Trading and Corporate News in After Hours Market

Bei Cui* Monash University

Arie E. Gozluklu† University of Warwick

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ABSTRACT

This paper documents new evidence on after hours trading (AHT) activity in U.S. equity markets. We show that the landscape for AHT changes substantially over time. Following the emergence of alternative trading platforms, AHT activity has been shifting to these platforms. The highest proportion of negative news (on insider trading) are released after market close. AHT retail activity increases around scheduled corporate events (e.g., earnings announcements), while institutional trading is prevalent around unscheduled corporate news releases. In contrast with prior literature on regular trading hours, we show that AHT insider sales (primarily manager sales) rather than purchases are more informative.

JEL classification: G10, G12, G14.

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*Australian Ctr for Financial Studies, Monash University, Melbourne. Phone:+61 (0)421079140, e-mail: bei.cui@monash.edu

†Warwick Business School, Finance Group, University of Warwick, Coventry, CV4 7AL, UK. Phone: +44 (0)24 7657 4297, e-mail: arie.gozluklu@wbs.ac.uk.

I. Introduction

Incorporation of news into prices is one of the essential functions of financial markets and a litmus test for market efficiency. Thanks to increase in media outlets, market participants have access to abundant news (see Panel A of Figure 1), but given the limited attention of market participants timing of news releases becomes increasingly important, and firms strategically choose when to disclose news (Cuñat and Groen-Xu, 2017; Niessner, 2015). While most of the trading activity occurs during the normal trading hours, both exchanges and alternative trading platforms allow trading outside regular trading hours (RTH), that is, in the after hour market. Firms do release corporate news (e.g., earning announcements) outside RTH to reduce price impact (Martineau, 2017; Michaely, Rubin, and Vedrashko, 2014), presumably to reduce the amplified reaction of retail traders. However, after hours trading(AHT) has received relatively little attention. This is surprising, since bad news (relative to good news) mostly arrive after markets close (see Panel B of Figure 1).

[Figure 1 about here.]

We start with a comprehensive evidence on AHT activity in the U.S. markets. While many studies focus on the market quality of regular trading hours (e.g., Chordia, Roll, and Subrahmanyam, 2011), there is scant evidence on how trading evolves in the after hours, especially in the recent period after the financial crisis. We document that there is a sharp increase in AHT activity relative to RTH, in particular after 2007, following the regulatory changes promoting competition across trading venues (i.e., Regulation NMS). Parallel to the increase in RTH activity, there is substantial increase in executed trades in after hours markets in the last decade (i.e., daily average number of trades (dollar trading volume) increases by 1.5 (1.4) times to 40 (5.4 million U.S. Dollars), compared to days before 2007). However, in contrast to RTH, the trade size in AHT does not exhibit a similar decrease, if anything, there is an increase in trade size. This is somewhat expected, since the trading costs (e.g., quoted spreads or effective spreads) are significantly higher after the markets close. We show that the landscape for AHT changes substantially over time. According to a SEC report in 2000, a large part of AHT occurs on regular exchanges, however we note that that picture has changed: in the last few years most of the AHT trading activity occurs on alternative trading platforms such as ECNs (See Table 1), a continuation of the trend which had started following earlier tick size changes around the millennium (Conrad, Johnson, and Wahal, 2003).

After-hours trading (AHT) attract different types of traders, including institutional (Martineau, 2017) and high frequency traders (Cole, Daigle, Van Ness, and Van Ness, 2015).[1]

[1]Nasdaq provides AHT information on the most active stocks (e.g., Yahoo, Microsoft, Intel).

While both informed and informed traders are active in AHT, there is not much direct evidence on retail trading activity in AHT (Barclay and Hendershott, 2003).[2] Brokerage firms often publish a disclosure to warn retail traders against the dangers of AHT such as low liquidity (e.g., wider spreads), high volatility, disconnection with other markers, abrupt changes in prices, often linked to announcements.[3] On the other hand, there is recent evidence showing that profits to speculative trading strategies such as momentum mainly stem from overnight trading activity (Bogousslavsky, 2016; Lou, Polk, and Skouras, 2015) suggesting that some market participants are making money at the expense of other (naive) traders who are enticed to these (more accessible) trading venues despite the obvious disadvantages.

In this paper, we propose an identification strategy for retail activity in AHT. Earlier literature uses small versus large trades to distinguish retailers from institutional investors (e.g., Lee and Radhakrishna, 2000; Campbell, Ramadorai, and Schwartz, 2009). However, in the current trading environment small trades during RTH cannot be used to identify retailers. Due to the reduction in trading costs, all market participants, but in particular HTFs, follow order splitting strategies. Other papers use proprietary trading data to identify retail activity, however, these datasets are limited to certain time periods (Barber and Odean, 2000; Kelley and Tetlock, 2013) or only available for few countries such Finland (Grinblatt and Keloharju, 2000; Keppo, Shumway, and Weagley, 2016) or France (Barrot, Kaniel, and Sraer, 2016). In a recent paper, Boehmer, Jones, and Zhang (2017) offers an alternative measure using market orders and show that retail investors are indeed informed in small stocks but do not show market timing ability. However, this measure cannot be used to trace the retail activity in AHT since trading is mostly conducted through limit orders after regular markets close. Instead, we exploit the U.S. Securities and Exchange Commission (SEC) regulation change regarding the odd lot post-trade transparency in December 2013. As a response to the paper by O'hara, Yao, and Ye (2014), the SEC began requiring odd-lot (less than 100 shares) reporting of the tape as of 9 December 2013. We focus not only on odd lot trading activity, that is, trades and volume, but also on buyer initiated odd lot trades as a proxy for retail trading in the spirit of Barber, Odean, and Zhu (2008) who propose buyer initiated small trades as a proxy for individual trades. Our sorting exercise suggest that odd lot trading activity in AHT highly depends on firm characteristics such as price and firm size. But more importantly, odd lot activity during the AHT is fundamentally different than the odd lot activity observed during the RTH. For example, while buyer initiated RTH odd

[2]Retail traders are encouraged to trade using limit orders. Many brokerage firms only allow for limit orders (SEC Bulletin, 2011). Indeed liquidity provision is competitive during after hours while liquidity remain scarce (Barclay and Hendershott, 2004).

[3]FINRA members are obliged (FINRA Rule 2265) to disclose Extended Hours Trading Risk Disclosure Statement (See FINRA website: https://www.finra.org/industry/notices/14-54).

lot trades concentrate in lower price (higher market cap) stocks, the same metric measured during the AHT is significantly higher for higher priced (lower market) stocks suggesting that budget constraint traders prefer odd lots after regular markets close. In line with the latter observation, we also show that our AHT retail proxies are particularly elevated for stocks that grab retail investor attention (Berkman, Koch, Tuttle, and Zhang, 2012). The same is not true for the odd lot measures capturing RTH activity. This evidence provides strong support that our measures are different than the ones used in earlier studies based on RTH odd lots (Johnson, Van Ness, and Van Ness, 2017; Johnson, 2014; O'hara et al., 2014; Upson and Johnson, 2017). While AHT odd lot activities spike on corporate event days, the buyer initiated AHT odd lot trade, is mainly affected (positively) by spread and (negatively) by aggregate market uncertainty. This result hints at the market making role of individual traders (Barrot et al., 2016), but in contrast to the evidence provided by Barrot et al. (2016), they shy away from market making during market distress (high VIX).[4]

Next, we analyze the determinants of AHT activity by collecting not only scheduled corporate events, such as earning announcements, both during RTH and AHT, but also unscheduled (surprise) corporate events (Baruch, Panayides, and Venkataraman, 2016) such as dividend initiations, repurchases, stock splits, merger and acquisitions (M&A)[5] and seasoned equity offerings (SEO). Earlier papers suggest that AHT activity mainly concentrates on scheduled corporate event days, such as earning announcements (Cole et al., 2015; Jiang, Likitapiwat, and McInish, 2012). Using a comprehensive news dataset collected by Ravenpack, we look into news articles disseminated in AHT for S&P500 stocks during the period December 2013 and June 2016. We show that more and more news, especially bad news are announced and disseminated during AHT. We focus particularly on the insider trading announcements during AHT: Nearly two third of the insider trading news are released in the after hour market. More importantly, this is the news category where we observe the highest gloom (i.e., bad to good news ratio) after market close.

Finally, we provide a new evidence that not only insider purchases are informative generating positive (abnormal) returns (Rogers, Skinner, and Zechman, 2016), even more so during AHT, but also insider sales are informative followed by negative (abnormal) returns only when they are released during AHT. The negative news prevail up to ten days if the sales orinate from managers. To the best of our knowledge, the latter evidence has not been documented before in a high-frequency environment. Cross-sectional regressions suggest that AHT market participants absorb the bad news, and partially revert the downward trend in

[4]HFT traders may be in a better position to adapt to hard information such as VIX (Zhang, 2013), hence will be more active in liquidity supply during volatile markets.

[5]We filter out those M&A announcements with prior rumors and analyze them separately.

prices over the next two days.

The remainder of the paper is organized as follows; Section II describes the data sources and introduces key variables of interest. Section III presents AHT information environment. Section IV shows how AHT trading and market quality measures evolve over time and around corporate events. Section V concludes.

II. Data and variables of interest

A. Data

Our data come from a variety of sources. We use the DTAQ to collect intraday (millisecond) transactions and quotations. The DTAQ database is recommended by (Holden and Jacobsen, 2014) to be the first-best solution to measure liquidity in today's fast and competitive U.S. equity market. Following Holden and Jacobsen (2014), we filter the transaction and quotation data for errors.[6] To provide evidence on AHT and to compare between RTH and AHT, We use trade executions for the constituents of the S&P500 index for the period September 10, 2003 to June 30, 2016. Due to the data availability of DTAQ database, our analysis of AHT covers the sample from September 10, 2003 to June 30, 2016. We restrict my main sample to S&P500 constituents for liquidity purposes. Regular trading hours (RTH) refers to trading session during 09:30 a.m. to 04:00 p.m. EST. After-hours trading (AHT) refers to trading session during 04:00 p.m. to 08:00 p.m. EST, which are identified in DTAQ as sale condition code "T". NYSE "Closing Auction" (with DTAQ sale condition code "6") and NASDAK "Closing cross" (with DTAQ sale condition code "M") are printed in DTAQ with timestamps right after 04:00 p.m but we eliminate these trades from my analysis of AHT because they represent different trading mechanism. We also deliberately eliminate pre-open trades since pre-open market attracts a different clientle and hence it exhibits substantially different trading characteristics (Barclay and Hendershott, 2008). We apply our analysis of AHT odd-lot trades during the period from December 9, 2013 to June 30, 2016, because the odd-lot trades are not reported in any of the consolidated public tapes, and therefore are not available prior to December 9, 2013. As a response to the paper by O'hara et al. (2014), the SEC began requiring odd-lot reporting of the tape as of December 9, 2013, which is identified in DTAQ as sale condition code "I".

News sentiment data are obtained from RavenPack, which is a comprehensive news dataset containing real-time news releases for stocks listed on the NYSE, Amex, and Nasdaq. They cover news articles commonly used by institutional and individual investors.

[6]The detailed procedure to clean the DTAQ are explained in Appendix A.

Ravenpack also provide a score which is determined by systematically matching stories typically categorized by financial experts as having short-term positive or negative financial or economic impact. The strength of the score is derived from a collection of surveys where industry experts with extensive backgrounds in finance and economics rated entity-specific events as conveying positive or negative sentiment and to what degree. Their ratings are encapsulated in an algorithm that generates a score ranging from 0-100 where 50 indicates neutral sentiment, values above 50 indicate positive sentiment and values below 50 show negative sentiment. The Ravenpack news sentiment scores are capable of differentiating the degree of sentiment. For example, the algorithm generates a lower (more negative) sentiment score for stories about an analyst downgrade from a "Strong Buy to a Strong Sell" than from a "Buy to a Neutral". We only focus on firm-relevant news by setting the news-relevance score (NRS) to be 100.

