Many Shades of Gray:

Retail Trading around the Clock

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Abstract

With extended equity market hours expanding to 23/5, we compare equity price execution outside core market hours by placing 32,000 trades across three retail brokers. Roundtrip costs are, at minimum, 500% (800%) higher during extended (overnight) hours than core hours. Average price execution varies across brokers. Consistent with core hour markets, differential broker pricing is created through systematically different off-exchange pricing. However, we also observe systematically worse pricing on parallel exchange-executed and dark pool-exchange trades, implying execution inferior to prevailing lit quotes. PFOF and price execution variation are similar. Our results highlight significant gaps in non-core hours investor protections.

JEL Classifications: G12, G14, G18, G50

Keywords: retail trading, execution quality, overnight, after hours, market microstructure, payment for order flow, broker-dealers

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1. Introduction

Over the last several decades, U.S. equity markets have extended their hours. Exchanges first lengthened their open hours from 10AM–3:30PM to 9:30AM–4PM. Starting in 1991, exchanges then introduced "extended hours," which originally ran only from 4PM to 5:15PM. By 2006, extended hours ranged from a pre-market session (4AM–9:30AM) to an after-hours session (4PM–8PM). Those extended exchange hours have held steady for two decades. More recently, following several retail brokers' introduction of overnight trading, exchanges have been approved or applied to extend their hours to 23-hour trading, five days a week.

Many core components and protections for investors, however, do not apply outside core market hours. For example, designated market makers, i.e. specialists, are not active and therefore have no quoting obligations. Only electronic exchanges are open. More importantly, many investor protections are absent. Regulation National Market System (Reg NMS), adopted by the Securities and Exchange Commission (SEC) in 2005, does not apply outside core hours. This includes the order protection rule (i.e. Rule 611), which prohibits execution at prices inferior to the best protected quote available at another venue. Thus, while the National Best Bid and Offer (NBBO) is quoted during extended hours and "lit" venues quote during overnight hours, those quotes are not binding with respect to execution. Additionally, neither the aggregated execution quality disclosures required under Rule 605 nor the order routing disclosures under Rule 606(a) have dedicated extended hours trade requirements.

In this paper, we evaluate the price execution of retail trades outside core market hours across brokers. Such analysis, however, is not feasible with the standard databases. As noted in Schwarz et al. (2025), the New York Stock Exchange's (NYSE) Trades and Quotes (TAQ)

database does not contain information concerning the originating broker or the venue that handled the trade. It also does not indicate if the trade is a buy or a sell or if the trade is a retail trade or not. TAQ also does not contain trades that occur after 8PM each day. While these data are available for NYSE listed stocks, no such data source exists for NASDAQ listed stocks. No trade data is reported anywhere, even to Financial Industry Regulatory Authority (FINRA), for Sunday evening trades. Most importantly, because only limit orders are permitted during extended hours, standard analyses of trade execution face significant endogeneity concerns — the price at which an order executes is mechanically tied to the limit price the investor chose, making it difficult to isolate execution quality from order placement decisions.[1]

Thus, to provide direct evidence on retail equity trade execution outside market hours, we conduct a controlled experiment where we place "aggressive" limit orders across three brokers that allow for 24-hour trading.[2] Two of the brokers route virtually all their order flows through wholesalers, while the third broker routes through a mixture of third party market makers, wholesalers, direct routing to exchanges, and its own automated trading systems (ATSes). We place trades during the first and last 30 minutes of core hours and every hour outside core hours. We then use these trades to evaluate execution prices across brokers during non-core hours.

Our experiment generated approximately 32,000 trades from January 2025 to July 2025. We selected 20 symbols that represent different levels of liquidity. These symbols were available for trading on all of the brokers during overnight hours. We buy and sell immediately, randomizing

[1] Anand et al. (2024) examine the use of limit orders by retail investors in equity markets while Barardehi et al. (2025) examine the use of limit orders by option traders.

[2] We use the term "aggressive" to indicate we place trades with limit prices even higher than the offer on buys and lower than the bids on sells to ensure our trades execute immediately. Simply using the bid or offer may lead to our trades not executing due to split second quote changes.

the order of the brokers, and use these trades to directly compare our execution costs of parallel trades across our brokers.[3] We then examine execution prices across brokers and venues our trades were routed to as well as whether our trades were executed on or off exchange.

Before we examine potential broker differences, we report basic statistics on order execution costs given that currently little is known about the cost of immediate liquidity during extended and overnight hours. In aggregate, during extended hours, we find that roundtrip trade costs vary from 500% higher for our most liquid symbols to 3,000% or more for six of our eight liquidity groups, as compared to core hours. During overnight hours, roundtrip trade costs approximately double from extended hours across all of our liquidity groups. These costs are especially striking given that our overnight sample is limited to the approximately 10% of U.S. listed companies available for trading on all platforms. These stocks that are substantially more liquid than those excluded.

These trading costs are not uniform across brokers. During extended hours, the two wholesaler-routing brokers occupy opposite ends of the execution quality spectrum: one averages the best execution among all three brokers, while the other averages the worst, with a gap of 22.3 bps in roundtrip trade prices for parallel trades. The mixed-routing broker falls in between, 13.5 bps behind the best. The overnight session shows a different pattern. The two wholesaler-routing brokers, which diverge sharply during extended hours, converge to similar execution quality overnight, while the mixed-routing broker now falls behind by approximately 6 bps. These patterns suggest that the interaction between routing infrastructure and market conditions may play an important role in explaining execution quality variations.

[3]Since NBBO does not apply after hours and disseminated quotes across brokers are inconsistent, we compare execution prices to overcome the quoting inconsistencies. As discussed later, brokers also have different restrictions on limit prices. Using parallel trades allows us to control for these differences and is important for measuring price differences across brokers.

To begin our evaluation of how execution differences arise, we examine how brokers use venues. In summary, we find substantial variation in how our orders are routed across broker and time. Brokers that rely on wholesalers even vary how they route in extended hours, with one using their core market routing and another concentrating their routing among a small number of venues. Overnight, both brokers route all of their trades to a monopolistic wholesaler. Our non-wholesaler broker routes trades across a mix of exchanges, dark pools, and its own internal ATSes, with the composition varying dramatically depending on the time of day. While their own ATSes do not operate in extended hours, a majority of our orders are routed to its own dark ATS overnight.

When we examine our price differences by routing, we find that relative broker performance depends on whether our trades go to the same or different venues at the same time. For our two wholesaler utilizing brokers, price differences are *six* times larger when our trades go to different venues than the same venue. When comparing our wholesaler brokers to our third broker, our wholesaler brokers perform significantly better when going to the same venue, but significantly worse when going to different venues. These results differ from Schwarz et al. (2025) and Huang et al. (2025), which find that the relative performance of brokers does not depend on whether orders are routed to the same venues or not. If we examine the difference between whether both pairwise trades are executed at the same location (on vs. off exchange) or different, we find similar inconsistencies.

By splitting our pairwise trades into the four possible exchange location combinations, we find that the relative performance of our pair trades depends strongly on the on- or off-exchange location combination. As we expect given prior findings in the literature, parallel trades that are both executed off exchange receive systematic differential pricing. However, we find two

surprising results. First, we find that differential pricing exists even when both trades are being executed on exchanges. Given the randomization of broker order, this could only occur if one broker's trades are being systematically routed to a worse quote. Indeed, we only have different execution if the trades are routed to different exchanges.

Secondly, we find that, when only one of our brokers' trades is executed off-exchange, they receive systematically worse pricing than the other broker, who was executed on-exchange. While this result applies for either broker in the pair, it is most dramatic for the overall better broker. In that case, the off-exchange execution is significantly *worse* than the exchanged-executed parallel trade. We find these results regardless if our two pair trades were sent to the same venue or not. We also find this to be true during overnight hours. BlueOcean operates as a lit venue during overnight hours. Trades executed in dark pools during the same period receive significantly worse pricing than those executed on BlueOcean. These finds are in contrast to Battalio and Jennings (2025) and Dyhrberg et al. (2025) who document that wholesalers provide better pricing than exchanges.

Finally, we find that 4AM to 7AM is a "twilight" period for the markets. During this period, routing and execution behavior is unique. Our two wholesaler utilizing brokers continue to route almost all of their orders exclusively to the overnight monopolistic wholesaler, but more than 80% of our orders are executed on exchanges. Our third broker, who usually uses a variety of venues, directly routes all of our orders to exchanges. In other words, during this period, there is almost no dark pool or internalization activity. This likely stems from the actual pre-market start time of retail brokers. Almost all brokers, including E*TRADE, Fidelity, Robinhood, and Schwab, do not start pre-market trading until 7AM. Prior to 7AM, when exchanges are the dominant execution location, there are much smaller levels of differential pricing across brokers.

Importantly, we do not find differences between dark pool and exchanged executed during this time. The large differential pricing we observe only begin at 7AM, which coincides precisely with the activation of dark pool and internalization infrastructure across the industry.

Our findings have policy implications. First, important investor protections, such as National Market System (NMS) and its '611 Rule,' also known as the order protection rule, do not apply outside core market hours. Essentially, NBBO is non-binding during extended and overnight hours. In practice, we find trades are routed to exchanges with inferior quotes or executed in dark markets at prices worse than those available at lit exchanges and ATSes. Second, there is no regulatory requirement for the disclosure of execution quality statistics for equities after hours or overnight. These disclosure requirements only apply to covered orders. Thus, an equivalent rule of the new Order Disclosure rule is needed to help investors understand their trading costs and make proper broker selections.

Finally, for our two wholesaler brokers, the difference in our pricing equals the difference in payment for order flow (PFOF). One broker receives, at most, \$0.0012 per share roundtrip for extended hours orders. The other broker receives 18 percent of quoted spread on a roundtrip trade. For example, Nvidia has the lowest average spread in extended hours at \$0.038. This would result in \$0.0068 in PFOF for the second broker on a roundtrip trade, which is more than five times higher than the first broker. More generally, the second broker receives 180 times the PFOF of the first broker across all our trades. These amounts are even higher than those observed by Boulton et al. (2025) in crypto markets. On the other hand, in overnight hours where the PFOF amounts are equal, we find execution prices are on average equal.[4] Thus,

[4]The first broker does not explicitly quote their overnight PFOF. We assume it is similar to their extended hours amount. The second broker started our trading period charging \$0.0009 per share for overnight trades and decreased that to \$0.0006, which matches the extended hours amount for the other broker.

both the within-period and cross-period differences support PFOF being a driver of execution quality differences.

This paper makes several contributions to the literature. We conduct a uniquely large and long-running experiment trading during extended and overnight hours simultaneously across multiple brokers to evaluate the cost of immediate liquidity on extended and overnight orders. We document economically significant differences in price execution between brokers. We show that these differences are driven by how venues vary pricing through on- or off-exchange execution (extensive margin), as well as pricing when both our pairwise trades go to the same location (intensive margin). In addition, we find that the variation in extended and overnight price execution is similar to the differences in PFOF. Extended hours execution differences are approximately equal to the difference in PFOF across brokers, while execution quality converges in overnight markets where PFOF rates are equal. Finally, we show that, when trades are almost exclusively executed on exchanges, our broker differences are mitigated substantially.

Our paper also extends the literature on differential pricing in financial markets by focusing on the non-core equity market. We show that non-core hours equity trades also receive differential pricing across brokers. Battalio et al. (2001) create a model to show that verifiable characteristics of orders can lead to differential pricing. Empirically, Schwarz et al. (2025) and Levy (2022) document differential pricing in equities, where wholesalers know the originating broker and can use this information to adjust prices. Huang et al. (2025) shows a similar dynamic in options markets, even though all trades are routed to exchanges and affiliated MMs do not have direct access to broker identity due to anonymity requirements of exchange trading.[5]

[5]In options markets, wholesalers still have tools to create differential pricing through selecting trading mechanism or setting starting price improvement in auctions.

