-Pacific business day. These brokers either have partnerships with the ATSs, such as BOATS or IBEOS, or access the platforms through a U.S. registered sponsoring broker.

BOATS and IBEOS both invite professional liquidity providers, such as Virtu Financial and Jane Street, to their platforms. In addition, OTC market makers act as executing brokers for some zero commission U.S. retail brokers. Therefore, these brokers do not route to the ATSs directly, instead relying on wholesalers to either execute the nocturnal orders on a principal basis or route them to the ATS. While the HFT liquidity providers are present, conversations with market observers suggest that retail investors also contribute to liquidity provision in the nocturnal market.

3 Data

We obtain data from a variety of sources. To capture the nocturnal session, we obtain comprehensive BOATS trade and quote data directly from Blue Ocean ATS as well as from the Intercontinental Exchange (ICE). To measure trading and quoting activity during extended and regular hours, we use Daily TAQ (DTAQ). Additionally, we access FINRA ATS Transparency Data to collect measures of trading activity, such as volume and number of symbols traded, at the ATS level. These data include not only BOATS, but also the other nocturnal trading platforms, including IBEOS and the now defunct PROS. We obtain Rule 605 data to measure market quality

during regular hours at retail trading venues. Finally, we use CRSP/Compustat data to obtain security characteristics.

Our analysis covers January 1, 2024 through January 27, 2025, except for August 2024, which we omit because BOATS experienced an extended service disruption during that month (see the Internet Appendix for more details). To analyze BOATS and TAQ trade and quote data, we apply many of the filters recommended by Holden and Jacobsen (2014). However, because our focus is on a trading period that can be relatively illiquid, we relax certain filters typically used for regular trading hours. For TAQ data, we retain quotes that have conditions A, B, H, O, R, W, or C; are not canceled; and do not have a missing SIP message ID. We delete locked and crossed quotes but do not impose an upper bound on quoted spreads. We delete trade sale conditions that include L, P, U, Z, B, W, C, Y, N, R, 1, A, G, and 4; and trade corrections not equal to 00 or 01.

To ensure sufficient data for assessing market quality, we require that a security has at least ten trades in a nocturnal session to appear in our sample that night. We also require that the average nocturnal trade price exceeds $1. The resulting sample includes 3,897 securities that trade on BOATS and also trade in the U.S. pre-open, regular trading, and after-hours sessions on at least one day during the sample period. We further partition this sample into the 200 securities that trade the most actively during the nocturnal session (the frequently traded sample) and a non-overlapping remainder (the less frequently traded sample). The 200 securities in the frequently traded sample, which comprise over 90% of nocturnal volume in our data, are those that have the most nights of at least ten nocturnal trades during our sample period.

3.1 Nocturnal Trading Patterns

To get a better sense for the type of securities that are traded nocturnally, we first focus on the securities that trade most frequently during the nocturnal session. Table 1 summarizes the top

ten symbols traded both overall and separately for January - June, 2024, and July 2024 - January 2025 (skipping August, 2024). Panel A lists the top ten symbols by share volume and shows that nocturnal traders favor leveraged ETFs of Chinese market indices, including the Direxion Daily FTSE China Bull 3x Shares (YINN) and the Direxion Daily FTSE China Bear 3X Shares (YANG). They also actively trade leveraged ETFs on semi-conductor indices such as the Direxion Daily Semiconductor Bear 3X Shares (SOXS) and the Direxion Daily Semiconductor Bull 3X Shares (SOXL), and on U.S. market indices such as ProShares UltraPro Short QQQ (SQQQ) and ProShares UltraPro QQQ (TQQQ) which are leveraged 3X. Furthermore, nocturnal traders favor leveraged single name ETFs such as Direxion Daily TSLA Bull 2X Shares (TSLL) and single names such as Tesla (TSLA) and Nio Inc (NIO). There is some variation between the sub-periods, the most notable one being that Gamestop (GME) is in the top ten for the early part of the sample.

[Table 1]

Panel B repeats the analysis based on dollar volume and includes more single name securities such as Nvidia (NVDA), Tesla (TSLA), Microsoft (MSFT), and Apple (AAPL). Dollar volumes are significant in the top ten symbols: over $17 billion for Nvidia and nearly $16 billion for Tesla over the full sample period. The difference between symbols and the order of ranking across the panels is a reflection of the fact that single name securities such as these trade at higher stock prices than the leveraged ETFs. However, note that there is significant overlap in terms of top-ten presence for leveraged ETFs such as SOXL, TQQQ, and YINN, as well as NVDA as TSLA. By dollar volume, index ETFs such as Invesco QQQ Trust (QQQ) and the SPDR S&P 500 ETF Trust (SPY) are also heavily traded overnight. Other popular retail stocks, such as GameStop (GME), Coinbase (COIN), and Strategy inc. (MSTR) are also heavily traded during the nocturnal session.

We next consider concentration in nocturnal trading symbols, and how it compares to concentration in other periods of the trading day. This analysis sheds light on whether the significant nocturnal trading volume we find in the top ten lists for stocks such as NVDA and TSLA is rep-

resentative of the universe of securities that are traded on Blue Ocean. Figure 4 compares the cumulative percent of dollar volume for the 400 stocks with the highest dollar volume on Blue Ocean to cumulative percent of dollar volume for all stocks trading during the rest of the 24-hour cycle.

[Figure 4]

The figure shows that approximately 50% of nocturnal dollar volume is concentrated in just ten symbols. More than 80% of volume is concentrated in 50 symbols, over 90% in 100 symbols, and nearly all nocturnal volume is accounted for by 300 securities. Pre-open trading is also highly concentrated, though the accumulation of volume is somewhat less steep. Regular-hours trading exhibits substantially less concentration: only about 25–30% of dollar volume is accounted for by the ten most actively traded symbols. The top 400 securities during regular trading hours account for about 75% of total volume, compared with nearly 100% during the nocturnal period. After-hours trading largely mirrors regular hours, though its cumulative volume rises more quickly, indicating greater concentration. In the trade and quote analysis that follows, we focus much of our attention on a frequently traded sample of fewer than 200 securities. These concentration patterns indicate that this sample captures the vast majority of nocturnal trading volume.

Finally, we briefly explore patterns of nocturnal trading activity by day of the week and time of day in Figures 2 and 3, respectively. Monday includes activity from Sunday 8 p.m. through Monday 4 a.m., Tuesday includes activity from Monday 8 p.m. through Tuesday 4 a.m., and so on. Many observers have told us that nocturnal activity peaks on Sunday evening leading into Monday as Asian traders react to news that has arrived over the weekend. Instead, Figure 2 shows that dollar volume is close to evenly distributed throughout the week.

[Figures 2 and 3]

In terms of time of night, Figure 3 shows that the highest share of dollar volume on Blue Ocean, about 12% of the ATS' volume, occurs right after the nocturnal trading session starts at

8 p.m. ET. This peak is at 9 a.m. in Hong Kong, Shanghai, and Singapore, 10 a.m. in Korea and Japan, and 12:00 p.m. in Sydney, Australia. There is also an increase in trading in the penultimate half hour of nocturnal trading, 3:00-3:30 a.m. About 7-8% of nocturnal dollar volume occurs during this window. This increase coincides with European market open at 9 a.m. Central European Time.

4 Market Quality

What is the nature of nocturnal market quality, and how competitive is liquidity provision in this market? This section addresses these questions by first examining nocturnal trading activity and transaction costs in subsection 4.1. We then compare nocturnal trading costs with those observed during other segments of the trading day in subsection 4.2.

4.1 Nocturnal Period

We evaluate nocturnal activity and market quality using trade and quote data for BOATS from January 1, 2024 through January 27, 2025, omitting August 2024 due to a BOATS service disruption. We consider two sub-samples: a frequently traded (FT) sample consisting of the 200 most actively traded nocturnal securities, which make up the vast majority of overnight volume; and a less frequently traded (LFT) sample, which consists of the remaining 3,697 symbols that trade on BOATS at least one night (and each intraday session within that day) during the sample period. The statistics for the LFT sample cover only the nights when there is nocturnal trading for a particular stock.

We report nocturnal quote and trade statistics in Table 2. The statistics are volume-weighted within stock-night, then dollar volume averaged. For the frequently traded (FT) sample, the nocturnal period exhibits substantial trading and quoting activity. There are 26,680 (3,335) quote updates per night (hour) with an average time-weighted quoted depth of 1,449 shares. Average

trade size is 78 shares and there are 9,550 (1,194) trades per night (hour) on average for a quote-to-trade ratio of 2.79. The average nocturnal price is $255, which means that the average trade is for $19,840. Stocks in the LFT sample have a lower price on average ($76), and it is therefore not surprising that the quoted depth at 5,014 shares is greater than for the FT sample. Quoting activity for these stocks is quite high with 19,863 (2,483) quote updates per night (hour) resulting in a quote-to-trade ratio of 3.58. Average trade size is 159 shares, which translates into an average trade size in dollars of $12,070.

[Table 2]

Next, we summarize nocturnal market quality for our two sub-samples in Table 3. Measures are again volume-weighted within stock-night, then dollar volume averaged. For the frequently traded stocks, which we saw in Figure 4 make up the vast majority of BOATS volume, quoted and effective spreads are not too large, at 7.75 and 8.72 basis points, respectively. As expected, the spreads are wider for the LFT sample at 35.05 bps for quoted and 37.86 bps for effective spreads. Furthermore, quoted spreads are narrower than effective spreads for both sub-samples, resulting in an effective-to-quoted spread ratio (E/Q) of 1.13 for the FT sample and 1.08 for the LFT sample. BOATS operates as a pure limit order market in which all order sizes are fully displayed, and hidden or reserve orders are not permitted during our sample period. Consequently, no price improvement mechanisms operate in this market, and the E/Q ratio is greater than 1.0 because orders that exceed displayed depth must walk the book.

[Table 3]

Table 3 also provides an alternative measure of effective spread following Hagströmer (2021). This measure, the "weighted midpoint effective spread," captures the difference between the price of a trade and an adjusted midquote that reflects depth imbalances. For example, if the bid depth Q_B is larger than the ask depth Q_A, the weighted midquote between the bid P_B and the ask P_A

is $(P_B \cdot Q_A + P_A \cdot Q_B)/(Q_B + Q_A)$, which is greater than the midquote $(P_B + P_A)/2$. For both subsamples, the Hagströmer effective spreads are larger than the traditional effective spreads, suggesting that the BOATS limit order book is relatively uninformed about future price movements.

Panel B reports price impacts and realized spreads at different horizons: 5 seconds, 60 seconds, and 5 minutes. For the FT sample, price impact at the 5-second horizon already consumes more than two-thirds of the effective spread. The price impact continues increasing, resulting in a negative realized spread of -2.75 basis points at the 5-minute horizon. The evidence for the LFT sample is similar, as large price impacts consume most of the effective spread at the 5-second horizon, and become ever larger at longer horizons, resulting in a negative realized spread at the 5-minute horizon. Hence, on average, liquidity providers would need to exit their positions in less than 5 minutes to make money in the FT sample. Is this possible given the nocturnal trading activity? If we assume buys and sells are equally likely, and that trades arrive smoothly throughout the night, the number of trades per nocturnal session in Table 2 suggests that liquidity providers as a group can, under ideal circumstances, expect to exit a position in 10 seconds for FT stocks and 20 seconds for stocks in the LFT sample. Granted, trade clustering and herding would imply that it likely takes longer than this to complete a round-trip. Further, there is likely heterogeneity, as professional liquidity providers are likely to move faster than retail traders providing liquidity.

Finally, we compare conventional and Hagströmer measures of price impacts and realized spreads as both heavily rely on the midquote. Specifically, we replace the midquote with the weighted midquote defined above. Hagströmer price impacts are uniformly larger for both subsamples and across all horizons, reinforcing the notion that nocturnal limit order book imbalances contain relatively little information about future price movements.

4.2 Nocturnal Trading, Other Extended Hour Periods, and Regular Hours

A natural question is how does nocturnal trading compare to regular and extended hours? Prior research documents that pre-open and after-hours trading sessions are characterized by a small number of relatively large trades (Jiang, Likitapiwat, and McInish, 2012, Barclay and Hendershott, 2003, 2004). This is still true for the after-hours session based on more recent data. Cui, Gozluklu, and Haykir (2024) find 153 trades on average per stock and day and a dollar average trade size of $177,931 during the after-hours period for S&P 1500 stocks from 2004-2022. They document that trading activity has risen over time, but trading activity after-hours remains modest with roughly 190 trades per stock on a given day even at the end of their sample period. Similarly, Gregoire and Martineau (2022) document a median (75 percentile) number of trades on a given day for S&P 500 stocks during the after-hours period to be 17 (31) based on data from 2011-2015. After-hours trades are large also in their sample, with 19% of trades exceeding $50,000.

Is this pattern of sparse quote and trading activity but very large trades documented in prior work for the pre-open and after-hours periods still evident? And, how does the nocturnal period compare to extended hours? To answer these questions, we use DTAQ to measure trading activity and market quality for the pre-open (4:00 a.m. to 9:30 a.m.), regular trading hours, and after-hours (4:00 p.m. to 8 p.m.) periods and compare these statistics to the evidence from the nocturnal period. We exclude open and closing auctions and market-on-open and market-on-close orders from the analysis on market quality. For this analysis, we focus on the frequently traded sample of 200 stocks to ensure comparability across trading periods, as these securities trade consistently during each nocturnal session.