To measure the information content of insider trading announced in RTH and AHT, we need the precise time the media disseminates filing. So we collect news category regarding "Insider trading" from Ravenpack to get the timestamps. Given that we concentrate on the announcement effect of insider trading filings, we only keep the news category regarding regulatory release of insiders' transactions. In addition, in order to understand the different market reaction to trading by different groups of insiders, we obtain Form 4 insider filings from Thomson Reuters, and match with SEC filings on EDGAR. Then we can match with Ravenpack to obtain the timestamped data. However, this match is complicated by the fact that Ravenpack does not include the identity of the insider, and hence does not allow us to match the article to the SEC filings in cases where there are multiplier insider filings by a given firm in a short period. We follow Rogers et al. (2016) to eliminate observations for which two or more insider filings for a given form occur within 15 min of each filing. We follow Lakonishok and Lee (2001) to classify insiders into two groups: "manager" group includes CEOs, CFOs, chairman of the board, directors, officers, presidents, and vice presidents while "Other" are all investors who are required to report their trading to the SEC but are not managers.[7]

Then we identify corporate events using several sources. We focus on two types of events: *scheduled* corporate announcements, that is, earnings announcements and *unscheduled* corporate announcements related to insider purchases, insider sales, M&As, Seasoned Equity Offerings (SEOs), stock repurchases, dividend initiation and stock splits. We use I/B/E/S to identify the date and time stamp of quarterly earnings announcements in order to distinguish between earnings announcements made during AHT (4:00PM-8:00PM) and those

[7]We do not have "Large shareholders" as a separate group because they only have less than 10 observations in our sample of S&P 500 firms.

outside AHT (0:00AM-4:00PM). While the quality of the I/B/E/S time stamp data has been criticized, the effect on our sample is very minimal since I/B/E/S time stamps are overwhelmingly correct for AHT, as documented in Michaely et al. (2014). We identify insider trading announcement events from Ravenpack and concentrate on regulatory release of insiders' transactions (i.e., SEC filings on EDGAR). Rogers et al. (2016) verify that media disseminates insider filings quickly and 82% of dissemination timestamps in Ravenpack is within half a minute or so of EDGAR dissemination. Given that we explore the symmetric effect of insider trading announcement on AHT trading activity, we exclude the firms with both insider purchases and insider sales announcements on the same day.[8] We identify M&As, stock repurchases and SEOs announcement dates using Global SDC Platinum. We minimize the impact of leakage before the news release by deleting all M&As pre-event "rumors" reported in press articles based on the information provided by Global SDC Platinum. We collect cash dividend initiation and stock splits from CRSP.Cash dividend initiations include ordinary quarterly cash dividend (with CRSP distribution code 1232 and 1238) and special cash dividend (with CRSP distribution code 1262 and 1272, the CRSP code numbers for dividends labeled year-end, final, extra, or special).

B. Variables of Interest

The liquidity measures that we analyze for RTH and AHT are standard measures of market quality: spread measures (quoted, effective and realized spread), depth, price impact and order-to-trade ratio (OTR).

The first category of liquidity measure evaluates the quoted and effective spread. For a given time interval s, the quoted spread is defined as

$$Percent\ Quoted\ Spread_s = \frac{A_s - B_s}{M_s} \tag{1}$$

where A_s is the National Best Ask and B_s is the National Best Bid assigned to time interval s and M_s is the midpoint. Aggregating over the sample period, a stock's *Percent Quoted Spread* is the time-weighted average of $Percent\ Quoted\ Spread_s$ computed over all time intervals. For a given stock, the percent effective spread is on the k^{th} trade is defined as

$$Percent\ Effective\ Spread_k = \frac{2D_k(P_k - M_k)}{M_k} \tag{2}$$

where D_k is an indicator variable that equals +1 if the k^{th} is a buy and -1 if the k^{th} trade

[8] It eliminates 9.4% of the insider trading announcements.

is a sell and M_k is the midpoint of the quotes assigned to the k^{th} trade by Lee and Ready (1991) convention. Aggregating over the sample period, a stock's *Percent effective spread* is a dollar-volume-weighted average of the *Effective Spread*$_k$ computed over all trades.

The second category of liquidity measures the realized spread and price impact. For a given stock, the percent realized spread is on the k^{th} trade is defined as

$$Percent\ Realized\ Spread_k = \frac{2D_k(P_k - M_{k+5})}{M_k} \tag{3}$$

where M_{k+5} is the midpoint five minutes after the midpoint M_k. Aggregating over the sample period, a stock's *Percent Realized Spread* is a dollar-volume-weighted average of the *Percent Realized Spread*$_k$ computed over all trades. For a given stock, the percent price impact is on the k^{th} trade is defined as

$$Percent\ Price\ Impact_k = \frac{2D_k(M_{k+5} - M_k)}{M_k} \tag{4}$$

Aggregating over the sample period, a stock's *Percent Price Impact* is a dollar-volume-weighted average of the *Percent Price Impactd*$_k$ computed over all trades.

The third category of liquidity measures evaluates share bid and ask depth. The share ask (bid) depth is the share amount available at the best ask (bid) quote from the exchange or market maker with the largest size quoted at that price. *depth* is time-weighted average of the sum of share ask and bid depth.

The final measure is the order-to-trade ratio, *OTR*, is the ratio of number of quotes over number of trades, a metric closely followed by market regulators (Friederich and Payne, 2015; Hagströmer and Norden, 2013).

Then we obtain odd-lot trades from DTAQ, and exclude the trades from NYSE and Amex. Given NYSE and Amex use level-book method to print an aggregate message for execution at the same price level, it may affect the computation of odd-lot order execution. We include most exchanges reported to public tape, such as NYSE Arca, BATS EDGA, BATS BYX, Bats BZX, EDGA, EDGX, Chicago (CHX), Nasdaq, Nasdaq BX, Nasdaq PSX, FINRA, and National. However, the effect of exclusion of NYSE and Amex is minimal because the trading volume of these two exchanges during AHT are nearly zero percent during the period between December 9, 2013 and June 30, 2016 (See Table III). Our analysis of trading patterns of odd-lot trades focus on several measures: The first odd-lot measure, *OLtrade* is the number of odd-lot trades as a percentage of total transactions. The second measure, *OLbuy* is the Lee and Ready (1991) liquidity-demander "buy" odd-lot trades as a percentage of total odd-lot trades.

To investigate the relation between the stocks followed by retail investors and AHT, we explore two proxies (tightly linked to volatility) for retail investor attention. First, we use squared intraday return on day t as the proxy for the news which could attract retail investor attention. Barber and Odean (2008) measure the extent to which a stock grabs investor attention by the level of absolute (previous) daily return, and find significant association between stocks with extreme one-day return and individual investors' buying activities. Specifically, following Berkman et al. (2012) we construct daily return using open and close quotations from DTAQ. The opening price and closing price for RTH is the first valid NBBO after 09:30am and before 04:00pm, respectively. Hence, RTH *intraday open-to-close return* is measured as the log of the closing quotation relative to opening quotation during the RTH:

$$Return^{intraday}_{open-to-close} = OTC_{t,RTH} = log(CLOSE_t/OPEN_t) \tag{5}$$

Then the first proxy($OTC^{Vol}_{t,RTH}$) is defined as the squared of the above measure, $OTC^2_{t,RTH}$. Note that this measure is by construction sensitive to the opening and closing prices which are likely to be determined mainly by institutional trading activity. Therefore, we introduce a second proxy ($DHL^{Vol}_{t,RTH}$) of retail attention which is the daily *high-low ratio* of each individual stock, defined as the highest midpoint in a day minus the lowest midpoint in the same day (intraday range) divided by the midpoint between the high and low midpoints (Bae, Jang, and Park, 2003; Buti, Rindi, and Werner, 2011). Arguably, the extreme intraday values are more salient and likely to draw retail traders' attention to individual stocks (Bordalo, Gennaioli, and Shleifer, 2012).

III. News release during AHT

How does news dissemination change between RTH and AHT? In Table I below, we report the frequency of news from different categories both during RTH and AHT along with the news sentiment, that is, good vs. bad news. We start with some interesting observations. First, among the top 20 news articles covered in Ravenpack for S&P500 stocks during the period between December 09, 2013 and June 30, 2016, AHT covers 336,442 news articles compared to 582,990 news articles covered during RTH. Second, earnings announcements rank the largest category among news articles disseminated during AHT, closely following by insider trading announcements. In total, earnings announcements and insider trading capture 36.63% of all news articles disseminated during AHT. Third, in line with the recent literature (Michaely et al., 2014), we find that proportionally less bad earnings announcements are made during AHT compared to those during RTH. This is in contrast with the

earlier view (Gennotte and Trueman, 1996; Patell and Wolfson, 1982) that firms time their earnings strategically by hiding bad earning announcements in low-attention period. Taken together, these observations show that the study of AHT activity is becoming more important because more and more information releases take place during AHT.

[Table I about here.]

Next, we test the information content of news articles disseminated by media during AHT. The information content is measured in terms of stock returns and trading volumes. The announcement of good news (bad news) is expected to generate positive returns (negative returns), which we confirm in our analysis in Table II. Meanwhile, trading volume increases in the presence of both good and bad news. The trading volume suggest that AHT trading activity plays an important role in incorporating the news into prices.

[Table II about here.]

IV. AHT activity

A. RTH vs. AHT

This section starts with a comparison of trading activity during RTH and AHT. Most of the evidence on trading activity and market quality of RTH in recent years has been already documented in earlier papers (e.g., Chordia et al., 2011). We report here RTH activity as a benchmark to assess the recent evolution of AHT, a relatively unexplored territory. Though some recent studies allude to the importance of AHT activity in the context of corporate announcements (Cuñat and Groen-Xu, 2017; Jiang et al., 2012) and price discovery (Barclay and Hendershott, 2003; Martineau, 2017), relatively little is known about the microstructure of the after hours market.

A.1. Trading volume

We first document in Panel A of Figure 2 below the ratio of total daily dollar trading volume during after-hours trading (AHT) over volume during regular trading hours (RTH) over the last decade. We make several interesting observations: i) While on average AHT volume is low compared to RTH volume, there is a sharp increase in the post-2007 period (initial jump with gradual decrease to a level which is **1%** higher than the pre-2007 level **2.95%**, ii) There are frequent spikes in the AHT volume, presumably coinciding with concentration of corporate events on specific days, iii) The spikes are much larger in the post-2009 period,

reaching occasionally almost half of the RTH volume, in line with the Cuñat and Groen-Xu (2017) evidence that more and more corporate announcements are made after market close, iv) The top three spikes are coinciding with day when FTSE Russell is rebalancing the large-cap Russell 1000 and the small-cap Russell 2000 indexes, which show that after-hour market is also the platform where funds trade shares to track index.

[Figure 2 about here.]

Panel B of Figure 2 shows the value-weighted daily number of trades in both markets. The figures show similar patterns: relatively stable number of transactions (even a decrease in AHT) in the pre-2007 period followed by a sharp increase and a decline during crisis period which stabilizes around a higher level (almost twice in the case of AHT) compared to pre-2007 level. Clearly, the y-axis scales are substantially different suggesting that the entry of new market participants such as HFTs are much less pronounced in the after hours markets.[9]

The last panel of Figure 2 which reports the dollar trade size per transaction in both markets reveal a stark contrast: while there is a strong downward trend in RTH trade size up to 2009, also documented by Chordia et al. (2011), there is no such a trend in trade size of AHT. On the contrary, we observe a sharp increase in AHT trade size after 2007 which remains at higher levels in the post-2010 period. We also note that on average trade sizes are much larger in the after hours markets. This is partly due to occasional submission of very large (block) trades. Nonetheless, the figures reveal that trading dynamics are substantially different in after hours markets compare to regular trading hours.

Next, we look at the TAQ reporting facilities (for the period Dec, 9 2013 - Jun 30, 2016) to see on which platforms AHT and RTH activity occurs. In Table III we also note a sharp difference between AHT and RTH activity. Though regular exchanges (e.g., NYSE, NASDAQ, BATS) face severe competition from alternative trading systems (ATS), they still play an important role in RTH activity. This is not the case for AHT. Most of the trading (around 91%) occur on ATS (e.g., electronic communication networks (ECNs)) which are FINRA members and hence report to FINRA.[10]

[Table III about here.]

In Figure 3 below, we show how the trading volume ratio between ATS and traditional exchanges evolve during the post-2007 period both for AHT and RTH. Between 2007 and

[9]Using the Nasdaq HFT sample from 2008-2009, Cole et al. (2015) and Martineau (2017) show that around 30% (33%) share volume (trades) involve HFTs either in one or both sides of the trades. HFT liquidity supply significantly drops on after hour earning announcement days, in particular the liquidity supply to non-HFT traders, that is, institutions and retail traders (Cole et al., 2015).

[10]Here is the list of firms regulated by FINRA: http://www.finra.org/about/firms-we-regulate.

2009, the RTH volume share of ATS increases from less than 20% to more than 45%. Then there is a sharp decline by the end of 2008 which recovers and fluctuates around 45% until recently. In other words, in line with the numbers in Table III, less than half of the RTH trading occurs on ATS. The picture is quite different for AHT. ATS volume share is more than ten times on average in the post-2007 period, with frequent spikes in ATS volume share. We also note that the volume ratio is substantially volatile in the last two years of the sample with higher ATS volume share. These figures reflect the ever changing trading landscape, especially for the after hours trading.

[Figure 3 about here.]

A.2. Market Quality

Next we turn to the market quality measures introduced above. Panel A of Table IV provides summary statistics for the trading activity and market quality measures for the longer period, Sep 2003 - Jun 2016. Confirming the evidence from the figures above, there are massive differences between RTH and AHT activities: more transactions (about thousand times) and dollar volume (around 50 times) take place during RTH, and the trade size is smaller (about 5% of the AHT trade size). This is suggestive of different trader types being dominant in those markets. We will return to this point in the next sections.

[Table IV about here.]

Our first liquidity measure shown in Figure 4 is the quoted spread, a cost measure for a round-trip transaction. On average it is 5.3 basis points (b.p) during RTH and significantly larger (224.5 b.p) during AHT. We note that there has been a decrease in RTH quoted spread until 2007, down to 4 basis points, which doubles during the crisis period, and converges back to the pre-2007 levels.[11] Not surprisingly, justifying the warnings of FINRA for retail customers, AHT is much more illiquid with quoted spreads above 1 percent most of the sample period. AHT quoted spread reach the around January 2005 and has been declining since then, fluctuating around 1 percent in the recent sample. By construction, quoted spreads do not reflect transaction price, while effective spreads measure the distance between the transaction price and the prevailing midquote. As we note from Panel B of Figure 4, effective spreads are lower than quoted spreads both during RTH (4.25 b.p) and AHT (80.30 b.p), suggesting that trades are initiated when quoted spreads are relatively low (De Jong and Rindi, 2009). We also observe that the difference between quoted and effective spread is

[11] One exception is the day, Aug 24, 2015, when 1278 circuit breakers were triggered due to many flash crashes.

much larger during after hours - effective spread is almost half of the quoted spread, around 50 basis points (except the crisis period).