Our setting in this paper is similar to core market hours in that the venues know the originating broker (or are the originating broker) and can use this information to systematically adjust prices.

We also provide more context on what potentially drives differential pricing. Schwarz et al. (2025) find that in the equity market, across-broker price differences are more likely driven by broker-specific order flow toxicity than by PFOF.[6] On the one hand, order flow toxicity is more heterogeneous across brokers in equities during market hours (Eaton et al. (2022)) but more likely homogeneous in the extended and overnight hours, similar to what is found in options markets (Eaton et al. (2024)). On the other hand, differences in PFOF for equity trades during market hours is relatively low compared to spreads (Schwarz et al. (2025); Ernst and Spatt (2022)), while differences in PFOF are large and significant in the non-core hours equity and options markets. Therefore, in core market hours, toxicity likely dominates PFOF in influencing differential pricing, whereas like in options, PFOF seems to play a larger role in non-core market hours.

Finally, our paper is also related to other papers that discuss overnight trading. Eaton et al. (2025) obtain data from BlueOcean ATS, which during our time period was the only 'lit' ATS offering overnight execution. They find that overnight spreads, while larger than during core hours, are approximately 60% higher on average than during core hours. We find roundtrip trading cost differences that far exceed this magnitude outside of core hours. Our paper complements their findings by examining broker-level execution differences across multiple venues and extending the analysis to pre-market and after-hours sessions. Blonien and Ober (2025) model whether or not the market should be open 24/7 or have a close. They find

[6] Levy (2022) also documents large across-broker price differences in the equity market.

a market close is useful for coordinating liquidity and lowering trading costs.

Importantly, we acknowledge that we only examined one specific aspect of brokerage trading and only examine the time period from January 2025 to July 2025. Overnight markets are evolving rapidly, although extended hours have remained unchanged now for two decades. Our experiment was based solely on placing one share "aggressive" marketable limit orders. We do not evaluate other types of orders, such as non-marketable limits. We only examine execution quality, while other aspects may be important as well such as symbol availability or restrictions on limit order prices. We do not consider other features that investors might value when selecting brokers.[7] So, price execution is only one part of the mosaic of information available to evaluate brokerages.

The remainder of the paper is organized as follows. Section 2 provides institutional details about extended hours and overnight trading. Section 3 discusses the setup for our trading experiment. Section 4 presents our results, comparing price execution across brokers, which are found to vary widely. Section 5 shows how our trades are routed to venues and exchanges after hours and delves into how execution location is being used to create price variation. Section 6 shows how our results are largely consistent across time, outside of "twilight" hours. Section 7 then discusses the implications of our results. The final section concludes and provides policy prescriptions.

[7]These other features could include the breadth of offerings, the ability to short, investment and margin fees, the quality of research and educational products, the ease of platform use, trading tools, and mobile apps, customer service, and so on.

2. Institutional Details

In this section, we provide some institutional details related to extended hour and overnight trading in U.S. equity markets.

2.1. History of Extended Hour Markets

In the early 1970s, the U.S. equity market was only open from 10AM to 3:30PM. In 1974, hours were extended 30 minutes such that the market closed at 4PM, where the official close still stands today. Then in 1990, the market open was moved to 9:30AM, which established today's official open hours, from 9:30AM to 4:00PM. Currently, a large amount of the volume in the market occurs when the market opens and in the thirty minutes before market close. This is due to most material news occurring outside market hours (volume at the open) and likely indexing products at the end of the day.[8]

The first extended hours began in 1991. The market continued to close officially at 4PM, however, there was still the ability to place orders on exchange until 5:15PM. There were many restrictions on how these trades could take place, such as trading at the closing price (i.e. no price discovery after the close) or trading in large one-million dollar baskets of stocks. The main motivation for adding extended hours was to "regain trading volume in ... stocks ... from foreign markets..." One important distinction of this volume is that the orders bypassed the specialists (DMMs).[9]

During the late 1990s, the ability to trade stocks extended through Electronic Communication Networks such as Island and Archipelago Exchange (ArcaEx). The final expansion was

[8]Decades ago a majority of earnings announcements were during the day (Patell and Wolfson (1982), but now almost none occur during the day. Michaely et al. (2016)

[9]"NYSE Sets 1st After-Hours Trading This Year," Chicago Tribune

announced in 2004 when ArcaEx extended their open hours to 4AM for all U.S. listed and OTC stocks. As with the 1991 extended hours, this was timed to align with European Markets. ArcaEx merged with the NYSE in 2006, becoming NYSE Acra and establishing the 4AM to 8PM extended market hours that have been the standard since.

The idea of 24-hour trading actually began back in 2018. TD Ameritrade launched 24-hour trading in January of that year for a select set of ETFs such as SPY. These trades, like those in the late 1990s and early 2000s, were executed on an ECN. Part of the rational for offering all-day access to equity trading for U.S. retail investors was other products, like bitcoin and other cryptocurrencies, trade 24 hours a day. However, it was noted those more generic products have global demand relative to many U.S. equities.

Currently, 24 hour trading occurs on ATSes. The largest is BlueOcean ATS, which allows for the trading of any U.S. Equity and ETF and is open from 8PM to 4AM. While there is no securities information processor (SIP), BlueOcean is 'lit' and provides quotes and level 2 market depth.[10] Additional ATSes exist and operate 24 hours, such as Interactive Brokers (IBKR) IBEOS ATS exchange. IBEOS, however, is dark. Even users of IBKR are given quotes from BlueOcean when placing overnight trades. IBKR and IBEOS also allow for trading in any U.S. equity. IBKR uses its 'smart routing' technology to route overnight trades.

Many exchanges have now applied to open for some variation of 23 hours a day, five days a week. Both the NYSE and NASDAQ have filed proposals with the Securities and Exchange Commission (SEC) to open 23 hours a day, five days a week. The NYSE will run this through ARCA, consistent with their current extended hours trading. 24X, another exchange, has

[10]One reason BlueOcean has 'lit' quotes is beacuse it wanted to be a pseudo-SIP overnight. see https://blueocean-tech.io/2025/10/07/pr-newswire-blue-ocean-technologies-integrates-real-time-overnight-data/

already been approved for 23 bour, five day a week trading. That exchange is planning to begin operations in the second half of 2026 as soon as the SIP is available.[11]

2.2. Investor Protection during non-Core Hours

During extended hours trading, investors lose access to several of the most significant structural protections that govern core market sessions. Regulation NMS does not apply outside of core hours, which means its cornerstone provision Rule 611, aka the Order Protection Rule, is unavailable. Rule 611 is the mechanism that prevents the execution of trades at prices inferior to a protected quotation displayed by another trading center. Its absence means an order can legally be filled at an inferior price while a better quote exists elsewhere. Similarly, the National Best Bid and Offer (NBBO) — the consolidated best bid and ask across all exchanges that brokers use as a pricing benchmark during core hours — has no formal application in extended sessions. While the SIP does broadcast an "NBBO" outside market hours, it is not binding as it is during core hours.

Compounding these execution issues is a lack of disclosures to investors. SEC Rule 605 and the new Order Disclosure RUle only apply to covered orders. Orders outside core hours do not fit into this category and are therefore not part of the report.[12]. While the SIP is active from 4AM to 8AM, TRF reporting is unavailable until 8AM, creating a window of reduced post-trade transparency. More importantly, trading from 8PM to 12AM on Sundays and holidays is not even reported to FINRA.

That said, not all protections evaporate after the closing bell such as best execution obli-

[11]Recently, 24X has requested approval to being operations before the SIP is available.

[12]Brokers are inconsistent even how they handle overnight trades. Some brokers treat these as "Held" while others treat them as "Not Held."

gations. This primarily comes from FINRA Rule 5310, which requires broker-dealers to use reasonable diligence to ascertain the best market for a security and to buy or sell in that market so that the resultant price to the customer is as favorable as possible under prevailing market conditions. Rule 5310 applies during extended and overnight hours, though the standard is evaluated in the context of the thinner, more volatile conditions of those sessions rather than against the NBBO.[13] Form 606 reports generally provide information on the PFOF paid to wholesalers during extended and overnight hours. However, these reports do not separate order routing between different market regimes.

In summary, while some best executions and secondary disclosure requirements exist, objective execution requirements such as mandatory routing to the best quote and execution disclosure reports are missing for extended and overnight hours.

2.3. Implementation at the Broker Level

The implementation of extended hours and overnight trading at the various brokers is quite heterogeneous. In fact, there appears to be a fairly large disconnect to when retail investors can trade via their brokers and the underlying market structure. Electronic exchanges are currently active and the SIP is available starting at 4AM and ending at 8PM each day, with core hours operating from 9:30AM to 4PM. The overnight infrastructure operations as a complement to these hours, with BlueOcean and IBEOS open from 8PM to 4AM with BlueOcean broadcasting quotes overnight.

However, most retail brokers offer trading differently than this schedule. To provide some

[13]Implementation of best executions for the retail brokers is generally about routing aggregate order flow to venues rather than actually executing the orders themselves. See Dyhrberg et al. (2025), Ernst et al. (2023), and Huang et al. (2025).

context, in Table 1, we provide data on brokers extended hours as well as overnight hours. We also provide data on what symbols are available overnight if the broker provides overnight trading.

<Insert Table 1 about here>

Interestingly, we find that many brokers offer extended hours trading only starting at 7AM, even if they allow for overnight trading. Both Robinhood and Schwab being their extended hours at 7AM even though they offer extensive overnight trading. This is similar to Fidelity and Etrade, both who allow either limited or no overnight trading. The only exception to this is Webull and IBKR who starts their extended hours at 4AM. Regardless of their extended hours start time, all of these brokers offer trading until 8PM. Vanguard is even more restrictive: it only allows trades from 4PM to 5:30PM each day.

A majority of brokers now offer some sort of "overnight" trading except for Fidelity and Vanguard. However, even this differs across brokers in multiple dimensions. First, each broker offers a different set of symbols that clients can trade. IBKR allows for essentially all symbols. Etrade is the most restrictive with just a small number of ETFs that can be traded. Schwab, Webull, and Robinhood each have a distinct set of symbols their clients can trade. It is unclear who sets the list or why only a limited list is available as BlueOcean supports trading for any symbol. Figure 1 summaries these data.

<Insert Figure 1 about here>

To investigate which stocks are selected for overnight availability, we calculate some basic statistics on those stocks included and excluded for overnight trading on Robinhood as of

January 2025. We separate our analyses into two groups: U.S. Domestic Companies and other listings such as ADRs and ETFs. For each stock, we capture the stock price and market capitalization at the end of December 2024. Using data from the fourth quarter of 2024, we calculate the average daily volume, the three-month return, and the daily volatility, estimated using the daily returns squared. These are all computed using the core market data available in CRSP. We report the mean and median values for each group along with the difference across groups and the t-value of the difference. We report results in Table 2, with U.S. Domestic Companies in Panel A and other listings in Panel B.

<Insert Table 2 about here>

As would likely be expected, large, liquid stocks are more likely to be available for overnight trading. Only approximately 16% of listed companies are available for overnight trading on Robinhood. The percent available for ADRs and ETFs is even lower at 6%. The average (median) company that is available has volume that is five (nine) times higher than compared to those stocks that are not listed. The market capitalization difference between the two groups is even higher. This is consistent across both panels, with more dramatic differencs for ADRs and ETFs. We do not find that volatility or past three-month returns consitently impact availability decisions.

