# 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]

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

[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.

(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.

[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..

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 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 noc-

turnal 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, Ghysels, 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.

Continuous nocturnal trading in U.S. equities dates back at least to 2018 via tZERO Group. Initially, tZERO operated through its broker-dealer subsidiary, PRO Securities, before taking over an alternative trading system in 2019 under the Market Maker ID (MMID) PROS. Around the same time, tZERO acquired the assets of Blue Ocean Financial Technology and formed Blue Ocean Technologies, which subsequently established a new subsidiary, Blue Ocean ATS (BOATS), with the goal of operating an overnight trading venue.

BOATS went live for trading U.S. NMS securities in June of 2021 (MMID: BLUE), taking

over the nocturnal trading business from tZERO ATS, which ceased its operations in NMS securities. 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 directly 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 measure trading and quoting activity during extended and regular hours, we use Daily TAQ (DTAQ). In the current regulatory reporting framework, DTAQ reports only the nocturnal trades and quotes that occur between midnight and 4:00 a.m. Activity between 8:00 p.m. and midnight is reported via "as-of/prior-day" messages the next morning, and those records are not included in Daily TAQ. To capture the full nocturnal session, we obtain comprehensive BOATS trade and quote data directly from the Intercontinental Exchange (ICE), which distributes these data as a separate product.[5] 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. 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

[5]ICE trade and quote data are at the nanosecond frequency, and the quotes reflect odd lots. Although we do not observe the extent to which nocturnal round-lot quotes differ from odd-lot quotes, Bartlett, McCrary, and O'Hara (2023) report that, during regular trading hours, round-lot (SIP) quotes are 24% wider than odd-lot quotes.

(see the Internet Appendix for more details). According to weekly FINRA ATS Transparency data, 6,495 unique symbols trade on BOATS during this period. As shown in Figure 2, trading activity is highly uneven: 942 symbols (14.5%) trade in only one week, and the majority trade in fewer than eight of the 22 weeks. Moreover, eight percent of symbol-week observations consist of a single trade for a single share. At the same time, a meaningful subset of symbols trade regularly, with 1,112 symbols (17.1%) trading in every week of the sample, though not necessarily every day.[6] For comparison, among the same 6,945 symbols, 85.6% trade every week during the pre-open, 94.0% during regular trading hours, and 83.5% during the after-hours session.

[Figure 2]

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

[6] A total of 1,772 unique symbols trade on IBEOS during the sample period. Of these, 47.0% trade for only one week and 63.3% trade for at most two weeks, while just 49 symbols trade in every week of the sample.

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 Top Ten Securities

To begin discussing nocturnal trading activity, it is useful to focus first on the securities that trade most frequently during the nocturnal session. Table 1 summarizes the top ten symbols traded both overall and by month. Panel A lists the top ten symbols by share volume and shows that nocturnal traders favor 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. They also actively trade 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). Furthermore, nocturnal traders favor leveraged single name ETFs such as Direxion Daily TSLA Bull 2X Shares (TSLL) and T-Rex 2x Long Tesla Daily Target ETF (TSLT), and single stocks focusing on electric vehicles (NIO and FFIE), AI (SOUN), and crypto (COIN). While many symbols appear consistently in the top ten by share volume, there is quite a bit of variation across the months suggesting that individual securities experience bursts of trading activity possibly related to news (LUNR, MARA, IBIT, LICY, and NKLA). In May 2024, we even see the meme stock GameStop (GME) appearing as number three in terms of share volume.

[Table 1]

Panel B repeats the analysis based on dollar volume and includes many more single name securities such as Nvidia (NVDA), Tesla (TSLA), Microsoft (MSFT), and Apple (AAPL). Dollar volumes are significant in the top ten symbols: almost $6 billion for Nvidia and more than $3 billion for Tesla over our five-month sample period. The difference between symbols comparing

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. 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. Across the months, other semiconductor- and technology-related stocks appear intermittently (AMD, META, MSTR, SMCI, and TSM), and in May the meme stock GameStop (GME) also emerges among the top ten.

We briefly explore patterns of nocturnal trading activity by day of the week and time of day in Figures 3 and 4, 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 3 shows that dollar volume is close to evenly distributed throughout the week.

[Figures 3 and 4 ]

In terms of time of night, Figure 4 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.

## 3.2 Concentration

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 representative of the universe of securities that are traded on Blue Ocean. Figure 5 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 5]

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.

## 3.3 Transition Matrices

Having documented the degree of concentration across sub-periods of the 24-hour trading day, we next examine whether the same stocks trade consistently on Blue Ocean over time. Table 1 has provided some indication that the composition of the top ten symbols varies across months. Another approach to this question is to examine the stability of trading activity on Blue Ocean over time. Figure 6 reports transition matrices for all securities traded on Blue Ocean, grouped into dollar-volume deciles. The top panel reports transitions from one night to the next, while the

bottom panel shows transitions from one week to the next. If trading activity is stable, such that a security tends to remain in the same decile over time, we would expect the transition matrix to exhibit mass concentrated along the diagonal, with relatively little off-diagonal movement.

[Figure 6]

While securities do transition across deciles over time, predominantly between adjacent categories, trading activity exhibits substantial persistence among the most actively traded securities. In particular, the highest volume decile shows pronounced stability both on a night-to-night basis (0.71) and from week to week (0.73). More moderate persistence is also observed in the second-highest decile (0.39 night to night and 0.45 week to week) and the third-highest decile (0.27 and 0.32, respectively). In contrast, securities with lower trading activity experience significantly greater mobility across dollar-volume deciles.

We repeat this analysis in Figure 7 by comparing nocturnal trading with subsequent trading activity in the same-day pre-open and regular sessions to assess whether nocturnal traders concentrate on the same securities as traders in later periods. There is substantial overlap at the top of the distribution; securities in the highest nocturnal dollar-volume decile remain in the top decile with probability 0.60 during the pre-open and 0.45 during regular trading hours. As one moves down the nocturnal dollar-volume deciles, the degree of overlap with subsequent trading activity rankings declines markedly.

[Figure 7]

In summary, while retail investors trading nocturnally tend to concentrate on largely the same securities across consecutive days and weeks, their trading preferences appear to differ somewhat from those of market participants active outside the nocturnal session. This pattern is consistent with prior evidence showing that retail investors' stock selection preferences systematically differ from those of institutional investors (e.g., Barber and Odean (2008), Laarits and Sammon (2025)).

# 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 dollar-volume weighted across firms within each day and then averaged across trading days. For the frequently traded (FT) sample, the nocturnal period exhibits substantial trading and quoting activity. There are 20,649 (2,581) quote updates per night (hour) with an average time-weighted quoted depth of 1,520 shares. Average trade size is 77 shares and there are 6,869 (859) trades per night (hour) on average for a quote-to-trade ratio of 3.01. The average nocturnal price is $252.85, which means that the average trade is for $19,442. Stocks in the LFT sample have a lower price on average ($80.14), and it is therefore not surprising that the quoted depth at 2,523 shares is greater than for the FT sample. Quoting activity for these stocks is quite high with 13,604 (1,700) quote updates per night (hour) resulting in a quote-to-trade ratio of 3.94. Average trade size is 144 shares, which

translates into an average trade size in dollars of $11,579.

[Table 2]

Next, we summarize nocturnal market quality for our two sub-samples in Table 3. Measures are again value-weighted across stocks and then averaged across days. For the frequently traded stocks, which we saw in Figure 5 make up the vast majority of BOATS volume, quoted and effective spread are not too large, at 8.06 and 9.18 basis points, respectively. As expected, the spreads are wider for the LFT sample at 37.37 bps for quoted and 40.98 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 1.14 for the FT sample and 1.10 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. Although wholesalers such as Virtu and Jane Street are active on BOATS, they do not provide the price improvement typically observed during regular trading hours. 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 sub-samples, the Hagströmer effective spreads are larger than the traditional effective spreads, showing 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

one-third of the effective spread. The price impact continues increasing, resulting in a negative realized spread of -1.27 basis points at the 5-minute horizon. The evidence for the LFT sample is similar, but the larger effective spreads leave more room for the price impact, resulting in positive albeit declining realized spreads out to 5 minutes. 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, 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. Hagströmer realized spreads are also uniformly larger because Hagströmer effective spreads are sufficiently wider than conventional effective spreads.

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

A natural question is how nocturnal trading compares to regular and extended hours. To shed light on this issue, 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.

Prior research documents that pre-open and after-hours trading sessions are characterized by a small number of relatively large trades. For example, Jiang, Likitapiwat, and McInish (2012) study S&P 500 stocks during 2004-2008 and document on average 267 (194) quotes, 44 (20) trades, and an average trade size of $304,069 ($574,681) during pre-open (after-hours). Barclay and Hendershott (2003, 2004) document similar findings for the largest Nasdaq stocks in 2000. These patterns still hold during the after-hours session based on more recent data. Cui, Gozluklu, and Haykir (2024) rely on data for S&P 1500 stocks from 2004-2022 to calculate value-weighted average trading activity and find 153 trades on average and dollar average trade size of $177,931 during the after-hours period. The activity has risen over time based on their data, but trading activity after-hours is modest with roughly 190 trades on a given day even at the end of their sample period. Similarly, Gregoire and Martineau (2022) study data for S&P 1500 stocks from 2011-2015 and 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). Trading in S&P 400 (Mid Caps) and S&P 600 (Small Caps) is even more sparse based on their data. After-hours trades are larger 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?

The results for continuous trading during each sub-period of the 24-hour trading cycle are in Table 4. We repeat some of the results for the nocturnal period for convenience. Despite its rapid growth, nocturnal quoting and trading activity is still relatively modest. Between 7 and 8 million shares trade a 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%.

Pre-open and after-hours each comprise about a 2 to 3% share of daily volume.[7] We also 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 11,134 and 7,332 respectively. Similarly, the average number of quotes and trades in the after-hours period are 6,209 and 5,984 on average. Trading and quoting activity during nocturnal and extended hours still however pales in comparison to regular hours trading, with on average 143,701 quotes and 75,941 trades per hour.

[Table 4]

Table 4 also shows that nocturnal traders favor lower price stocks ($253) compared to traders that are active during other periods of the day ($309 to $365 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 (583). Finally, the quote-to-trade ratio is actually highest for the nocturnal period at 3.01, followed by the regular trading hours at 1.89 and pre-open at 1.52. Quoting activity relative to trades is much lower for the after-hours period (1.04). It is worth mentioning that we only observe best quote updates, and we do not observe new orders further down the book.

Prior research has 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 value-weighted quoted and effective spreads of 162.6 and 71.2 bps

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

during after hours compared to 4.9 and 5.1 bps during regular trading hours. They find that five-minute price impacts are larger during after-hours (5.6 compared to 3.2 bps), but the difference is not nearly large enough to wipe out the differences in effective spreads. As a result, after-hours realized spreads in their data are much larger at 54.5 bps compared to realized spreads of 1.9 bps during regular trading hours.

This evidence raises the concern that market quality during the nocturnal period may be substantially worse than during regular trading hours, given the relatively thin trading activity and limited competition among professional liquidity providers. It also raises the question of whether market quality during extended trading hours has improved relative to regular trading hours, as off-hours trading activity is now considerably greater than in the sample periods studied in earlier work.

Table 5 summarizes our findings. Panels A and B show the results for the conventional market quality measures that reference the algebraic midquote. Panel A reveals that quoted spreads are a little more than two times wider during the nocturnal period (8.06 bps) than during regular trading hours (3.38 bps), but they are in line with quoted spreads during the pre-open (8.28) and after-hours period (7.34). E/Q ratios are larger than one for three out of the four sub-periods, including regular hours trading. In fact, the ratios are remarkably similar for the nocturnal and regular trading periods. This shows that large orders also walk the book during regular trading hours, creating slippage. The E/Q ratio is less than one (0.90) for the pre-open period, suggesting that hidden and reserve orders, as well as odd-lot limit orders are prevalent during the pre-open. The E/Q ratio is particularly large (1.73) for the after-hours trading period, as a result of the large trades we see coupled with lower depth documented earlier in Table 4.