[Figure 4 about here.]

The effective spread can be decomposed into realized spread (Panel C), that is, profit to the liquidity supplier, and the price impact of trades (Panel D). While the profits to market making has been declining during RTH (on average 0.7 b.p.), the benefits to supplying liquidity during AHT, seem to be relatively stable, around 40 b.p., except the periods with high volatility (on average 70.1 b.p). As expected, price impact of trades (in level) is also much larger in the after hours market, but relatively stable during the sample period. However, this decomposition reveals that the major part of the trading cost is the price impact during RTH, whereas it is the realized spread during AHT.

Panel E of Figure 4 show another dimension of liquidity, namely depth, measured in shares, on top of the book. We notice that in the early part of our sample, the after hours market is much more shallow compared to the RTH market, however there is a strong downward trend in RTH during recent years narrowing the gap between two markets. Finally we look at the order-to-trade ratio, OTR, a metric that has been used to capture market making algo trading (Friederich and Payne, 2015; Hagströmer and Norden, 2013). Parallel to the increase in algorithmic trading in financial markets, we observe the increase in OTR during RTH, while such a trend is not visible in after hours market, though there is a large increase after 2009 which coincides with the period of rapid increase in algo trading. We conclude this section by noting that AHT OTR has been larger also reflecting the fact that most AHT venues require traders to submit only limit orders.

A.3. Odd-lot trades

There is a revived interest in odd lot trades after the change in post-trade transparency regime in December 2013.[12] Prior to O'hara et al. (2014)'s study, odd lot trades have been used as a proxy for retail trading in earlier literature Dyl and Maberly (1992); Lakonishok and Maberly (1990); Ritter (1988). O'hara et al. (2014) challenge this view and argue that odd lots are also used by HFTs and informed traders who exploited the lack of transparency prior to the SEC post-trade odd-lot reporting rules. Recent studies (Johnson et al., 2017; Upson and Johnson, 2017), including the one conducted by the SEC (see footnote 12) also question O'hara et al. (2014)'s findings and show that odd lot trades are not necessarily

[12]See the SEC website on odd lot trades: https://www.sec.gov/marketstructure/research/highlight-2014-01.html#.WYxZIlWGPX5.

informed, and the majority of odd lot trades involve non-HFT market participants.[13] Yet, most of these studies mainly focus on the RTH odd lot activity. Therefore we first provide comprehensive evidence on AHT odd lot activity in the post-transparency period, namely Dec 2013 - Jun 2016.

Odd lot trades are defined as trades that are below 100 (round lot) shares, so in principle there might be some heterogeneity in trade size among odd lot trades. We start by plotting the histogram of odd lot trade size both for RTH and AHT. First Panel of Figure 5 confirms the evidence on RTH documented by O'hara et al. (2014): i) odd lot trade sizes cluster around round numbers, e.g., 10, 20, 50, etc, ii) one share and 99 shares are more likely than the other trade sizes, iii) 50 shares is the mostly likely odd lot trade size. We make similar observations for AHT, however there are differences: 50 shares and round number shares below 50 are more likely to appear in the AHT. Both one share and 99 shares are, on the other hand, less likely to be seen during after hours. The fact that 99 shares are less likely in the AHT may suggest that there is less strategic trading around 100 shares.

[Figure 5 about here.]

Next we check whether there are calendar, day-of-the-week, and intraday patterns in odd lot trades. Earlier literature has documented such effects for RTH odd lot trades at the turn of the year (Dyl and Maberly, 1992; Ritter, 1988), around weekends (Johnson, 2014; Lakonishok and Maberly, 1990) and at the beginning of the after hours trading due to high investor attention and firms' news releases (Cuñat and Groen-Xu, 2017).

In Panel B of Figure 5, we note that the proportion of odd lot trades are lower in the after hours over the year showing a different calendar pattern. While the RTH odd lot trades are still high in December (with the lowest figures in January and February), we see a particularly sharp decrease in AHT odd lot trades during December (after a peak in November). In Panel C of Figure 5, in contrast to the evidence provided by Johnson (2014), we see the highest odd lot trade proportions on Monday, both for RTH and AHT, with an almost monotonic decline during the week, with the lowest ratio on Friday. Both calendar and day-of-the-week patterns hint at the retail trader participation using odd lots (Dyl and Maberly, 1992), especially in the after hours trading.

Panel D of Figure 5 splits the trading activity into 15-minute time brackets. We notice that the trading volume peaks at the first 15-min in line with the recent observation of increased corporate announcements and investor attention documented by Cuñat and Groen-Xu (2017). The volume gradually decreases during the after hours. Odd lot volume exhibits

[13] We still do not know whether the non-HFT market participants who use odd lots are primarily institutions or individuals.

a similar pattern, however, it starts at a lower level compared to aggregate volume including round and mixed lot trades in the first half an hour, but then stays relatively at a higher level until 8.00pm EST. Strikingly, we see that odd trade proportion starts at around 25% and increases during after hours reaching nearly 45% towards the end.

We showed earlier that most of the AHT occur on the alternative trading platforms (ATS) rather than regular exchanges. Now, we show how trading, both odd lot and round/mixed lot, is split between ATS and exchanges during RTH and AHT. Panel E of Figure 5 reveals that only 15% of odd lot trades (in the recent part of the sample) and around 50% of non odd lot trades take place on ATS during RTH. Again the picture entirely different for AHT: most trades happen on ATS, but particularly so for round/mixed lot trades. In the early part of the post-transparency sample, odd lot trades are more likely to come from exchanges, whereas later in the sample there are large spikes indicating a migration of odd lots to ATS on certain days. In term trade sizes, larger RTH trades are likely to occur on exchanges, however this has been changing for odd lots in the last part of the sample. On the contrary, AHT round/mixed lot trades are much larger on ATS compared to exchanges, but this is not true for odd lots with slightly larger AHT odd lot trades on exchanges.

A.4. Trading activity by firm characteristics

Certain firm characteristics are likely to be linked to odd lot use by different type of market participants. For instance, Kumar and Lee (2006) show that retail traders prefer low price and low market capitalization stocks. Round lots may prevent them buying high price stocks due to budget constraints. However, this constraint is eliminated if odd lots are used. On the other hand, other papers show that HFTs are also active in odd lot trades (O'hara et al., 2014) and prefer low price, but high market cap stocks (Brogaard et al., 2010; Ye, Yao, and Gai, 2013). However, we do not know whether these findings hold in after hours markets.

We sort the trading information based on price and market capitalization groups for S&P500 stocks from December 9, 2013 to June 30, 2016. We report all of the measures for a 5×1 scheme of portfolios where stocks are partitioned each day into quartile by the level of price or market capitalization. For every portfolio, we first compute the mean value of each measure across firms every day, and then average these cross-sectional means across all days in the sample. The t-statistics are based on the Newey-West (1987) adjusted standard errors of the time-series means.

[Table V about here.]

Panel A of Table V shows the sorting results based on price. We first note both dollar

volume increase in price, both during RTH and AHT, as one would expect. The same holds for *OLtrade*, that is, the higher the price, in proportion there are more odd lot trades. A similar result has been documented by O'hara et al. (2014) during RTH. The number trades monotonically decrease in stock price, but there is a u-shape pattern for AHT trades as both low price and high price stocks are preferred in the after hours. Importantly, *OLbuy*, which we argue is a better proxy for retail trading in the after hours, decreases as the stock price increases during RTH, but increases in stock price during AHT. In other words, purchases using odd lots is more prevalent in after hours markets to buy high price stocks in line with the view that odd lots are preferred because of budget constraints.

In Panel B of Table V, we repeat the same sorting exercise with firm size, that is, market capitalization. Number of trades and dollar trading volume increases in firm size. We find the opposite results for *OLtrade* and *OLbuy* during RTH and AHT: the fact both AHT (RTH) variables decrease (increase) as market cap increases highlight the fact that AHT odd lot trading is different from the RTH odd lot activity and in line with conjecture that AHT odd lot measures are cleaner measures of retail activity given the retail traders' preference for low market cap stocks (Kumar and Lee, 2006). Next we test the latter conjecture in a similar setting using investor attention measures.

A.5. Trading activity by investor attention

We sort the trading information based on attention measures, namely $OTC^{Vol}_{t,RTH}$ and $DHL^{Vol}_{t,RTH}$ for S&P500 stocks. Both measures are computed using information before after hours market opens. Since stock price is correlated with our proxy measures and odd-lot trade activity, for each day, we control for stock price by initially sorting all firms into price quartiles, based on the firms mean price over the previous 20 trading days.[14] Then, within each price quartile, we form 5 finer portfolios by independently sorting based on each proxy for attention. For each portfolio, we first compute the mean value of each measure across firms every day, and then average these cross-sectional means across all days in the sample. The t-statistics are based on the Newey and West (1987) adjusted standard errors of the time-series means.

The first part of both panels in Table VI show the contemporaneous relation between investor attention proxies, which are based on daily volatility, and trading activity. Not surprisingly, they are positively linked to RTH trades and volume as long documented empirically (Karpoff, 1987) and predicted by early microstructure models (Admati and Pfleiderer, 1988; Easley and O'hara, 1992). The negative relation of volatility measures with RTH

[14]The results are robust when we do not control for price in this partitioning scheme or use market capitalization rather than stock price.

odd-lot trades is not new (O'hara et al., 2014). However, the interesting and new finding here is that while odd-lot measures are negatively linked to (retail) attention measures, the opposite is true for AHT measures lending further support to the idea that after hours odd-lot trading is fundamentally different than the RTH counterpart and is a better proxy for retail participation in the markets.[15]

[Table VI about here.]

B. Corporate events

In this section we explore how the AHT activity response to corporate events and in particular how AHT activity matters in one particular but important corporate event, i.e, insider trading announcement. We use panel regressions including time and firm fixed effects, but more importantly we control for all the scheduled and unscheduled corporate events that occur during our sample period and market-wide uncertainty proxied by VIX. Earlier literature (Cole et al., 2015; Jiang et al., 2012; Martineau, 2017) mainly focus on AHT around earning announcements (EA). For example, Jiang et al. (2012) point out the contribution of AHT to price discovery around EAs and emphasize the role of informed traders (institutions) rather than noise traders in price informativeness. Recent studies using NASDAQ HFT database (Martineau, 2017; Cole et al., 2015) show that HFT activity is reduced on EA days, especially in the after hours market replaced by non-HFT liquidity provision.[16] Much less is known on what is happening in the after hours during unscheduled (surprise) corporate events such as insider trading, dividend initiations, repurchases, stock splits, merger and acquisitions (M&A) and seasoned equity offerings (SEO)(Baruch et al., 2016). A separate literature documents that liquidity provision depends market uncertainty (Barrot et al., 2016; Nagel, 2012) and prices react differently to announcement depending on market conditions (Gulen and Hwang, 2012). Therefore, we also control for VIX in our panel regressions.

B.1. AHT activity during corporate events

The general view is that after hours trading is mostly relevant around scheduled corporate events such as earnings announcements (Cole et al., 2015; Jiang et al., 2012). In Figure 6 below, we plot *OLtrade*, odd lot trade ratio, indicating the days with more than ten earnings announcements, separating those made in the after hours and outside AHT and the days

[15] One can clearly argue that these are not only retail attention, but also investor attention measures in general. However, if that is the case, it is not clear why we obtain opposite results for RTH and AHT.

[16] These studies cannot identify whether non-HFTs are institutional traders or individuals.

with more than twenty insider trading announcements.[17] We notice that large spikes in $OLtrade$ and $\$Volume_t^{AHT}$ during AHT indeed coincide with days when quarterly earnings announcements cluster.

[Figure 6 about here.]

B.2. Determinants of AHT Activity

In Table VII we report the results of the panel regression where the dependent variables are AHT trading activity measures including all lot (round, mixed and odd lots) and only odd lot trading measures. In particular, we include $Trades_t^{AHT}$ and $\$Volume_t^{AHT}$ which are the logarithm of number of trades and dollar trading volume for all trades during the AHT. Odd lot measures are $OLtrade_t^{AHT}$ and $OLbuy_t^{AHT}$, which represents the percentage of odd-lot trades and the buyer initiated odd lot trade ratio, respectively.