3. Trading Experiment

There is generally availability of data on extended and overnight trades in the New York Stock Exchange (NYSE)'s Trades and Quotes (TAQ) database. However, it has several limitations when evaluating extended hours and overnight trades. First, all trades during this

time are limit orders. Limit order prices, cancelations, and execution are all endogenous. It is unknown whether the original order was a marketable or non-marketable limit. Thus, without further information, one cannot use these data to measure the true cost of immediate liqudity. Second, TAQ is missing data from 8PM to 12AM. While data for trades from the NYSE via prior day files, the same is not true for NASDAQ listed stocks. Trades on Sunday nights and holiday evenings are also not available in TAQ or even reported to FINRA. Finally, TAQ does not have any identifying information as to the customer, broker, venue, and trade direction, as is also the case with TAQ for core hours equity trades. This makes it very difficult, if not impossible, to pursue a direct analysis of potential determinants of prices, such as broker pricing effects, the impact of PFOF, and how trades are being routed and executed after hours.

To overcome these limitations, we place simultaneous identical trades (i.e., in the same order for the same symbol at the same time) across multiple brokerage accounts. In addition to the trade execution prices, we also capture several other variables. We log the time that we enter the order as well as the trade execution time provided by the broker. We used the latter time to match our trades with the TAQ database as well as NYSE's prior day files. Next, we describe our trading sample.

3.1. Symbol Selection

Because extensive trading of the entire universe of symbols is infeasible, we created a representative sample by selecting a subset of stocks based on their overnight liquidity. Specifically, we downloaded the list of available symbols from Robinhood in early January 2025. Using TAQ data for these symbols during the fourth quarter of 2024, we compute the number of trades and volume from 12AM to 4AM. We then use these data to rank the available stocks on Robinhood

and place the stocks in eight liquidity bins. From each of the eight bins, we select two stocks. We then select four data stocks that are popular with trades overnight to end up with a list of twenty symbols.[14] We report our symbol list in Table 3.

<Insert Table 3 about here>

Early in the experiment, BlurOcean suspended trading in YINN, which is a levered China ETF, due to the SEC's ATS Fair Access Rule.[15] Given YINN was one of the most popular symbols on BlueOcean's platform, we replaced this symbol in SPY.

3.2. Equity Trading

We trade across three different brokerages, namely IBKR, Robinhood, and Schwab. As shown in Table 1, we traded these particular brokers because all of them allow for a large selection of stocks across 24/5 trading. This allows us to examine the same brokers across all market regimes and across the widest variety of symbols. For IBKR, we use a "Pro" account that charges commissions, but does not have payment for order flow (PFOF). Our other two brokers are commission free, but charge PFOF. We will discuss PFOF for these two brokers later.

Whenever possible, we use the Application Programming Interface (API) to automatically trade. This allows us to process a large number of trades each day as well as to ensure that trades are executed at nearly identical times. At its peak, our trades numbered approximately 300 per day. Unfortunately, we lost access to one of our APIs in May 2025. After that time, that

[14]BlueOcean posts their top ten trades stocks every night on their website. We selected symbols that show up on this list regularly that were not randomly selected such as Apple, Gamestop, Bitcoin ETFs, and Nvidia.

[15]See https://blueocean-tech.io/blue-ocean-ats-service-status/. Interestingly, although IBKR allows trading overnight through YIMM also became unavailable on that platform.

broker was traded by hand at times matching the times of the other brokers.[16] Schwab largely allows for API trading; however, overnight trading (8PM to 7AM) is restricted to trades placed through their ThinkorSwim platform. During this time, we placed a more limited number of trades during this time period as a robustness check.[17]

Our program begins trading on Sunday night at 8PM EST when overnight trading begins. It runs through 10AM at which it breaks until 3:30PM and then trades continuously until the next morning at 10AM. Our trades are placed evenly throughout the day, trading two or three symbols per hour. We randomized the ordering of symbols each day to avoid any time-of-day effect (in addition to randomizing broker order). After purchase, we closed the position immediately to minimize any changes in pricing. Because quotes can be inconsistent, we will rely on rountrip trade costs as well as pairwise price differences to evaluate execution quality.[18] Because of the high spreads and high prices, we traded one share per trade. This resulted in an average trade size of $111, which is similar to Schwarz et al. (2025) who traded an average size of $100 per trade.

To control order submission times, our trading program is run as a single thread sequentially placing trades across all of our brokers. Even so, it cannot place orders at the same millisecond. To control for this issue, the program randomizes the order of the brokers on both the buy and sell trades to ensure that no broker has a systematic time advantage. We began trading on Janaury 19, 2025 and ended on July 11, 2025. In total, we placed 31,912 orders that cover a

[16]There are no significant differences in our findings across time periods.

[17]In additional analyses, we perform broker-pairwise comparisons using only overlapping trades, which show similar results to our uneven panel broker averages.

[18]During our experiment, we found several reporting issues with quotes. First, quotes across brokers are very inconsistent. For example, for one trade of NTES, Robinhood displayed a quote of 215.18/227.00 whereas Schwab displayed a quote 220.92/223.30. Second, it was clear that some market makers or high frequency traders were 'trolling' quotes. We could watch the bid start at 75, cycle up in increments of two cents until it reached 77, and then cycle back to 75. this would happen repeatedly.

six-month period.[19]

4. Price Execution, or the "Actual Retail Price"

To our knowledge, no prior studies have provided data on the cost of immediate liquidity during extended and overnight hours for retail trades. Thus, before we report data across our brokers, we first report aggregate statistics on the cost of roundtrip trades. For each trade, we calculate the roundtrip trade cost by calculating the difference in buy and sell prices and divide by the sell price. We sell immediately after buying to minimum any price movements in our roundtrip trade measure. Across our tens of thousands of trades, any movement should average out to noise.

To give a sense of how spreads compare across market hours, in Figure 2 we plot our average roundtrip trade costs by hour across all of our trades. The figure starts at market open and runs until 9AM pre-market hours. We extrapolate average spreads in the middle of the day as the average of our market open trades near the open and close. Overall, we see a sharp spike in costs immediately after the close and immediately when overnight trading hours start. We also see a difference in trading costs during twilight and pre-market hours. Overall, it appears costs during extended and overnight hours are orders of magnitude higher than during core hours.

<Insert Figure 2 about here>

To more formally investigate the cost of trading outside core hours, in Table 4, we report our average spread during core, extended and overnight hours in Panel A. We report the difference as well as the t-statistic of the difference. In Panel B, we report the results for each one of our

[19] Schwarz et al. (2025) perform a similar experiment in equity markets. They perform approximately 85,000 trades over a six-month period with 128 symbols. Thus, on a per broker-per symbol basis we have a higher number of trades. Additionally, as shown later, our results have high statistical significance.

eight liquidity groups. We report the core average, the difference between core and extended hours, and then the difference between extended and overnight hours. We also report the t-statistics for the difference.

<Insert Table 4 about here>

We find a huge increase in spreads after the market closes. Our average extended hours roundtrip trading costs are 83 basis points (bps) relative to only 3 bps during core hours. This increased to 146 bps, or trading costs that are approximately 50 times higher, during the overnight hours than during core hours. As shown in Panel B, the absolute cost varies depending on overnight liquidity. While our core hour costs only vary by nine bps across all of our liquidity groups, the difference in extended hours varies by 331 bps. The additional difference overight varies by another 334 bps.

All told, trading after hours is significant more expensive than core hours. For our most liquid group, roundtrip trade costs are nine bps during overnight versus one bps in core hours, an increase of 800%. For our least liquid group, roundtrip trade costs are 683 bps as compared to just 10 bps during core hours, an increase of 6700%. Note these estimates are biased low as we often have trades in the less liquid bins that are rejected due to spreads that are too high to trade.[20]

Schwarz et al. (2025) and Huang et al. (2025) find that execution prices vary by broker for core equity markets and options trades respectively. To begin our investigation into potential price differences in non-core market hours, we graph our roundtrip trade costs across time by broker in Figure 3. Costs are calculated similarly to that reported in the prior figure and table.

[20]BlueOcean imposes limits on how far a limit order can be from the last price. At this time the limit is 20%. For some of our symbols, quoted overnight spreads can bemore than 50%.

<Insert Figure 3 about here>

We find differences across brokers. Schwab, which completely merged with TD Ameritrade in 2024, has the lowest overall costs in every time period. The difference in overnight hours is extremely pronounced. Interestingly, Robinhood relative position changes over time.

One of the reasons for Schwab's low overnight trade costs is how they allow you to place orders. All brokers only allow limit orders outside of market hours. However, the limits that you are allowed to place are much more limited on Schwab than the other brokerage platforms, especially after hours. This caused many of our higher spread orders to be rejected by Schwab's platform. In Figure 4, we graph the percentage of our orders that were rejected or missing from Schwab conditional on us placing and having a matched trade execute at Robinhood on the y-axis while the x-axis represents the average round-trip trading cost for that symbol during overnight hours. We plot the estimated linear relation between costs and missing trades as well.

<Insert Figure 4 about here>

As would be expected due to the restrictive limit prices, the higher the average cost for a symbol, the more likely we are missing the paired Schwab trade. The correlation between the two variables is 0.9.

Thus, to control for these heterogeneous limit order restrictions, we focus our comparison on pairwise differences for our brokers, where we have parallel trades, to evaluate price execution difference across brokers. For each parallel trade across two brokers, we calculate the price difference and index the difference by the price of the stock. Positive values means Broker A receives worse pricing (i.e. higher buy price, lower sell price). We report our differences in bps.

In Panel A, we report results for the Extended Hours period while in Panel B we report results for the Overnight period. We report these differencs as well as t-statistics in 5r.

<Insert Table 5 about here>

We find significant differences in our segments. Schwab has significant lower pricing in extended hours relative to both Robinhood and IBKR while IBKR has better pricing than Robinhood. For overnight trades, we find that Robinhood and Schwab have similar pricing whereas IBKR has significantly worse pricing.

Overall, we find that trading costs during extended hours are orders of magnitude higher outside of core hours. Although markets are much more illiquid, we still find differential pricing across brokers, similar to Schwarz et al. (2025) and Huang et al. (2025). These differences are economically large and statistically significant.

5. Use of On- and Off-Exchange Execution Locations

In the prior section, we find that there are systematic price differences across brokers outside core market hours. In this section, we examine the potential impact of routing on these price differences.

5.1. Routing Venues and Execution Locations

To understand how routing venues and execution locations impact pricing, we obtain SEC Form 606(b)(1) reports from our brokers, which identify where each order is routed for execution, and match our trades to TAQ, which provides an exchange code indicating whether each order executed on a registered exchange or off-exchange.

Panel A of Figure 5 examines the routing dimension. We classify routing venues into three broad categories: wholesalers (grouped by parent firm), dark pools (distinguishing between a broker's own dark ATS and third-party dark ATSes), and lit venues — which include registered exchanges during their operating hours (4:00 AM–8:00 PM) and Blue Ocean, which maintains lit quotes during the overnight session. Panel B turns to reporting where orders ultimately execute, classifying each trade as on- or off-exchange based on the TAQ exchange code. The distinction between the two panels is important: orders routed to a wholesaler, for instance, may ultimately execute on an exchange if the wholesaler passes the order through rather than internalizing.