The results for continuous trading during each sub-period of the 24-hour trading cycle are in Table 4. Pre-open and after-hours each comprise about a 2 to 3% share of daily volume.[5] We also

[5]We fold market-on-close orders into the closing volume figures and exclude VWAP and NAV trades, which impacts extended-hours volume estimates.

find that there has been a substantial increase in quoting and trading activity during both the pre-open and after-hours periods compared to what prior research has documented based on earlier sample periods. On a per hour basis, the average number of quotes and trades in the pre-open period are 12,934 and 9,336 respectively. Similarly, the average number of quotes and trades in the after-hours period are 7,870 and 9,211 on average. Despite its rapid growth, nocturnal quoting and trading activity is still relatively modest. Between 7 and 8 million shares trade per day for sample stocks during the nocturnal period, making up 0.26% of daily share volume. The nocturnal share of daily number of trades is a little higher at 0.57%. Trading and quoting activity during nocturnal and extended hours still however pales in comparison to regular hours trading, with on average 146,309 quotes and 77,647 trades per hour.

[Table 4]

Table 4 also shows that nocturnal traders favor lower price stocks ($255) compared to traders that are active during other periods of the day ($308 to $371 depending on period), and the trade size in terms of shares is 77 compared to 98 and 112 for pre-open and regular hours, respectively. The relatively low nocturnal trade size is unsurprising, given that retail traders dominate the nocturnal market. Echoing findings in the prior literature, we find much larger average trade size in the after-hours period (611). Finally, the quote-to-trade ratio based on the top of the book is high for the nocturnal period at 2.77 if we include odd lot quotes. Though if we make the nocturnal period comparable to the other periods by only using best round lot quotes, the nocturnal Q/T ratio is 1.81, which is slightly lower than regular trading hours at 1.88, but higher than the pre-open (1.39) and after-hours (0.85) periods.

Prior research has furthermore documented poor market quality outside of regular trading hours. For example, Barclay and Hendershott (2004) and Jiang, Likitapiwat, and McInish (2012) find quoted, effective, and realized spreads during pre-open and after-hours trading to be at least five to ten times the size of spreads during regular trading hours. Based on more recent data, Cui,

Gozluklu, and Haykir (2024) document after hours quoted spreads that are more than thirty times and effective spreads that are more than thirteen times those during regular trading hours. While they document 5-minute price impacts are larger during the after-hours period, the difference does not eliminate the difference in effective spreads. As a result, they find that after-hours realized spreads are more than twenty-five times larger than realized spreads during regular trading hours.

We document that extended-hours trading activity has increased substantially, but has that translated into improved market quality during pre-open and after hours? Table 5 summarizes our findings for pre-open and after hours trading alongside the results for other periods of the day. Indeed, Panel A shows that pre-open and after hours quoted and effective spreads are much closer to those prevailing during regular trading hours than what has been documented in prior studies. For example, pre-open and after hours-quoted spreads are 8.27 bps and 7.81 bps, respectively, compared to regular hours quoted spreads of 3.41 bps – a dramatic improvement relative to what has been documented in the literature. The improvement relative to earlier periods for pre-open for effective and 5-minute realized spreads (Panel B) is similar in magnitude, at roughly twice those prevailing during regular hours. However, after-hours effective and 5-minute realized spreads are still elevated at more than three times those during regular hours.[6]

[Table 5]

If market quality is positively related to trading activity, as suggested by the improved market quality for pre-open and after hours, does the low trading activity during the nocturnal period mean that market quality during the nocturnal period is substantially worse than during other periods of the day?

To answer this question, we need to calculate round lot quotes for BOATS. The reason is that DTAQ relies on SIP quotes, and these are based on round lot quotes during our sample period. Constructing round lot quotes for the nocturnal period requires data on all limit orders on

[6]Some slippage occurs during the after-hours as a result of the large trades we see coupled with lower depth documented earlier in Table 4.

BOATS. We therefore obtain order-level data directly from Blue Ocean ATS. These data allow us to construct top of book quotes based on odd lots as well as round lots, where we define round lots as quoted size rounded down to the nearest hundred shares. This dataset is missing a few nocturnal sessions (April, 19, 2024 and September 3–10, 2024), and we drop those trade days for this analysis. Since the sample period is slightly different, the odd lot statistics reported in this section are slightly different from those reported elsewhere (Tables 2 and 3 for example, which only report odd lot nocturnal statistics).

Finally, we also include regular hours market quality statistics from Rule 605 data reported by major U.S. wholesalers. This data provides market quality measures for (mostly) retail orders (Dyhrberg, Shkilko, and Werner, 2025), and serve as a useful benchmark because, as discussed above, the nocturnal period is dominated by retail traders.[7] Since Rule 605 variables are at a monthly frequency, they are dollar volume averaged across months. The Rule 605 reports do not include all of the variables we analyze. For example, they only include price impacts and realized spreads at a 5-minute horizon.

Table 5 summarizes our findings for nocturnal market quality based on round lot quotes, providing the nocturnal odd lot quote market quality measures for reference. Panel A reveals that the nocturnal quoted round lot spreads are 19.28 basis points. These are about six times bigger than those from regular hours and about two or three times those from the pre-open or after-hours sessions. Nocturnal round lot effective spreads are 15.60 basis points on average, which a is about twice those from the pre-open, but comparable to the after-hours session. Regular hours overall effective spreads are about 4.38 bps, but they are only 1.67 bps for retail trading through wholesalers as reflected in the Rule 605 reports, due to retail price improvements provided by wholesalers. Thus, in a like-for-like comparison of round lot spreads for (mostly) retail orders, nocturnal effective spreads are almost ten times those from the regular hours benchmark.

[7] We include the following market center Rule 605 reports: Citadel, G1 Execution Services, HRT Financial, Jane Street Capital, Two Sigma Securities, UBS Securities, and Virtu Americas.

Panel A also reports absolute order imbalances defined as the absolute difference in buy and sell share volume, scaled by total share volume, where trade direction is signed with the Lee-Ready algorithm. Order imbalances are large for the nocturnal period (0.15 or 0.16) suggesting that nocturnal traders tend to herd. They are even larger for the after-hours period (0.28), which, coupled with the large trade sizes from Table 4 and the relatively low price impacts, particularly at longer horizons, in Panel B, likely reflects large orders executing throughout the after-hours session that are pegged to the close. By comparison, order imbalances are smaller for pre-open (0.09) and regular hours trading (0.05). The trade-matched mid-quote return volatility is actually lowest for the nocturnal session (0.30 for round lot quotes) followed by regular-hours trading (0.43), suggesting relatively smooth adjustment of quotes to trading activity. By contrast, mid-quote volatility is several times higher for the pre-open and after-hours sessions.

We consider price impacts and realized spreads at different horizons in Panel B. Nocturnal trade price impacts based on round lot quotes are larger than those from the pre-open and regular hours, but smaller compared to after-hours at the 5-second horizon. At longer horizons, nocturnal price impacts are larger than those from the other trading periods. Nocturnal realized spreads are around zero at these horizons, which are near those for the pre-open and regular hours, and lower compared to the after-hours. Coupled with the evidence on order imbalances, these findings are consistent with herding behavior and active price discovery during the nocturnal period, which we analyze in more detail in Section 6. Thus, while round lot nocturnal effective spreads are significantly wider than effective spreads during regular hours, once we take the toxicity of the nocturnal flow into account, realized spreads are commensurate to or lower than during other trading periods on average. Only retail trades executed by wholesalers pay lower realized spreads, largely because competition has resulted in significant price improvements and retail order flow has more limited price impacts.

Table 6 reports regression results for trading cost measures across the different sessions of the 24-hour trading cycle. This analysis allows us to test for statistical significance and to include

controls. Each trading cost measure is regressed on indicator variables for the trading sessions, with regular trading hours serving as the omitted category. Thus, the regressions tests for significant differences between regular hours and the other hours of the day. Since analysis earlier in this section shows cross-sectional variation across periods, some specifications control for lagged dollar volume, price volatility, and average trade price. We also include firm-day fixed effects. The regressions are weighted by dollar volume. The conclusions are qualitatively similar to the univariate evidence from Table 5. Quoted and effective spreads are significantly greater for the nocturnal period compared to regular hours. Nocturnal realized spreads are 4.01 (6.65) bps higher at 5-second horizons but are insignificantly different from (1.60 bps higher than) those for regular hours at the 5-minute horizon in regressions without (with) controls.

[Table 6]

5 Event Studies

While the previous section shows that nocturnal market quality is relatively good during the first five months of 2024, that year was nonetheless rather turbulent for the BOATS platform. As described in the Internet Appendix, the platform was forced to shut down temporarily in early August 2024 after a surge in trading activity culminated in a system failure on August 5, before BOATS adopted the more resilient MEMX technology. Following this disruption, Korean regulators prohibited local brokerages from allowing their customers to trade on BOATS, leading to a substantial decline in BOATS trading activity. At the same time, 2024 also saw a notable increase in professional liquidity provision. In particular, based on discussions with Blue Ocean representatives, we learned that a major professional liquidity provider began participating in nocturnal trading in November 2024.

In this section, we study both these events in difference-in-differences regression analyses where we use the regular trading hours as a control. For the analyses, we add data from June

2024 through January 2025 to our sample.

5.1 Change in Investor Composition

We examine how BOATS trading activity and market quality change following the departure of Korean brokerages. Korean investors comprised as much as 40% of BOATS volume, and investor composition might drastically change following their departure, which could have significant effects on the proportion of informed trading and market quality. We compare the June-July 2024 to the September-October 2024 periods, dropping the turbulent month of August 2024. To control for market developments, we use regular hours trading as a control sample. Because the level and volatility of market quality measures across days is significantly greater during the nocturnal period than during regular hours, we standardize each stock series across days so it has a zero mean and unitary standard deviation for each stock-period.[8]

Table 7 reports coefficients from difference-in-differences regressions examining market activity (Panel A) and market quality (Panel B). We report the estimated β_1 from the following specifications:

$$DepVar_{it} = \alpha_i + \gamma_t + \beta_1 Post_t \times Nocturnal_{it} + \varepsilon_{it}, \tag{1}$$

where $DepVar_{it}$ is the number of quotes, number of trades, share volume, trade size, or order imbalance for security i on day t (Panel A). For market-quality outcomes, we estimate:

$$\begin{aligned} DepVar_{it} = \alpha_i + \gamma_t + \beta_1 Post_t \times Nocturnal_{it} + \beta_2 Volume_{it} + \beta_3 OrdImb_{it} + \beta_4 TrSize_{it} \\ + \beta_5 Volatility_{it} + \varepsilon_{it}, \end{aligned} \tag{2}$$

where $DepVar_{it}$ is the quoted spread, effective spread, price impact, or realized spread (Panel B). $Post_t$ is an indicator equal to one for September-October 2024 and zero for June-July 2024.

[8] As a robustness check, we also demean by stock-period, but scale by the standard deviation estimated for each stock, but not stock period. The results are qualitatively similar under this alternative specification.

$Nocturnal_{it}$ is an indicator equal to one for nocturnal period observations and zero for regular trading session observations from the same calendar day. All specifications include security fixed effects (α_i) and day fixed effects (γ_t). Standard errors are two-way clustered by security and day.

[Table 7]

Panel A shows that volume actually increases significantly, suggesting that nocturnal traders outside of Korea pick up more than the slack left behind by Koreans after the August crash. The size of non-Koreans trades are also significantly larger, suggesting that the type of trader changes. Panel B confirms this by showing that the non-Korean traders have significantly larger price impacts at all horizons, and while quoted spreads increase significantly, they fail to fully compensate for the higher toxicity of the remaining flow. As a result, realized spreads decline significantly at the one and five-minute horizons. We interpret this as suggesting that non-professional liquidity providers, i.e., non-marketable retail limit orders, supply a significant fraction of nocturnal liquidity.

5.2 Entry of a Professional Liquidity Provider

To test whether the the entry of a large professional liquidity provider, and the associated increase in capital commitment to nocturnal trading, improves market quality we conduct another batch of difference-in-differences regression analyses where we compare the September-October 2024 to the December 2024-January 2025 periods. We drop the month of November, both because we don't know the exact date of entry and because it is the month of the U.S. Presidential Election with associate market volatility.

Table 8 reports coefficients from difference-in-differences regressions examining market activity (Panel A) and market quality (Panel B) comparing the September-October 2024 to the December 2024-January 2025 period. The regression setup is the same as above, but the *POST*

dummy now takes on a value of one for the December 2024 and January 2025 observations and is zero otherwise.

[Table 8]

Consistent with more professional liquidity provision, Panel A shows that there was a significant increase in quote updates, trades, and volume following the entry. Note also that order imbalances decline significantly, suggesting that there is less nocturnal herding. Panel B confirms that the entry helped narrow the quoted and effective spreads significantly, and because order flow toxicity did not change, realized spreads also fall significantly following entry.

6 Price Discovery

We next consider to what extent the nocturnal period contributes to price discovery over the 24-hour trade cycle. Given the relatively small share of nocturnal volume and the paucity of U.S. nocturnal news releases, one could reasonably expect a trivial amount of price discovery in the nocturnal period. If this is the case, the significant nocturnal price impacts and order imbalances we document above could be the result of herding causing temporary price pressure. On the other hand, given that information in all its forms now disseminates around the clock, it is possible that the nocturnal period significantly contributes to price discovery. If this is the case, the significant price impacts and order imbalances could be the result of price discovery taking place nocturnally.