We have two different specifications based on investor attention measures, one that includes OTC_t^{Vol}, RTH squared close-to-open return (in basis point) as independent variable (Columns 1-4) and another one with DHL_t^{Vol}, RTH high-low ratio as the independent variable (Columns 5-8). We also control for $logprc_t$, the logarithm of firm's closing price at time t, $spread_t$, the percent effective spread (in basis point) and dummy variables capturing corporate events: $Purchases_{t,AHT}$,$Sales_{t,AHT}$, $EA_{t,nonAHT}$, $EA_{t,AHT}$, $dividend_t$, $stocksplit_t$, $M\&A_t$ and SEO_t indicate insider purchase announcement during AHT, insider sales during AHT, earnings announcements outside AHT, earnings announcements during AHT, dividend initiation (regular quarterly cash dividends and special cash dividends), stock splits, M&A activity and Seasonal Equity Offering (SEO) at time t, respectively.[18] VIX is the Chicago Board Options Exchange S&P 500 implied volatility index, is normalized to a daily volatility measure by dividing it by $\sqrt{250}$. We also include year, month and weekday fixed effects and firm fixed effects.

[Table VII about here.]

We first note that two attention measures have different effects on trading activity: while both measures increase AHT odd lot trade ratio, OTC_t^{Vol} decreases AHT trades (though not significantly) and volume whereas DHL_t^{Vol} has the opposite effect. The former measure presumably captures institutional trading activity as well, since it is based on both daily open and closing prices (Carhart, Kaniel, Musto, and Reed, 2002; Comerton-Forde and

[17] the number of announcements is ad hoc, we experimented with different numbers, e.g., 5 or 25, and obtain similar results.

[18] In Panel B of Table IV we report the number of each event in our sample.

Putniņš, 2011), and it may deter some participants from the after hours markets, but not all, since odd lot activity is still strong. However, none of the measures significantly affect the $OLbuy_t^{AHT}$ once we include all the controls. Ceteris paribus, stock price is positively related to all AHT activity measures, so the higher the price the more active is the AHT. Liquidity, measured via effective spread, on the other hand, increases trades and odd lot trading, but is negatively related to dollar volume, suggesting that these measure capture the market activity of different trader types. Importantly, spread is one of the few measures that explains the retail activity proxy, that is, buyer initiated odd-lot trade ratio, a measure which is hard to explain (in line with the noise trading interpretation), as the very low R^2 of the panel regression reveals. And the positive sign suggests that the retail participation coincides with the period of high adverse selection: since most of retail trading is conducted via limit orders in the after hours market, they become de facto liquidity providers (Barrot et al., 2016), but given the lack of reaction to most corporate events (as discussed below), their stale orders are likely to be picked up by other market participants. The other factor that explains $OLbuy_t^{AHT}$ significantly is VIX, our proxy for market uncertainty. The strong negative sign is an indication of retail withdrawal from the AHT during market turmoil. This result is to some extent[19] in contrast with the findings of Barrot et al. (2016) who find that French retail investors replace the institutional traders during market stress. This seems not to be the case for AHT.

The corporate events also do not have an uniform effect on AHT activity. All the corporate events result in a strong increase of number of trades, while dividend initiations, stock splits and SEOs do not have an effect on dollar volume. Insider purchases announcements and insider sales announcements, as an important information events, successfully attract after hour trading activities without increasing the number of odd lot trades, which indicates the increase in number of round/odd lot trades. Interestingly, while earning announcements (EAs) that occur outside AHT increase total dollar trading volume and odd lot trade ratio, the EAs that are made in the after hours only significantly attract total dollar trading volume, capturing institutional trading activity. Stock splits are one of the few corporate events that would directly effect retail participation, since it is an exogenous shock which affects the stock price without an effect on fundamentals (Kumar, Page, and Spalt, 2012). Indeed, we see that stock splits increase the number (odd lot) trades, suggesting more trading activity.

B.3. Insider trading announcements

Filings of insider trades with SEC are important informational events. It has been widely documented that insider trading filings can generate market response and profit for outsiders

[19] Their evidence is from regular trading hours.

from the information contents of insider trades (see, e.g., Seyhun, 1986, 1992; Brochet, 2010). In contrast, Lakonishok and Lee (2001) find that in general, very little market movement is observed when insiders report their trades to the SEC. In an intraday analysis, Rogers et al. (2016) find that for purchases, prices increases responding to the first news dissemination while no price movement is observed for sales. Rogers, Skinner, and Zechman (2017) document a significant price movement prior to the insider trading filings are posted in EDGAR, which is explained by trading of traders who have privileged (faster) access to news. However, prior literature studies primarily regular market hours. To our knowledge, little or no empirical evidence exists on the insider trading announcements in after hour markets.[20]

The insider trading filings announced in AHT offers an ideal setting to investigate the information content of insider trades. First, a large portion of insider trading announcements are made during AHT compared to RTH. As shown in table I, of the 64,732 insider trading announcements news articles, 41,700 occur during AHT. Second, as the second largest news group covered by media during AHT (i.e., 12.34% of AHT news articles), it is not negligible. Third, as illustrated in figure 7, the increasing trend of insider sales filing announcements during AHT seem to suggest that managers have an incentive to strategically time Form 4 Filings, as in the case of earnings news releases (see, e.g., Doyle and Magilke, 2009; Jiang et al., 2012).

[Figure 7 about here.]

We first look at the graphic illustration (see figure 10) of market reaction to insider trading announcements during RTH and AHT. At a first glance, it seems that insiders purchase (sale) when the price move down (up). However, SEC vigorously pursues illegal insider trading cases and is extremely strict with those who trade at the expense of other investors. Therefore, illegal insider trading should only occur in rare occasions. It is more conceivable that insiders purchase when they think the stock is undervalued and signal to the market that they are optimistic about future prospects of the firms. There is no reason why they should strategically time this signalling device (Rogers et al., 2016), hence we see a positive reaction to filings of insider purchases, both during RTH and AHT. Not surprisingly, insider sales coincide with an increasing price trend before they announce their sales. We observe no abnormal return for insider sales announced during RTH in line with earlier evidence Brochet (2010) while insider sales announced during AHT result in negative abnormal returns starting from the next trading day, and persistently drift until ten trading days after the release date. This finding suggests that insider sales indeed have stronger information content once released during the AHT.

[20] One exception is the working paper by Biggerstaff, Cicero, and Wintoki (2017) who look at the AHT insider trades in lower frequency.

[Figure 10 about here.]

Next, we distinguish between insider sales from managers such as CEO, CFO, chairmen of the board or other directors who are more informed about the company fundamentals compared to other employees. In figure 9, we plot the CAR associated with actual transactions rather than news announcements about insider sales. In line with the previous figure, neither the manager sales nor the sales of others are informative during RTH, with not particular trend in CAR after the transactions. On the other hand, there is a large drop in CAR on the first day of sales both for managers and others (with even a larger drop). However, the reduction in CAR only persists in case of manager sales suggesting a greater information content which unravels over several days.

[Figure 9 about here.]

Finally, we test whether trading activity during AHT reacts to the abnormal return following insider trading announcements during ATH. Since purchases and sales reveal different type of news regarding the firm value, we report our results separately. We measure the cumulative abnormal return over different window sizes to capture market reactions as time passes by. $CAR_{t,t+1}$, $CAR_{t,t+2}$ and $CAR_{t,t+3}$ are the one-day, two-day and three-day cumulative abnormal returns taking into account the 4-factor model (Fama-French three factor plus Carhart momentum factor)[21] after the AHT insider trading announcements. $OLtrade_t^{AHT}$ and $\$Volume_t^{AHT}$ are the standardized odd-lot trades and dollar trading volume during AHT on the AHT insider trading announcement dates. We observe that while odd lot trades, a proxy for retail trading activity, do not react to these unscheduled announcements of insider sales, dollar trading volume, on the other hand, presumably a crude proxy for institutional trading activity during AHT, leads to positive and significant price changes in the following two trading days contributing to the reversion of the negative price trend after the information release. In other words, AHT participants act as a counterparty, say through their stale limit orders, and adversely selected by insider sales and by those who are able to chase insider trades. AHT provides a new venue for corporate insiders to correct the mispricing (overvaluation) of the firm without having a material effect on trading during RTH at the expense of AHT market participants.

[Table VIII about here.]

[21] Alternative CAR measures using constant return, market model or 3-factor model deliver qualitatively similar results.

V. Conclusion

We first provide comprehensive evidence on AHT activity on the U.S. markets. We start by documenting that there is a sharp increase in AHT activity relative to RTH, in particular after 2007, following the regulatory changes promoting competition across trading venues (i.e., Regulation NMS). We show that the landscape for AHT changed substantially over time. In the past, a substantial part of AHT occurred on regular exchanges. That picture has changed: in the recent years most of the AHT trading activity occurs on alternative trading platforms such as ECNs.

One of our key contributions is that we analyze news releases in the after hours market and the reaction of different type of market participants. We propose an identification strategy for retail activity in AHT. We exploit the SEC regulation change regarding the odd lot post-trade transparency. The SEC began requiring odd-lot (less than 100 shares) reporting of the tape in December 2013. We focus on both odd lot trading activity, that is, trades, but also on buyer initiated odd lot trades as a proxy for retail trading. Our sorting exercise suggest that odd lot trading activity in AHT highly depends on firm characteristics such as price and firm size. But more importantly, odd lot activity during the AHT is fundamentally different than the odd lot activity observed during the RTH.

Earlier papers suggest that AHT activity mainly concentrates on scheduled corporate event days, such as earning announcements. We analyze the determinants of AHT activity by collecting not only scheduled corporate events, such as earning announcements, both during RTH and AHT, but also unscheduled (surprise) corporate events such as dividend initiations, repurchases, stock splits, merger and acquisitions (M&A) and seasoned equity offerings (SEO). We show that while both scheduled and unscheduled events are important triggers for AHT, but attract different types of traders. Special attention need to be placed on insider trade filings in the after hours market. In particular, insider sales announcements generate significant (negative) abnormal returns at the expense of AHT participants. Overall, AHT activity is worth paying attention to in order to understand the current trading environment and leveling the playing field for AHT market participants.

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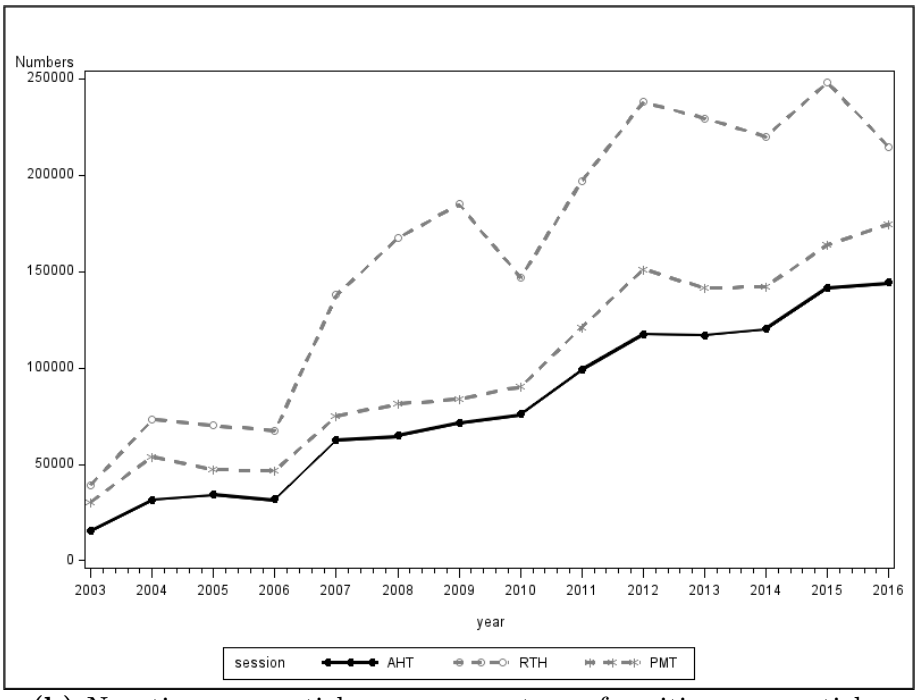
Figure 1. News Articles per year over time

The figure plots the number of news articles (from Ravenpack) announced in AHT per year for S&P500 stocks. Panel A reports the total number of news articles per year. Panel B reports the ratio of negative news articles over number of positive news articles. The sample period is from 2003 to 2016. Pre market trading (PMT) refers to trading session during 04:00 a.m. to 09:30 a.m. EST. Regular trading hours (RTH) refers to trading session during 09:30 a.m. to 04:00 p.m. EST. After hours trading (AHT) refers to trading session during 04:00 p.m. to 08:00 p.m. EST.