<Insert Figure 5 about here>

Routing and execution patterns vary substantially *both* across brokers within a given market regime *and* across regimes for a given broker. During core market hours (9:30AM–4PM), the three brokers reflect two distinct routing models. Robinhood and Schwab, which rely on payment-for-order-flow arrangements, route nearly all orders to wholesalers, and execute the vast majority of trades off-exchange as wholesalers internalize retail order flow.[21] In contrast, IBKR Pro, as a non-PFOF broker operating under an agency model, routes a substantial share to its own dark ATS and lit exchanges, producing a higher on-exchange execution share (approximately 20%).

The routing and execution landscape changes dramatically outside core market hours. During after hours (4–8PM), Robinhood and Schwab maintain their wholesaler-heavy routing,

[21] As discussed in Huang et al. (2025), Robinhood uses a selective routing system where breakdown varies across symbols; Schwab uses a proportional routing system where breakdown stays the same across symbols. The routing breakdown of both brokers during core market hours is close to their public 606(a) document.

though the venue mix shifts relative to core hours. On-exchange execution rises noticeably, possibly due to wholesalers less willing to internalize when liquidity thins and price uncertainty increases, instead passing orders through to lit exchanges. IBKR Pro's routing shifts its concentration from its own dark ATS toward a mix of wholesalers, dark pools, and exchanges, with a corresponding increase in on-exchange execution — suggesting that even an agency broker adjusts its routing in response to the different liquidity landscape of extended hours.

The overnight session (8PM–4AM) reveals a distinct pattern. Robinhood and Schwab concentrate their routing entirely with Virtu, which then routes orders to Blue Ocean for execution. This concentration likely reflects the severe thinning of available infrastructure: Virtu is one of very few wholesalers willing to handle overnight flow, and Blue Ocean is essentially the only centralized matching venue operating in this window.[22] Interactive Brokers takes a different path, routing orders through either Blue Ocean or its own dark ATS, matching orders internally rather than depending on the limited overnight wholesaler pipeline.

As the cycle transitions through the twilight period (4–7AM), exchanges have reopened but the official market session has not yet begun. Trading volume during this window is thin, accounting for approximately 1% of daily extended hours volume in our sample, yet the routing and execution patterns are distinctive. Robinhood and Schwab continue routing through wholesalers, yet the majority of orders now execute on-exchange. IBKR Pro, by contrast, routes and executes all orders directly on exchanges. The broad shift toward on-exchange execution likely reflects that thin twilight liquidity makes off-exchange alternatives less viable: wholesalers face greater inventory risk from internalizing, while IBKR's dark ATS has fewer customer orders

[22]Since no registered exchange operates during the overnight session, all orders are classified as off-exchange in TAQ data. However, Blue Ocean operates as an ATS rather than a registered exchange, so despite functioning as a centralized matching venue, its executions are classified as off-exchange.

available to cross internally.

The pre-market session (7–9:30AM) exhibits a broadly similar pattern to after hours, completing a cycle in which routing and execution infrastructure contracts sharply during overnight hours and then gradually re-expands as the next core hour approaches.

5.2. Impact of Venue and Location on Pricing

One of the first potential reasons we observe different pricing is not due to venues discriminating against certain brokers, but related to the use of venues. Unlike market hours where venue use is more homogeneous, venue use outside core hours is much more heterogeneous. Thus, although prior studies found differential pricing regardless of whether pairwise trades when to the same venue or not (e.g. Schwarz et al. (2025) and Huang et al. (2025)), our results could be much different.

To investigation this question, for each of our broker pairs during extended hours, we first examine the difference in our pricing on each trade based on whether our trades went to the same venue or not. Values are reported in bps and negative values indicate that Broker A has better pricing. We report these results in Panel A. In Panel B, we report results on whether or not both our trades both executed in the same location or not, i.e. if both trades executed in dark pools or exchanges or one or the other. In all cases, we report the t-statistic of the difference. Results are reported in Table 6

<Insert Table 6 about here>

We find that both the venue to whom our trade is routed as well as the execution location has a significant impact on our pairwise differences. While Schwab has better pricing than Robinhood in either scenario, the differnece is six times higher when trades are routed to

different venues. We find similar differences for our other broker pairs. The same issue is apparent with our execution location. If trades are executed in the same locatiom (on- or off-exchange), the execution can be very different than if they are executed in the different locations. The Robinhood and Schwab to IBKR comparisons are most dramatic, with the PFOF brokers outperforming when trades are executed in the same location, but underperforming when trades are executed in different locations.

We further decompose the impact of execution location on the relative difference by performing a double sort. For each broker pair, we report results if both broker's trades were executed on exchange, if both brokers' trades were executed in dark pools, and then differences if one broker was executed on the exchange and one in the dark pool. For each category, we report the number of observations as well as the price difference and the t-statistic of the difference. These results are reported in Panel A of Table 7.

<Insert Table 7 about here>

We find the joint execution location is an important determine of price execution differences. Importantly, these findings are consistent across all of our broker pairs. As expected given the prior research, we find that two trades both executed in dark pools results in systematically different pricing. However, we also find two surprising results. First, we find that two pairwise trades, both executed on exchanges, receive different pricing. This occurs when a Schwab or Robinhood trades is executed on-exchange a the same time as an IBKR trade. These differences are highly statistically significant.

In Panel B, we decompose the dual exchange executed pair. For each broker pair, we examine price differences when both trades are routed to the same exchange versus when our two trades

are routed to different exchanges. For Schwab and Robinhood, 76% of the time both trades hit the same exchange. Regardless, in both cases, there is no difference in exechtion prices. However, when both brokers are executed on an exchange with an IBKR exchange executed trade, less than 50% of both trades are routed to the same exchange. Price execution is similar to the trades are routed to the same exchange. However, IBKR trades on a round-trip basis have 16 to 20 bps worse pricing on average when those trades go to different exchanges. It seems in these cases, IBKR trades are routed to exchanges with worse quotes.

The second surprising result is that when one broker is executed in a dark pool and the other is executed on an exchange, the dark pool trade systematically gets worse pricing. This is most obvious for Broker A. Broker A has better differential pricing in every other category, except in this case where they under perform the parallel broker. However, this other performance occurs in the opposite situation as well. In Panel C, we report the difference between Broker A and Broker B's dark executed trades when the other broker is executed on exchange and price differences when both trades are executed in dark pools. We find that, in both directions, trades executed in dark pools significantly underperform relative to when both trades are executed in the dark. Figure 6 again clearly shows the underperformance of Broker A when it is the only trade in the pair executed in the dark pool.

<Insert Figure 6 about here>

We finally examine if this phenomenon occurs when both of our trades go to the same venue. To examine this issue, we examine price execution of Schwab and Robinhood pairs. In this case, both brokers are using the same dark pool (i.e. wholesaler) at each firm. We report results in Panel A similar to Panel A of Table 7, but separate results into when both trades

are routed to the same venue or not. In Panel B, we report the relative difference when one trade is executed on exchange and the other is executed in the dark pool relative to when both trades are executed in the dark pool. We report results in Table 8

<Insert Table 8 about here>

Overall, our results are consistent when either the trades are routed to the same venue or not. In both cases, the dark pool executed trade underpeforms significantly relative to when both trades are executed on exchanges.

In summary, while differential pricing for two dark pool exeuted trades is consistent with prior findings, we also find that differential broker pricing is being created through unexpected ways. First, two trades both routed to exchanges are receiving different pricing. Second, relative to an exchange executed trades, dark pool trades are receiving worse pricing, regardless of broker. In two of our four routing combination paris, trades are, on average, receiving worse execution than a lit quote on an exchange. These findings apply to all of our broker pairs.

6. Impact of Mechanisms across Market Hours

One interesting time period is the twilight hours. During this time period, it seems as if there is minimal internalization by broker-dealers. All of IBKR's trades are routed to exchanges. Even Schwab and Robinhood, who almost exclusively route to Virtu, have almost all of their orders routed to exchanges. This contrasts significant with both the pre-market and after market hours. In those cases, 50% of IBKR orders are executed in dark pools while 75% to 80% of Robinhood and Schwab trades are executed off exchange. Thus, we may find differences in how execution location impacts pricing during different market regimes.

We examine this possibility by separating our trades into market regimes and examining the differences for Robinhood to IBKR. We focus on these two brokers as we have a large number of trades in both the twilight and overnight market stages.[23] For each market regime, we report the overall price difference and then the price differences in our four execution location possibilities. We report results in Table 9.

<Insert Table 9 about here>

We find that the twilight period is indeed unique. As noted, IBKR trades always execute on exchanges during that period. Interestingly, if our trade for Robinhood is executed in a dark market, we get the same price as IBKR does on the exchange, indicating the dark pool is pricing our trade, on average, equal to the IBKR price. However, if both trades are executed on exchanges Robinhood receives seven bps better pricing than IBKR. Alternatively, one could argue that Robinhood is receiving seven bps worse pricing in dark markets than when they are also executed on exchange.

However, relative price quality flips in the pre-market and after-hours markets. Robinhood has worse average pricing of more than 12 bps. Robinhood trades continue to receive better pricing if both trades are on the exchange as seen during twilight. The difference, however, is more than double. More importantly, Robinhood trades change from having equal pricing with IBKR when IBKR is executed on exchanges during twilight hours to have significantly worse pricing in pre-market and after hours. The change is by 50 bps or more. In fact, pricing for

[23] As shown previous, there is no difference between Robinhood and Schwab overnight execution. Both route all of their trades to Virtu and all of those trades are executed on BlueOcean. We only have a handful of Schwab trades during twilight hours. Interesting, in all cases, both Robinhood and Schwab trades are routed to the same execution location and the difference in execution prices is only -0.7 bps, which is insignificant. These results are consistent with our twilight results reported for Robinhood and IBKR.

these trades is so much worse for Robinhood, even though they receive better pricing in the other three execution location scenarios, their overall execution quality is worse than IBKR.

We find a similar pattern overnight. BlueOcean is the "defacto" exchange overnight with lit quotes. IBKR even displays BlueOcean quotes on their platform because IBEOS is dark. When IBKR chooses to execute trades on their own dark ATS, IBKR receives on average 13.5 bps worse price execution than the execution we receive on a Robinhood trade executed on BlueOcean.[24]

Collectively, these results suggest that internalization is important impacts on price execution.

7. Discussion

Our findings show systematic price differences across brokers, with execution location as an important determinant. In this section, we discuss implications for investor protections as well as potential economic explanations.

7.1. Investor Protections

One of the most surprising findings is the execution prices of our trades relative to exchange quotes. Across multiple scenarios, we find a consistent pattern: broker-dealers are executing trades at prices worse than the best lit quote they have access to.

When both brokers' trades execute on exchanges, the broker that receives overall worse pricing systematically routes to an exchange with the inferior quote. This pattern does not appear to be a latency issue: our randomized order of submission rules out systematic speed

[24]We are able to identify where our trades are routed on IBKR due to our 606(b)(1) data. With that said, during our time period, BlueOcean reported their trades to the NYSE TRF whereas IBEOS reported trades to the NASDAQ TRF. Thus, simply using these flags, one could identify where our trades are executed.

disadvantages; and when both brokers' trades are routed to the same exchange, they receive similar pricing. The pricing difference emerges only when both trades are routed to different exchanges.

When one trade executes on an exchange and the other off-exchange, trades internalized by wholesalers or matched in dark pools receive prices that are also systematically worse than the lit quote available at the time of execution. This pattern is not broker specific: regardless of which broker receives better overall execution prices, the trades execute off-exchange receive worse pricing. This pattern also extends to the overnight session, where trades executed in dark pools receive worse pricing than those matched on Blue Ocean's lit quotes. The implication is that the venue itself, not just the broker, is also a key driver for execution price differences outside core market hours.