To examine nocturnal price discovery, we document the 24-hour evolution of mid-quote returns. We take the last midquote in each half-hour period and compute the cumulative midquote returns. For the nocturnal period, we use the BOATS platform and for the other periods (pre-open, regular trading hours, and after-hours trading) we use the NBBO midquote. Because we are interested in price discovery by liquidity-demanding retail traders, we condition the analysis on the nocturnal order imbalance. The idea is that the nocturnal order imbalance captures overnight

price pressure to the extent that overnight cumulative returns are reversed in subsequent periods while it captures price discovery if overnight cumulative returns are not reversed. Slightly more than half (52%) of our sample stock-nights are characterized by sell order imbalances, the remaining (48%) being buy order imbalances.

Figure 5 displays the value-weighted average cumulative returns for 24-hour periods with positive nocturnal order imbalances (red line) and negative nocturnal order imbalances (blue line) over the different trading periods (nocturnal, pre-open, regular, and after-hours) separated by vertical dashed lines. The sample is all FT stocks and the sample period is January-May 2024. For each line, we also plot 90% confidence intervals. These intervals are relatively wide because the sample spans only five months, leaving a limited number of daily observations for estimation.

[Figure 5]

For positive nocturnal order imbalances plotted as the red line, there is significant price pressure during nocturnal hours. The cumulative return is almost 100 basis points. Trading during pre-open gradually reverses about one-third of this cumulative return, but it is not until the start of regular trading hours that prices discretely fall about 40 basis points. The returns remain flat after this correction at about 25 basis points. Given the confidence intervals, these point estimates are not significantly different from zero. Thus, while nocturnal traders appear to create substantial price pressures that subsequently partly reverse, they are trading in the right direction based on the point estimates and therefore contribute to price discovery.

Cumulative returns for negative nocturnal order imbalances are depicted by the blue line. Short-selling by retail traders is typically not allowed during the nocturnal period, which potentially accounts for the more modest reaction of returns to nocturnal selling. In contrast to nocturnal periods with positive order imbalances, there is no evidence of overshooting on the negative side. If anything, there is a dampening of the downwards pressure on prices because of a slight initial increase in returns immediately after nocturnal trading starts. Cumulative returns

continue declining during the remainder of the 24-hour period. The exception is the bump in cumulative returns during pre-open, but that can almost entirely be explained by two earnings announcements by NVIDIA Corporation that temporarily push prices higher. Cumulative returns continue declining after market open and during after-hours trading, and this is true even taking the confidence intervals into account. We conclude that nocturnal traders contribute to price discovery and predict future prices without evidence of overshooting when they are net sellers.

The evidence of reversals for 24-hour periods with positive nocturnal order imbalances suggests that herding by nocturnal traders in individual stocks may cause prices to overshoot as documented during regular-hour herding events (Barber, Huang, Odean, and Schwarz, 2022). We would expect herding to be less likely to produce overshooting for ETFs than for individual stocks for two reasons. First, ETFs are more likely to be linked to a derivative traded in a parallel 24-hour market such as the e-mini futures. Such markets attract institutional traders, and therefore are likely less susceptible to retail price pressure. Second, the effect of firm-specific news such as earnings announcements is diluted for ETFs consisting of a portfolio of securities.

To test whether this expectation is confirmed in the data, we split the sample into stocks in Panel A and ETFs in Panel B of Figure 6. The evidence is striking. The overshooting is concentrated in stocks as expected, and the magnitude of the effect is larger than for the overall sample with cumulative returns reaching 116 basis points. The reversals are even larger, gradual during pre-open followed by a dramatic drop in prices in the first half-hour of regular trading. The pattern for negative order imbalances in stocks is virtually identical to the patterns discussed in Figure 5 above. By contrast, for ETFs, the nocturnal period closing prices are essentially equal to market open prices both for nights with positive and negative order imbalances, with subsequent regular-day patterns resembling those for stocks, but more subdued for periods with positive nocturnal imbalances. Both for positive and negative order imbalances, the ability of nocturnal traders to predict returns are significant given the confidence intervals. In other words, meaningful price discovery appears to be taking place overnight in ETFs.

[Figure 6]

Finally, to shed light on the source of the return overshooting following positive nocturnal order imbalances, we further divide the stock sample into retail favorites (Panel A) and other stocks (Panel B) in Figure 7. We define retail favorites based on media coverage of the stocks that attracted the greatest attention from U.S. retail traders in spring 2024. This group includes Coinbase Global Inc., GameStop Corporation, NIO Inc., Palantir Technologies Inc., Rivian Automotive Inc., Robinhood Markets Inc., Strategy Inc., and Tesla Inc., among several others. Together, these stocks account for 17% of nocturnal dollar volume over the sample period.

[Figure 7]

The overshooting of prices during positive nocturnal order imbalances is essentially entirely explained by the trading of stocks favorited by retail investors. For the rest of the stocks and ETFs in Panel B, there is significant nocturnal price discovery. As mentioned earlier, short-sale constraints hamper the ability of nocturnal traders to incorporate negative news, so prices continue drifting down during regular and after-hours trading following negative nocturnal order imbalances. The evidence for retail favorites in Panel A is dramatic. Nocturnal traders push prices up more than 230 basis points on average on nights with positive nocturnal order imbalances. Over two-thirds of this overshooting is corrected during pre-open.By contrast, we see no evidence of overshooting on nights with negative order imbalances for these stocks.

Not only are retail traders contributing to price discovery, but they are also active precisely during the interval in which the aggregate equity premium tends to accrue. A growing literature documents that a disproportionate share of stock returns is earned outside regular trading hours (close-to-open), with intraday returns (open-to-close) much smaller on average and often of opposite sign. Related evidence from around-the-clock S&P 500 futures shows that market returns are concentrated in the overnight window surrounding the European market open (Boyarchenko,

Larsen, and Whelan, 2023). From this perspective, nocturnal retail trading can be interpreted as taking place during the part of the day when risk premia are earned.

While our results suggest that retail investors are unlikely to benefit from trading their most favored stocks during the sample period, they may nevertheless gain from trading other securities in the nocturnal window, when they face less direct competition from institutional traders than during the regular session. In the other-stocks-and-ETFs subsample, the implied return differential is economically meaningful, at approximately 59 bps following net buying and 53 bps following net selling. Capturing these gains likely requires trading relatively early in the nocturnal period, especially on nights with positive imbalances, and it comes with higher execution costs. However, our estimates imply that nocturnal trading costs exceed regular-hours costs by only about 7.09 bps. This calculation assumes that, during the day, retail orders are routed to wholesalers, who typically provide meaningful price improvement; we use a 28% price-improvement statistic from Dyhrberg, Shkilko, and Werner (2025). Taken together, the evidence suggests that, outside of the most favored stocks, nocturnal trading may be economically worthwhile for retail investors.

7 Conclusions

Nocturnal trading in U.S. equities has grown rapidly since 2022 and now constitutes a meaningful share of retail trading activity, particularly for a set of actively traded securities. Using comprehensive transaction-level data from Blue Ocean ATS, we provide novel evidence on this new market. Despite thinner trading and lower participation by professional liquidity providers, quoted and effective spreads during the nocturnal session are comparable to those observed during extended hours, though wider than during regular trading hours. Once adverse selection is accounted for however, realized spreads are even slightly negative at longer horizons, indicating that liquidity during nocturnal hours is supplied at relatively favorable terms for liquidity deman-

ders. At the same time, the low realized spreads suggests that there is a significant amount of retail liquidity provision at night.

While having grown by leaps and bounds recently, nocturnal trading is still in many way nascent. The nocturnal landscape is changing both in terms of the addition of new venues, and because the trader composition and professional liquidity provision within a venue are changing as the market attracts more participants. To shed light on this dynamic, we explore two events. We first show that when more sophisticated traders enter the market following a platform outage in August 2024, quoted spreads increase but not sufficiently to compensate for the higher order flow toxicity. This suggests that a non-professional traders supply a significant fraction of nocturnal liquidity. We then show that when an additional market maker enters in November 2024, quoting and trading activity increases as expected. However, since the mix of traders stays constant there is no change in order flow toxicity. Yet, quoted, effective, and realized spreads decline presumably as a result of the increased competition. Since we understand from representatives from Blue Ocean that more than a dozen professional liquidity providers now are active on their platform, spreads are likely even tighter now than they were in 2024.

We also document substantial price discovery during the overnight session. When nocturnal liquidity demanders are net buyers, overnight prices rise, and they fall when nocturnal traders are net sellers. Nocturnal prices do not reverse before market open on nights with net buying, except in the case of the group of retail darling stocks for which prices tend to overreact. When nocturnal traders are net sellers, the downward drift of prices continues throughout the following sessions. Our evidence suggests that nocturnal investors trading ETFs and other stocks may be better off trading overnight as opposed to waiting until subsequent sessions. Nocturnal traders incorporate fundamental value relevant information overnight.

Our findings carry implications for market structure beyond the United States. As exchanges and regulators in other jurisdictions weigh extended and around the clock trading – Canada's TMX Group, for instance, has publicly described an active proposal to authorize extended trading

hours in domestically listed equities – the evidence here provides an early, empirically grounded benchmark. It suggests that off-hours liquidity need not be prohibitively expensive once adverse selection is accounted for, that competition among professional liquidity providers materially improves market quality, and that the absence of a consolidated cross-venue tape complicates best execution assessment during these hours. These considerations are likely to be central to the design and oversight of extended hours markets internationally.

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Table 1
Popular Symbols on Blue Ocean

The table reports the top ten symbols traded on Blue Ocean by share volume in Panel A and by dollar volume in Panel B. We report total volumes for the full sample period, which begins on January 1, 2024 and ends on January 27, 2025, as well as sub-periods that break the sample approximately into half. Units are in million shares (dollars).

Full		Jan–Jun 24		Jul 24–Jan 25	
Symbol	Volume	Symbol	Volume	Symbol	Volume
Panel A: Top Ten by Share Volume					
YANG	177	SOXS	130	YANG	137
SOXS	159	SQQQ	64	TSLL	91
TSLL	140	SOXL	60	YINN	76
YINN	120	TSLL	50	NVDA	66
SQQQ	118	YINN	44	SQQQ	54
SOXL	100	YANG	40	SOXL	40
NVDA	92	TQQQ	30	TSLA	39
TSLA	59	NVDQ	27	NIO	32
TQQQ	58	GME	26	SOXS	29
NIO	57	NVDA	26	TQQQ	28
Panel B: Top Ten by Dollar Volume					
NVDA	17,512	NVDA	8,862	TSLA	12,268
TSLA	15,992	TSLA	3,724	NVDA	8,650
MSTR	4,691	SOXL	2,531	MSTR	3,986
QQQ	4,296	TQQQ	1,757	QQQ	2,875
SOXL	4,121	NVDL	1,441	YINN	2,737
TQQQ	3,851	QQQ	1,422	TQQQ	2,094
YINN	3,605	SPY	1,128	SPY	2,092
SPY	3,220	AAPL	1,105	SOXL	1,591
NVDL	2,653	MSFT	1,024	TSLL	1,569
COIN	2,280	GME	946	COIN	1,448

Table 2
BOATS Quoting and Trading Activity

The table presents summary statistics on quoting and trading activity on Blue Ocean ATS (BOATS). The sample begins on January 1, 2024 and ends on January 27, 2025. Results are reported for two samples: (i) the 200 most actively traded stocks on BOATS (frequently traded sample), and (ii) the remaining 3,697 BOATS-traded stocks that appear in our sample at least one night during the sample period (less frequently traded sample). The reported statistics include the following stock-night averages: (i) number of quotes, (ii) time-weighted average best quoted depth (in shares), (iii) number of trades, (iv) trade size, (v) trade price, and (vi) the ratio of quotes to trades (Q/T). These statistics are volume-weighted within stock-night, then dollar volume averaged.

	# Quotes	Quoted depth	# Trades	Trade size	Price	Q/T
Frequently traded (FT)	26,680	1,449	9,550	78	255	2.79
Less frequently traded (LFT)	19,863	5,014	5,544	159	76	3.58

Table 3
BOATS Trading Costs

The table presents trading costs on Blue Ocean ATS (BOATS). The sample begins on January 1, 2024 and ends on January 27, 2025. Results are reported for two samples: (i) the 200 most actively traded stocks on BOATS (frequently traded sample), and (ii) the remaining 3,697 BOATS-traded stocks that appear in our sample at least one night during the sample period (less frequently traded sample). The reported trading cost measures include the quoted spread, which reflects the prevailing spread at the time of trades; the effective spread, defined as twice the signed difference between the traded price and the prevailing BBO midquote; the price impact, measured as twice the signed difference between the midquote at the time of the trade and the midquote at a future time; and the realized spread, which is the difference between the effective spread and the price impact. The future midquote times we use to compute price impact are 5 seconds, 60 seconds, or 5 minutes ahead. In addition to the conventional effective spread measure, we also construct the Hagströmer measure, which captures the difference between the price of a trade and an adjusted midquote that reflects depth-imbalances. Trades are signed using the Lee-Ready algorithm. The statistics are volume-weighted within firm-day, then dollar volume averaged.