(a) Total number of news articles



(b) Negative news articles as a percentage of positive news articles

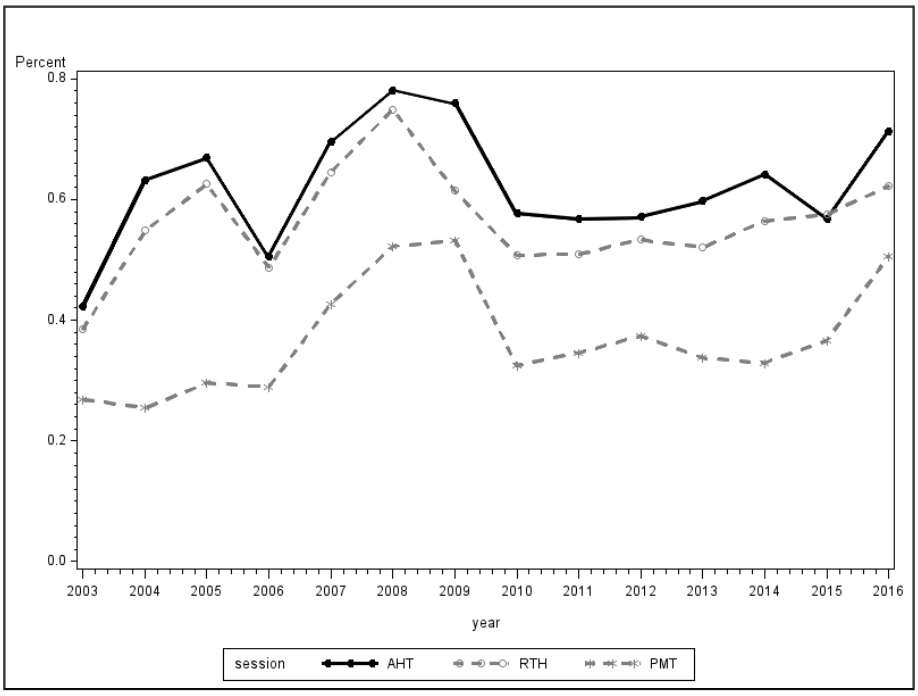
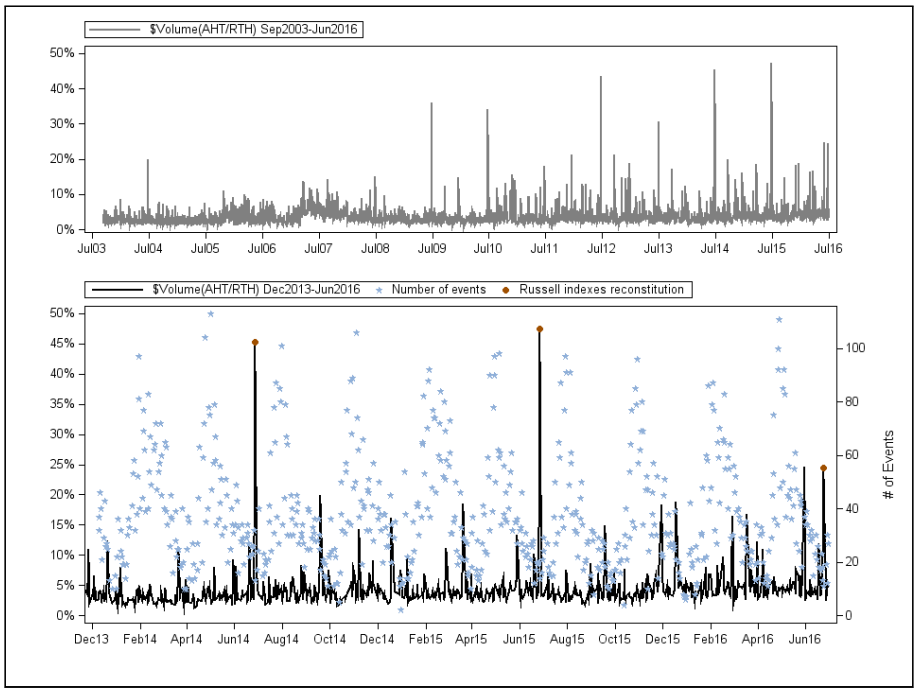


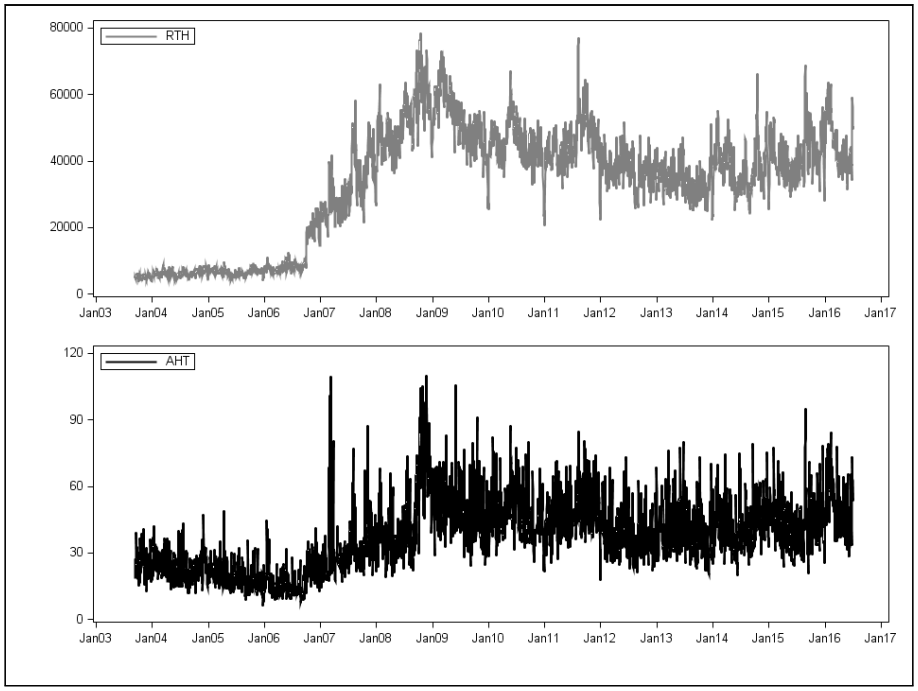
Figure 2. Trading activity per day over time

The figure plots the time-series of daily average of S&P500 stocks, during the period Sep 2003 to Jun 2016. The figure show the average of ratio of total daily dollar trading volume for after-hours trading (AHT) over those for regular trading hours (RTH) (Panel A), value-weighted daily number of transactions (Panel B) and value-weighted daily dollar trade size per transaction (Panel C) of S&P500 stocks. The trading volume ratio are calculated for dollar volumes of each S&P500 stock reported by TAQ Reporting Facility on each day for AHT over those for RTH. The grey solid stars represent number of events happened on trading date t. Events include *scheduled* corporate announcements, that is, earnings announcements and *unscheduled* corporate announcements related to insider purchases, insider sales, M&As, Seasoned Equity Offerings (SEOs), stock repurchases, dividend initiation and stock splits. The solid circle represents the date when Russell announced its annual index reconstitution. The number of transactions and the average dollar trades size are calculated for each stock on each day for each S&P500 stock and then value-weighted across stocks using market capitalization at the end of the previous year. Data for the trading volume, number of transactions and dollar trade size are obtained each day from the DTAQ data set. All variables are winsorized at 0.5% and 99.5% cutoffs. Regular trading hours (RTH) refers to trading session during 09:30 a.m. to 04:00 p.m. EST. After hours trading (AHT) refers to trading session during 04:00 p.m. to 08:00 p.m. EST.

(a) Trading volume ratio (AHT/RTH)



(b) Number of trades



(c) Trade size ($thousands)

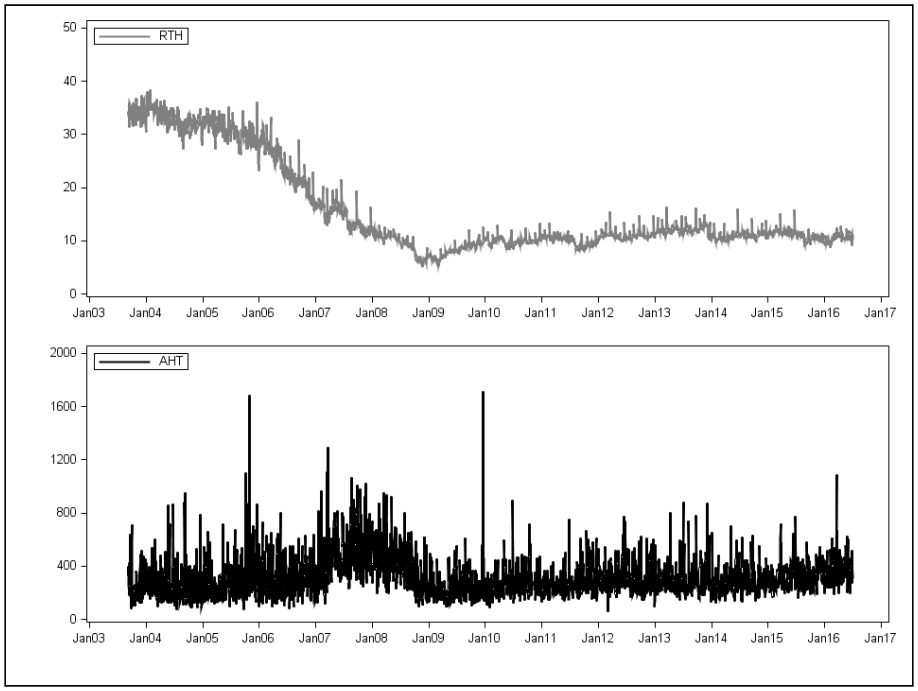


Figure 3. Consolidated trading volume ratio across trading venues

The figure plots the time-series of daily consolidated dollar trading volume ratio of ATS over traditional exchanges for S&P500 stocks, during the period March 5, 2007 to June 30, 2016. The trading volume are calculated for all dollar volumes of each S&P500 stock on each day and then value-weighted across stocks using market capitalization at the end of the previous year. All variables are winsorized at 0.5% and 99.5% cutoffs. Regular trading hours (RTH) refers to trading session during 09:30 a.m. to 04:00 p.m. EST. After-hours trading (AHT) refers to trading session during 04:00 p.m. to 08:00 p.m. EST.

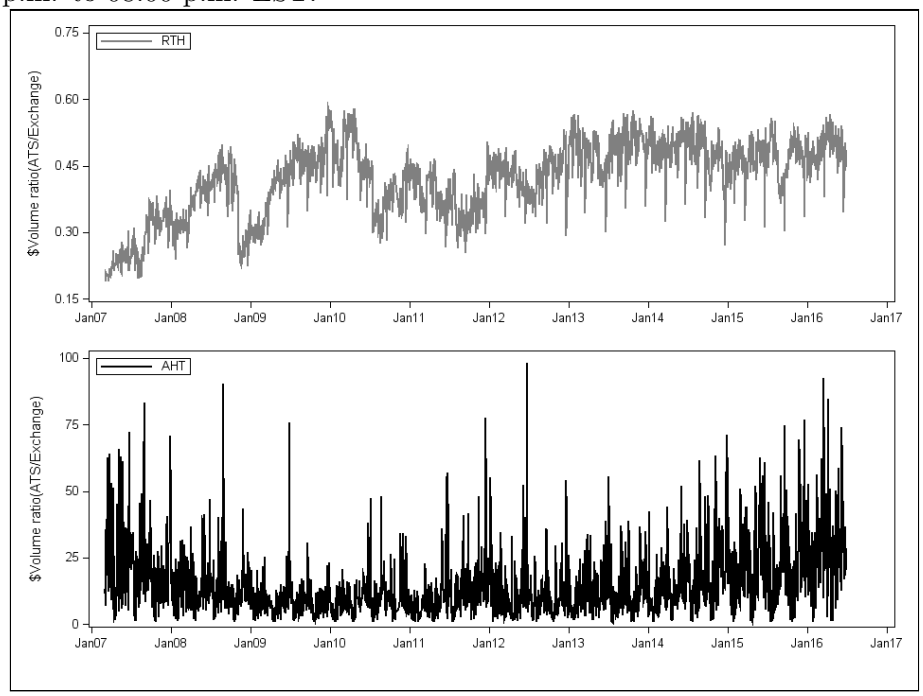
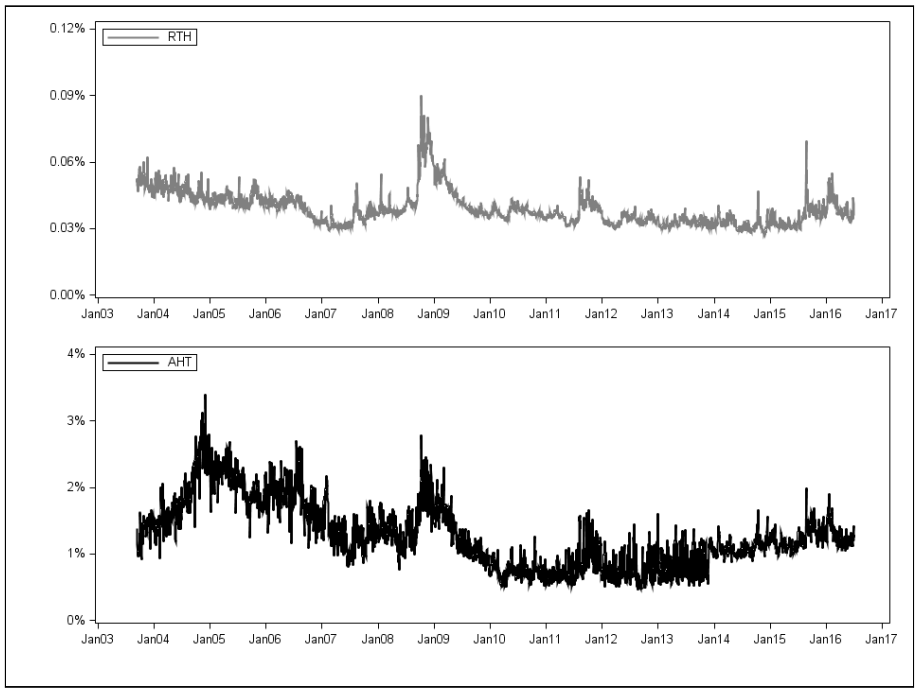