Our findings empirically demonstrate that exactly the behavior Rule 611 was designed to prevent, i.e. routing to inferior venues and dark pool execution at prices worse than available lit quotes, is occurring in extended and overnight hours. Naturally, the 611 Rule does not exist during these times so there is no violation of the rule. However, there is a recent push to eliminate this rule even during market hours. Our results demonstrate that there is the potential for harm to retail investors if this rule is eliminated.[25] We should note that our trades are odd-lots whereas protected quotes, i.e. NBBO, are for usually 100 share quotes or more. With that said, exchange feeds would supply executing broker-dealers with the entire order book and therefore they would be aware of the best lit quote for our trade size.

Regardless of the 611 Rule, as mentioned previously, to the best of our knowledge, best

[25]Last year, the SEC held a day-long roundtable discussing the possible elimination of the Order Protection Rule. Curent SEC leadership is open to eliminating the order protection rule. See https://www.sec.gov/newsroom/meetings-events/roundtable-trade-through-prohibitions

execution duties apply even outside market hours. Specifically, FINRA Rule 5310 applies. Rule 5310 requires brokers to use reasonable diligence to find the best market for the security and execute at the most favorable price possible under prevailing conditions. While there is wide latitude in how broker-dealers achieve best execution and best execution includes other factors including price, it seems executing at prices worse than the best lit quotes is a violation of best execution, yet this behavior persists without apparent consequence. Clarifying best execution duties after hours would also help protect retail investors.

Additionally, retail brokers currently execute their best execution duties by calculating scorecards for wholesalers on an aggregate execution basis and adjusting routing share accordingly. It may also be helpful to have retail brokers have separate scorecards for after hours trades and set a separate routing percentages to wholesalers during that time. Schwab, for example, uses the same routing criteria across their pre-market, market hours, and after hours trades. Regardless of whether they are only using core hours or combining all trades to evaluate wholesalers, extended hours trades are unlikely to have a significant impact given their relatively low volume. If so, wholesalers may cross subsidize or provide inferior execution during extended hours if competition is not being enforced (see Huang et al. (2025)).

Finally, as with options, there is currently no data disclosed about execution quality at either the venue or broker level. Extending Rule 605 disclosure requirements to cover extended hours and overnight trades—analogous to the new Order Disclosure Rule for market hour equity trades—would help provide some "light" on execution quality in these sessions.

7.2. Drivers of Differential Pricing

We find that execution quality differences across brokers and across regimes. Always one potential explanations for differential pricing is due to toxicity differences between brokers. For example, IBKR Pro could have more sophisticated, less "retail" traders, which may cause its trades to have higher levels of adverse selection and therefore higher effective spreads. Eaton et al. (2022) find that toxicity levels appears to be heterogeneous across brokers for equity trades. It is difficult, however, for toxicity to explain why we are receiving different pricing on two trades both routed to exchanges.

Whether or not this result extends to extended hours trading is unknown. However it could be that, regardless of broker, traders that place orders during extended and overnight hours are more homogenous in terms of their toxicity. For example, Eaton et al. (2024) find that options trade toxicity is homogenous across brokers. Huang et al. (2025) also find that order imbalance around their option trades does not explain any differences in options execution.

A second potential economic explanation is PFOF. Prior results on the impact of PFOF on execution quality is mixed. With Schwarz et al. (2025) find that the variation in PFOF cannot explain the variation in execution quality, Huang et al. (2025) find a strong negative correlation between execution quality and PFOF. One of the expanations for these different results is due to the magnitude of PFOF differences. For example, option PFOF rates appear to be multiple times that seeen for equity trades (Ernst and Spatt (2022). Boulton et al. (2025) find Robinhood's crypto PFOF can be up to 105 times more than equity or options PFOF and it has significant market impacts.

Extended hours trading has even higher differences in PFOF between Schwab and Robin-

hood. Based on public SEC Form 606a disclosures, Schwab charges $0.0006 per share at most or $0.0012 round-trip. Robinhood, on the other hand, charges 9% of the spread each direction, or 18% roundtrip. Our lowest average spread symbol is NVDA, which is $0.0038. On a roundtrip trade, Robinhood would receive $0.0684. This is 5.7 times the amount Schwab receives.

More generally, across all our trades, our average spread is $1.21, which would result in average PFOF of $0.22 for Robinhood. Given Schwab's PFOF amount is at most $0.0012, Robinhood still averages close to $0.22 more, or approximately 180 times more PFOF than Scwhab. This is orders of magnitude more than market hours PFOF differences or options PFOF differences and is even higher than estimated by Boulton et al. (2025). Interestingly, our roundtrip execution differences between Schwab and Robinhood in dollars is also $0.22. Thus, the difference in PFOF is equal to the difference in dollar execution quality, suggesting that PFOF has an impact on execution quality.

As a counterfactual, Robinhood lowers their PFOF to $0.0006 per share overnight, or $0.0012 roundtirp. This matches Schwab's overnight PFOF.[26] During the overnight, when PFOF is the same for both brokers, Schwab and Robinhood receive the same prices. The different in extended and overnight hours also suggests PFOF is an economic driver.

7.3. Competition and Routing

As noted previously, the number of wholesalers that operate during the extended hours and overnight periods are smaller than during core hours. In fact, during overnight hours, Virtu is a monopolistic wholesaler. During twilight hours, Virtu is still a monopolistic wholesaler for Schwab and handles a super majority of Robinhood trades. It is only during pre-market and

[26]For part of our sample period, Robinhood's PFOF was $0.0009 per share. Schwab does not explicitly state their overnight PFOF. We assume it is $0.0006 during that period.

after-hours that both brokers have three wholesalers competing for trades, althought Robinhood still routes a majority of its trades to Virtu.

It is somewhat unclear why other wholesalers do not operate during extended and overnight hours or why Virtu receives such an outsized amount of trades from Robinhood during all extended hours, even when Schwab starts routing its trades in the same proportion as market core hours. One potential explanation is that other wholesalers do not want to pay Robinhood's PFOF rates. Another is that Robinhood uses smart routing even during extended hours.

Ernst et al. (2023) and Huang et al. (2025) both show that the introduction of a new wholesaler leads to better execution due to a result of more competition in the wholesaler market. Huang et al. (2025) also show both empirically and theoretically that parts of order flow that are de-prioritized are liekly to have lower competition and worst pricing. As noted previously, if brokers are using their core market hours routing in extended hours, this could lead to extended hours trades having lower competition and worse execution. Thus the lack of wholesalers and majority market share may lead to worse execution after hours.

8. Conclusion

Extended equity market exchange hours have remained unchanged from 4AM to 8PM, Monday through Friday, for two decades. Even still, retail brokers largely did not allow retail traders to execute trades until 7AM. Over the last few years, however, most brokers have expanded trading to 24/5 through the use of wholesalers and ATSes. Many exchanges have now applied or been approved to run 23/5, which would put overnight trading on par with current extended hours. However, little is known about retail broker execution during extended or overnight hours, which could vary substantially from core hours since many investor protections

do not apply. Standard databases do not have broker or wholesaler information nor a retail trading flag or trade direction sign. Additionally, all trades after hours are limit orders and therefore their execution and pricing is likely endogenous.

In this paper, we examine non-core hours market execution by placing approximately 32,000 randomized marketable limit trades across three brokers starting at 8PM on Sunday and ending at 8PM on Friday. We find that roundtrip trading costs are markedly higher after hours. Even for our most liquid stocks, costs are 500% higher in extended hours and 800% in overnight hours relative to core hours. For our less liquid stocks, trading costs are thousands of times higher. This is even though most brokers only allow trading of a subset of the most liquid stocks overnight.

We also find that execution varies significantly across brokers. As seen in other studies, brokers receive differential pricing on trades executed off-exchange. However, we also find brokers receive systematically different pricing when both of their trades are executed on exchanges. Brokers receive systematically worse pricing when their trade is executed in the dark whereas another broker's trade is executed on an exchange. These relative execution differences are mitigated from 4AM to 7AM when essentially all trades are executed on exchange. We find an economic explanation for our results is payment for order flow, which can be hundreds of times different between brokers during extended hours.

Overall, our results emphasize the importance of investor protections. Reg NMS does not apply to trades placed outside market hours, including the order protection rule (Rule 611). Thus, the national best bid and offer (NBBO) is not binding and there is no requirement trades are routed to the exchange with the best quote. Investors currently have no disclosure about price execution or aggregate order routing after hours. Orders are being executed at prices worse

than the best lit quote, which seems inconsistent with best execution requirements. Given the rapid expansion of retail trading during non-market hours and the documented differences in execution quality, extending investor protections to these sessions warrants serious consideration by regulators.

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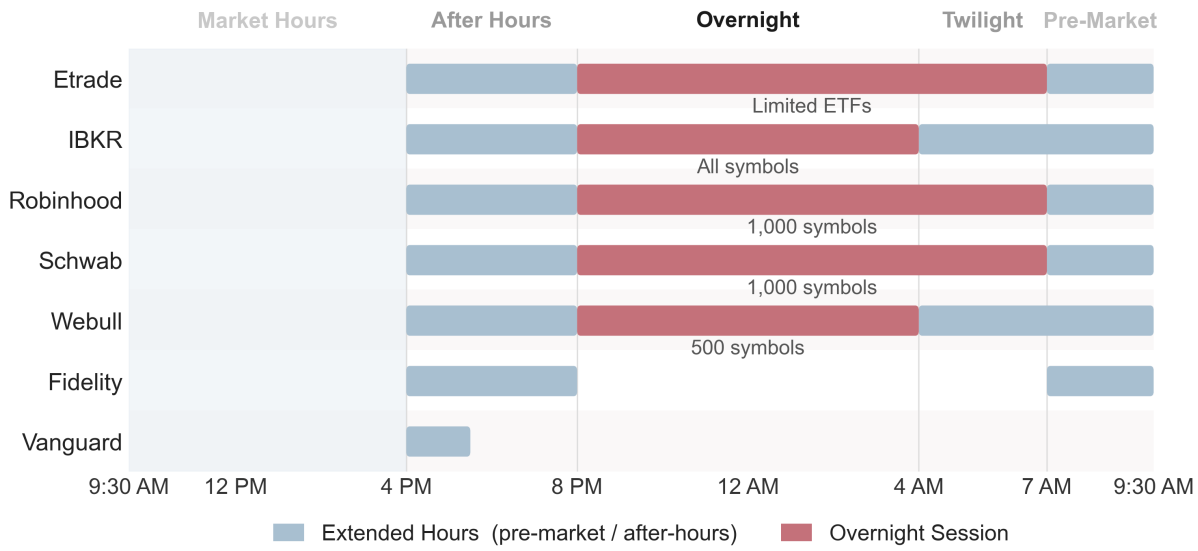


Figure 1: Extended and Overnight Trading Hours by Broker
This figure illustrates the available trading hours at major U.S. retail brokers as of early 2026. The timeline spans a 24-hour period from 12:00 PM to 12:00 PM (ET). Extended hours (blue) represent pre-market and after-hours trading windows (4:00 AM–8:00 PM ET) outside core market hours (9:30 AM–4:00 PM ET), during which brokers permit immediate order execution. Overnight sessions (maroon) represent trading windows offered outside exchange hours by select brokers. The Overnight Symbols column reports the securities accessible during overnight sessions. All brokers restrict orders to limit orders outside core market hours; the set of eligible symbols and specific restrictions vary across brokers.