Panel A: Quoted and Effective Spreads

	Conventional		Hagströmer
	Quoted spread	Effective spread	Effective spread
Frequently traded (FT)	7.75	8.72	10.28
Less frequently traded (LFT)	35.05	37.86	48.35

Panel B: Price Impact and Realized Spread

	Conventional		Hagströmer	
	Price impact	Realized spread	Price impact	Realized spread
Frequently traded (FT), 5 seconds	6.60	2.11	8.58	1.70
Frequently traded (FT), 60 seconds	9.29	-0.59	11.02	-0.76
Frequently traded (FT), 5 minutes	11.42	-2.75	13.07	-2.84
Less frequently traded (LFT), 5 seconds	29.60	8.24	40.88	7.45
Less frequently traded (LFT), 60 seconds	37.01	0.81	47.60	0.71
Less frequently traded (LFT), 5 minutes	42.84	-5.09	54.30	-6.10

Table 4
Quoting and Trading Activity Across the Trading Day

The table presents summary statistics on quoting and trading activity across the trading day. We analyze the nocturnal (8:00 p.m. – 4:00 a.m.), pre-open (4:00 a.m. – 9:30 a.m.), regular hours (9:30 a.m. – 4:00 p.m.), and after-hours (4:00 p.m. – 8:00 p.m.) periods. The sample begins on January 1, 2024 and ends on January 27, 2025. Results are reported for the 200 stocks in the frequently traded sample. We consider two versions of the nocturnal period variables, one based on round lot quotes, to make them comparable to the observed data from the other periods in the day, and another that includes odd lot quotes, which represent the actual quotes nocturnal traders face. Panel A reports the following stock-day-period averages: (i) number of quotes, (ii) time-weighted average best quoted depth (in shares), (iii) number of trades, (iv) trade size, (v) trade price, and (vi) the ratio of quotes to trades (Q/T). These statistics are volume-weighted within stock-day-period, then dollar volume averaged within each period. Panel B report alternative volume metrics for each period. The totals, in millions, are summed across firms each day then averaged across days. Percent is each period's market share of daily volume. Panel B include the open and close. Trades within ten minutes following the open with sale condition 4 and the same price as the open are considered market-on-open orders, and we lump them in with open volume. Trades within ten minutes following the close and the same price as the close are considered market-on-close orders, and we lump them in with closing volume.

Panel A: Mean Statistics

	# Quotes	Quoted depth	# Trades	Trade size	Price	Q/T
Nocturnal (round lot quotes)	17,420	1,726				1.81
Nocturnal (odd lot quotes)	26,716	1,444	9,640	77	255	2.77
Pre-open	71,135	2,531	51,345	98	308	1.39
Regular	951,011	5,182	504,703	112	317	1.88
After-hours	31,479	1,699	36,845	611	371	0.85

Panel B: Daily Volume Totals and Percentages

	Daily dollar volume		Daily share volume		Daily # Trades	
	Total (mil)	Percent	Total (mil)	Percent	Total (mil)	Percent
Nocturnal	451.9	0.16%	7.89	0.26%	0.12	0.57%
Pre-open	7,343.02	2.58%	93.99	3.09%	0.86	4.22%
Open	3,129.38	1.10%	29.98	0.99%	0.05	0.23%
Regular	244,866.09	86.09%	2,656.71	87.42%	19.00	93.19%
Close	2,360.11	7.86%	195.99	6.45%	0.01	0.03%
After-hours	6,271.30	2.20%	54.54	1.79%	0.36	1.75%

Table 5
Trading Costs Across the Trading Day

The table reports trading cost variables across the trading day for a sample of 200 frequently traded securities. We analyze the nocturnal (8:00 p.m. – 4:00 a.m.), pre-open (4:00 a.m. – 9:30 a.m.), regular hours (9:30 a.m. – 4:00 p.m.), and after-hours (4:00 p.m. – 8:00 p.m.) periods. The sample begins on January 1, 2024 and ends on January 27, 2025. We consider two versions of the nocturnal period variables, one based on round lot quotes, to make them comparable to the observed data from the other periods in the day, and another that includes odd lot quotes, which represent the actual quotes nocturnal traders face. We also consider two versions of regular hours, one from all trading venues using DTAQ, and another from Rule 605 data, which captures retail trading. The reported trading cost measures include the quoted spread, which reflects the prevailing spread at the time of trades; the effective spread, defined as twice the signed difference between the traded price and the prevailing best midquote; the price impact, measured as twice the signed difference between the midquote at the time of the trade and the midquote at a future time; and the realized spread, which is the difference between the effective spread and the price impact. The future midquote times we use to compute price impact are 5 seconds, 60 seconds, or 5 minutes ahead. Other statistics include the E/Q ratio, which is effective spread over quoted spread, order imbalances (OIB) defined as the absolute difference in buy and sell share volume, scaled by total share volume, and volatility of trade-matched midpoint returns. All statistics besides the regular hours variables from Rule 605 data are volume-weighted within stock-day-period, then dollar volume averaged within each period. Since the Rule 605 data are at the monthly level, they are dollar volume averaged across months. Unless specified otherwise, the trading costs and volatility measures are in percentage form and reported in basis points.

Panel A: Spread and Trading Measures

	Quoted spread	Effective spread	E/Q	OIB	Volatility
Nocturnal (round lot quotes)	19.28	15.60	0.81	0.16	0.30
Nocturnal (odd lot quotes)	7.68	8.63	1.12	0.15	0.18
Pre-open	8.27	7.48	0.90	0.09	1.82
Regular	3.41	4.38	1.28	0.05	0.43
Regular (605)	3.81	1.67	0.44		
After-hours	7.81	14.15	1.81	0.28	1.30

Panel B: Price Impact and Realized Spread

	5-second horizon		60-second horizon		5-minute horizon	
	Price impact	Realized spread	Price impact	Realized spread	Price impact	Realized spread
Nocturnal (round lot quotes)	5.97	9.62	12.06	3.54	14.23	1.37
Nocturnal (odd lot quotes)	2.05	6.58	9.24	-0.61	11.25	-2.62
Pre-open	3.26	4.02	5.46	1.82	6.09	1.19
Regular	2.63	1.67	1.83	2.46	1.86	2.43
Regular (605)					0.99	0.68
After-hours	10.75	3.25	4.65	9.38	5.81	8.20

Table 6
Regression Analysis of Trading Costs Across the Trading Day

The table presents regression analysis of trading costs variables across the trading day for a sample of 200 frequently traded securities. We analyze the nocturnal (8:00 p.m. – 4:00 a.m.), pre-open (4:00 a.m. – 9:30 a.m.), regular hours (9:30 a.m. – 4:00 p.m.), and after-hours (4:00 p.m. – 8:00 p.m.) periods. The sample begins on January 1, 2024 and ends on January 27, 2025. The key x-variables are dummy variables representing alternative trading periods, where regular trading hours (from the DTAQ data) are the excluded group. The alternative y-variables are trading cost measures that are volume-weighted within stock-day-period. The variables include the quoted spread, which reflects the prevailing spread at the time of trades; the effective spread, defined as twice the signed difference between the traded price and the prevailing best midquote; and the realized spread, which is the difference between the effective spread and the price impact. The future midquote times we use to compute realized spreads are 5 seconds, 60 seconds, or 5 minutes ahead. The regressions are weighted by dollar volume. Some specifications include dollar volume in billions, trade-matched midpoint return volatility, and average trade price for controls, which are measured for each stock-day-period and lagged to the previous trade day in the sample. The trading costs are percentage measures reported in basis points. Standard errors are reported in parentheses and clustered by firm-day. Statistical significance is reported at the 1% (***), 5% (**), or 10% (*) levels.

	Quoted spread		Effective spread		5-min Realized spread		60-sec Realized spread		5-sec Realized spread	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Nocturnal (round lot quotes) dummy	14.56***	17.29***	11.02***	14.50***	-0.37	1.60***	1.91***	4.23***	4.01***	6.65***
	(0.57)	(0.57)	(0.44)	(0.51)	(0.43)	(0.50)	(0.35)	(0.43)	(0.34)	(0.42)
Nocturnal (odd lot quotes) dummy	2.95***	5.73***	4.05***	7.58***	-4.35***	-2.36***	-2.24***	0.11	0.09	2.75***
	(0.12)	(0.14)	(0.16)	(0.30)	(0.29)	(0.39)	(0.17)	(0.29)	(0.12)	(0.26)
Pre-open dummy	4.37***	6.61***	2.45***	5.46***	-1.52***	0.18	-0.83***	1.19***	0.39*	2.70***
	(0.07)	(0.24)	(0.22)	(0.40)	(0.25)	(0.39)	(0.22)	(0.36)	(0.21)	(0.36)
After-hours dummy	4.60***	7.15***	8.05***	11.43***	4.49***	6.44***	5.39***	7.67***	6.46***	9.04***
	(0.13)	(0.24)	(0.53)	(0.61)	(0.56)	(0.62)	(0.52)	(0.58)	(0.51)	(0.58)
Lagged volume		0.20***		0.26***		0.15***		0.17***		0.20***
		(0.01)		(0.03)		(0.02)		(0.02)		(0.02)
Lagged volatility		0.31***		0.31***		0.18**		0.20**		0.22***
		(0.12)		(0.12)		(0.07)		(0.08)		(0.08)
Lagged price		0.03*		0.02		-0.02		-0.01		0.01
		(0.02)		(0.02)		(0.02)		(0.02)		(0.02)
Obs.	230,355	229,355	230,355	229,355	230,355	229,355	230,355	229,355	230,355	229,355
Within R^2	0.11	0.16	0.07	0.10	0.02	0.03	0.03	0.05	0.04	0.06
Firm x Day FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 7
Event Study: Change in Investor Composition

The table reports coefficients from difference-in-differences regressions examining market activity (Panel A) and market quality (Panels B and C). For Panels A and B, we report the estimated β_1 from:

$$DepVar_{ijt} = \alpha_{ij} + \gamma_t + \beta_1 Post \times Nocturnal_{ijt} + \varepsilon_{ijt},$$

where $DepVar_{ijt}$ is the number of quotes, number of trades, share volume, trade size, or order imbalance for security i, period j (nocturnal or regular trading session) on day t in Panel A, and the quoted spread, effective spread, price impact, or realized spread in Panel B. *Post* is an indicator that equals one over the 30 trading days starting in September 2024 and zero over the 30 trading days prior to August 2024. *Nocturnal* is an indicator equal to one for nocturnal period observations and zero for regular trading session observations from the same calendar day. For Panel C, we estimate:

$$DepVar_{ijt} = \alpha_i + \gamma_t + \beta_1 Post \times Nocturnal_{ijt} + \beta_2 Volume_{ijt} + \beta_3 OrdImb_{ijt} + \beta_4 TrSize_{ijt} + \beta_5 Volatility_{ijt} + \varepsilon_{ijt},$$

where price impact and realized spread are computed over 5-, 60-, and 300-second horizons. All non-indicator variables are standardized to have zero mean and unit standard deviation. All specifications include security-period fixed effects (α_{ij}) and day fixed effects (γ_t). Standard errors are two-way clustered by security and day. Statistical significance is denoted at the 1% (***), 5% (**), and 10% (*) levels.

Panel A: Market activity								
	# Quotes	# Trades	Volume	Trade size	Ord. Imb.			
Post × Nocturnal	0.069	0.076	0.528**	0.919***	-0.017			
	(0.22)	(0.22)	(0.20)	(0.13)	(0.08)			
Obs.	23,778	23,778	23,778	23,778	23,778			
Adj. R^2	0.305	0.219	0.184	0.094	0.087			
Panel B: Market quality, without controls								
	Spread		Price impact			Realized spread		
	Quoted	Effective	5 sec	60 sec	5 min	5 sec	60 sec	5 min
Post × Nocturnal	0.545**	0.262*	0.331***	0.557**	0.574**	-0.009	-0.424**	-0.522**
	(0.23)	(0.16)	(0.12)	(0.21)	(0.25)	(0.10)	(0.20)	(0.24)
Obs.	23,778	23,778	23,778	23,778	23,778	23,778	23,778	23,778
Adj. R^2	0.200	0.109	0.106	0.100	0.091	0.078	0.090	0.097
Panel C: Market quality, with controls								
Post × Nocturnal	0.580**	0.115	0.307**	0.572***	0.603**	-0.141	-0.582***	-0.661***
	(0.26)	(0.18)	(0.14)	(0.18)	(0.23)	(0.13)	(0.21)	(0.25)
Volume	0.156	0.099**	0.404***	0.268***	0.226***	-0.116**	-0.121**	-0.134***
	(0.10)	(0.04)	(0.06)	(0.05)	(0.04)	(0.05)	(0.05)	(0.04)
Order Imbalance	-0.031	0.183***	-0.061**	0.052**	0.133***	0.201***	0.125***	0.030
	(0.02)	(0.03)	(0.03)	(0.03)	(0.02)	(0.03)	(0.04)	(0.05)
Trade Size	-0.118	0.114*	-0.195***	-0.159***	-0.150***	0.215***	0.241***	0.224***
	(0.13)	(0.06)	(0.07)	(0.05)	(0.02)	(0.03)	(0.04)	(0.04)
Volatility	0.058***	0.041***	0.067***	0.054***	0.047***	0.006	-0.018***	-0.022**
	(0.02)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Obs.	23,757	23,757	23,757	23,757	23,757	23,757	23,757	23,757
Adj. R^2	0.241	0.182	0.231	0.167	0.155	0.139	0.140	0.130

Table 8
Event Study: Arrival of a New Market Maker

The table reports coefficients from difference-in-differences regressions examining market activity (Panel A) and market quality (Panels B and C). For Panels A and B, we report the estimated β_1 from:

$$DepVar_{ijt} = \alpha_{ij} + \gamma_t + \beta_1 Post \times Nocturnal_{ijt} + \varepsilon_{ijt},$$

where $DepVar_{ijt}$ is the number of quotes, number of trades, share volume, trade size, or order imbalance for security i, period j (nocturnal or regular trading session) on day t in Panel A, and the quoted spread, effective spread, price impact, or realized spread in Panel B. *Post* is an indicator equal to one for the period spanning 30 trading days after November 20, 2024 and zero for 30 trading days prior to October 20, 2024. *Nocturnal* is an indicator equal to one for nocturnal-period observations and zero for regular trading-session observations from the same calendar day. For Panel C, we estimate:

$$DepVar_{ijt} = \alpha_{ij} + \gamma_t + \beta_1 Post \times Nocturnal_{ijt} + \beta_2 Volume_{ijt} + \beta_3 OrdImb_{ijt} + \beta_4 TrSize_{ijt} + \beta_5 Volatility_{ijt} + \varepsilon_{ijt}.$$

Price impact and realized spread are computed over 5-, 60-, and 300-second horizons. All non-indicator variables are standardized to have zero mean and unit standard deviation. All specifications include security-period fixed effects (α_{ij}) and day fixed effects (γ_t). Standard errors are two-way clustered by security and day. Statistical significance is denoted at the 1% (***), 5% (**), and 10% (*) levels.