[Table 5]

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 (0.16) suggesting that nocturnal traders tend to herd. They are even larger for the after-hours period (0.29), which, coupled with the large trade sizes from Table 4 and the relatively low price impacts 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 mid-quote volatility is actually lowest for the nocturnal session (1.16) followed by after-hours trading (1.23), suggesting relatively smooth adjustment of quotes to trading activity. By contrast, mid-quote volatility is nearly twice as high for regular trading hours (2.24).

We consider price impacts and realized spreads at different horizons in Panel B. Nocturnal trade price impacts are on par with pre-open price impacts at the 5-second horizon, but are much larger than price impacts from the other periods at longer horizons. The nocturnal period is also the only period with negative realized spreads, as they turn negative at the 5-minute horizon (-1.27 bps). For all other periods, the effective spreads are wide enough to cover the adverse selection cost all the way out to the 5-minute horizon, resulting in positive realized spreads throughout. These are particularly large for the after-hours period (7.94 bps at the 5-minute horizon), but meaningful also for the pre-open (1.43) and regular (2.31) trading periods. 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 the following section.

Table 6 reports regression results for trading cost measures across the different sessions of the 24-hour trading cycle. Each trading cost measure is regressed on indicator variables for the trading cycle 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, but realized spreads at horizons longer than 5 seconds are significantly lower.

[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 signif-

icant 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 hour trading as a control sample and therefore focus on the FT sample since these stocks trade nocturnally every night in our sample. Because the level and volatility of market quality measures across days is significantly higher 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.

Table 7 reports coefficients from difference-in-differences regressions examining market activity (Panel A) and market quality (Panel B). We report the estimated $\beta_1$ 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. $Nocturnal_{it}$ 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 ($\alpha_i$) and day fixed effects ($\gamma_t$). 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 8 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 8]

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 sug-

gests 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 9. 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 8 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 9]

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 10. 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 Automo-

tive 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 10]

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 demanders. 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.

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## Table 1
## What is Traded 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. The sample period in column (1) is January through May 2024, while column (2)-(6) reports results for each month separately. Units are in million shares (dollars).

| All | | Jan | | Feb | | Mar | | Apr | | May | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Symbol | Volume | Symbol | Volume | Symbol | Volume | Symbol | Volume | Symbol | Volume | Symbol | Volume |
| Panel A: Top Ten by Share Volume | | | | | | | | | | | |
| SOXS | 123 | SOXS | 26 | SOXS | 22 | SOXS | 52 | SOXS | 18 | FFIE | 20 |
| SQQQ | 52 | YINN | 11 | LUNR | 12 | SOXL | 11 | SQQQ | 14 | YANG | 12 |
| SOXL | 52 | SOXL | 11 | YINN | 11 | SQQQ | 10 | SOXL | 13 | GME | 11 |
| YINN | 40 | SQQQ | 10 | SOXL | 8 | YINN | 8 | TSLL | 13 | SQQQ | 10 |
| TSLL | 35 | TQQQ | 5 | SOUN | 8 | SOUN | 7 | TQQQ | 8 | SOXL | 9 |
| YANG | 34 | TSLL | 5 | SQQQ | 8 | IBIT | 5 | YANG | 5 | TSLL | 9 |
| TQQQ | 25 | NIO | 5 | YANG | 6 | YANG | 5 | TSLT | 5 | AMC | 8 |
| NIO | 23 | YANG | 4 | NIO | 5 | TSLT | 5 | TSLA | 5 | YINN | 5 |
| FFIE | 20 | TSLA | 3 | MARA | 4 | NIO | 5 | YINN | 5 | NVDL | 5 |
| SOUN | 19 | MARA | 3 | TSLL | 4 | LICY | 5 | NKLA | 4 | SOXS | 5 |
| Panel B: Top Ten by Dollar Volume | | | | | | | | | | | |
| NVDA | 5,847 | TSLA | 726 | NVDA | 1,113 | NVDA | 1,632 | NVDA | 1,101 | NVDA | 1,505 |
| TSLA | 3,087 | NVDA | 497 | TSLA | 530 | TSLA | 620 | TSLA | 792 | TSLA | 419 |
| SOXL | 2,060 | SOXL | 336 | SOXL | 297 | SOXL | 520 | SOXL | 505 | SOXL | 403 |
| TQQQ | 1,444 | TQQQ | 284 | SMCI | 236 | MSTR | 317 | TQQQ | 432 | GME | 400 |
| QQQ | 1,214 | QQQ | 277 | QQQ | 213 | TQQQ | 268 | QQQ | 330 | NVDL | 272 |
| SPY | 964 | MSFT | 215 | TQQQ | 210 | SMCI | 264 | SPY | 263 | TQQQ | 251 |
| MSFT | 863 | AMD | 197 | YINN | 190 | COIN | 243 | SOXS | 190 | AAPL | 206 |
| AAPL | 806 | SPY | 190 | MSFT | 178 | QQQ | 227 | META | 180 | QQQ | 168 |
| YINN | 758 | YINN | 172 | SPY | 167 | NVDL | 200 | TSM | 173 | SPY | 161 |
| COIN | 745 | AAPL | 171 | COIN | 151 | AMD | 196 | MSFT | 170 | YINN | 153 |

## Table 2
## BOATS Quoting and Trading Activity

The table presents summary statistics on quoting and trading activity on Blue Ocean ATS (BOATS) from January 1, 2024 through January 27, 2025, excluding August 2024 due to a service disruption. 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 dollar volume averaged across stocks and then averaged across days.

| | # Quotes | Quoted depth | # Trades | Trade size | Price | Q/T |
|---|---|---|---|---|---|---|
| Frequently traded (FT) | 20,649 | 1,520 | 6,869 | 77 | 252.85 | 3.01 |
| Less frequently traded (LFT) | 13,604 | 2,523 | 3,457 | 144 | 80.14 | 3.94 |

## Table 3
## BOATS Trading Costs

The table presents trading costs on Blue Ocean ATS (BOATS) from January 1, 2024 through January 27, 2025, excluding August 2024 due to a service disruption. 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, dollar volume averaged across stocks, and then averaged across days. The trading costs are percentage measures reported in basis points.

Panel A: Quoted and Effective Spreads

| | Conventional | | Hagströmer |
|---|---|---|---|
| | Quoted spread | Effective spread | Effective spread |
| Frequently traded (FT) | 8.06 | 9.18 | 10.68 |
| Less frequently traded (LFT) | 37.39 | 40.98 | 51.45 |

Panel B: Price Impact and Realized Spread

| | Conventional | | Hagströmer | |
|---|---|---|---|---|
| | Price impact | Realized spread | Price impact | Realized spread |
| Frequently traded (FT), 5 seconds | 3.22 | 5.96 | 4.21 | 6.47 |
| Frequently traded (FT), 60 seconds | 7.36 | 1.82 | 8.67 | 2.01 |
| Frequently traded (FT), 5 minutes | 10.45 | -1.27 | 11.88 | -1.20 |
| Less frequently traded (LFT), 5 seconds | 11.38 | 29.60 | 35.84 | 15.61 |
| Less frequently traded (LFT), 60 seconds | 22.67 | 18.31 | 28.70 | 22.75 |
| Less frequently traded (LFT), 5 minutes | 30.77 | 10.21 | 38.32 | 13.13 |

## Table 4
## Quoting and Trading Activity Across the Trading Day

The table presents summary statistics on quoting and trading activity across the trading day from January 1, 2024 through January 27, 2025, excluding August 2024 due to a service disruption. Results are reported for the 200 stocks in the frequently traded sample. 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 dollar volume averaged across stocks and then averaged across days. 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 | 20,649 | 1,520 | 6,869 | 77 | 252.85 | 3.01 |
| Pre-Open | 61,236 | 2,719 | 40,326 | 98 | 308.77 | 1.52 |
| Regular | 934,059 | 5,213 | 493,620 | 112 | 313.04 | 1.89 |
| After-hours | 24,837 | 1,801 | 23,935 | 583 | 364.72 | 1.04 |

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 | 451.93 | 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 | 20,679.19 | 7.27% | 182.16 | 5.99% | 0.00 | 0.00% |
| After-hours | 7,952.22 | 2.80% | 68.37 | 2.25% | 0.36 | 1.78% |

## 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 from January 1, 2024 through January 27, 2025, excluding August 2024 due to a service disruption. 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 and order imbalances (OIB) defined as the absolute difference in buy and sell share volume, scaled by total share volume. The statistics are volume-weighted within firm-day, dollar volume averaged across stocks, and then averaged across days. Unless specified otherwise, the trading costs are percentage measures reported in basis points.

Panel A: Conventional Spread and Volatility Measures

| | Quoted spread | Effective spread | E/Q | OIB | Midquote vola | Quoted spread ($c) |
|---|---|---|---|---|---|---|
| Nocturnal | 8.06 | 9.18 | 1.14 | 0.16 | 1.16 | 14.46 |
| Pre-open | 8.28 | 7.44 | 0.90 | 0.09 | 1.75 | 26.83 |
| Regular | 3.38 | 4.21 | 1.25 | 0.05 | 2.24 | 13.08 |
| After-hours | 7.34 | 12.72 | 1.73 | 0.29 | 1.23 | 22.99 |

Panel B: Conventional 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 | 3.22 | 5.96 | 7.36 | 1.82 | 10.45 | -1.27 |
| Pre-open | 3.91 | 3.33 | 5.22 | 2.02 | 5.81 | 1.43 |
| Regular | 1.65 | 2.48 | 1.81 | 2.32 | 1.81 | 2.31 |
| After-hours | 2.72 | 9.85 | 3.77 | 8.83 | 4.64 | 7.94 |

## 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 from January 1, 2024 through January 27, 2025, excluding August 2024 due to a service disruption. The key x-variables are dummy variables representing alternative trading periods, where regular trading hours are the excluded group. The alternative y-variables are trading cost measures that 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, price volatility, and average trade price for controls, which are measured for each stock-day-period and lagged by one day. 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 dummy | 3.02*** | 5.51*** | 4.13*** | 7.37*** | -4.07*** | -2.06*** | -0.72*** | 1.57*** | 3.39*** | 5.95*** |
| | (0.12) | (0.14) | (0.16) | (0.30) | (0.26) | (0.36) | (0.18) | (0.31) | (0.15) | (0.28) |
| Pre-open dummy | 4.38*** | 6.97*** | 2.43*** | 5.83*** | -1.55*** | 0.53 | -0.85*** | 1.55*** | 0.38* | 3.07*** |
| | (0.07) | (0.12) | (0.22) | (0.35) | (0.25) | (0.37) | (0.21) | (0.33) | (0.20) | (0.32) |
| After-hours dummy | 4.60*** | 7.37*** | 8.02*** | 11.69*** | 4.52*** | 6.72*** | 5.39*** | 7.97*** | 6.45*** | 9.39*** |
| | (0.13) | (0.17) | (0.51) | (0.57) | (0.55) | (0.60) | (0.51) | (0.55) | (0.50) | (0.55) |
| Lagged Volume | | 0.21*** | | 0.28*** | | 0.16*** | | 0.19*** | | 0.23*** |
| | | (0.01) | | (0.02) | | (0.02) | | (0.02) | | (0.02) |
| Lagged Volatility | | -0.16*** | | -0.24*** | | -0.03 | | -0.14** | | -0.22*** |
| | | (0.04) | | (0.06) | | (0.07) | | (0.06) | | (0.06) |
| Lagged Price | | 0.02** | | 0.01 | | -0.02 | | -0.01 | | -0.00 |
| | | (0.01) | | (0.02) | | (0.02) | | (0.02) | | (0.02) |
| Obs. | 190,124 | 189,324 | 190,124 | 189,324 | 190,124 | 189,324 | 190,124 | 189,324 | 190,124 | 189,324 |
| Within $R^2$ | 0.18 | 0.26 | 0.07 | 0.10 | 0.02 | 0.03 | 0.03 | 0.05 | 0.05 | 0.07 |
| 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 (Panel B). We report the estimated $\beta_1$ from the following specifications:

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

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:

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

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. $Nocturnal_{it}$ is an indicator equal to one for nocturnal period observations and zero for regular trading session observations from the same calendar day. 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 fixed effects ($\alpha_i$) and day fixed effects ($\gamma_t$). 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 | OIB |
|---|---|---|---|---|---|
| Post × Nocturnal | 0.069 | 0.076 | 0.528** | 0.919*** | -0.017 |
| | (0.22) | (0.22) | (0.20) | (0.13) | (0.08) |
| Adj. $R^2$ | 0.305 | 0.219 | 0.184 | 0.094 | 0.087 |

Panel B: Market quality

| | Spread | | Price impact | | | Realized spread | | |
|---|---|---|---|---|---|---|---|---|
| | Quoted | Effective | 5 sec | 60 sec | 5 min | 5 sec | 60 sec | 5 min |
| Post × Nocturnal | 0.580** | 0.115 | 0.443*** | 0.748*** | 0.727*** | -0.137 | -0.678*** | -0.749*** |
| | (0.26) | (0.18) | (0.12) | (0.20) | (0.23) | (0.15) | (0.23) | (0.24) |
| Volume | 0.156 | 0.099** | 0.407*** | 0.269*** | 0.227*** | -0.118** | -0.122** | -0.134*** |
| | (0.10) | (0.04) | (0.06) | (0.05) | (0.04) | (0.05) | (0.05) | (0.04) |
| Order Imbalance | -0.031 | 0.183*** | -0.062** | 0.051** | 0.132*** | 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* | -0.197*** | -0.160*** | -0.150*** | 0.217*** | 0.242*** | 0.225*** |
| | (0.13) | (0.06) | (0.07) | (0.05) | (0.02) | (0.03) | (0.04) | (0.04) |
| Volatility | 0.058*** | 0.041*** | 0.066*** | 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) |
| Adj. $R^2$ | 0.241 | 0.182 | 0.233 | 0.167 | 0.156 | 0.139 | 0.141 | 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 (Panel B). We report the estimated $\beta_1$ from the following specifications:

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

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:

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

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 December 2024 and January 2025 and zero for September-October 2024. $Nocturnal_{it}$ is an indicator equal to one for nocturnal period observations and zero for regular trading session observations from the same calendar day. 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 fixed effects ($\alpha_i$) and day fixed effects ($\gamma_t$). 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 | OIB |
|---|---|---|---|---|---|
| Post × Nocturnal | 0.812*** | 0.612*** | 0.659*** | 0.136 | -0.341*** |
| | (0.13) | (0.09) | (0.09) | (0.14) | (0.07) |
| Adj. $R^2$ | 0.316 | 0.291 | 0.250 | 0.147 | 0.052 |

Panel B: Market quality

| | Spread | | Price impact | | | Realized spread | | |
|---|---|---|---|---|---|---|---|---|
| | Quoted | Effective | 5 sec | 60 sec | 5 min | 5 sec | 60 sec | 5 min |
| Post × Nocturnal | -0.592*** | -0.518*** | -0.043 | -0.019 | -0.067 | -0.661*** | -0.452*** | -0.228** |
| | (0.11) | (0.08) | (0.10) | (0.10) | (0.08) | (0.06) | (0.10) | (0.11) |
| Volume | 0.077 | 0.057 | 0.322*** | 0.229*** | 0.216*** | -0.085* | -0.126** | -0.165*** |
| | (0.05) | (0.04) | (0.06) | (0.05) | (0.05) | (0.05) | (0.05) | (0.05) |
| Order Imbalance | -0.030 | 0.180*** | -0.053** | -0.017 | 0.088*** | 0.197*** | 0.159*** | 0.041 |
| | (0.03) | (0.03) | (0.02) | (0.02) | (0.03) | (0.03) | (0.03) | (0.04) |
| Trade Size | 0.009 | 0.159*** | -0.061 | -0.047 | -0.068 | 0.182*** | 0.209*** | 0.184*** |
| | (0.06) | (0.06) | (0.07) | (0.05) | (0.05) | (0.04) | (0.04) | (0.06) |
| Volatility | 0.061*** | 0.064*** | 0.063** | 0.029 | 0.034* | 0.032 | 0.031 | -0.002 |
| | (0.01) | (0.01) | (0.03) | (0.03) | (0.02) | (0.02) | (0.03) | (0.02) |
| Adj. $R^2$ | 0.361 | 0.229 | 0.249 | 0.156 | 0.146 | 0.153 | 0.129 | 0.107 |

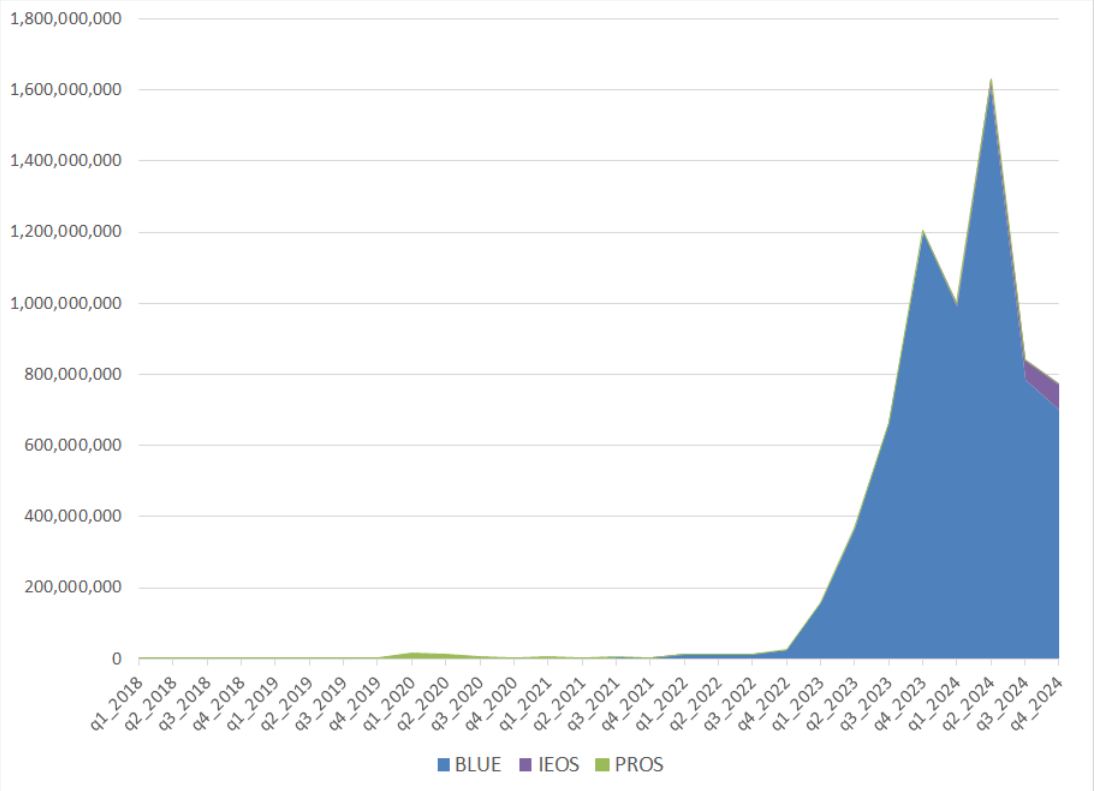



**Figure 1. Nocturnal Trading**

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.

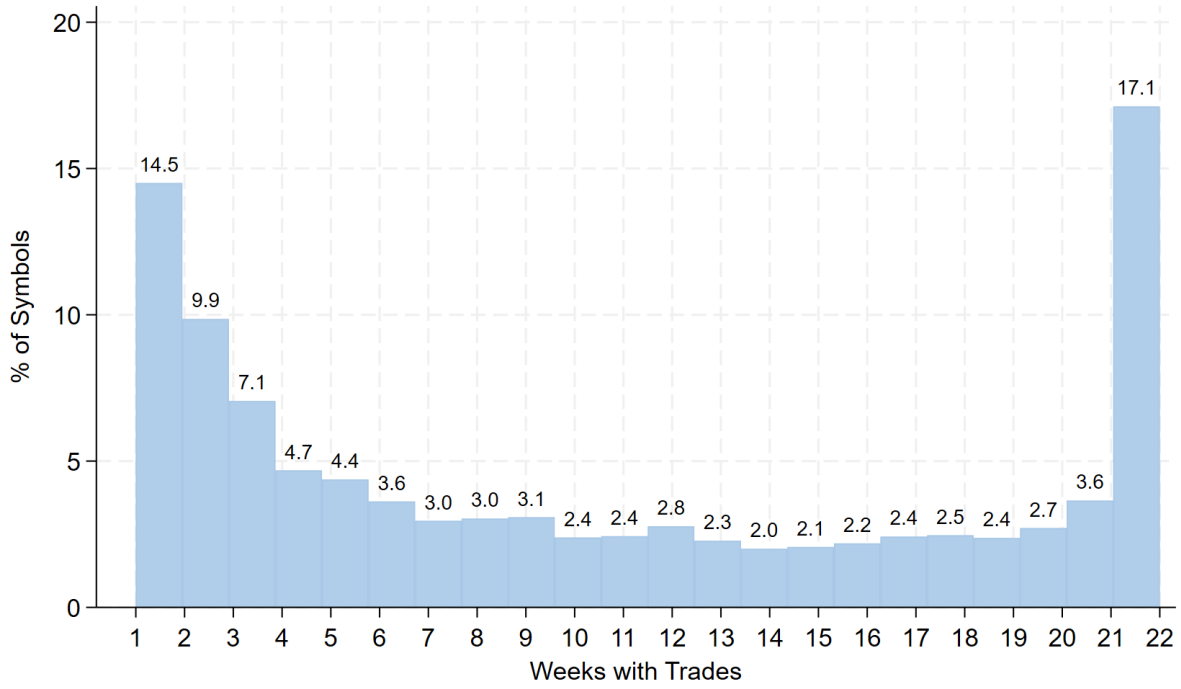



**Figure 2. Nocturnal Trading**

The figure reports the frequency distribution of the 6,495 unique symbols trading on Blue Ocean ATS (BOATS) by the number of weeks that there is nocturnal trading during the period January through May 2024. The source for the data is the FINRA ATS Transparency data for all NMS securities.