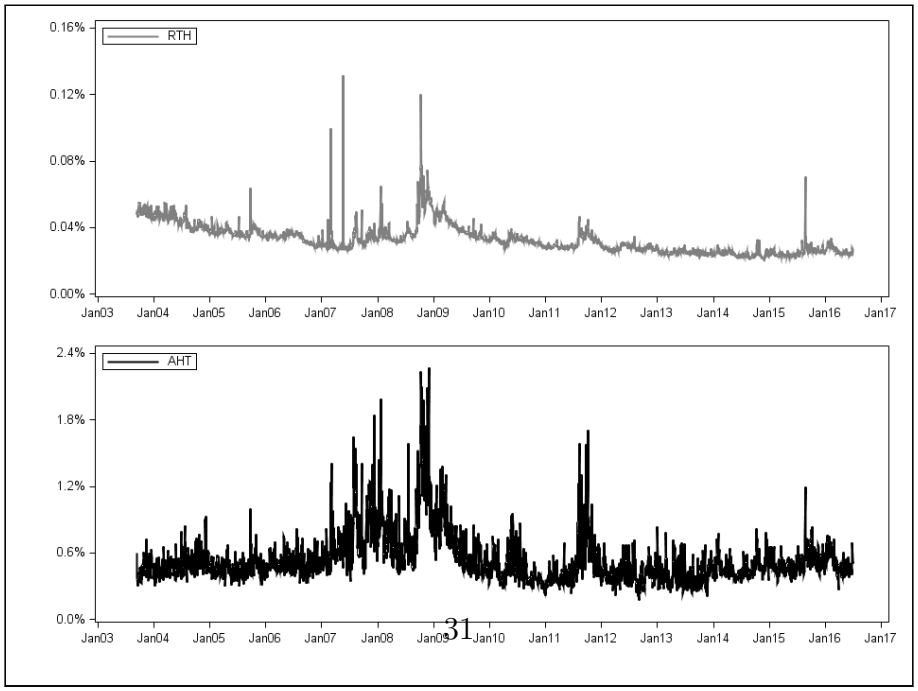
Figure 4. Market quality per day over time

The figure plots the time-series of daily average of S&P500 stocks, during the period 2003 September to 2016 June. This figure presents the daily value-weighted average percent quoted spreads (Panel A), value-weighted average percent effective spread (Panel B), value-weighted mean of realized spread (Panel C), value-weighted mean of price impact (Panel D), value-weighted mean depth (thousands) (Panel E), and value-weighted mean of OTR (Panel F). All the variables are for each stock on each day and then value-weighted across stocks using market capitalization at the end of the previous year. All variables are winsorized at 0.5% and 99.5% cutoffs. Regular trading hours (RTH) refers to trading session during 09:30 a.m. to 04:00 p.m. EST. After hours trading (AHT) refers to trading session during 04:00 p.m. to 08:00 p.m. EST.

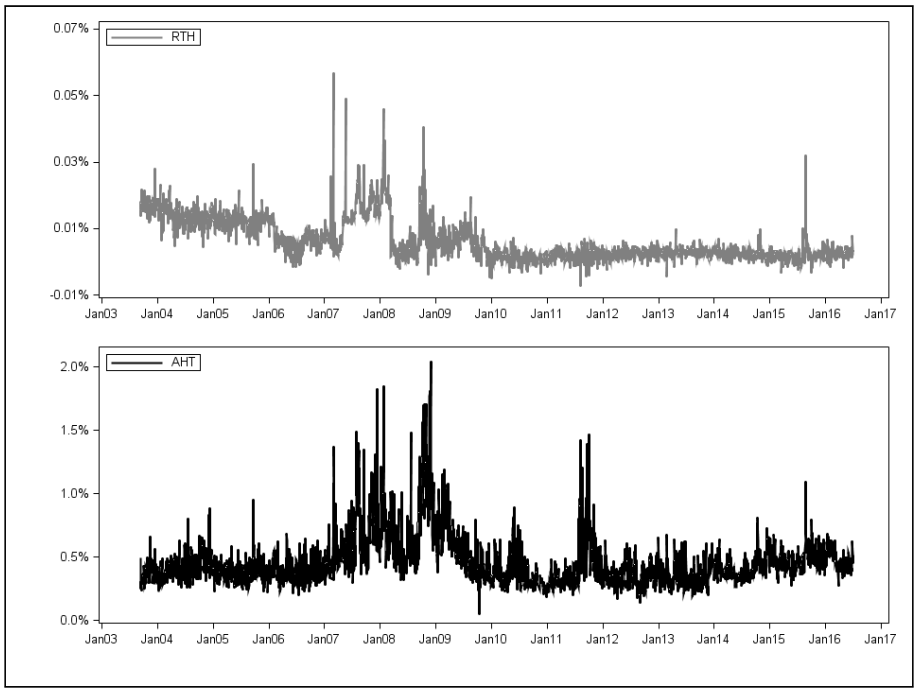
(a) Quoted spread



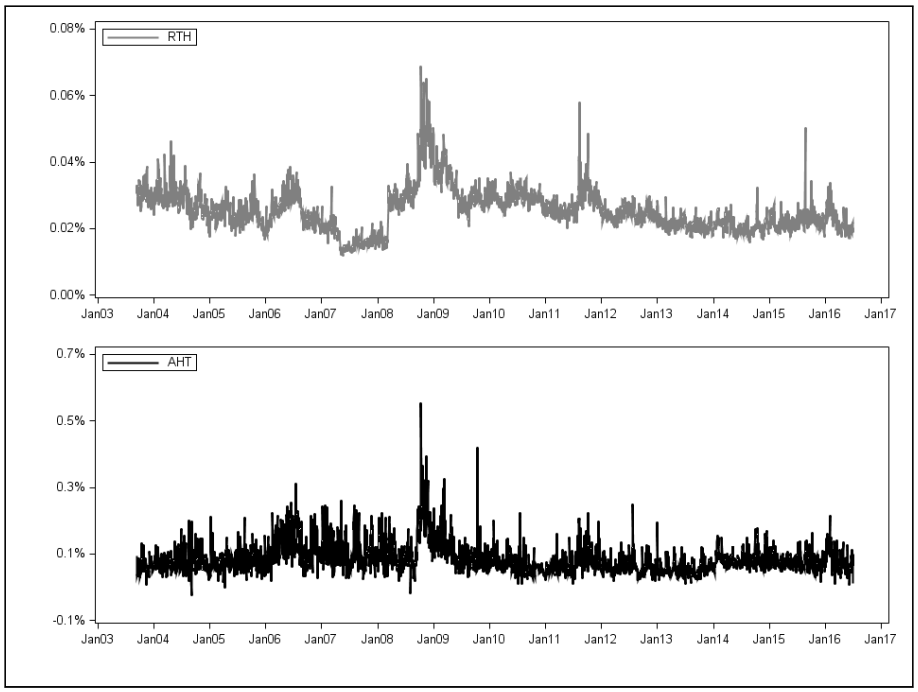
(b) Effective spread



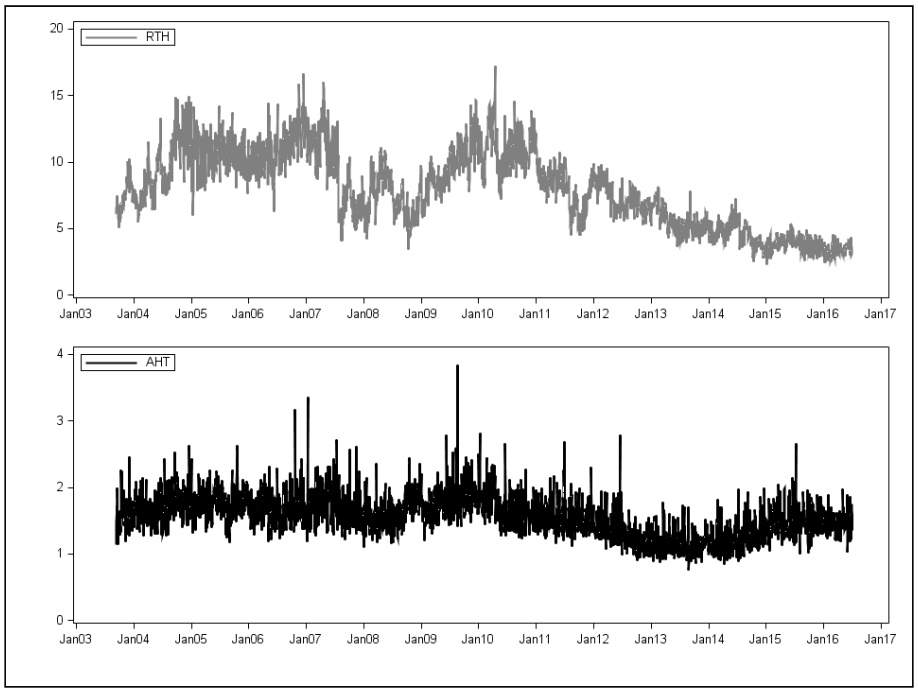
(c) Realized spread



(d) Price impact



(e) Share depth



(f) OTR

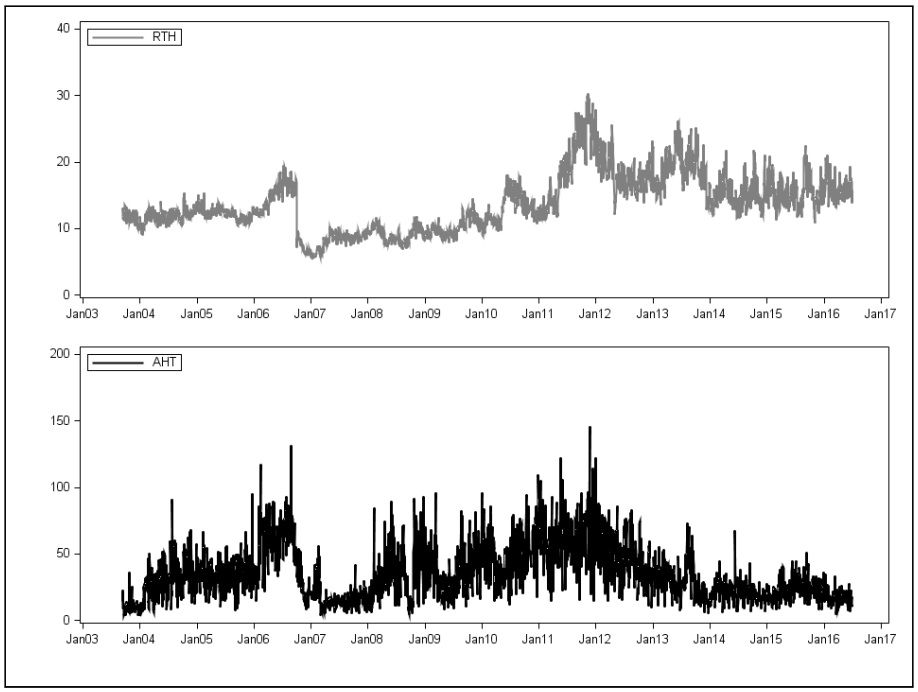
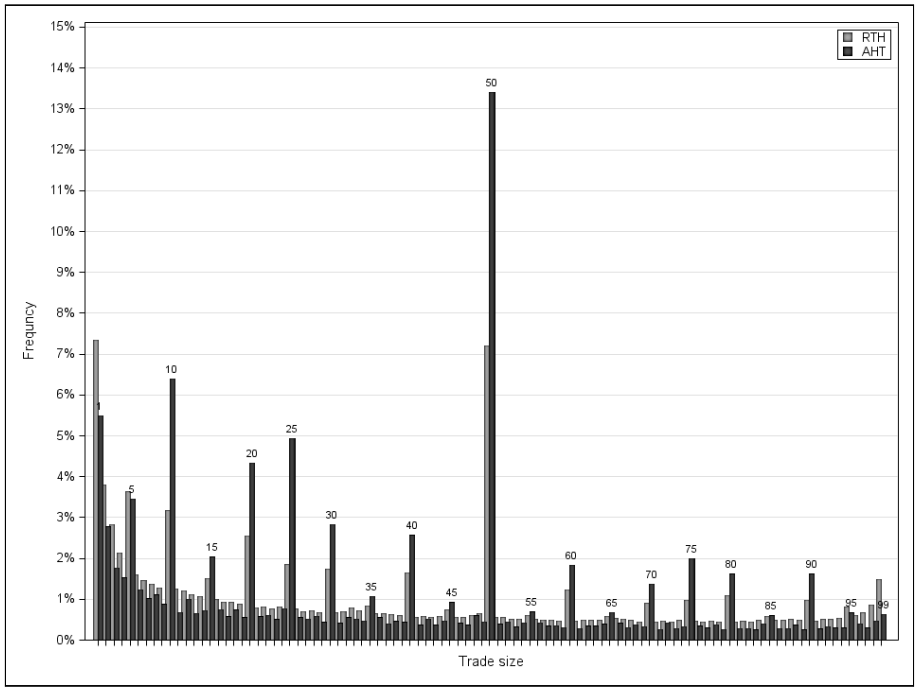