Panel A: Market activity					
	# Quotes	# Trades	Volume	Trade size	Ord. Imb.
Post × Nocturnal	0.858***	0.667***	0.683***	0.014	-0.332***
	(0.14)	(0.11)	(0.12)	(0.12)	(0.08)
Obs.	24,632	24,632	24,632	24,632	24,632
Adj. R^2	0.338	0.265	0.241	0.151	0.053

Panel B: Market quality, without controls								
	Spread		Price impact			Realized spread		
	Quoted	Effective	5 sec	60 sec	5 min	5 sec	60 sec	5 min
Post × Nocturnal	-0.679***	-0.710***	-0.428***	-0.242***	-0.150	-0.518***	-0.312***	-0.160
	(0.16)	(0.12)	(0.11)	(0.07)	(0.09)	(0.12)	(0.09)	(0.11)
Obs.	24,632	24,632	24,632	24,632	24,632	24,632	24,632	24,632
Adj. R^2	0.317	0.146	0.137	0.116	0.087	0.103	0.087	0.077
Panel C: Market quality, with controls								
Post × Nocturnal	-0.705***	-0.642***	-0.604***	-0.364***	-0.220**	-0.386***	-0.166**	-0.066
	(0.16)	(0.11)	(0.13)	(0.09)	(0.09)	(0.10)	(0.08)	(0.10)
Volume	0.085	0.047	0.298***	0.211***	0.189***	-0.076*	-0.117**	-0.137***
	(0.07)	(0.05)	(0.07)	(0.06)	(0.04)	(0.04)	(0.05)	(0.04)
Order Imbalance	-0.024	0.174***	-0.046*	0.003	0.103***	0.181***	0.138***	0.011
	(0.03)	(0.02)	(0.03)	(0.03)	(0.04)	(0.03)	(0.03)	(0.04)
Trade Size	-0.004	0.151*	-0.045	-0.045	-0.061	0.169***	0.217***	0.176**
	(0.08)	(0.08)	(0.08)	(0.06)	(0.05)	(0.06)	(0.05)	(0.07)
Volatility	0.059***	0.065***	0.061*	0.028	0.035*	0.032	0.033	-0.000
	(0.02)	(0.01)	(0.03)	(0.03)	(0.02)	(0.02)	(0.03)	(0.02)
Obs.	24,599	24,599	24,599	24,599	24,599	24,599	24,599	24,599
Adj. R^2	0.358	0.228	0.241	0.156	0.132	0.152	0.132	0.098

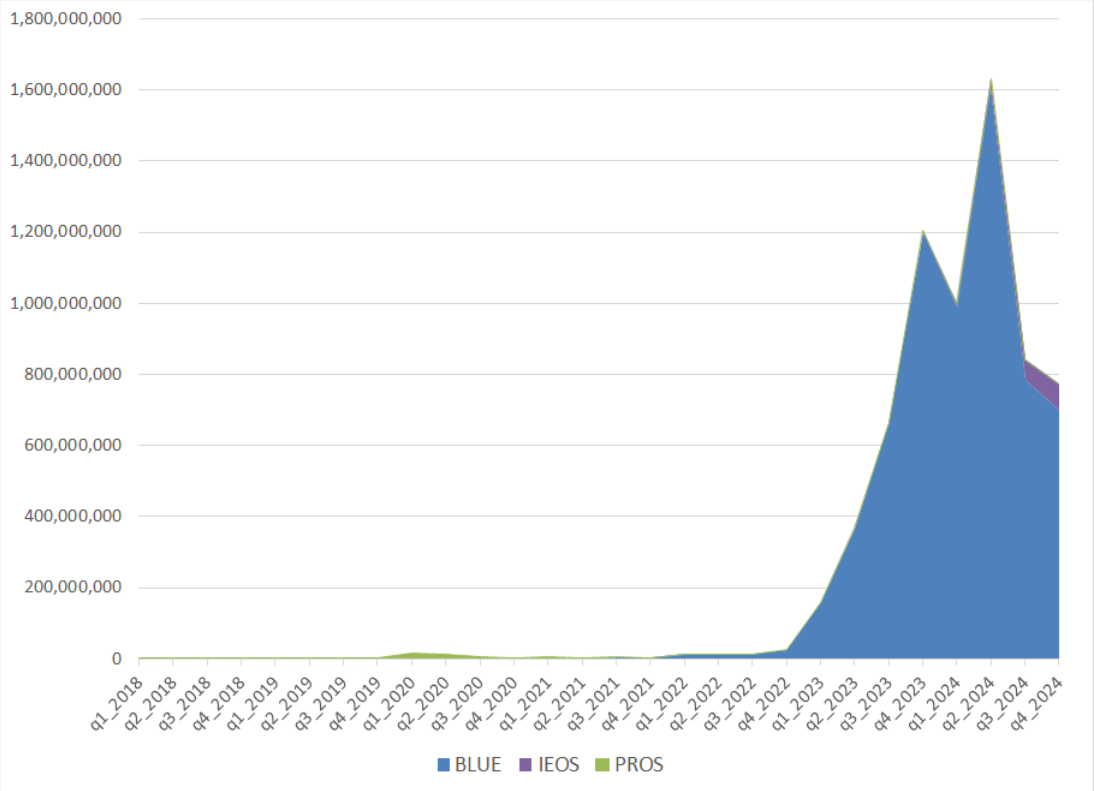


Figure 1. Nocturnal Trading

The figure reports quarterly share volume by PRO Securities ATS (PROS), Blue Ocean ATS (BOATS), and Interactive Brokers EOS ATS (IBEOS) for the Q1 2018 - Q4 2024 period. These ATSs operate exclusively in the overnight period, 8 p.m. to 4 a.m., starting 8 p.m. on Sunday, ending at 4 a.m. on Friday. The source for the data is the FINRA ATS Transparency data for all NMS securities.

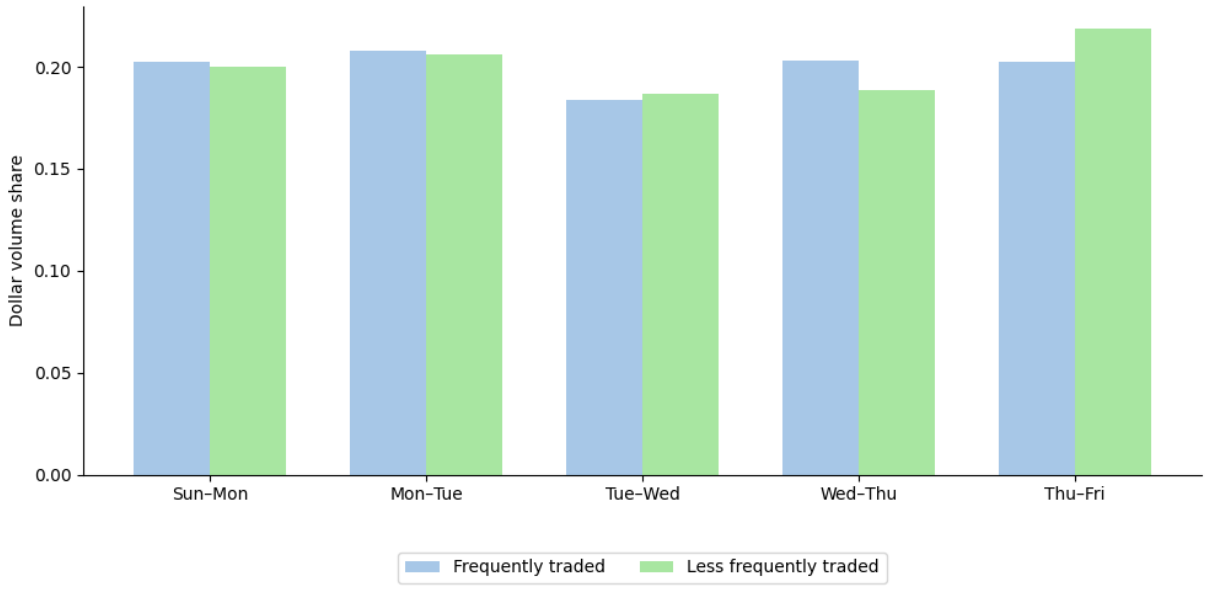


Figure 2. Intraweek Dollar Volume

The figure reports the distribution of nocturnal dollar volume on the Blue Ocean ATS (BOATS) across weeknights. Sunday-Monday (Sun-Mon) includes activity from Sunday 8 p.m. through Monday 4 a.m., Mon-Tue includes activity from Monday 8 p.m. through Tuesday 4 a.m., and so on. The dollar volume shares, defined as each night's dollar volume divided by that week's total nocturnal dollar volume, are shown separately for the frequently traded sample (blue bars) and the remaining stocks (green bars). All statistics are dollar-volume-weighted across stocks.

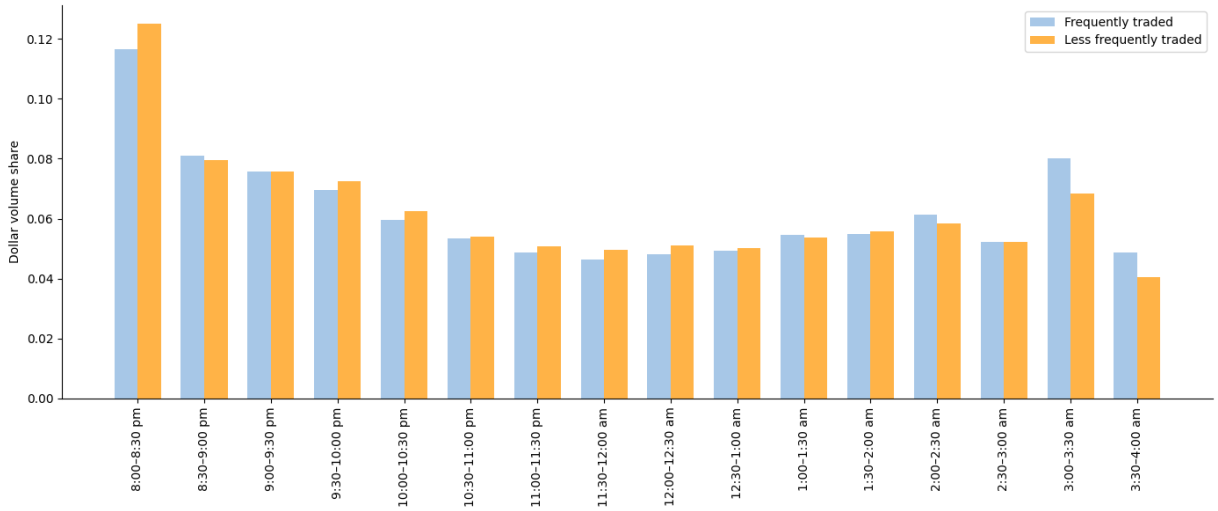


Figure 3. Intranight Dollar Volume

The figure reports the distribution of nocturnal dollar volume on the Blue Ocean ATS (BOATS) across half-hour intervals from 8 p.m. to 4 a.m. The shares, defined as each interval's dollar volume divided by total intranight volume, are shown separately for the frequently traded sample (blue bars) and the remaining stocks (orange bars). All statistics are dollar-volume-weighted across stocks.