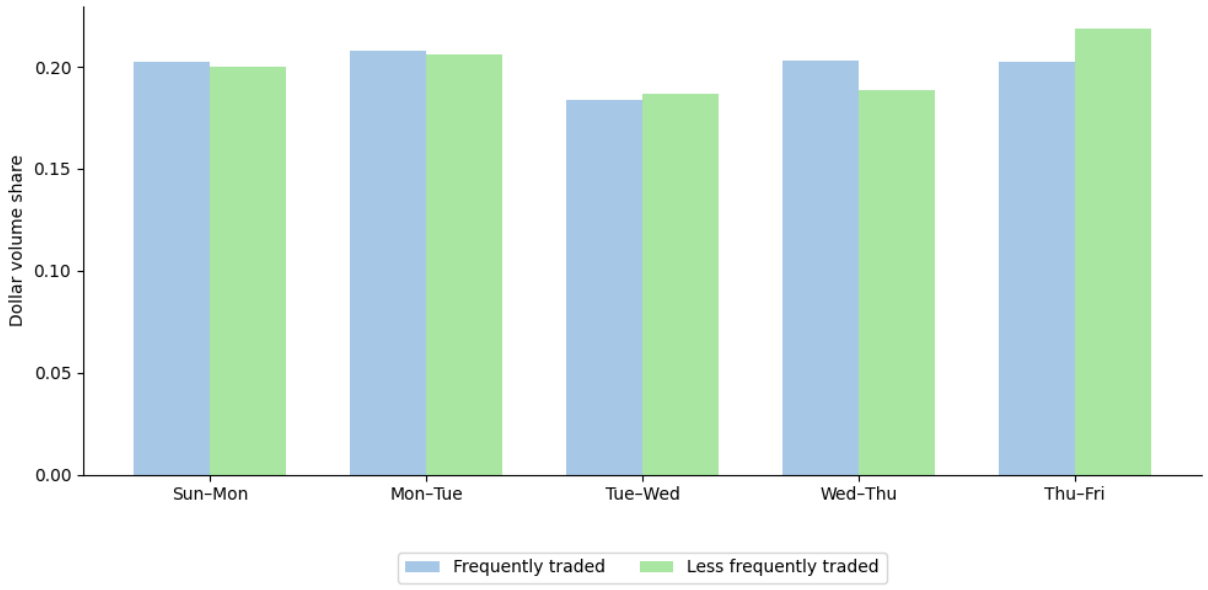



**Figure 3. Intraweek Dollar Volume**

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.

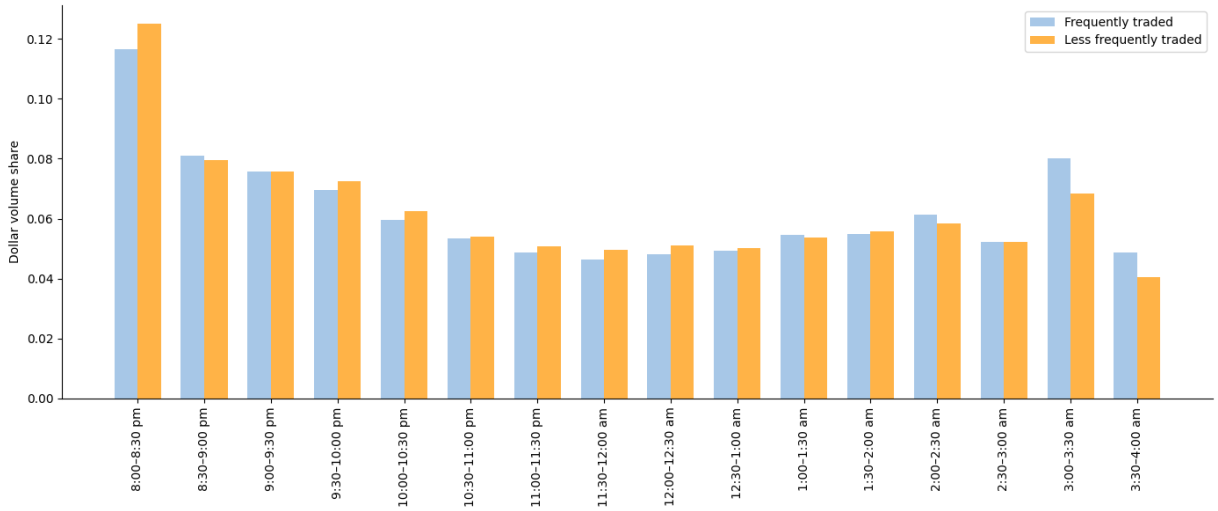



**Figure 4. Intranight Dollar Volume**

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.

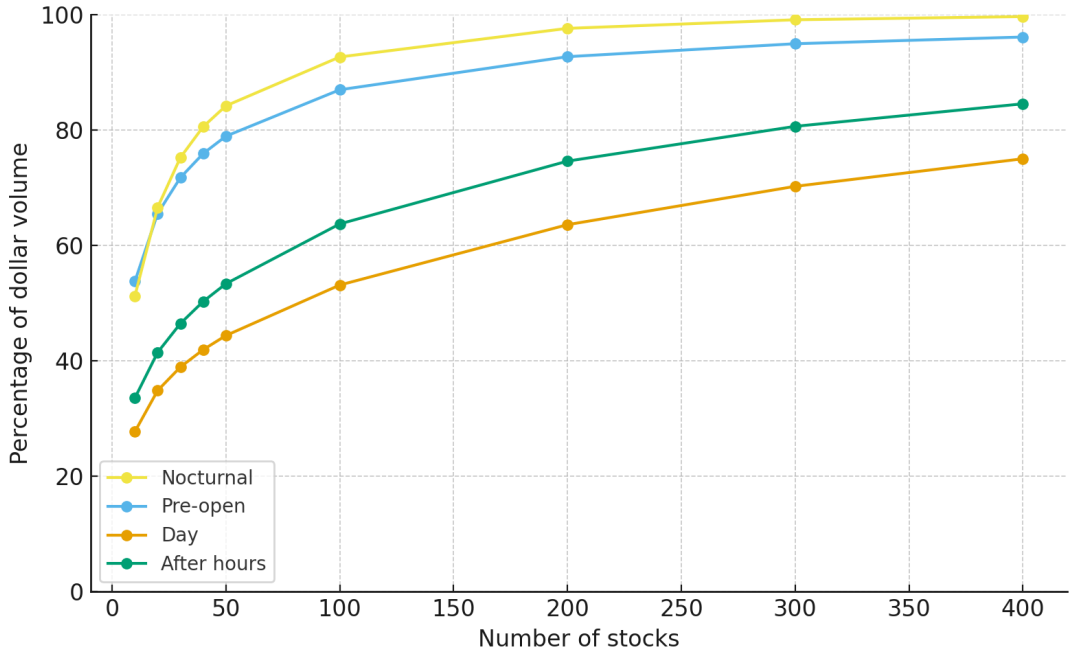



**Figure 5. Concentration**
The figure shows the cumulative distribution of dollar volume by sub-period of the day for the 400 stocks with highest dollar volume on the Blue Ocean ATS (BOATS).

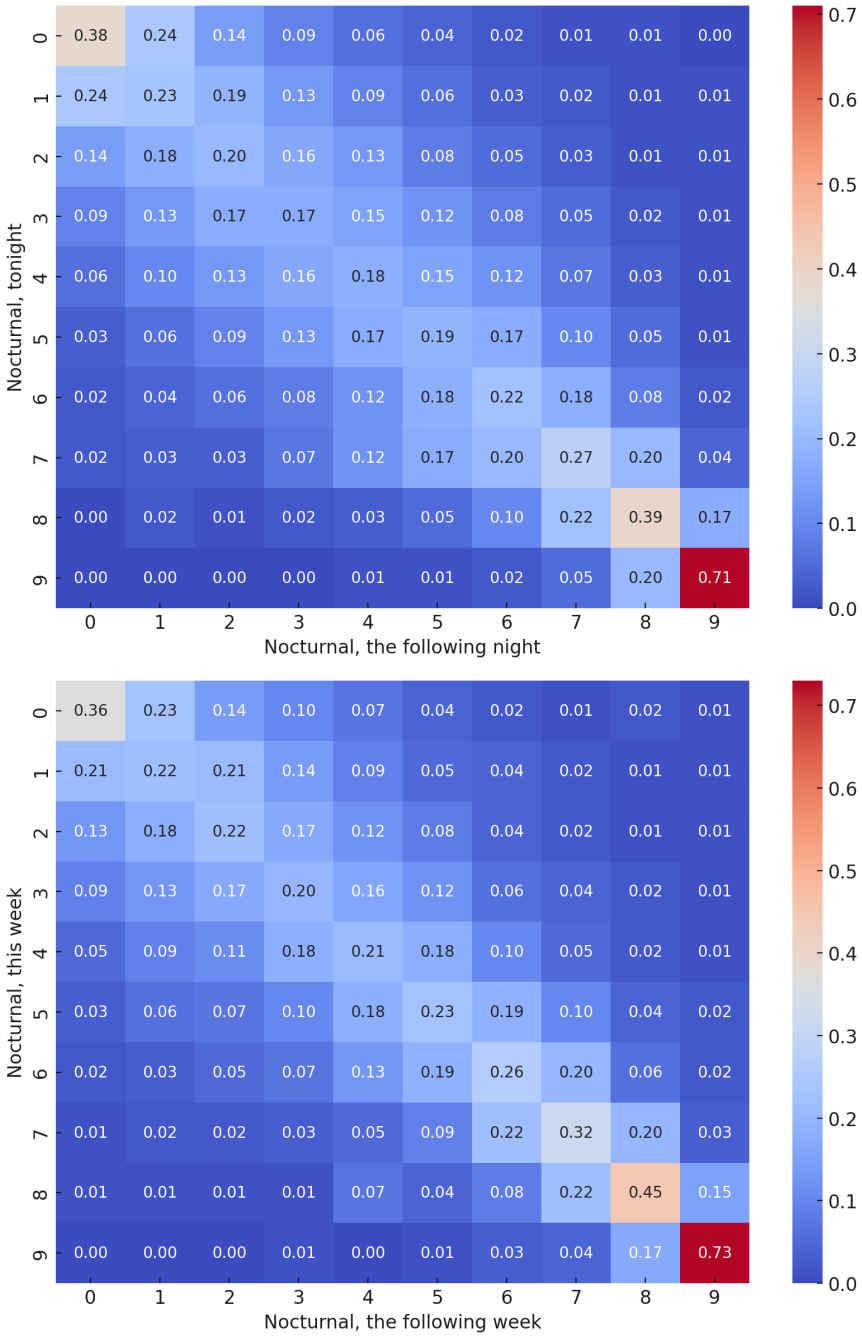



**Figure 6. Transition Matrix Blue Ocean to Blue Ocean**
This figure displays the transition matrix between Blue Ocean ATS (BOATS) trading tonight/tomorrow night (top) and this week/next week (bottom).