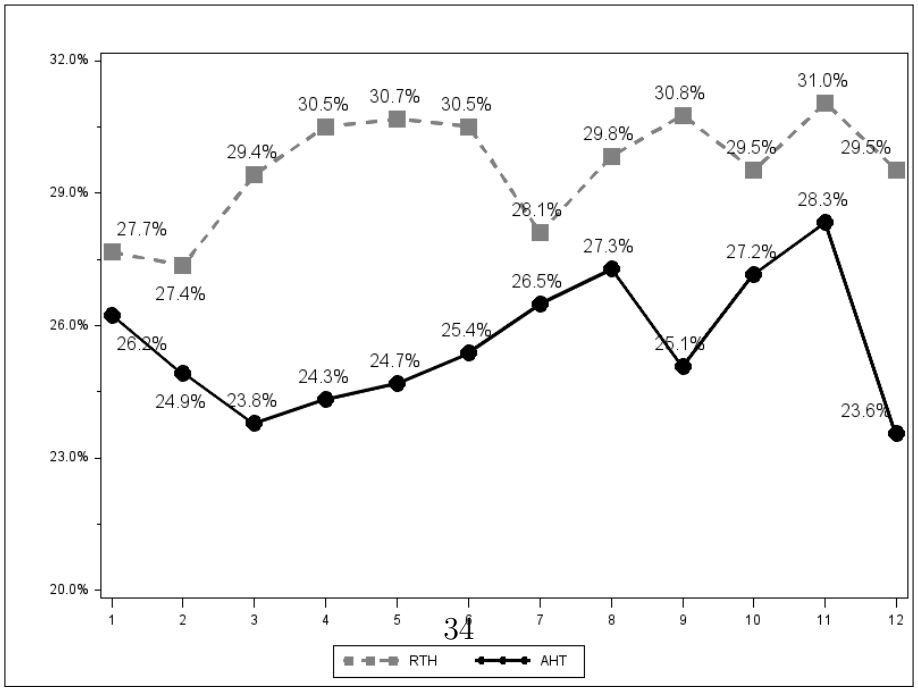
Figure 5. Odd-lot trades: trade size, month, weekday, intraday

The figure plots the distribution of odd-lot trades of S&P500 stocks, during the period 2013 December to 2016 June. The figure plots the histogram of odd-lot trade size both during RTH session and AHT session(Panel A), the distribution of odd-lot trades by month of the year (Panel B), the distribution of odd-lot trades by day of the week (Panel C), the distribution of dollar trading volume of odd-lot trades by every 15-min interval of the AHT session (Panel D), the trading volume ratio across trading venues for odd-lot and non odd-lot trades (Panel E), and the trading size ratio across trading venues for odd-lot and non odd-lot trades (Panel F). Regular trading hours (RTH) refers to trading session during 09:30 a.m. to 04:00 p.m. EST. After hours trading (AHT) refers to trading session during 04:00 p.m. to 08:00 p.m. EST.

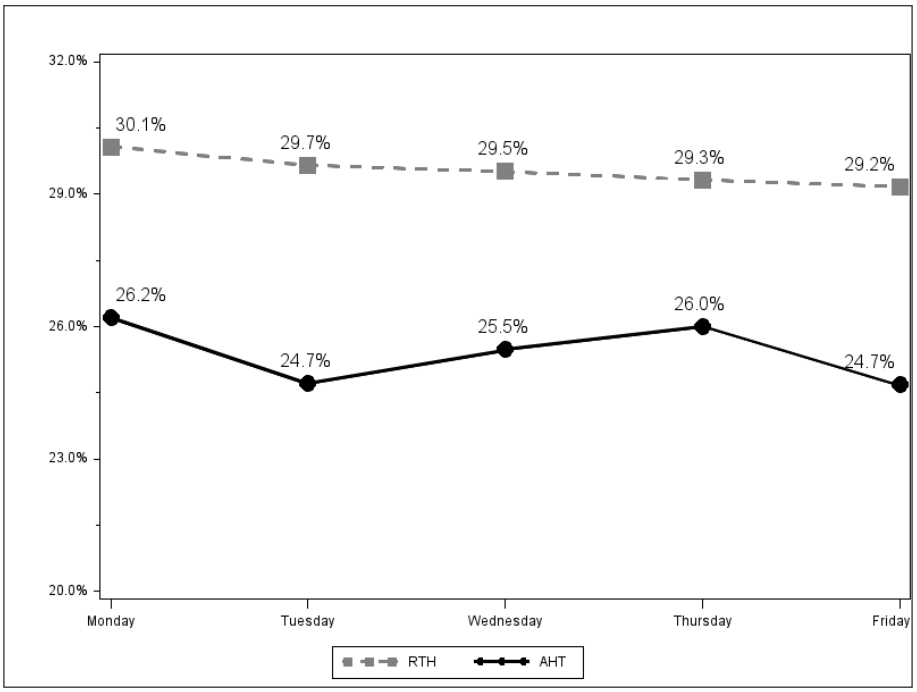
(a) Odd-lot trades by trade size



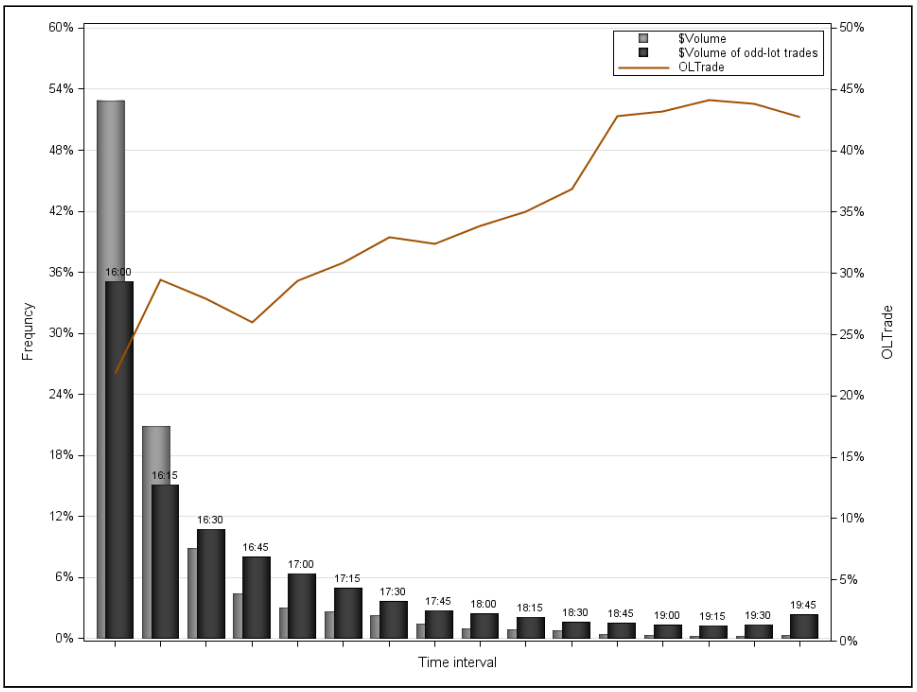
(b) Odd-lot trades by month of the year



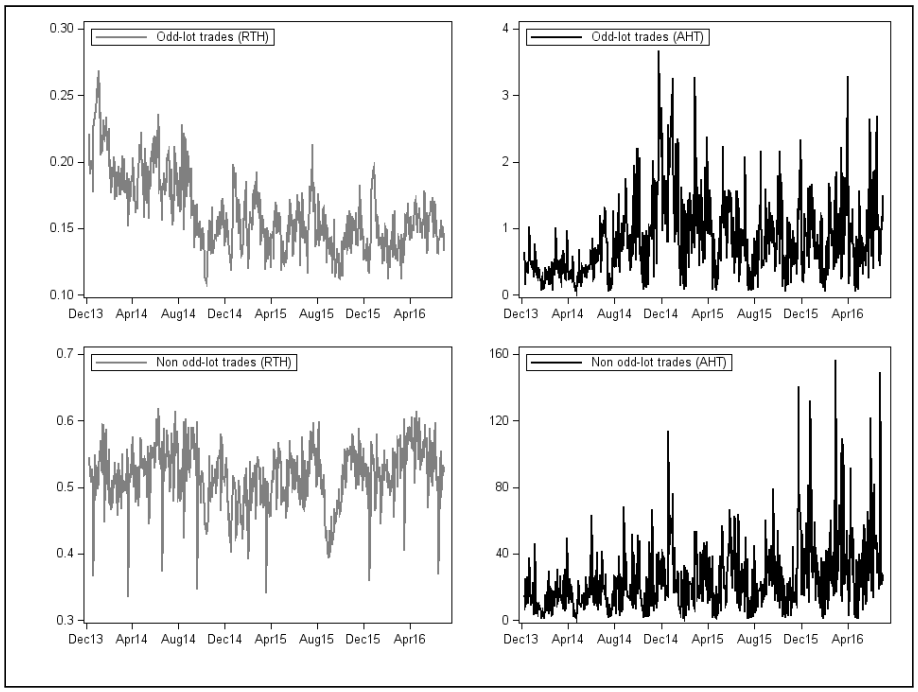
(c) Odd-lot trades by day of the week



(d) Odd-lot trades by 15-min intervals



(e) Trade volume ratio across trading venues(ATS/Exchange) for odd-lot trades versus non odd-lot trades



(f) Trade size ratio across trading venues(ATS/Exchange) for odd-lot trades versus non odd-lot trades

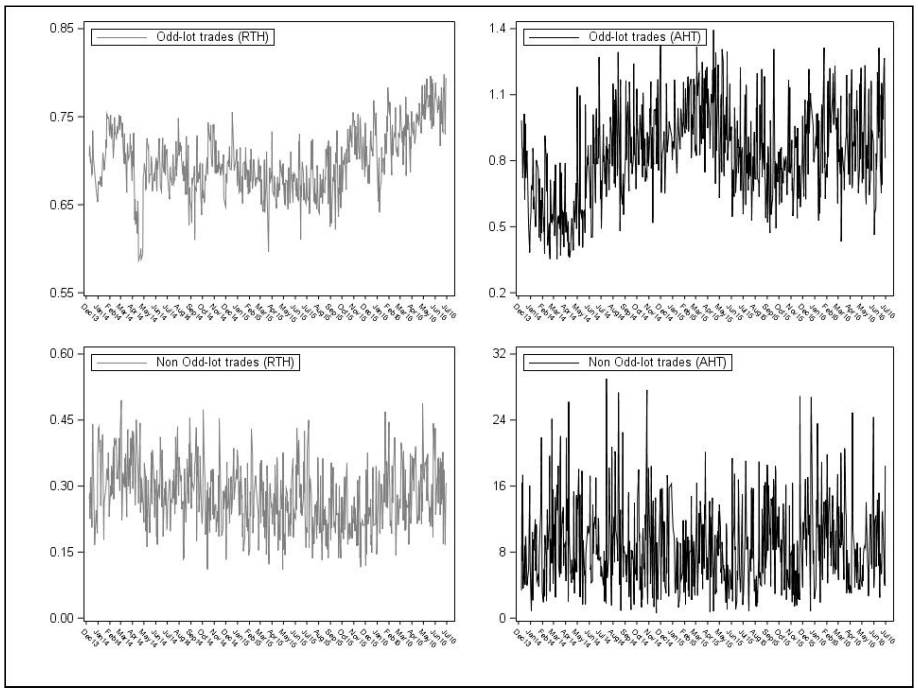
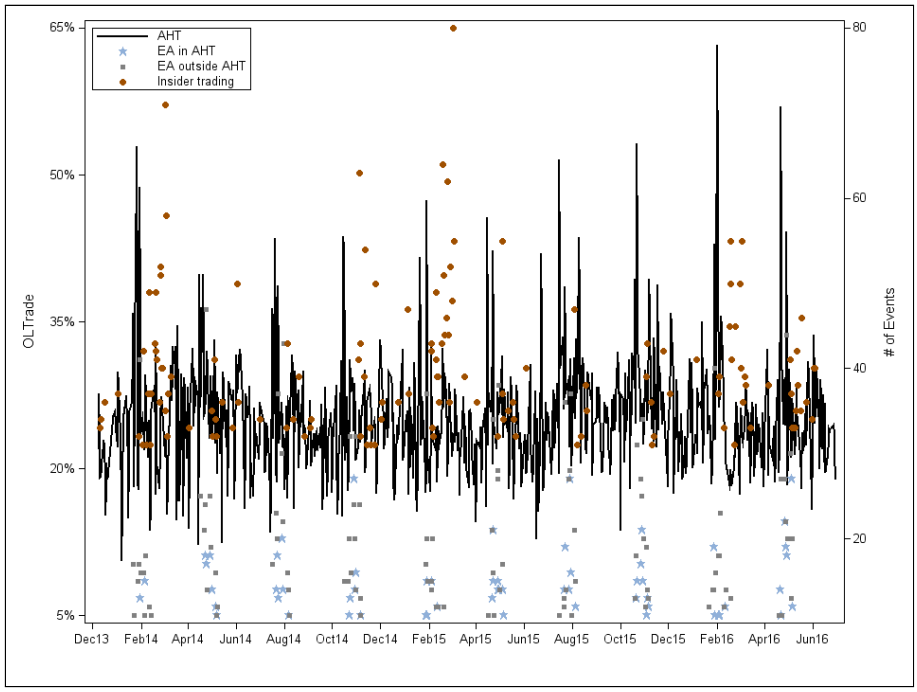


Figure 6. AHT trading activity during corporate events

This figure shows the total level of odd-lot rate and dollar trading volume during earnings announcements and insider trading events announcements for S&P500 stocks from December 9, 2013 to June 30, 2016. Panel A depicts the number of odd-lot trades as a percentage of total number of transactions. Panel B depicts the AHT dollar trading volume. The solid star represents the days which have more than 10 firms announcing quarterly earnings during AHT, i.e.,04:00 p.m. to 08:00 p.m. EST. The solid square represents the days which have more than 10 firms announcing quarterly earnings outside AHT, i.e., between 04:00 p.m of previous trading date *t-1* and 04:00 p.m. of trading date *t*. The solid circle represents the days which have more than 20 firms announcing insider trading during AHT,i.e.,04:00 p.m. to 08:00 p.m. EST.