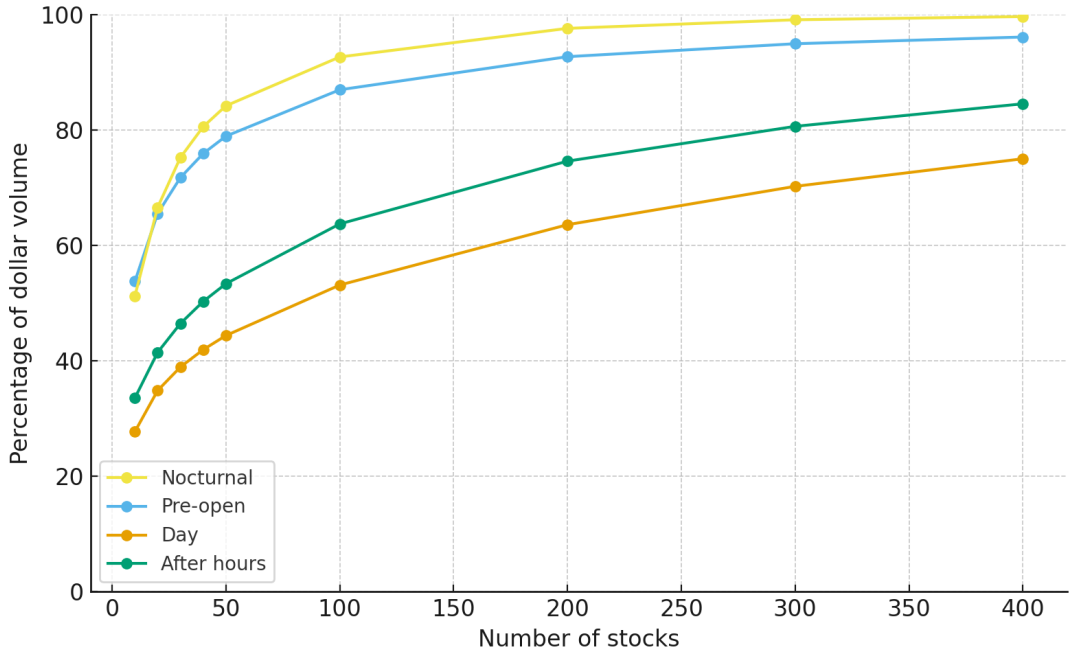


Figure 4. Concentration
The figure shows the cumulative distribution of dollar volume by sub-period of the day for the 400 stocks with highest dollar volume on the Blue Ocean ATS (BOATS).

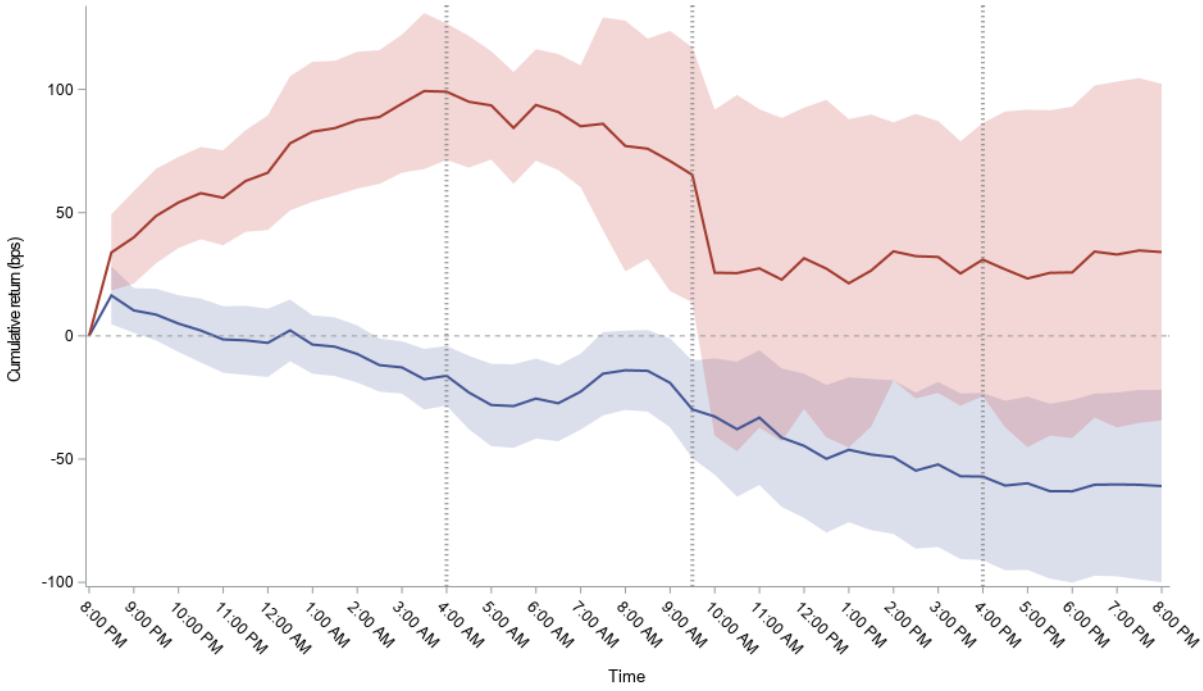
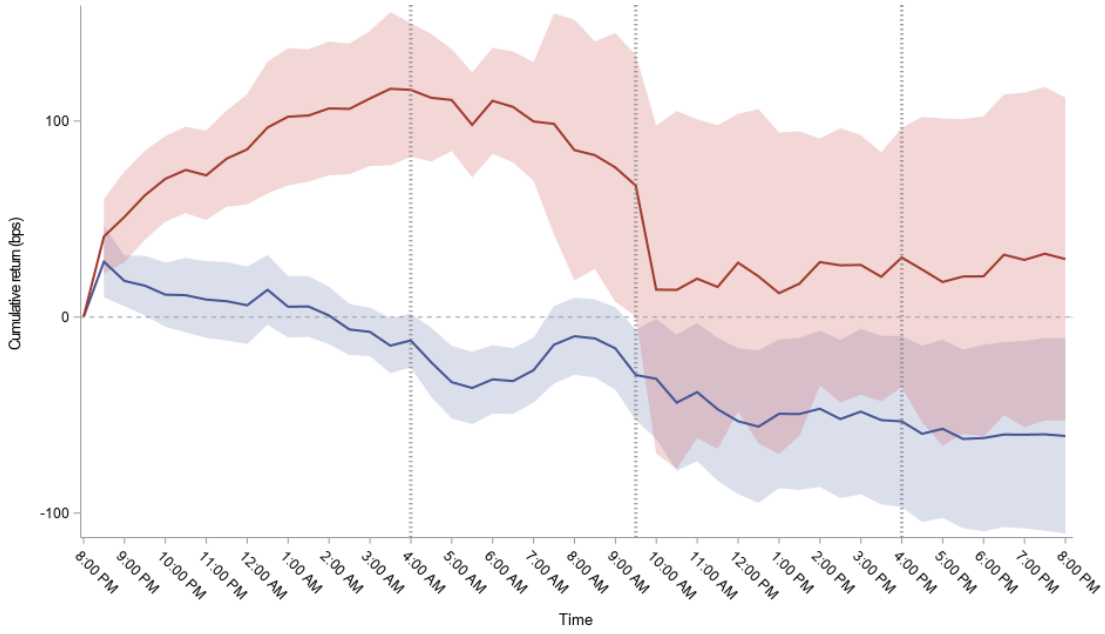
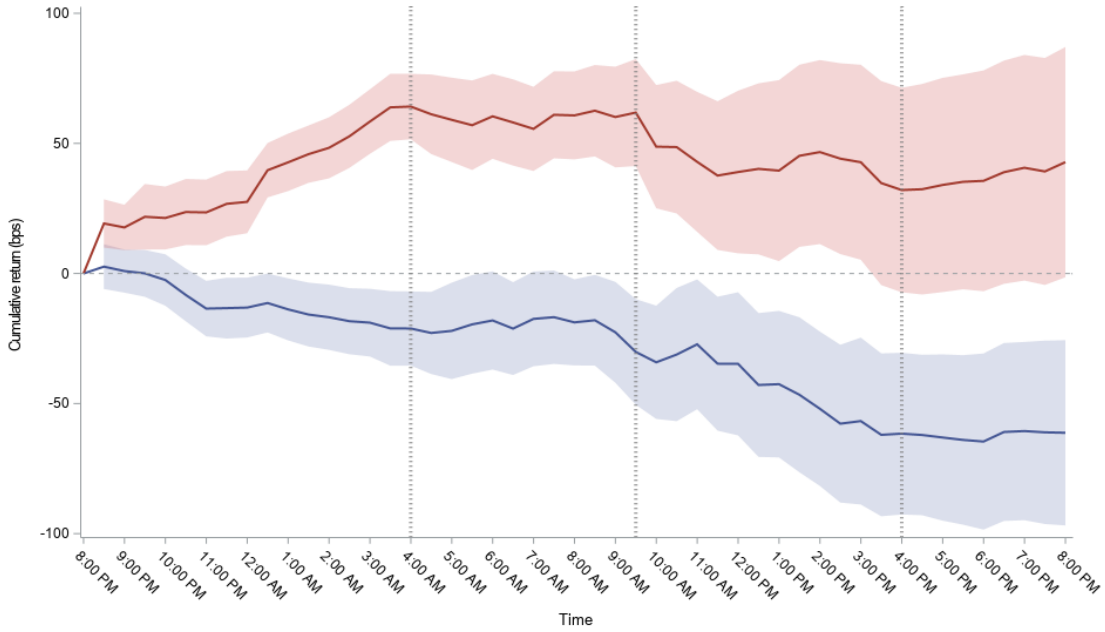


Figure 5. 24-hour Returns

The figure plots the 24-hour evolution of cumulative midquote returns together with the corresponding confidence intervals. The sample is partitioned by the sign of nocturnal order imbalance (*noimb*), allowing comparison of return dynamics following positive versus negative overnight pressure.



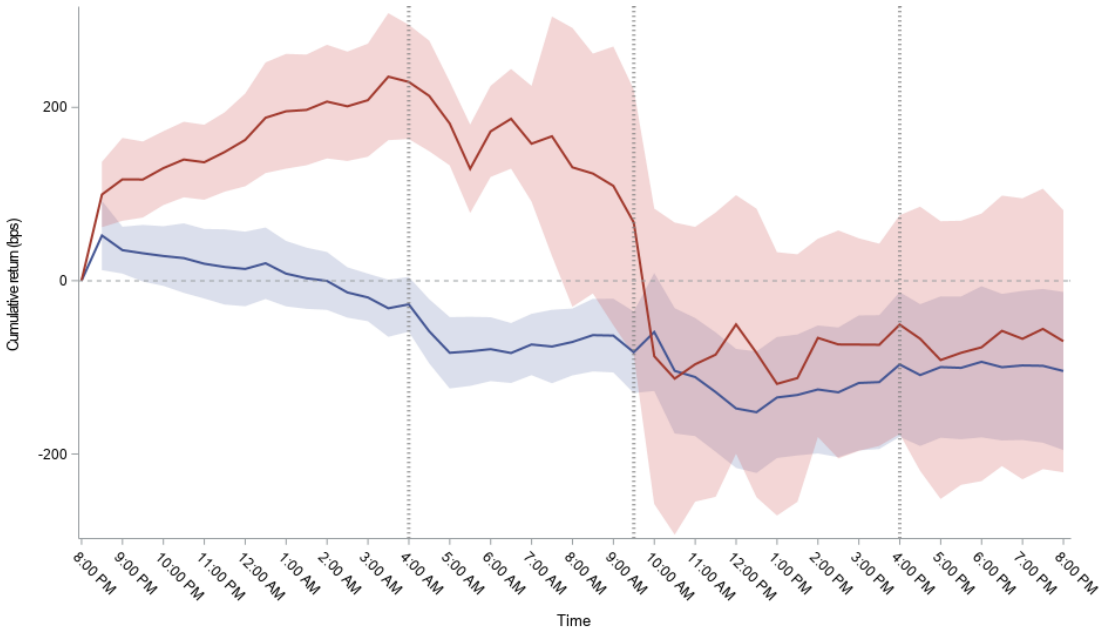
Panel A: Common stocks



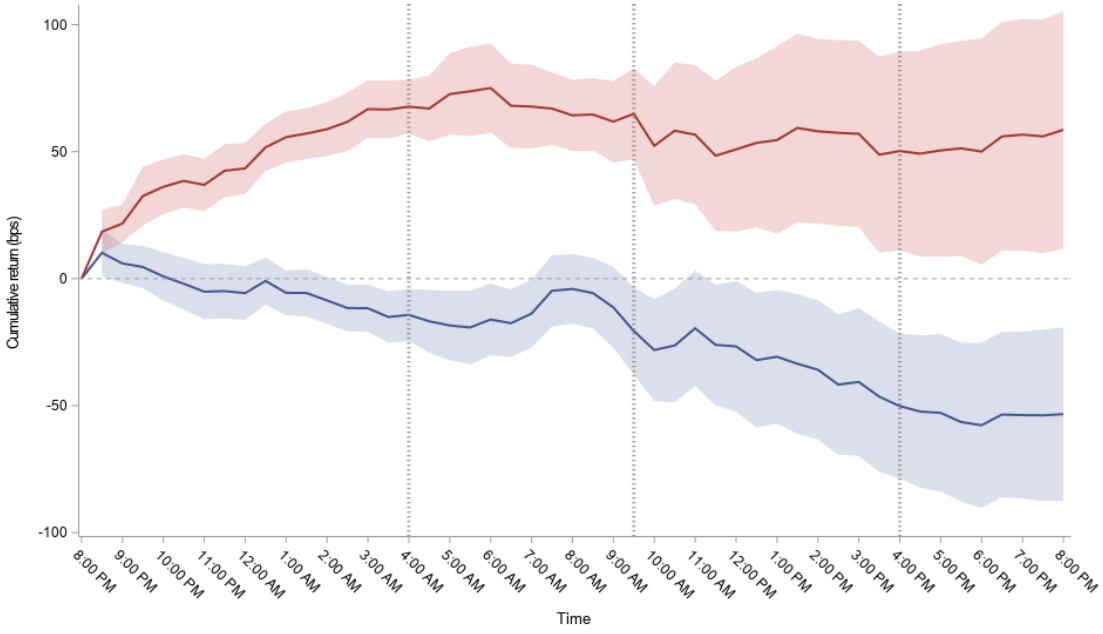
Panel B: ETFs

Figure 6. 24-hour Returns, Common Stocks v. ETFs

The figure plots the 24-hour evolution of cumulative midquote returns, together with the corresponding confidence intervals. The sample is partitioned by the sign of nocturnal order imbalance (*noimb*), allowing comparison of return dynamics following positive versus negative overnight order pressure. Panel A presents common stocks, and Panel B presents ETFs.