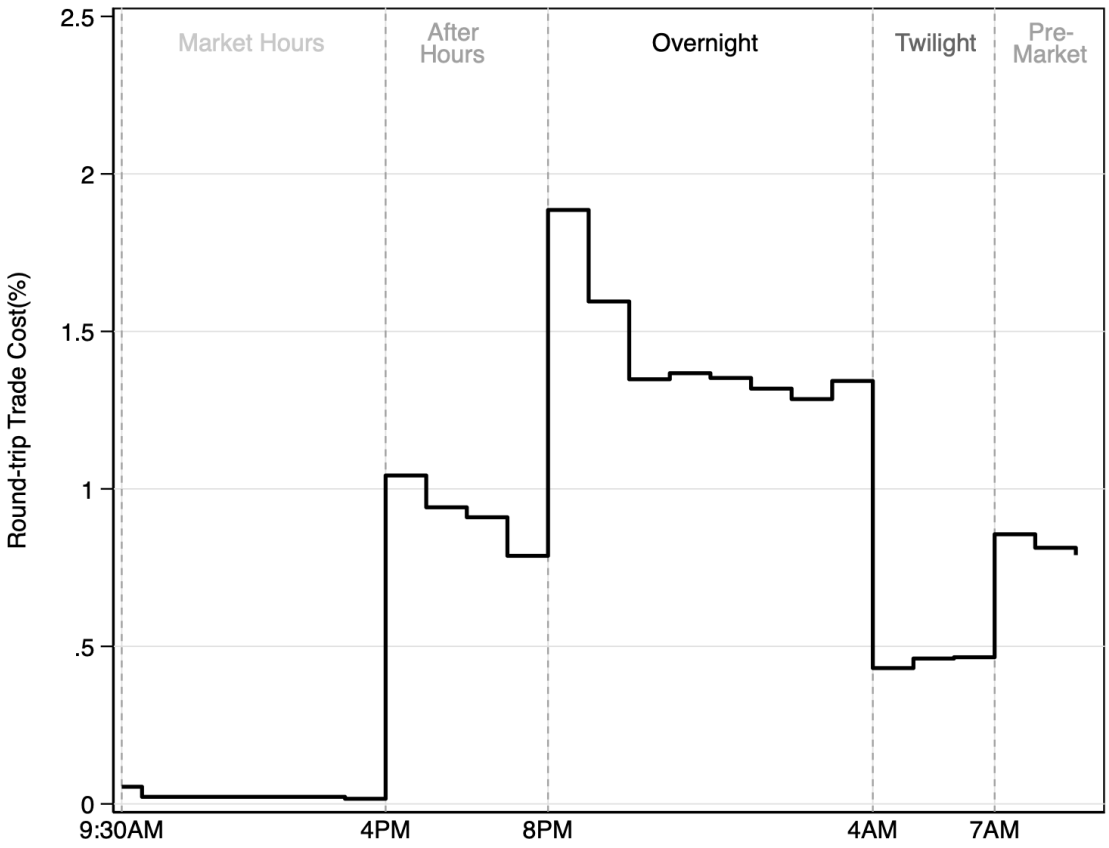


Figure 2: Round-trip Trading Costs across Time
This figure presents the average round-trip trading costs across time. To compute round-trip trade costs, we buy and then immediately sell. The round-trip trading costs is then measured as the difference between the sell and buy price, indexed by the sell price. We average across all trades that occur within the same hour for each broker. Trades are placed Sunday night starting at 8 PM EST and end Friday night at 8 PM EST. We extrapolate costs for 11AM to 2PM using the 9:30AM, 10AM, and 3PM hour trades. Symbols are rotated across hours each day across time.

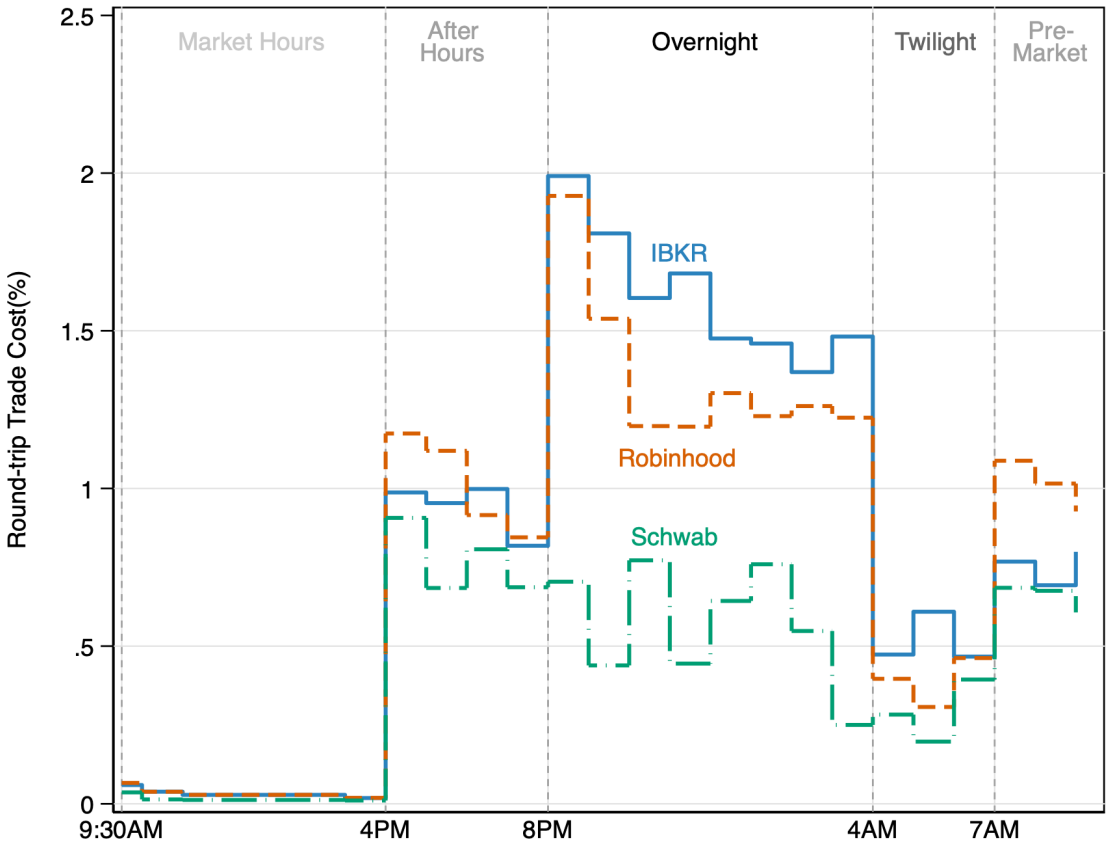


Figure 3: Round-trip Trading Costs across Time by Broker
This figure presents the average round-trip trading costs across time by broker. To compute round-trip trade costs, we buy and then immediately sell. The effective spread is then measured as the difference between the sell and buy price, indexed by the sell price. We average across all trades that occur within the same hour for each broker. Trades are placed Sunday night starting at 8 PM EST and end Friday night at 8 PM EST. We extrapolate costs for 11AM to 2PM using the 9:30AM, 10AM, and 3PM hour trades. Symbols are rotated across hours each day across time.

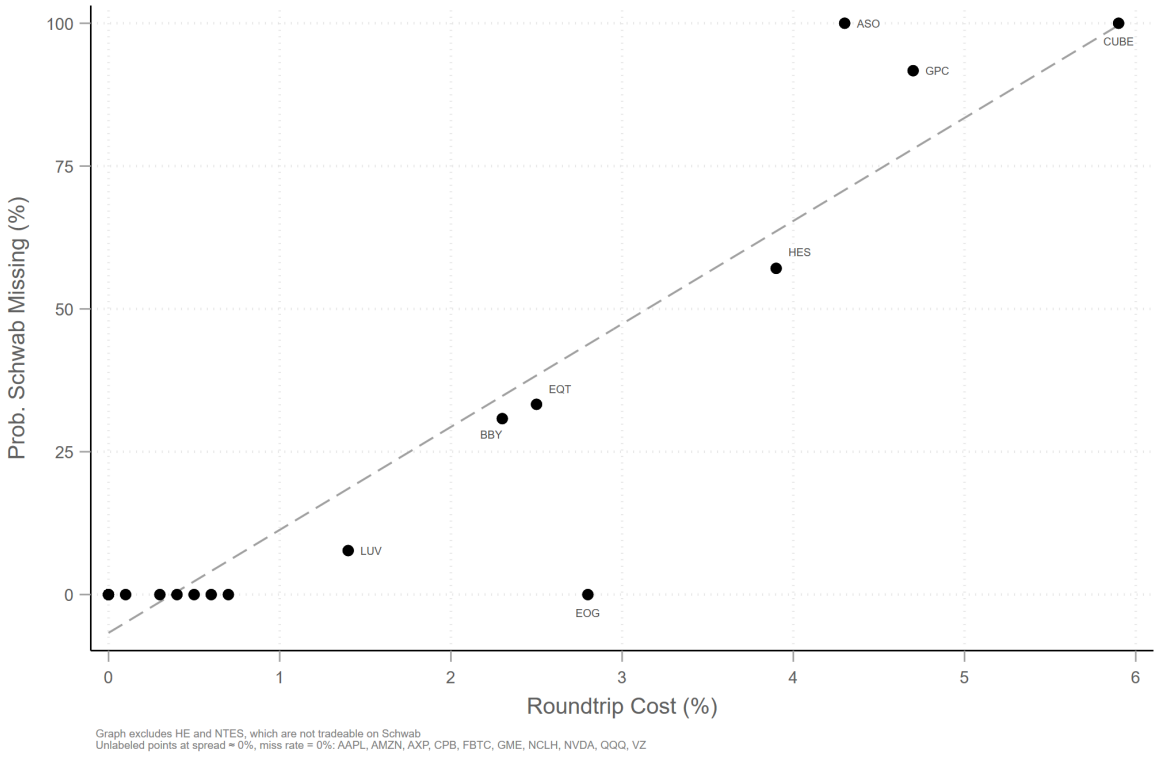
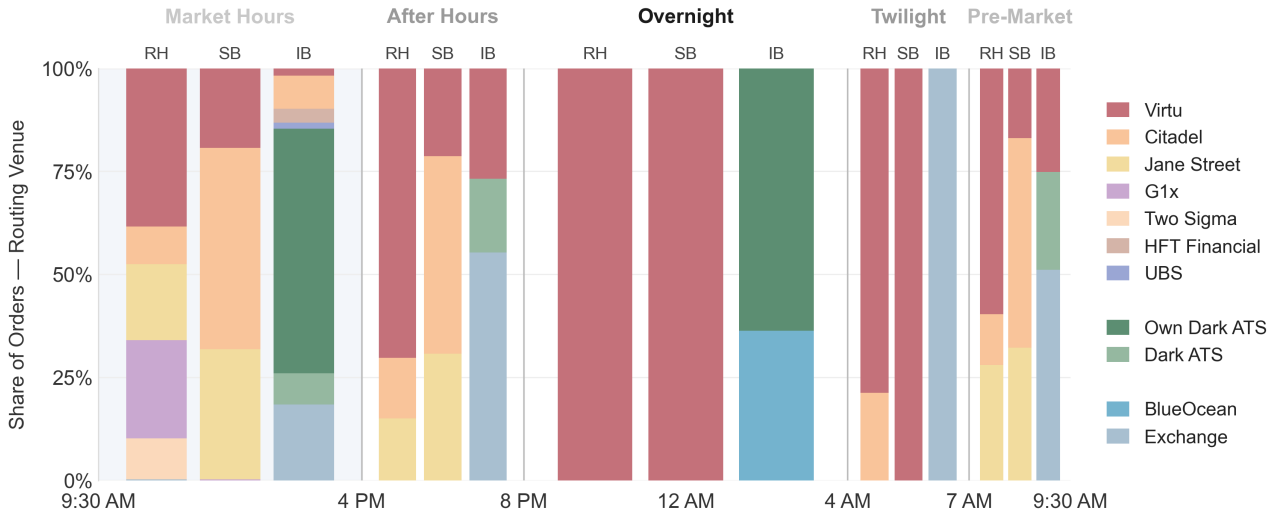


Figure 4: Unsuccessful Overnight Schwab Trades by Symbol
This figure presents the percentage of parallel trades that were unsuccessful on Schwab while successful on Robinhood by symbol during the overnight (8PM to 4AM) hours. On the x-axis, we report the average overnight spread across our sample. The y-axis reports the percentage of trades that were unsuccessful at Schwab. The line is a linear approximation of the relation.