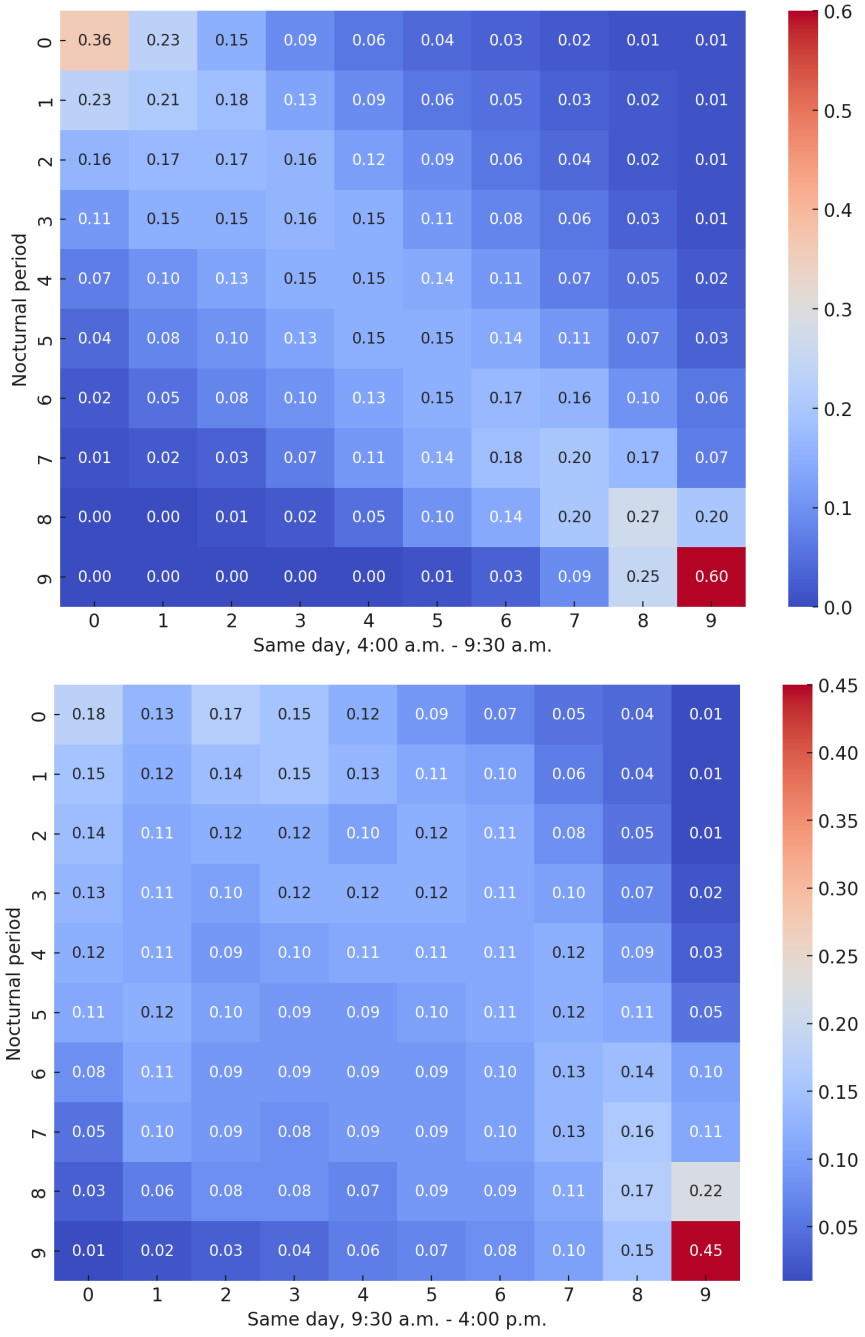



**Figure 7. Transition Matrix Blue Ocean to Subsequent Periods**

This figure displays the transition matrix between Blue Ocean ATS (BOATS) trading tonight and subsequent periods; pre-open (top) and regular trading hours (bottom).

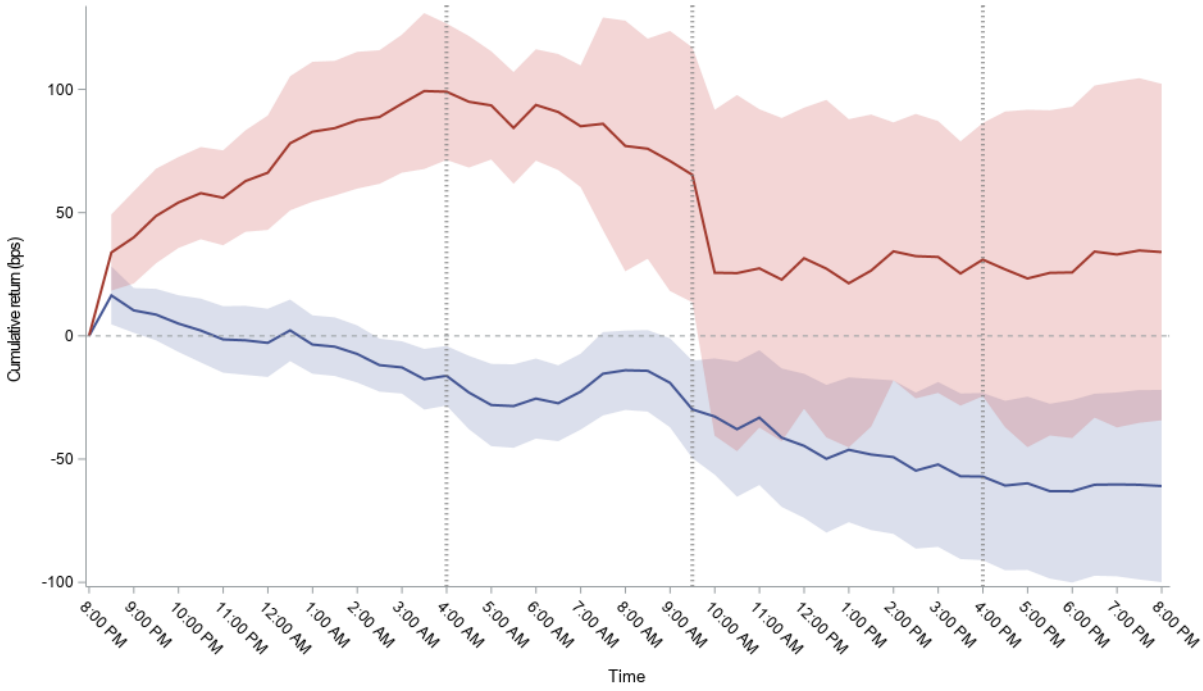
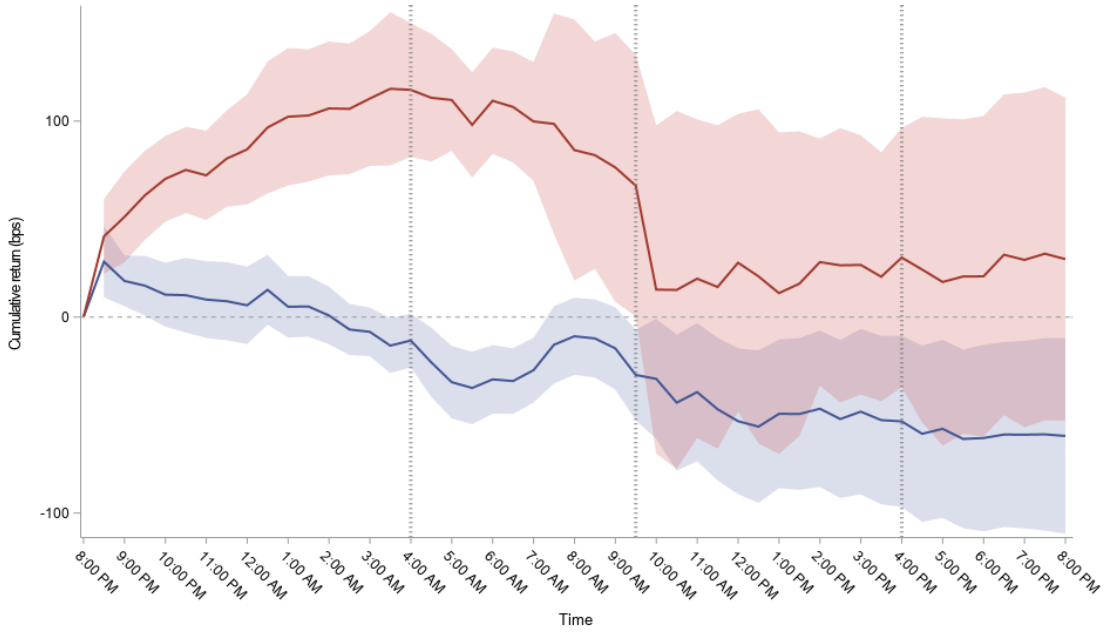
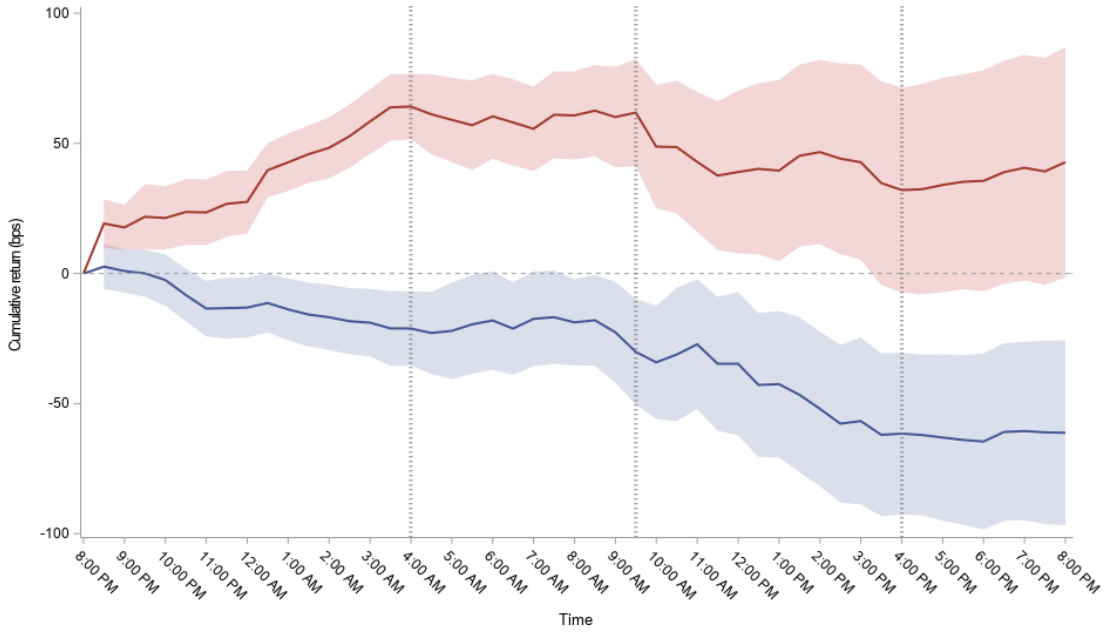



**Figure 8. 24-hour Returns**

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.