Panel A: Retail favorites



Panel B: Others

Figure 7. 24-hour Returns, Retail Favorites and Others

The figure plots the 24-hour evolution of cumulative midquote returns, together with the corresponding confidence intervals. The sample is partitioned by the sign of nocturnal order imbalance (*noimb*) to compare return dynamics following positive versus negative overnight order pressure. Panel A reports results for stocks classified as retail favorites, while Panel B reports results for the remaining stocks and ETFs. Retail favorites are identified based on media coverage during January through May 2024.

Internet Appendix to "Nocturnal Trading"

Gregory W. Eaton, Andriy Shkilko, Ingrid M. Werner

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Internet Appendix to "Nocturnal Trading"

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IA1 Extended Discussion of Institutional Details

This section provides further discussions of the institutional details of nocturnal trading. The New York Stock Exchange (NYSE) introduced after-hours trading in June 1991 by extending trading hours by an hour in response to overseas competition, and the after-hours trading period has gradually been extended to cover the period 4 p.m. to 8 p.m. In 1999, Nasdaq moved its opening hour to 7 a.m. The NYSE, facing increased competition, countered in 2005 by allowing traders to start at 4 am. Nasdaq did the same in 2013. However, it was not until 2018 that the concept of nocturnal trading for retail investors was introduced to the U.S. public when TD Ameritrade promoted "All Night Long" trading with a February 4, 2018, Superbowl ad featuring Lionel Richie.[9] Hence, nocturnal trading actually dates back to at least early 2018.

IA1.1 Blue Ocean ATS (BOATS)

tZERO Group was founded in 2014 with the goal of utilizing blockchain technology and is a portfolio company of Medici Ventures, a subsidiary of Overstock.com. tZERO Group provided broker-dealer services through broker-dealer subsidiaries PRO Securities, LLC, and SpeedRoute, LLC. Starting as early as 2014, tZERO Group's subsidiary PRO Securities, LLC, operated an ATS for trading NMS securities pursuant to a Form ATS. By December 2014, tZERO Group and its affiliated broker-dealer had an arrangement with an unregistered Singaporean firm Blue Ocean Financial Technology, Pte. Ltd. to facilitate trading in certain NMS stocks and ETFs after U.S. markets had closed.[10]

[9] https://bit.ly/3PI086E
[10] https://bit.ly/4h2udK8

In early 2017, tZERO Group (t0.com) formed Blue Ocean Technologies, LLC after acquiring the assets of Blue Ocean Financial Technology, Pte. Ltd. According to the January 12, 2017 press release:[11]

The newly-formed Blue Ocean Technologies will offer the first transparent, electronic marketplace for trading U.S.-listed securities during non-U.S. trading hours. This electronic marketplace creates a new opportunity for firms, traders, and investors to manage risk and take advantage of opportunities created outside of U.S. regular trading hours. Also, foreign investors will have after-hours access to the full capabilities of the U.S. capital markets, which make up the second largest class of investments across Asia and Europe (behind country-specific home markets), while allowing for U.S.-based traders to track off-hours market movement and react accordingly.

"Blue Ocean Technologies will provide investors in the rapidly growing Asian region with an avenue to execute U.S. equities during their usual business hours," said t0 President Joe Cammarata. "This concept is the first of its kind, and has already attracted the attention of several large market-making clients to provide daily liquidity within our platform."

PRO Securities operated an ATS for NMS securities that reported to the FINRA ATS transparency data as early as the week of February 19, 2018. Starting in October 2019, once its initial Form ATS-N became effective, tZERO LLC, took over the operations of PRO Securities ATS and continued reporting under the same MMID, PROS. tZERO ATS subscribers/sponsored access clients could submit orders to the ATS beginning at 6:15 p.m. on the days of operation of the ATS. Matching in NMS Stocks on the ATS occurred from 8 p.m. to 4 a.m. the following day if the TRF was open for trade reporting on that following day. The tZERO ATS for NMS securities ceased operations in June 2021, but continues operations in OTC securities.

Blue Ocean Technologies established another subsidiary, Blue Ocean ATS, LLC, (BOATS) with the intent to become a broker dealer and to operate an ATS in 2019. Blue Ocean ATS,

[11] https://bit.ly/40lBY6Y

LLC, became a FINRA member/broker-dealer in 2020, and the platform went live for trading U.S. NMS securities in June of 2021, with an official launch on October 5, 2021.[12] At this point, BOATS started reporting under MMID BLUE, and took over the business of nocturnal trading in NMS securities from tZERO ATS.[13]

BOATS' core offering is the Blue Ocean Session, which operates overnight in the U.S. from 8 p.m. to 4 a.m. (Sunday-Thursday). It operates only on those calendar days when the NYSE Trade Reporting Facility (TRF) is open for reporting the following morning. Trades executed between 8 p.m. and 12 a.m. carry a trade date of the following trade day. The settlement date reflects the first business day following the transaction (T+1). The platform is available to U.S. broker dealers registered with the SEC and a member of at least one U.S. self-regulatory organization (SRO). It operates as an electronic limit order book with price and time priority. The platform only accepts limit day (session) orders, does not accept fractional share orders, and does not accept orders in excess of $5 million. All orders on the ATS order book are canceled at the end the trading session. The only time-in-force instruction accepted by the ATS is DAY. BOATS does not route orders out.

BOATS uses a 20% price band during its trading session. Orders entered into the ATS at the open and during the trading session that are priced at more than 20% away from the reference price for that NMS Stock are rejected. The reference price is the last sale price for each security printed on a national securities exchange as of 7:30 p.m. In addition to the 20% band, BOATS also employs single order share size and notional value checks on each order.

BOATS charges subscribers a per-executed-share fee based on the following schedule:[14]

1. Early Adopters (Subscribers who were ATS participants as of its first operating session):

    (a) For adding liquidity, there is a rebate of $.0006

[12] https://bit.ly/4g7begi and https://bit.ly/4arRMd2
[13] Based on FINRA ATS Transparency data, tZERO LLC ATS continues trading OTC securities.
[14] https://bit.ly/4hmKg5f

(b) For taking liquidity, the charge is $.0014 - $.0015

2. Standard Pricing:

   (a) For adding liquidity, there is a rebate of $.0006

   (b) For taking liquidity, the charge is $.0020

3. For stocks below $1.00:

   (a) There is no rebate for adding liquidity

   (b) The fee for taking liquidity is $.0030 per dollar of volume (i.e., 0.0030%, thirty basis points).

BOATS subscribers can obtain full depth-of-book access directly from BOATS or from third-party distributors. BOATS charges subscribers and sponsored access clients for market data. Depending on setup costs, recurring fees, and technology integration costs, BOATS incurs costs to fully integrate its direct market data feed into the third-party distributors platform. BOATS charges $12,500 for the third-party distributors and charges $5,000 for receiving market data directly from BOATS (i.e., subscribers and sponsored access clients). As of March 13, 2023, ICE provides access to the BOATS real-time equity data feed.[15]

As illustrated in Figure **??**, many of the major U.S. retail brokers offer nocturnal trading, though the securities offered and how they were phased in varies across brokers (Figure IA1.1). BOATS' first U.S. retail broker client was TD Ameritrade that started offering nocturnal trading in 12 exchange traded funds on its Thinkorswim platform on January 22, 2018.[16] U.S. broker E*Trade announced nocturnal trading in the same 12 exchange traded funds on February 20, 2018.[17] Nocturnal trading by U.S. retail clients was slow to take off (Figure 1), and it was not

[15] https://bit.ly/3PEF1SL
[16] https://bwnews.pr/42lH4Td
[17] https://bwnews.pr/42jQ4YU

until May 11, 2023 that the next major U.S. retail broker, Robinhood, announced it was starting nocturnal trading in 43 symbols (ETFs and individual names) for active traders, with plans to gradually expand access to all users by June, 2023.[18] On July 25, 2023, Interactive Brokers announced that they have partnered with BOATS for supplemental liquidity.[19] U.S. retail broker TradeUP started offering nocturnal trading to its U.S. clients on June 25, 2024.

More recently, Schwab said on October 30, 2024, it plans a slow roll-out of nocturnal trading starting with its most active traders and a limited list of 24 ETFs. The rollout is expected to be completed midway through the first quarter of 2025, when clients will have access to nocturnal trading in all stocks listed on the Dow Jones Industrial Average, the Standard & Poor's 500 Index, the Nasdaq 100 Index, and hundreds of ETFs.[20] Finally, Webull announced the launch of nocturnal trading, powered by BOATS on November 12, 2024.

A major target audience for the nocturnal Blue Ocean session is retail investors in the Asia-Pacific region that want to trade U.S. securities during Asian business hours, and BOATS has gradually built this clientele through strategic partnerships. BOATS announced a strategic partnership with a Korean brokerage firm Samsung Securities to offer U.S. equity trading during local Asia-Pacific business hours on February 8, 2022.[21] And by now, at least 18 Korean retail brokers, e.g., Kiwoom Securities, Korea Investment & Securities, Mirae Asset Securities, and NH Investment & Securities, offer trading of U.S. stocks on BOATS during Asian business hours. A partnership between BOATS and Hong Kong based Futu Clearing Inc. to provide Futubull clients real-time trading of U.S. equities was announced on February 14, 2023.[22] BOATS and the Tokyo Stock Exchange (TSE) announced a strategic partnership on August 7, 2023.[23] In 2024, additional partnerships were announced, e.g., with the global broker GTN to launch extended trading

[18] https://on.wsj.com/3PGYxOl
[19] https://bit.ly/4apAoW8
[20] https://reut.rs/3PDETmu
[21] https://bit.ly/4anAKwo
[22] https://bit.ly/4h0sapY
[23] https://bit.ly/3E2Vyxa

hours trading for U.S. stocks from clients in the Asia-Pacific and Middle East markets, and the U.S. broker TradeUP started offering nocturnal trading through its overseas affiliate, Tiger Brokers, to its clients throughout the Asia-Pacific region (Auckland, Beijing, Singapore, and Sydney).

Several institutional agency brokers are also partnering with BOATS, including Cantor Fitzgerald, Clear Street, Eugene Investment & Securities (South Korea, retail and institutional), Instinet, Velocity Clearing, and Vision Financial Markets (active traders, retail and institutional). These are not just providing sponsored access, but also using BOATS to execute block trades according to BOATS leadership.

IA1.2 Retail Brokers

As discussed above, there are now at least six U.S. retail brokers that allow clients to trade in the nocturnal period. These include E*Trade, Interactive Brokers, Robinhood, Schwab (TD Ameritrade), TradeUP, and Webull. The current offerings differ slightly. Interactive Brokers has the broadest security coverage offering trading in all NMS securities, E*Trade, Robinhood, and Schwab offer nocturnal trading for select but growing list of securities, and so far Fidelity does not offer nocturnal trading at all.

Figure IA1.1 illustrates the U.S. retail broker phase-in of securities for which nocturnal trading is allowed. In 2018, the list comprised 12 liquid ETFs, and this list was augmented to 24 liquid ETFs by TD Ameritrade and E*Trade in 2019. Interactive Brokers adopted the same list when they launched their IBEOS ATS in 2022. Nocturnal trading for select mega-cap stocks did not begin until May 2023, and it was initially limited to Robinhood clients. Robinhood rapidly expanded its offerings to roughly 900 securities, and Interactive Brokers went even further when they announced nocturnal trading for 10,000 NMS securities just two months later. Meanwhile, both E*Trade and TD Ameritrade (now part of Schwab) maintained their original lists, although Schwab announced in October 2024 that it will expand its offerings to cover index stocks and

additional liquid ETFs.

[Figure IA1.1]

BOATS has announced large partnerships with several foreign brokers, including Samsung, Futubull, GTN, and Tiger Brokers. However, many more foreign brokers can be accessing BOATS through a U.S. registered sponsoring broker. It is unclear which U.S. NMS securities Asian brokers allow their retail investors to trade on the BOATS and IBEOS platforms, but it appears to have been a significantly broader list than the one offered by U.S. brokers. When Samsung Securities starts offering trading on BOATS in February 2022, the number of securities traded on the platform increases from 31 to 524. However, trading remains highly concentrated in a few popular symbols, with the number of actively traded symbols far lower than the total number of NMS securities. Additionally, Asia-focused leveraged ETFs are particularly popular. For example, trading activity for two Direxion Daily FTSE China 50 Index (3X) Leveraged ETFs – YINN (Bull) and YANG (Bear) – both exceeded the 5% of consolidated volume in December 2024, forcing BOATS to disable trading for these symbols for the month of January 2025, because of the SEC Regulation ATS' Fair Access Rules.[24] In practice, BOATS peaked at 4,222 unique symbols traded the week of July 15, 2024, while IBEOS peaked at 1,220 unique symbols traded the week of November 4, 2024 (the week of the U.S. Presidential election) based on weekly FINRA ATS Transparency data.