Panel A: Routing Venue Breakdown



Panel B: Execution Venue Breakdown

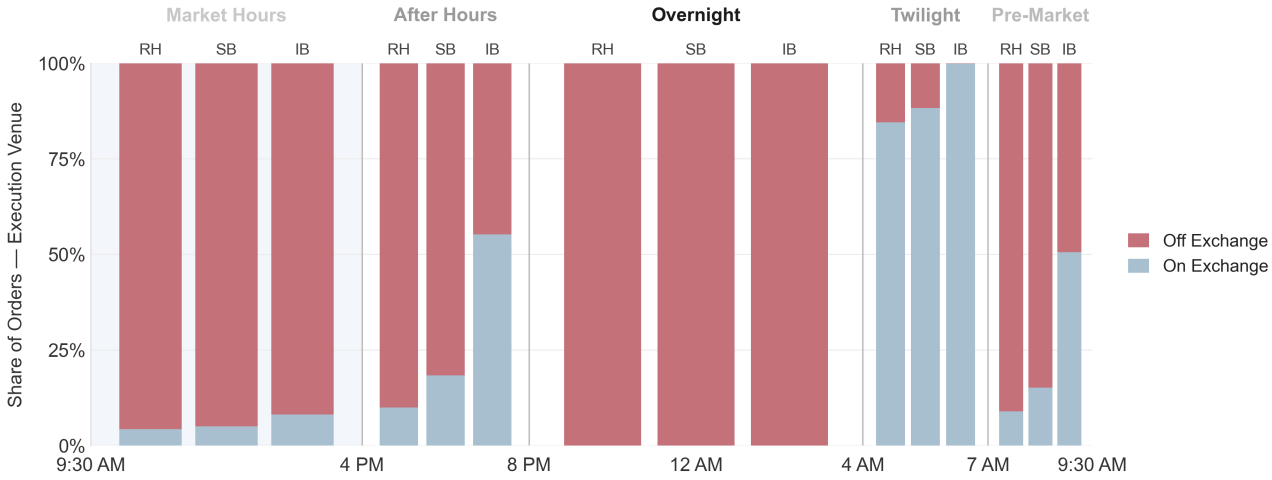


Figure 5: Order Routing and Execution Venue Across Trading Sessions and Brokers This figure presents order rouding and execution venue breakdowns for trades placed in the trading experiment at Robinhood (RH), Schwab (SB), and Interactive Brokers (IBKR) across five market regimes: Market Hours (9:30 AM–4:00 PM), After Hours (4:00–8:00 PM), Overnight (8:00 PM–4:00 AM), Twilight (4:00–7:00 AM), and Pre-Market (7:00–9:30 AM). Panel A shows the share of orders routed to a given venue within a session from our Form 606(b)(1) reports. Venues are grouped into wholesalers (ranked by average order share), dark pools (Own Dark ATS and Dark ATS), and lit exchanges (Blue Ocean and Exchange). Panel B shows the share of orders executed off-exchange versus on-exchange. These data are based on the exchange code by matching our trades to TAQ.

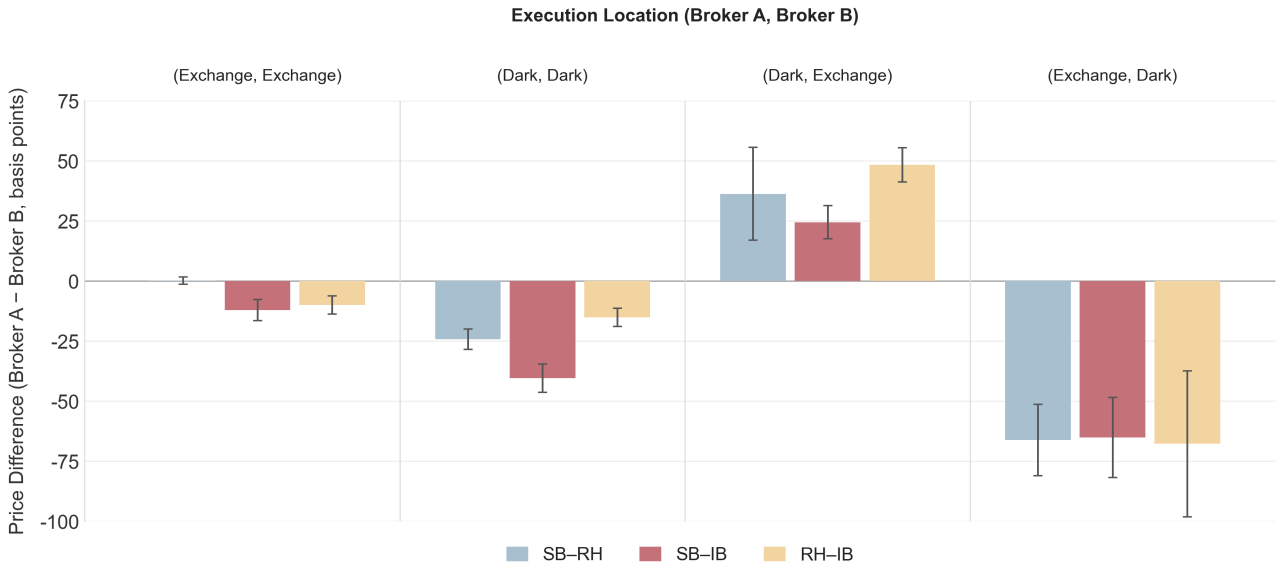


Figure 6:
This figure presents order rouding and execution venue breakdowns for trades placed in the trading experiment at Robinhood (RH), Schwab (SB), and Interactive Brokers (IBKR) across five market regimes: Market Hours (9:30 AM–4:00 PM), After Hours (4:00–8:00 PM), Overnight (8:00 PM–4:00 AM), Twilight (4:00–7:00 AM), and Pre-Market (7:00–9:30 AM). Panel A shows the share of orders routed to a given venue within a session from our Form 606(b)(1) reports. Venues are grouped into wholesalers (ranked by average order share), dark pools (Own Dark ATS and Dark ATS), and lit exchanges (Blue Ocean and Exchange). Panel B shows the share of orders executed off-exchange versus on-exchange. These data are based on the exchange code by matching our trades to TAQ.

Table 1: Extended and Overnight Trading Hours by Broker

In this table, we report the available hours of trading at various retail brokers as of early 2026. Extended hours represent the hours from 4:00AM to 8:00PM, outside the core hours of 9:30AM to 4:00PM, that brokers allow for the immediate execution of trades. Overnight hours represent the hours outside exchange hours that brokers allow for trading. We also provide information on what symbols their customers can trade during that time period. All broker only allow limit orders outside core hours and different brokers allow for different restrictions on limit order prices.

	Extended Hours		Overnight		
Broker	Start	End	Start	End	Symbols
E*TRADE	7:00 AM	8:00 PM	8:00 PM	7:00 AM	Limited ETFs
Fidelity	7:00 AM	8:00 PM			
IBKR	4:00 AM	8:00 PM	8:00 PM	4:00 AM	All
Robinhood	7:00 AM	8:00 PM	8:00 PM	7:00 AM	1,000
Schwab	7:00 AM	8:00 PM	8:00 PM	7:00 AM	1,000
Vanguard		5:30 PM			
Webull	4:00 AM	8:00 PM	8:00 PM	4:00 AM	5,00

Table 2: Stocks Available in Overnight Markets

Using Robinhood's list of overnight stocks in January 2025, this table reports a comparison on the stocks that are and are not available for overnight trading. We report the average and median price, market cap, average daily volume in the fourth quarter of 2024, the average return in the fourth quarter of 2024, and the average daily volitility, computed as the squared daily return. We then compute the difference across the two groups and report t-values of the difference. In Panel A, we report results for U.S. domestic companies and in Panel B we report results for other tickets, such as ADRs and ETFs. ** p<0.01, * p<0.05

Panel A: U.S. Domestic Companies

	Included		Excluded			
	Mean	Median	Mean	Median	Difference	t-value
Price ($)	175.47	76.04	42.62	15.40	132.85	6.74**
Market Cap ($Billion)	83.6	18.8	3.2	0.5	80.5	6.5**
Volume (Million)	5.9	2.7	1.2	0.3	4.8	8.56**
3-mo Ret	4.9%	0.7%	10.5%	0.2%	−5.6%	−2.56*
Daily Vol	1.6%	1.2%	2.3%	1.5%	−0.7%	−12.43**
N	568		2,947			

Panel B: Others (ADRs & ETFs)

	Included		Excluded			
	Mean	Median	Mean	Median	Difference	t-value
Price ($)	$67.65	$37.40	$35.42	$25.97	$32.23	6.69**
Market Cap ($Billion)	22.2	3.3	2.0	0.15	20.2	6.30**
Volume (Million)	5.6	2.2	0.6	0.04	5.0	8.81**
3-mo Ret	3.7%	−0.0%	0.7%	−1.1%	3.0%	1.94
Daily Vol	1.8%	1.1%	1.4%	0.5%	0.4%	3.03**
N	355		5,430			

Table 3: Stocks Selected for Trading Experiment

We report the set of stocks for our trading experiment. Using data from October to December 2024, we rank stocks available on Robinhood's platform available to trade by their number of trades from 12AM to 4AM as reported in the NYSE's TAQ. We split these stocks into eight groups and randomly select two stocks from each group. We also select four additional stocks that are popular overnight and retail stocks. We report the ticker and name as well as the number of trades and total volume over the sample period. Finally, we report the market capitalization as well as the group the stock was placed in.