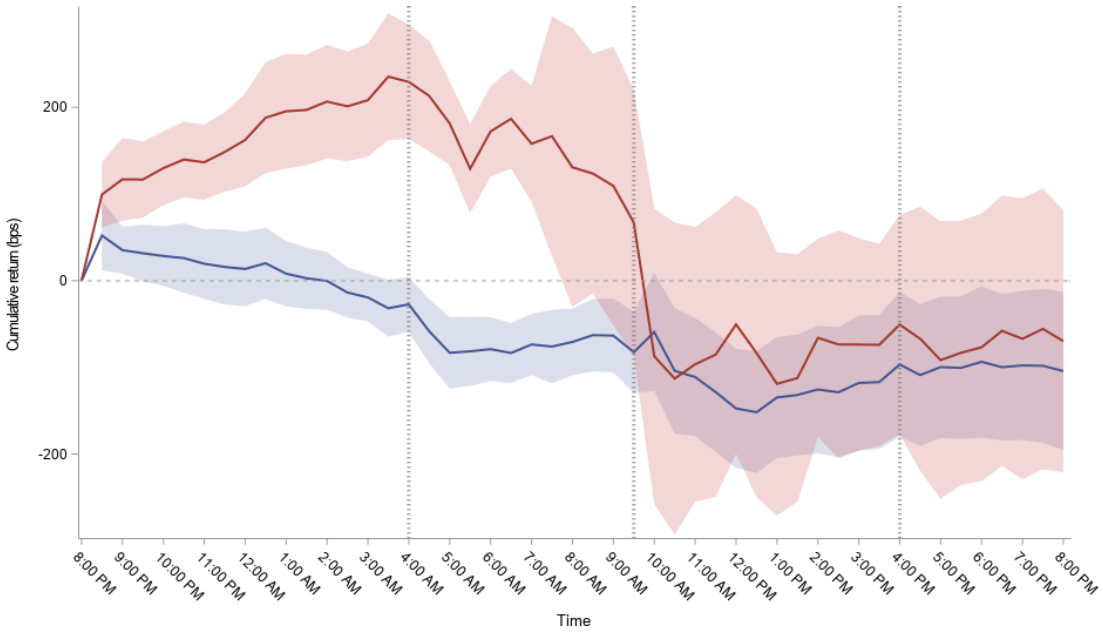

Panel A: Common stocks



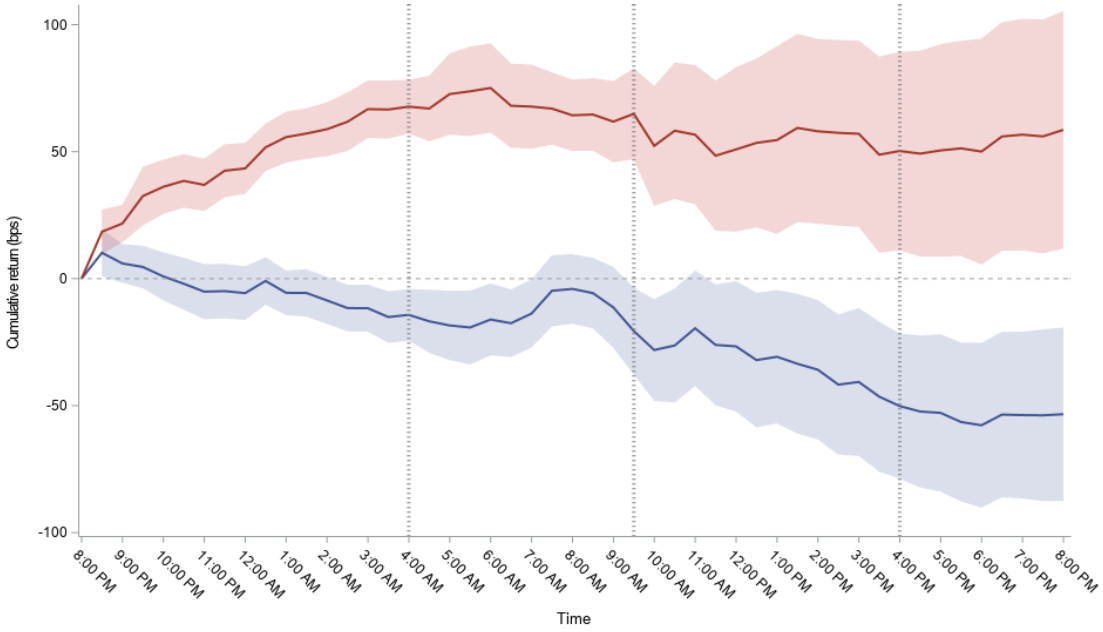

Panel B: ETFs

**Figure 9. 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 10. 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"

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

## 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.[8] 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, the blockchain subsidiary of Overstock.com. tZERO Group is not a registered broker-dealer, and any broker-dealer services were provided through broker-dealer subsidiaries PRO Securities, LLC, and SpeedRoute, LLC, both broker dealers registered with the SEC and members of FINRA and SIPC. Starting as early as 2014, tZERO Group's subsidiary PRO Securities, LLC, operated an ATS for trading NMS securities and in so-called "blockchain," "digital" or "digitally enhanced" securities pursuant to a Form ATS. By December 2014, tZERO Group and its affiliated broker-dealer had an arrangement with an unregistered

[8] https://bit.ly/3PI086E

Singaporean firm Blue Ocean Financial Technology, Pte. Ltd. to facilitate trading in certain NMS stocks and ETFs after U.S. markets had closed.[9]

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:[10]

*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 operated each evening before the NYSE Trade Reporting Facility is open so that trades effected on the ATS could be reported. 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 occurs from 8 p.m. to 4 a.m.

[9] https://bit.ly/4h2udK8
[10] https://bit.ly/40lBY6Y

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.

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, 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.[11] At this point, BOATS starts reporting under MMID BLUE, and takes over the business of nocturnal trading in NMS securities from tZERO ATS which has been reporting under MMID PROS.[12]

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. will carry a trade date of the following trade day. Settlement date will reflect 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.

[11] https://bit.ly/4g7begi and https://bit.ly/4arRMd2

[12] Based on FINRA ATS Transparency data, tZERO LLC ATS continues trading OTC securities.

BOATS charges subscribers a per-executed-share fee based on the following schedule:[13]

1. Early Adopters (Subscribers who were ATS participants as of its first operating session):
   (a) For adding liquidity, there is a rebate of $.0006
   (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.[14]

As illustrated in Figure IA2.5, 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 IA2.4). BOATS' first U.S. retail broker client was TD Ameritrade that started offering nocturnal trading

[13] https://bit.ly/4hmKg5f
[14] https://bit.ly/3PEF1SL

in 12 exchange traded funds on its Thinkorswim platform on January 22, 2018.[15] U.S. broker E*Trade announced nocturnal trading in the same 12 exchange traded funds on February 20, 2018.[16] Nocturnal trading by U.S. retail clients was slow to take off (Figure 1), and it was not 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.[17] On July 25, 2023, Interactive Brokers announced that they have partnered with BOATS for supplemental liquidity.[18] 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.[19] 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.[20] 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

[15] https://bwnews.pr/42lH4Td
[16] https://bwnews.pr/42jQ4YU
[17] https://on.wsj.com/3PGYxOl
[18] https://bit.ly/4apAoW8
[19] https://reut.rs/3PDETmu
[20] https://bit.ly/4anAKwo

real-time trading of U.S. equities was announced on February 14, 2023.[21] BOATS and the Tokyo Stock Exchange (TSE) announced a strategic partnership on August 7, 2023.[22] In 2024, additional partnerships were announced, e.g., with the global broker GTN to launch extended trading 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 Interactive Brokers EOS ATS (IBEOS)

Interactive Brokers announced on November 21, 2022, that they were offering nocturnal trading for the same list of widely-held U.S. ETFs as TD Ameritrade and E*Trade.[23] However, instead of joining the other brokers using BOATS, Interactive Brokers developed their own platform, the IBKR Eos ATS (IBEOS). Interactive Brokers already operated their own ATS for pre-open, regular market trading, and after-hours trading, so they had the technology in house. Moreover, Interactive Brokers has affiliates all over the world, including the Asia-Pacific region (Australia, Hong Kong, Japan, Singapore), that were given access to IBEOS for trading U.S. stocks during the overnight period, aiming to build a large pool of liquidity.

IBEOS offers trading from 8 p.m. to 3:50 a.m. with the week's first session starting on Sunday at 8 p.m. and the last session ending Friday at 3:50 a.m.[24] The IBEOS only accepts regular

[21] https://bit.ly/4h0sapY
[22] https://bit.ly/3E2Vyxa
[23] https://bwnews.pr/3EbUIOx
[24] https://bit.ly/4h0giEu

limit orders with the following time-in-force (TIF) instructions: (i) "day" (i.e., good for the duration of the trading session), (ii) immediate or cancel, and (iii) good-til-time (orders submitted with TIF instructions of longer than day are treated as day orders by the ATS and are canceled at the end of the trading session). Resting orders execute based on the following factors in order: price, time, and size. Trades executed in IBEOS are reported by 8:15 a.m. following the end of the relevant trading session to either the NASDAQ TRF Carteret and the NASDAQ TRF Chicago. IBEOS does not route orders out.

The following information is made available by IBEOS to brokerage customers and liquidity providers on a security-by-security basis during the ATS' regular trading hours: (i) highest resting bid price, lowest resting offer price, and aggregate size at such price level ("Top of Book Data") and (ii) price and size of the last sale within the ATS ("Last Sale Data"). This information is also made available to the IBKR Smart Order Router (SOR), although the SOR does not use such information for routing purposes. ATS market data is made available to brokerage customers and liquidity providers at no charge.

IBEOS exchange fees for Interactive Broker clients are as follows:[25]

1. For adding liquidity, there is a rebate of $.0000

2. For taking liquidity, the charge is $.0010.

Interactive Brokers has expanded the list of securities over time, and on July 25, 2023 announced that it is offering nocturnal trading for over 10,000 symbols. On the same date, it announced a partnership with BOATS for supplemental liquidity.[26] In addition to Interactive Broker's own foreign affiliates, the Taiwanese broker Sinopac started using IBEOS to access U.S. markets during Asian business hours for their clients on February 16, 2023.[27]

[25] https://bit.ly/3Cf4W06
[26] https://bit.ly/4apAoW8
[27] https://bit.ly/3WoAveK

## IA1.3 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 as summarized for major retail brokers in Figure IA2.5. 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. Note also that retail brokers define the pre-open period as between 7 a.m. and open, even though the SIP opens at 4 a.m.

[Figure IA2.5]

Figure IA2.4 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 IA2.4]

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.[28] 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 clients do not pay exchange fees, and thus the regular commission of $0.005 per share has to cover the BOATS/IBEOS fees.[29]

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 commis-

[28] https://bit.ly/4h6FGZ9
[29] https://bit.ly/3Cf4W06

sions 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).[30] 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.[31]

## IA1.4 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.[32] 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 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

[30] https://bit.ly/4hoAHTx
[31] https://bit.ly/4jjGlIf
[32] https://bit.ly/4apFMIQ

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:[33]

*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.*

Similarly, Webull states in their Extended Hour Trading Disclosure:[34]

*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*

[33] https://bit.ly/3PJfI1Y
[34] https://bit.ly/4h1lyaH

*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.

## IA1.5 SEC Rule 606(a) Reports

SEC Rule 606(a) requires reporting of routing of held orders both during and outside regular trading hours. As far as we have been able to discern, the only broker that reports order routing to BOATS is Interactive Brokers. Rule 606(a) does not require brokers to report every venue they route to, as long as the total reported flow exceeds 90%, and all venues receiving at least 5% of order flow are disclosed.

Interactive Brokers started reporting routing to BOATS for non-S&P 500 stocks in January 2024 and for S&P 500 stocks in August 2024 based on their Rule 606(a) filings, as their usage of the platform started to grow.

Figure IA2.2 shows Interactive Brokers' routing to BOATS for non-S&P 500 stocks, which quickly grew to reach 10.22% of all non-directed and a notable 13.52% of all non-directed limit orders (Panel A) and 7 million shares. Recall that BOATS does not accept market orders.

[Figure IA2.2]

Figure IA2.3 shows Interactive Brokers' routing to BOATS for S&P 500 stocks, which, as we mentioned, did not trigger reporting until August 2024 yet quickly grew to reach 7.74% of all non-directed orders and 10.90% of all non-directed limit orders (Panel A) and 38 million shares.

[Figure IA2.3]

Interactive Brokers so far has only reported routing to its own nocturnal ATS IBEOS in its Rule 606(a) report for August 2024, when the platform received a drastic increase in order flow due to the service interruption at BOATS. For that month, they report that 3.43% (5.04%) of all non-directed flow for S&P 500 (non-S&P 500) securities was routed to IBEOS.

It is clear from Figure IA2.2 and Figure IA2.3 that nocturnal trading has quickly become a significant fraction of Interactive Brokers' retail business. We have less information about BOATS usage by other U.S. retail brokers, as they may not yet have reached levels of routing that would require reporting. E*Trade appears to route directly to BOATS based on their Extended Hours Agreement:[35]

*During the overnight extended-hours trading session, we route orders to a single alternative trading system ("ATS"). During the overnight session, there is no consolidated quote and the ATS that we use is not required to display its orders to the public. In addition, ATSs are not required to provide orders "price protection" which means that you are not guaranteed execution at top-of-book prices, and other orders may execute at prices not available to you.*

TD Ameritrade also used to route directly to BOATS based on their January 21, 2018 Extended-Hours Session Rules. It is unclear if Schwab continues the historical practice of TD Ameritrade to route directly to BOATS, or if they route to an OTC market maker. Neither TD Ameritrade nor Schwab reports their routing on their Rule 606(a) reports, possibly because it does not reach a level which would be reportable.