Most U.S. retail brokers charge zero commissions, and this applies also for nocturnal trading at E*Trade, Robinhood, Schwab (TD Ameritrade), TradeUP, and Webull. Thus, these retail brokers have to cover the BOATS trading fees some other way (see next subsection). Interactive Brokers offer nocturnal trading to its IBKR PRO Clients who pay commissions either at a tiered or a fixed rate. In addition to commissions per share, IBKR Pro-Tiered clients pay exchange fees and thus pay the BOATS and IBEOS fees for nocturnal trading. By contrast, IBKR Pro-Fixed

[24] https://bit.ly/4h6FGZ9

clients do not pay exchange fees, and thus the regular commission of $0.005 per share has to cover the BOATS/IBEOS fees.[25]

We do not have detailed information on commissions for trading U.S. securities through retail brokers in the Asia-Pacific region, but it appears to be a mix of zero commissions and commissions and platform fees charged. Tiger Brokers Singapore charges a commission of $0.005 per share and a platform fee of $0.005 per share (presumably to cover the BOATS fees).[26] By contrast, Webull Singapore charges zero commissions also for trading U.S. securities on BOATS. In Hong Kong, Futubull charges commissions for trading U.S. securities, but Webull Hong Kong does not. As expected, Interactive Brokers' Asia-Pacific affiliates charge commissions for trading U.S. securities during Asian business hours. South Korean retail brokers like Kiwoon, Mirae, and Samsung charged commissions for retail trading in U.S. securities in 2022. However, a virtual marketing war broke out in South Korea in the summer of 2023 as brokers tried to court retail investors that were trading U.S. securities by offering commissions discounts (until year-end) and other incentives.[27]

IA1.3 Liquidity Providers

BOATS and IBEOS both invite professional liquidity providers to their platforms. Virtu Financial and Jane Street are explicitly mentioned as partners on BOATS' website (https://blueocean-tech.io/), and the role of liquidity providers is frequently mentioned by BOATS representatives as being crucial for the success of the platform.[28] IBEOS Form ATS-N states "Only market-makers and other principal trading firms willing to provide significant liquidity to IBKR's customers may, subject to the approval of IBKR management, access the ATS as Liquidity Providers." Hence, OTC market makers (wholesalers) such as Virtu and Jane Street are likely

[25] https://bit.ly/3Cf4W06
[26] https://bit.ly/4hoAHTx
[27] https://bit.ly/4jjGlIf
[28] https://bit.ly/4apFMIQ

active liquidity providers on both these platforms. It is our understanding that other major OTC market makers such as Citadel have so far elected not to participate in nocturnal trading.

In addition, OTC market makers act as executing brokers for zero commission U.S. retail brokers such as Robinhood and Webull. Therefore, these brokers do not route to BOATS and IBEOS directly, instead relying on wholesalers to either execute the nocturnal orders on a principal basis or route them to the BOATS platform. For example, Robinhood's customer agreement states:[29]

If Robinhood 24 Hour Market trading is available to you and you enter a limit order that is eligible for execution during the Robinhood 24 Hour Market, you understand that [...] (5) Robinhood will route such orders to a market center (a "24H Market Maker"), which may execute the order on a principal basis or route the order for execution to another market center; (6) between 8 p.m. and 4 a.m. ET ("Overnight Hours"), Robinhood will route such orders to a single 24H Market Maker, which may execute the order on a principal basis or route the order for execution to a single alternative trading system (the "24H ATS"); (7) the 24H ATS is not required to display prices publicly and may have very limited liquidity and/or high volatility; (8) such an order may not be price protected and so may be executed by a market center at a price that is worse than prices available at other execution venues; (9) if the order is unexecuted as of the beginning of, or shortly before, the next Overnight Hours session, the order will be canceled and, subject to the order's time-in-force instructions, re-routed to a single 24H Market Maker, which may execute the order on a principal basis or route the order for execution to the 24H ATS; (10) if the order is unexecuted as of the end of, or shortly before the end of, the Overnight Hours session, the order will be canceled and, subject to the order's time-in- force instructions, re-routed to a 24H Market Maker, which may execute the order on a principal basis or route the order for execution to another market center; and (11) if the order is canceled and re-routed as described in (9) or (10) above, the order will not be eligible for execution during the period of time between the cancellation of the order and its re-routing.

[29] https://bit.ly/3PJfI1Y

Similarly, Webull states in their Extended Hour Trading Disclosure:[30]

Webull's extended hours trading offering allows you to place limit orders outside of regular trading hours. These orders are sent to a market maker, who may fill the order directly or pass it to another trading venue. During overnight hours (8 p.m. to 4 a.m. ET) ("overnight trading"), Webull works with a single market maker who may execute orders themselves or send them to an alternative trading system (ATS). This ATS doesn't publicly display prices and may have low liquidity and high price volatility. Webull may decide to add or remove market makers or modify this order processing.

It is unclear whether OTC market makers pay for nocturnal order flow. However, given that retail brokers charge zero commissions and have no other revenue sources for these orders, it is likely that they do.

[30] https://bit.ly/4h1lyaH

TD Ameritrade January 22, 2018 (PROS)

FXI, SPY, EEM, GLD, SLV, DIA, UNG, TLT, IWM, QQQ, USO and SH.

E*Trade February 20, 2018 (PROS)

FXI, SPY, EEM, GLD, SLV, DIA, UNG, TLT, IWM, QQQ, USO and SH.

TD Ameritrade April 9, 2019 (PROS)

FXI, SPY, EEM, GLD, SLV, DIA, UNG, TLT, IWM, QQQ, USO, SH,
RWM, PSQ, AGG, DOG, EWA, EFA, EWJ, IJH, VTI, XLF, XLE, and XLK

E*Trade Summer, 2019 (PROS)

FXI, SPY, EEM, GLD, SLV, DIA, UNG, TLT, IWM, QQQ, USO, SH,
RWM, PSQ, AGG, DOG, EWA, EFA, EWJ, IJH, VTI, XLF, XLE, and XLK

BOATS launch June 14, 2021

Interactive Brokers October 22/November 21, 2021 (IBEOS)

FXI, SPY, EEM, GLD, SLV, DIA, UNG, TLT, IWM, QQQ, USO, SH,
RWM, PSQ, AGG, DOG, EWA, EFA, EWJ, IJH, VTI, XLF, XLE, and XLK.

Robinhood May 11, 2023 (BOATS)

FXI, SPY, EEM, GLD, SLV, DIA, UNG, TLT, IWM, QQQ, USO, SH,
RWM, PSQ, AGG, DOG, EWA, EFA, EWJ, IJH, VTI, XLF, XLE, and XLK

AAPL, MSFT, GOOGL, AMZN, NVDA, TSLA, META, DIS, F, AMD,
NIO, RIVN, COIN, TQQQ, LCID, CVNA, SOXL, SQQQ, SOXS,

Expanded to over 900 securities.

Interactive Brokers July 25, 2023 (IBEOS and BOATS)

All NMS stocks 10,000 symbols

Schwab October 30, 2024 (BOATS)

FXI, SPY, EEM, GLD, SLV, DIA, UNG, TLT, IWM, QQQ, USO, SH,
RWM, PSQ, AGG, DOG, EWA, EFA, EWJ, IJH, VTI, XLF, XLE, and XLK.

Planned roll-out: Constituents of Dow Jones Industrial Average, the Standard & Poor's 500 Index, and the Nasdaq 100 Index, plus hundreds of ETFs.

Figure IA1.1. List of Nocturnal Securities for U.S. Retail Brokers
Source: Web search for announcements.

IA2 Growth in Nocturnal Trading

Using FINRA ATS Transparency Data, Figure IA2.1 shows trading activity on the BOATS platform weekly since its inception in June 2021. The top panel illustrates the number of unique symbols traded on the platform, and the bottom panel reports share volume. The vertical lines indicate when large brokers started using BOATS. From left to right: Samsung Securities (South Korea), Futubull (China/Hong Kong), Robinhood (U.S. retail), and Interactive Brokers (U.S. advanced retail). The final vertical line indicates the week when the BOATS service was interrupted. Nocturnal trading volume on BOATS substantially increased from 2022 until the service disruption in August of 2024. On August 5, Blue Ocean shut down its system due to high demand from a global market selloff. The platform re-opened for limited trading in 29 ETFs on August 12, and fully resumed trading without restrictions on August 19. BOATS volume did not fully recover by the end of 2024 from pre-service interruption levels, as the association representing Korean brokerages prohibited them from trading on BOATS, citing investor protection concerns. Korean brokers started using BOATS again in November of 2025.

[Figure IA2.1]

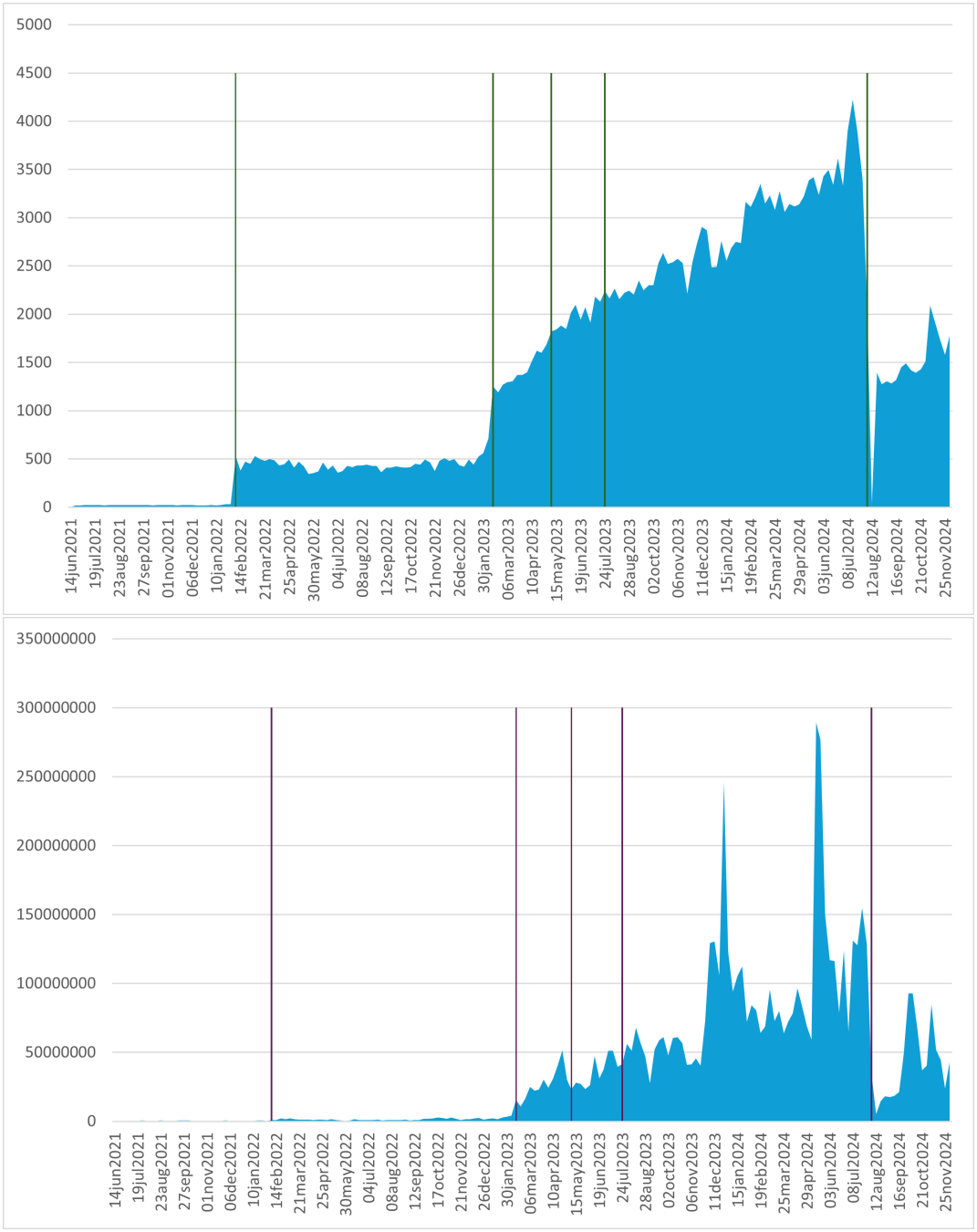

Figure IA2.1. Nocturnal Trading Activity on BOATS

The figure shows trading activity on the BOATS platform weekly since its inception. The top panel illustrates the number of unique symbols traded on the platform and the bottom panel reports share volume. The first vertical line indicates when Samsung Securities started using the platform, the second one when Futubull started using the platform, the third one when Robinhood started using the platform, the fourth one is when Interactive Brokers started using the platform, and the last one is the week when the BOATS service was interrupted. Source: FINRA ATS Transparency Data.