Panel A: Randomly Selected

Ticker	Name	Trades	Volume	Price	Mkt. Cap.	Group
AMZN	Amazon	19,931	683	226.38	2,390.0B	1
YINN	Direxion China Bull ETF	135,207	26,640.2	29.18	1.7B	1
NTES	NetEase	2,107	155.0	91.18	59.4B	2
VZ	Verizon	1,011	48.0	42.33	178.3B	2
NCLH	Norwegian Cruise Line	700	126.8	27.53	12.2B	3
AXP	American Express	622	7.7	303.99	214.1B	3
HE	Hawaiian Electric	282	18.1	10.50	1.8B	4
LUV	Southwest Airlines	348	37.9	34.11	20.5B	4
EQT	EQT	187	8.4	43.34	25.9B	5
BBY	Best Buy	162	5.5	88.17	18.9B	5
ASO	Academy Sports & Outdoors	97	2.1	50.40	3.5B	6
GPC	Genuine Parts	63	1.3	123.42	17.2B	6
HES	Hess	40	0.3	141.53	43.6B	7
EOG	EOG Resources	61	1.3	127.81	71.9B	7
DYN	Dyne Therapeutics	4	0.1	29.50	3.0B	8
RELY	Remitly Global	25	0.2	21.10	4.2B	8

Panel B: Additional Liquid Names

Ticker	Name	Trades	Volume	Price	Mkt. Cap.	Group
AAPL	Apple	15,213	569.7	242.30	3,670.0B	1
GME	GameStop	13,827	904.1	28.73	12.4B	1
NVDA	NVIDIA	153,193	13,011.4	141.92	3,500.0B	1
FBTC	Fidelity Bitcoin Fund	2,740	256,332	88.80	20.2B	2

Table 4: Spreads by Regime

We report the average roundtrip trading costs of our trades across regime. To calculate roundtrip trading costs, we buy and then sell the same stock immediately and then calculated the difference in price and index by price. In Panel A, we report the raw average roundtrip trading costs across our trades by market regime. Core is when the market is open (9:30 AM to 4:00 PM), extended are hours from 4:00 AM to 8:00 PM outside of core hours when exchanges are still lit. Finally, overnight hours are from 8:00 PM to 4:00 AM. We report the difference and t-value where standard errors are clustered by stock. In Panel B, we report our results by liquidity group. We report the difference between our roundtrip trade costs for extended and core hours and then extended and overnight hours. We report t-values of the differences. ** p<0.01, * p<0.05

Panel A: Spreads by Market Regime

	Average	Diff	t-value
Core	0.03%		
Extended	0.83%	0.80%	4.50**
Overnight	1.46%	1.43%	4.32**

Panel B: Spreads by Market Regime and Liquidity Group

		Extended vs. Core		Overnight vs. Extended	
Group	Core	Difference	t-value	Difference	t-value
1	0.01%	0.05%	11.63**	0.03%	6.71**
2	0.02%	0.33%	9.34**	0.20%	6.09**
3	0.01%	0.37%	13.00**	0.60%	12.05**
4	0.02%	0.78%	11.81**	1.09%	17.19**
5	0.02%	1.05%	12.98**	1.31%	16.75**
6	0.06%	2.23%	17.78**	2.17%	15.66**
7	0.02%	1.62%	14.66**	1.13%	8.22**
8	0.10%	3.36%	22.97**	3.37%	16.07**

Table 5: Comparison of Broker Execution

In this table, we compare our price execution across brokers. For parallel trades in Broker A (in rows) and Broker B (in columns), we report the mean difference in price (Broker A minus Broker B). Differences are indexed by the price and reported in basis points. In Panel A, we report results for Extended Hours, which is from 4AM to 8PM when the market is not open. In Panel B, we report the results from Overnight trading, which is from 8PM to 4AM. t-statistics in parentheses test the null hypothesis that the pairwise difference is zero. $^{**}p < 0.01$, $^{*}p < 0.05$.

Panel A: Extended Hours

Broker A:	Schwab	Robinhood	IBKR Pro
Schwab	–	−22.3	−13.5
		$(-7.68)^{**}$	$(-5.23)^{**}$
Robinhood	22.3	–	9.5
	$(7.68)^{**}$		$(3.81)^{**}$
IBKR Pro	13.5	−9.5	–
	$(5.23)^{**}$	$(-3.81)^{**}$	

Panel B: Overnight

Broker A:	Schwab	Robinhood	IBKR Pro
Schwab	–	5.7	10.7
		(1.45)	(1.16)
Robinhood	−5.7	–	−6.3
	(−1.45)		$(-3.28)^{**}$
IBKR Pro	−10.7	6.3	–
	(−1.16)	$(3.28)^{**}$	

Table 6: Extended Hours Price Execution by Routing and Execution Location

For parallel trades in Broker A (in rows) and Broker B (in columns), the table summarizes the mean difference in price (Broker A minus Broker B). Differences are indexed by the price and reported in basis points. Positive numbers indicate prices are worse (i.e. higher buy price, lower sell price). We also report the number of observations. In Panel A, we report results based on the venue the order was routed to from the broker, where same indicates it went to the same exchange, wholesaler, or dark pool. In Panel B, we report results by execution location where same indicates both trades were executed either both on exchange or both off exchange. t-statistics in parentheses test the null hypothesis that the pairwise difference is zero. $^{**}p < 0.01$, $^{*}p < 0.05$.

Panel A: Routing Venue

Broker A	Broker B	Venue	N	Price Diff.	t-statistics
SB	RH	Same	741	−5.5	−1.99**
		Different	2,023	−33.5	−12.40**
SB	IB	Same	360	−20.6	−7.33**
		Different	2,476	−15.7	−6.48**
RH	IB	Same	689	9.6	4.50**
		Different	3,001	−14.7	−6.79**

Panel B: Execution Location

Broker A	Broker B	Location	N	Price Diff.	t-statistics
SB	RH	Same	2,240	−23.6	−11.08**
		Different	524	−30.9	−5.55**
SB	IB	Same	1,546	−35.8	−13.98**
		Different	1,290	8.5	2.49*
RH	IB	Same	2,046	−13.3	−9.40**
		Different	1,644	40.8	11.35**

Table 7: Extended Hours Price Execution by On- and Off-Exchange

For parallel trades in Broker A (in rows) and Broker B (in columns), the table summarizes the mean difference in price (Broker A minus Broker B). Differences are indexed by the price and reported in basis points. Positive numbers indicate prices are worse (i.e. higher buy price, lower sell price). We also report the number of observations. In Panel A, we report results based on whether the trades were executed on- or off-exchange. *Exchange* is when both brokers trades execute on-exchange. *Dark* is when both brokers' trades excute off-exchange. *Broker A Dark Broker B Dark* is when Broker A (Broker B)'s trade executes off-exchange while Broker B (Broker A)'s trade executes on-exchange. In Panel B, we report the difference in difference results for off-exchange execution. *Broker A Dark Difference* (*Broker B Dark Difference*) is the difference in execution of Broker A (Broker B)'s trades when only its trade is off exchange versus when both trades are off exchange. t-statistics in parentheses test the null hypothesis that the pairwise difference is zero. $^{**}p < 0.01$, $^{*}p < 0.05$.

Panel A: Execution across On- and Off-Exchange Pairs

		Execution Location				
Broker A	Broker B	Broker A	Broker B	N	Price Diff.	t-statistic
SB	RH	Exchange	Exchange	108	0.2	0.26
		Dark	Dark	2,132	−24.2	−11.05**
		Dark	Exchange	159	36.3	3.68**
		Exchange	Dark	365	−66.2	−8.72**
SB	IB	Exchange	Exchange	252	−12.1	−5.41**
		Dark	Dark	1,294	−40.4	−13.41**
		Dark	Exchange	1,059	24.5	6.96**
		Exchange	Dark	231	−65.1	−7.68**
RH	IB	Exchange	Exchange	732	−10.0	−5.20**
		Dark	Dark	1,314	−15.1	−7.86**
		Dark	Exchange	1,537	48.4	13.39**
		Exchange	Dark	107	−67.7	−4.37**

Panel B: Price Execution by Exchange Routing

Exchanges	Broker A	Broker B	N	Percent	Price Diff.	t-statistic
Same	SB	RH	82	75.9%	0.9	0.76
	SB	IB	112	44.4%	−1.0	−0.98
	RH	IB	313	42.8%	−1.4	−1.54
Different	SB	RH	26	24.1%	−1.7	−1.25
	SB	IB	140	55.6%	−21.1	−5.54**
	RH	IB	419	57.2%	−16.9	−5.07**

Panel C: Single versus Both Broker Dark Execution

Internalized Broker	Broker A	Broker B	Price Diff.	t-statistic
Broker A	SB	RH	60.6	6.00^{**}
	SB	IB	65.0	14.01^{**}
	RH	IB	63.5	15.51^{**}
Broker B	SB	RH	-41.9	-5.31^{**}
	SB	IB	-24.7	-2.75^{**}
	RH	IB	-52.6	-3.38^{**}

Table 8: Comparing Same and Different Venue Execution

For parallel trades in Broker A (in rows) and Broker B (in columns), the table summarizes the mean difference in price (Broker A minus Broker B). Differences are indexed by the price and reported in basis points. Positive numbers indicate prices are worse (i.e. higher buy price, lower sell price). We also report the number of observations. In Panel A, we report results based on whether the trades were executed on- or off-exchange. *Exchange* is when both brokers trades execute on-exchange. *Dark* is when both brokers' trades excute off-exchange. *Broker A Dark Broker B Dark* is when Broker A (Broker B)'s trade executes off-exchange while Broker B (Broker A)'s trade executes on-exchange. In Panel B, we report the difference in difference results for off-exchange execution. *Broker A Dark Difference* (*Broker B Dark Difference*) is the difference in execution of Broker A (Broker B)'s trades when only its trade is off exchange versus when both trades are off exchange. t-statistics in parentheses test the null hypothesis that the pairwise difference is zero. $^{**}p < 0.01$, $^{*}p < 0.05$.

Panel A: Execution across On- and Off-Exchange Pairs

Venues	SB Location	RH Location	N	Price Diff.	t-statistic
Same	—	—	741	−5.3	−1.91
	Exchange	Exchange	67	−0.1	−0.17
	Dark	Dark	600	−4.4	−2.78**
	Dark	Exchange	35	60.8	1.99
	Exchange	Dark	39	−86.4	−2.55*
Different	—	—	2,023	−32.7	−12.34**
	Exchange	Exchange	41	0.1	0.38
	Dark	Dark	1,532	−32.0	−10.79**
	Dark	Exchange	124	29.4	3.17**
	Exchange	Dark	326	−63.8	−8.52**

Panel B: Single versus Both Broker Dark Execution

Internalized Broker	Venues	Price Diff.	t-statistic
Schwab	Same	65.3	2.16*
	Different	61.4	6.33**
Robinhood	Same	−81.9	−2.44**
	Different	−31.8	−3.95**

Table 9: Comparing Robinhood and IBKR Pricing by Location and Market Regime

For parallel trades of Robinhood and IBKR, this table summarizes the mean difference in price. Differences are indexed by the price and reported in basis points. Positive numbers indicate prices are worse (i.e. higher buy price, lower sell price) for IBKR. We also report the number of observations. We report results based on whether the trades were executed on- or off-exchange. *Exchange* is when both brokers trades execute on-exchange. *Dark* is when both brokers' trades execute off-exchange. *RH Dark IBKR Dark* is when Robinhood (IBKR)'s trade executes off-exchange while IBKR (Robinhood)'s trade executes on-exchange. For the overnight market regime, *BOATS* is when both trades execute at BOATS, which is a lit ATS, whereas *IBEOS* is when IBKR's trade executes on its own dark pool. t-statistics in parentheses test the null hypothesis that the pairwise difference is zero. $^{**}p < 0.01$, $^{*}p < 0.05$.

Market Regime	RH Location	IB Location	N	Price Diff.	t-statistic
Twilight	—	—	711	−5.7	−2.14
	Exchange	Exchange	569	−7.2	−3.33**
	Dark	Exchange	142	0.3	0.03
Pre-Market	—	—	1,175	12.2	3.34**
	Exchange	Exchange	53	−31.6	−2.75**
	Dark	Dark	543	−21.9	−5.48**
	Dark	Exchange	539	56.1	9.14**
	Exchange	Dark	40	−57.5	−3.15**
After Market	—	—	1,803	15.1	5.73**
	Exchange	Exchange	110	−15.6	−3.98**
	Dark	Dark	770	−10.8	−5.89**
	Dark	Exchange	856	49.5	10.66**
	Exchange	Dark	67	−76.3	−3.27**
Overnight	—	—	2,056	−8.4	−6.22**
	BlueOcean	BlueOcean	783	0.0	0.01
	BlueOcean	IBEOS	1,273	−13.5	−6.73**