Other brokers appear to view nocturnal orders as not-held and thus not reportable for Rule 606(a) purposes. For example, Robinhood's customer agreement states:[36]

*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 ... (4) Robin-*

[35] https://bit.ly/3CiwmCn
[36] https://bit.ly/3PJfI1Y

*hood deems each such order to be a "not held" order, i.e., an order with respect to which you have granted Robinhood discretion with respect to the price and time of execution...*

The reason may to be that they characterize nocturnal orders as 24-hour orders (Robinhood 24 Hour Market and Schwab EXTO orders). These orders can be submitted from 8 p.m. and 4 a.m. and remain active until 8 p.m. on the following day. An unexecuted 24-hour order from the overnight session, will be re-routed back to the market maker for execution, and the market maker in turn may rout to a pre-open venue, and subsequently possibly to another venue for the regular market session. It appears that these brokers believe that since discretion is involved, it becomes a not-held order. We have an indication that nocturnal trading is of growing importance at Robinhood based on a March 6, 2024, statement by its CEO Vlad Tenev on X:

*"Since we launched Robinhood 24 Hour Market last year, we've executed $10B in trading volume in overnight hours. On our busiest days, we've seen as much as 25% of the total daily trading volume come from outside regular trading hours."*

# IA2 Growth in Nocturnal Trading

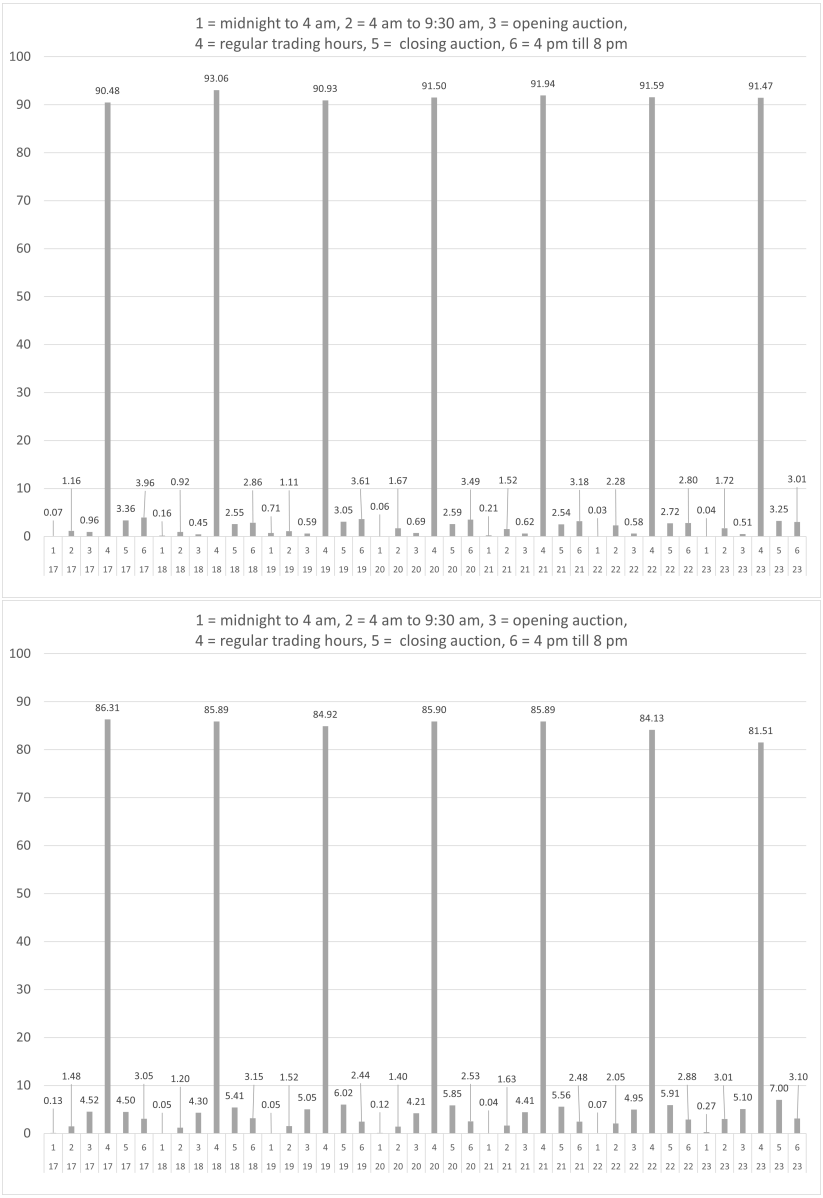
Using FINRA ATS Transparency Data, Figure IA2.6 shows trading activity on the BOATS platform weekly since its inception in June 2021. The top panel illustrates the number of unique symbols traded on the platform, and the bottom panel reports share volume. The vertical lines indicate when large brokers 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

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 IA2.6]

Figure IA2.7 shows weekly trading activity on the IBEOS platform since its inception in October 2022. We again report the number of unique symbols traded on the platform in the top panel, while share volume is reported in the bottom panel. The first vertical line indicates when Interactive Brokers announced that they were expanding the availability of overnight trading to 10,000 NMS securities and at the same time started offering their clients to use the BOATS platform. As volume for some symbols migrated to BOATS, which was more liquid based on share volume, the number of securities traded on IBEOS fell slightly despite the announced increased in overnight trading availability. The second vertical line indicates the BOATS service interruption, and shows that some volume migrated to IBEOS during and following the interruption. In terms of share volume, the loss of liquidity from BOATS is much more than the gain in liquidity on IBEOS. The reason is that IBEOS primarily caters to Interactive Brokers and its Asian affiliates, and other brokers would have had to develop connectivity to IBEOS for their retail clients which takes time. Hence, it is likely mostly Interactive Brokers' clients that switch to IBEOS during the BOATS service interruption.

[Figure IA2.7]




## Figure IA2.1. Intraday Trading Periods

The figure reports percent of total share volume reported during different intraday periods: 1 = midnight to 4 a.m., 2 = 4 a.m. to 9:30 a.m., 3 = opening auction, 4 = regular trading hours, 5 = closing auction, 6 = 4 p.m. till 8 p.m. The source for the data is the DTAQ for 24 ETFs in the top panel (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), and for All NMS securities in the bottom panel. Source: DTAQ. Note that DTAQ does not report trades occurring in the 8 pm to midnight period.

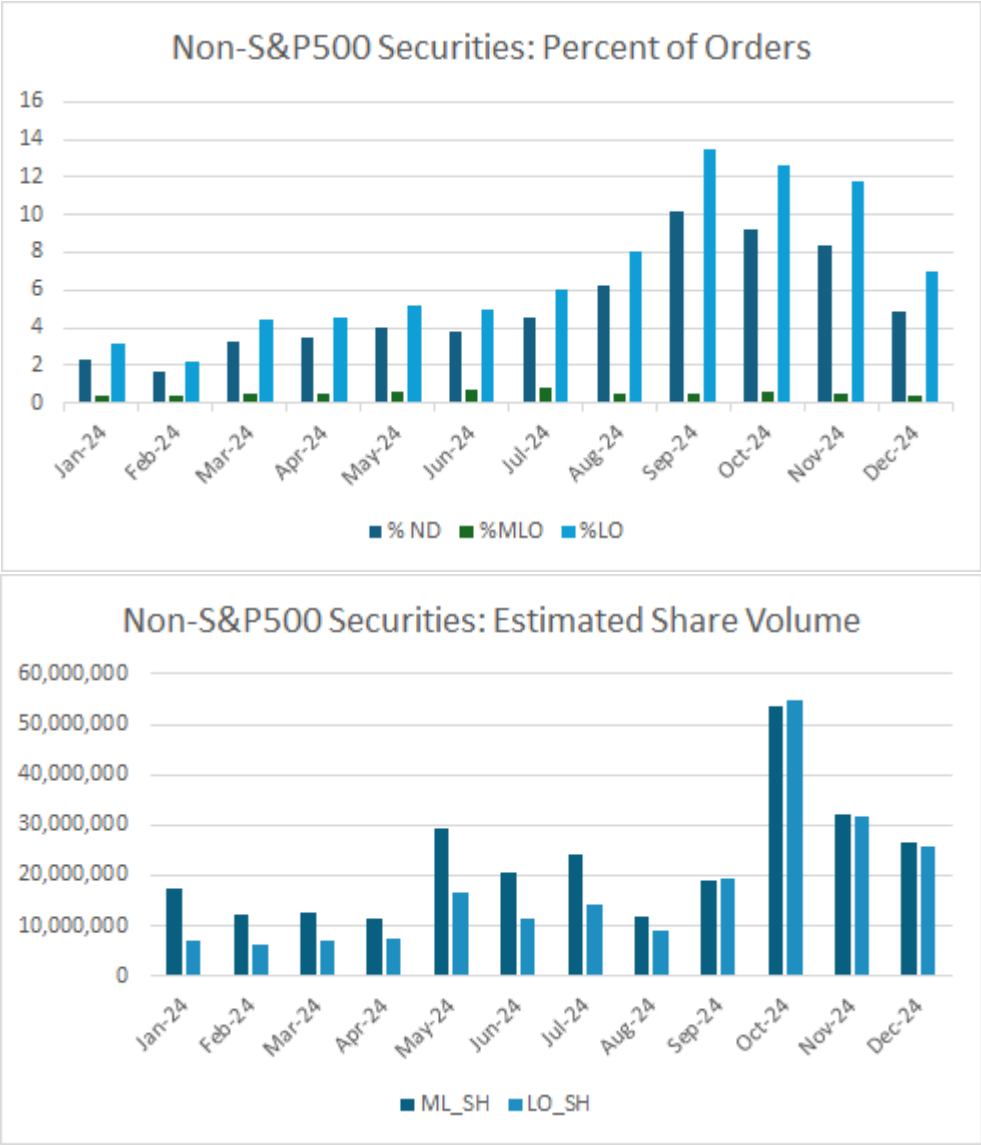



**Figure IA2.2. Interactive Brokers Routing Non-S&P 500 securities to BOATS**

This figure shows the percent of all Interactive Brokers non-directed held orders for Non-S&P 500 shares that are routed to BOATS by month for 2024 in Panel A, and the estimated share volume routed to BOATS in Panel B. %ND, %MLO, and %LO indicate the percent of all non-directed orders, marketable limit orders, and limit orders respectively. The estimated share volume is calculated based on the reported total dollar payments, divided by the cents per share. ML_SH and LO_SH are the estimated share volume for marketable limit orders and limit orders, respectively. Source: Rule 606 Reports.

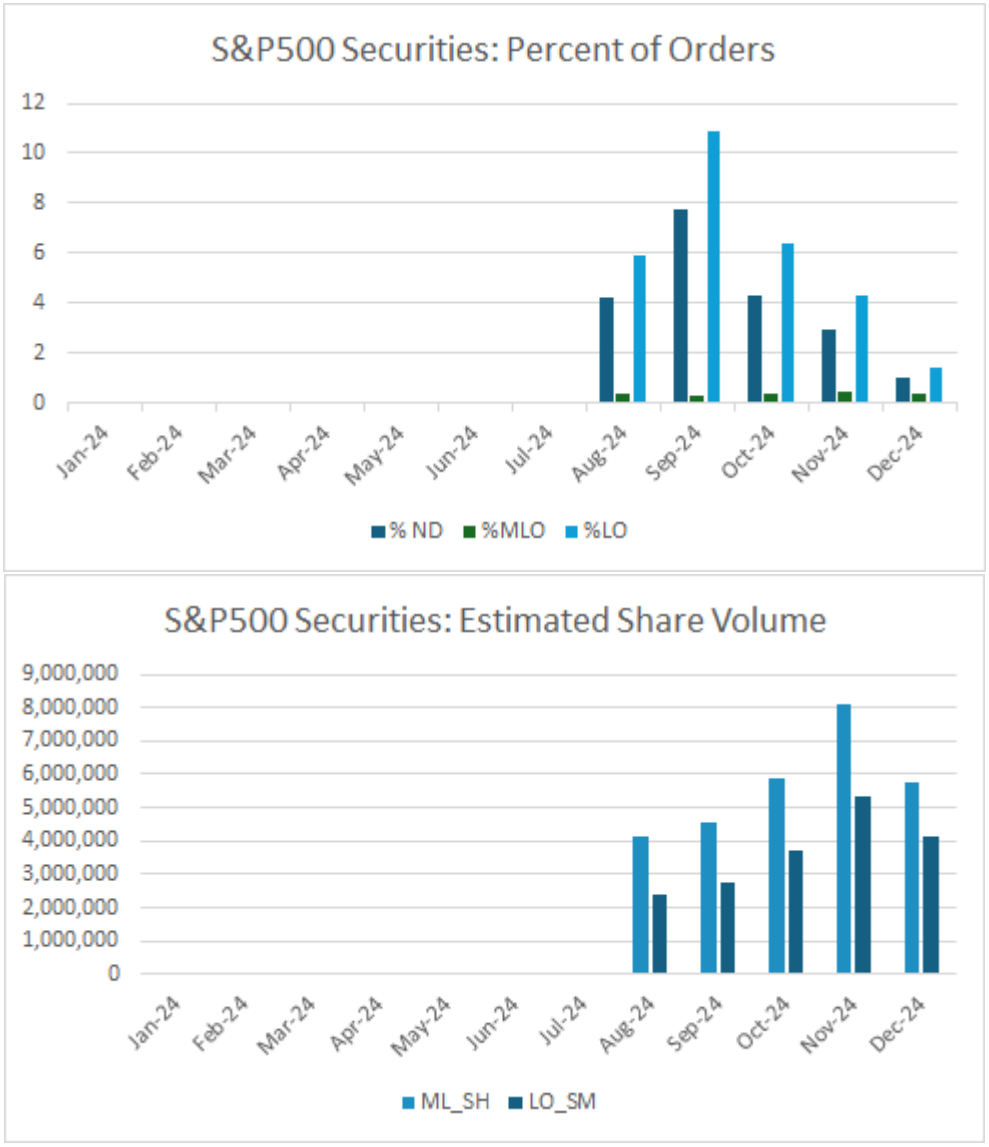



**Figure IA2.3. Interactive Brokers Routing S&P 500 securities to BOATS**

This figure shows the percent of all Interactive Brokers non-directed held orders for S&P 500 shares that are routed to BOATS by month for 2024 in Panel A, and the estimated share volume routed to BOATS in Panel B. %ND, %MLO, and %LO indicate the percent of all non-directed orders, marketable limit orders, and limit orders respectively. The estimated share volume is calculated based on the reported total dollar payments, divided by the cents per share. ML_SH and LO_SH are the estimated share volume for marketable limit orders and limit orders, respectively. Source: Rule 606 Reports.

**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 IA2.4. List of Nocturnal Securities for U.S. Retail Brokers**
Source: Web search for announcements.

## 24-Hour Trading for Major Brokerages

| Broker/Firm | Pre-Market | After-Hours | 24-Hour Trading |
|---|---|---|---|
| **Charles Schwab** | 7:00 a.m. - 9:25 a.m. | 4:05 p.m. - 8:00 p.m. | Gradually expanding 24-hour trading for S&P 500, Nasdaq-100, and ETFs as of early 2025. |
| **Fidelity Investments** | 7:00 a.m. - 9:28 a.m. | 4:00 p.m. - 8:00 p.m. | Does not offer 24-hour trading. |
| **Interactive Brokers** | 7 a.m. until 9:30 a.m. | 4:05 p.m. - 8:00 p.m. | Most extensive variety of tradeable securities; 8:00 p.m. - 3:50 a.m. for U.S. stocks and ETFs. |
| **Robinhood** | 7 a.m. until 9:30 a.m. | 4:05 p.m. - 8:00 p.m. | 8:00 p.m. (Sunday) to 8:00 p.m. (Friday) for select stocks and ETFs. |
| **E*TRADE** | 7 a.m. until 9:30 a.m. | 4:05 p.m. - 8:00 p.m. | Offers 24-hour trading for select securities. |

*All hours are given in Eastern Time. In addition, 24-hour trading begins at 8:00 p.m. Sunday and ends Friday at market close, 4:00 p.m. All information is courtesy of the individual brokerages and are subject to change.*

Table: Investopedia/Peter Gratton

Investopedia

**Figure IA2.5. Major Retail Broker Overnight Offerings**
Source: Investopedia.

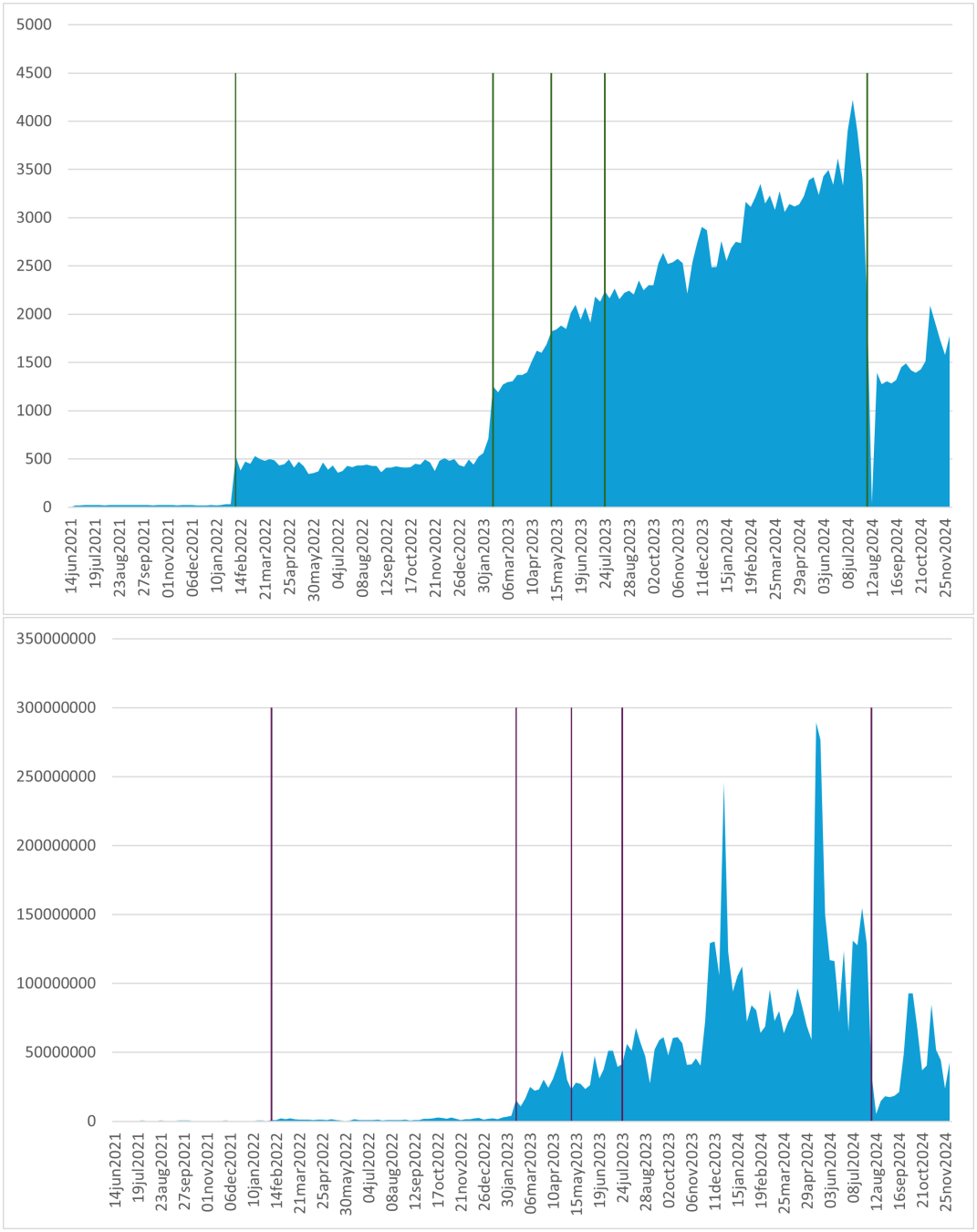



**Figure IA2.6. Nocturnal Trading Activity on BOATS**

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.

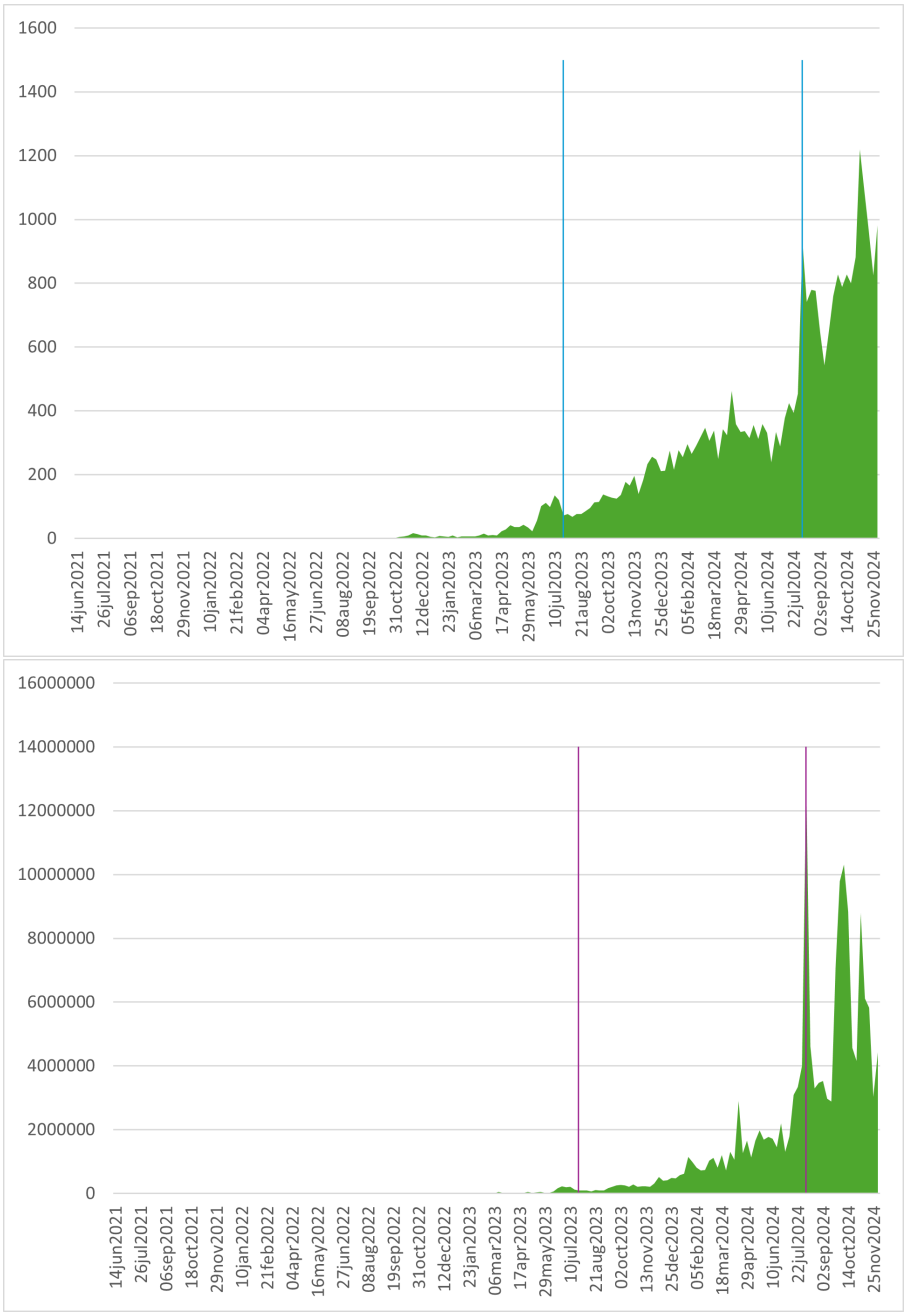



**Figure IA2.7. Nocturnal Trading Activity on IBEOS**

The figure shows trading activity on the IBEOS platform weekly. 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 Interactive Brokers started using BOATS as well as IBEOS and the second one indicates when the BOATS service was interrupted. Source: FINRA ATS Transparency Data.