(a) OLtrade



(b) Trading volume

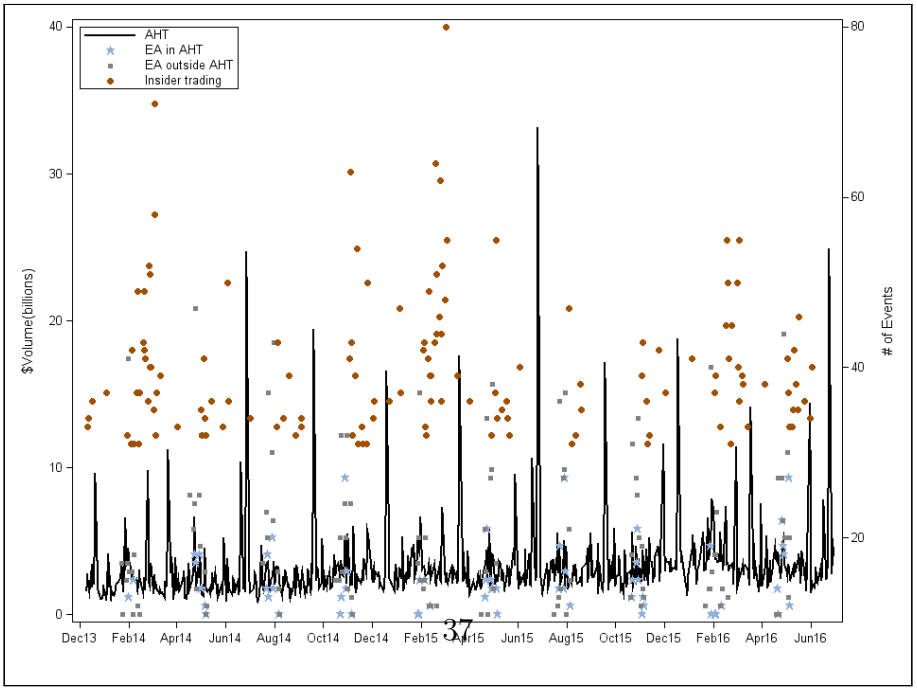
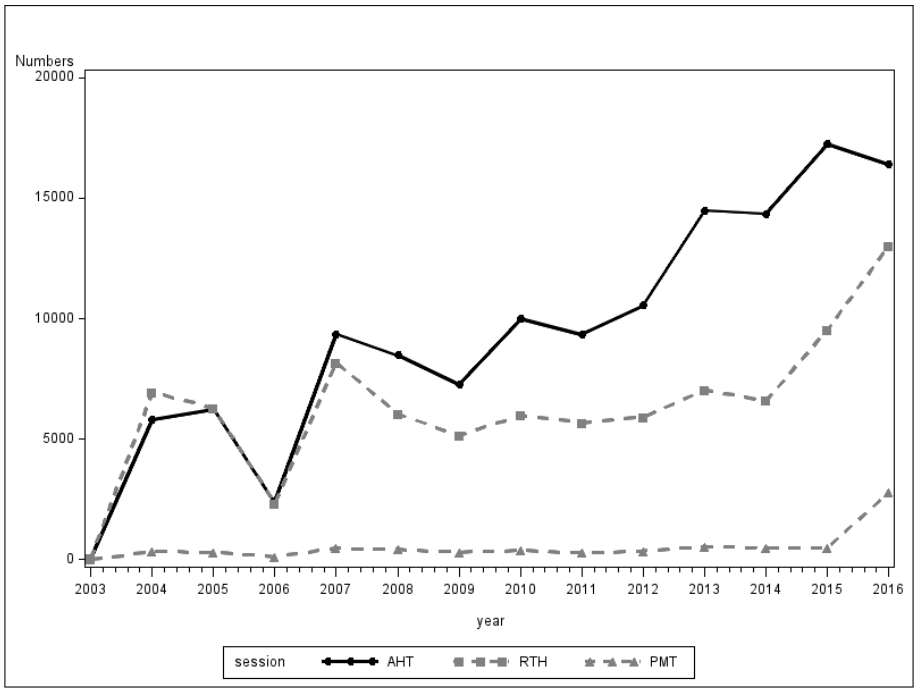


Figure 7. Insider trading announcements per year over time

The figure plots the number of news articles about insider trading announced in AHT per year for S&P500 stocks. Panel A reports the total number of news articles per year. Panel B reports the total number of insider sales news articles per year. The sample period is from 2003 to 2016. After hours trading (AHT) refers to trading session during 04:00 p.m. to 08:00 p.m. EST. Pre market trading (PMT) refers to trading session during 04:00 a.m. to 09:30 a.m. EST. Regular trading hours (RTH) refers to trading session during 09:30 a.m. to 04:00 p.m. EST. After hours trading (AHT) refers to trading session during 04:00 p.m. to 08:00 p.m. EST.

(a) Total number of insider trading news



(b) Total number of insider sales news

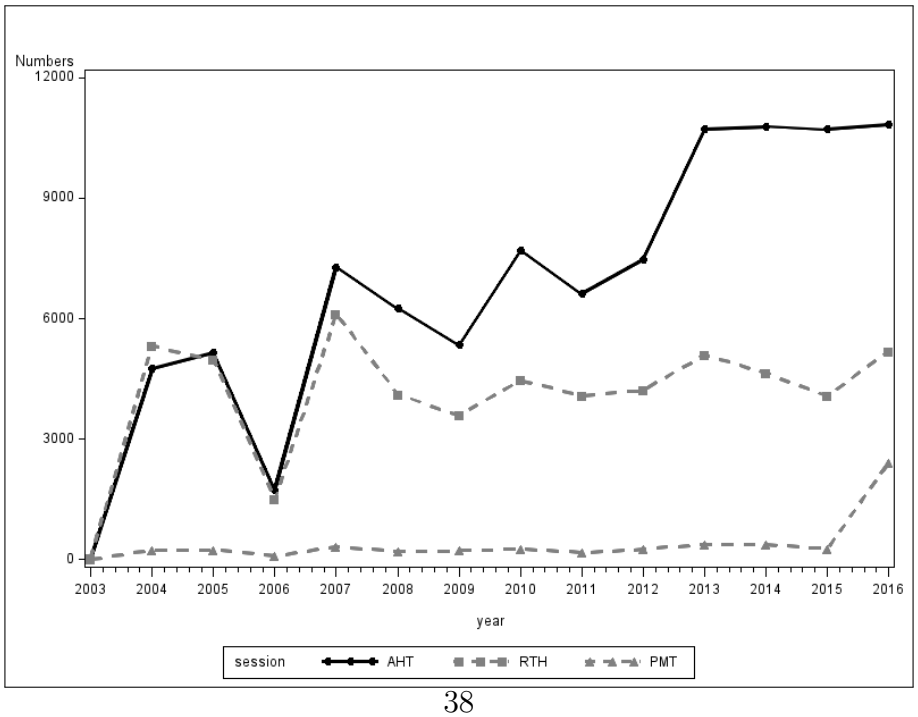
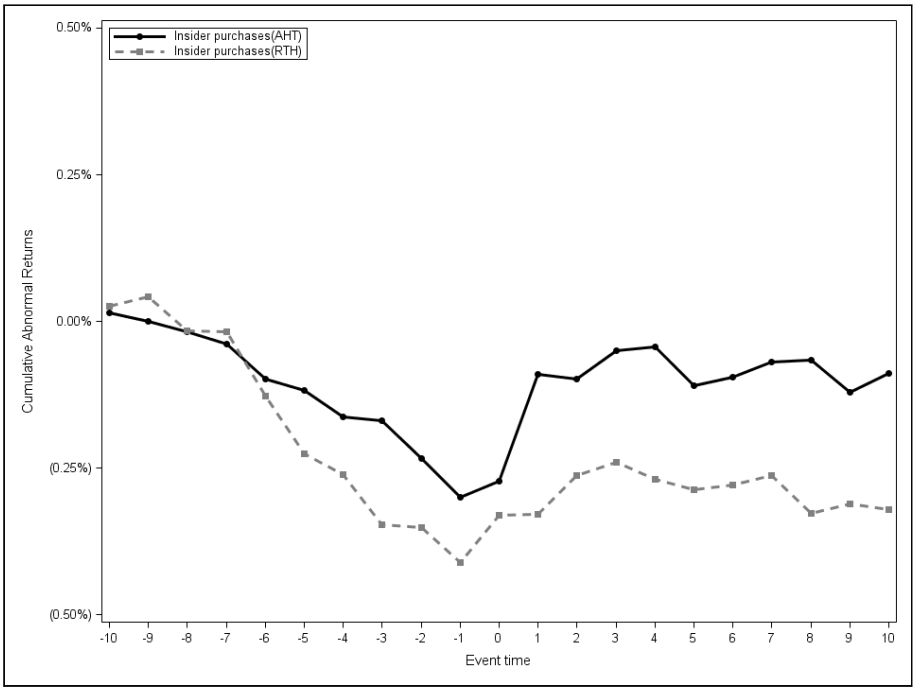


Figure 8. CAR for insider trading announcements

This figure shows the cumulative abnormal return on a -10/+10 window for insider purchases announcements (Panel A) and insider sales announcements (Panel B) during RTH and AHT for S&P500 stocks. Event time zero indicates that insider purchases and sales are announced during 09:30 a.m. to 04:00 p.m. EST. and 04:00 p.m. to 08:00 p.m. EST for RTH and AHT respectively on trading date t. Cumulative abnormal return (CAR) is the close-to-close return taking into account the 4-factor model. The sample period is from December 9, 2013 to June 30, 2016.

(a) Insider trading purchases



(b) Insider trading sales

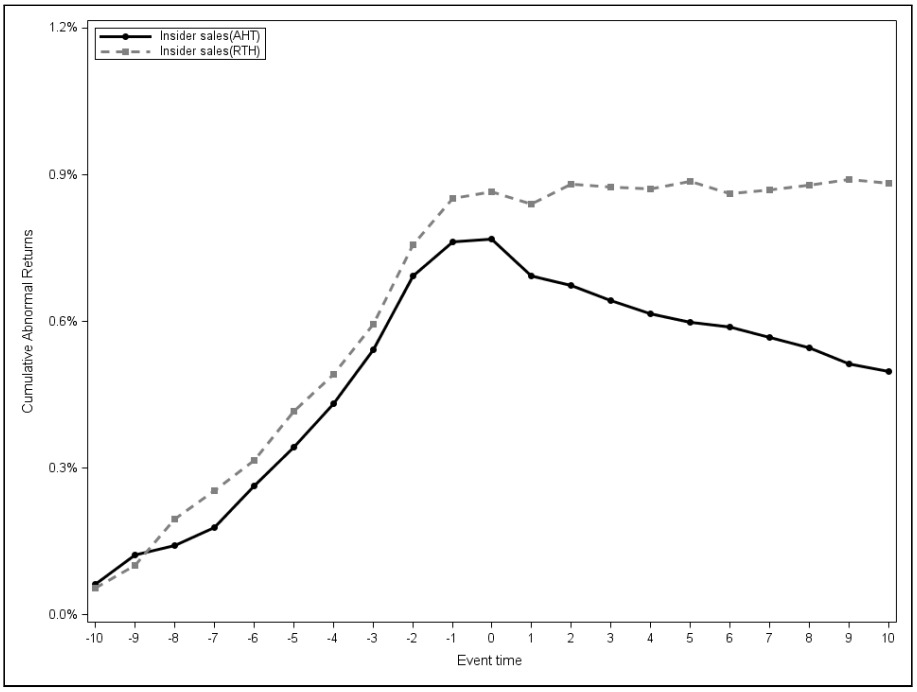


Figure 9. CAR around insider sales announcements: managers vs. others

This figure shows the cumulative abnormal return on a -10/+10 window for insider insider sales announcements by different groups of insiders during RTH and AHT for S&P500 stocks. Event time zero indicates that insider purchases and sales are announced during 09:30 a.m. to 04:00 p.m. EST. and 04:00 p.m. to 08:00 p.m. EST for RTH and AHT respectively on trading date *t*."Manager" group includes CEOs, CFOs, chairman of the board, directors, officers, presidents, and vice presidents. "Other" are all investors who are required to report their trading to the SEC but are not managers. Cumulative abnormal return (CAR) is the close-to-close return taking into account the 4-factor model. The sample period is from December 9, 2013 to June 30, 2016.

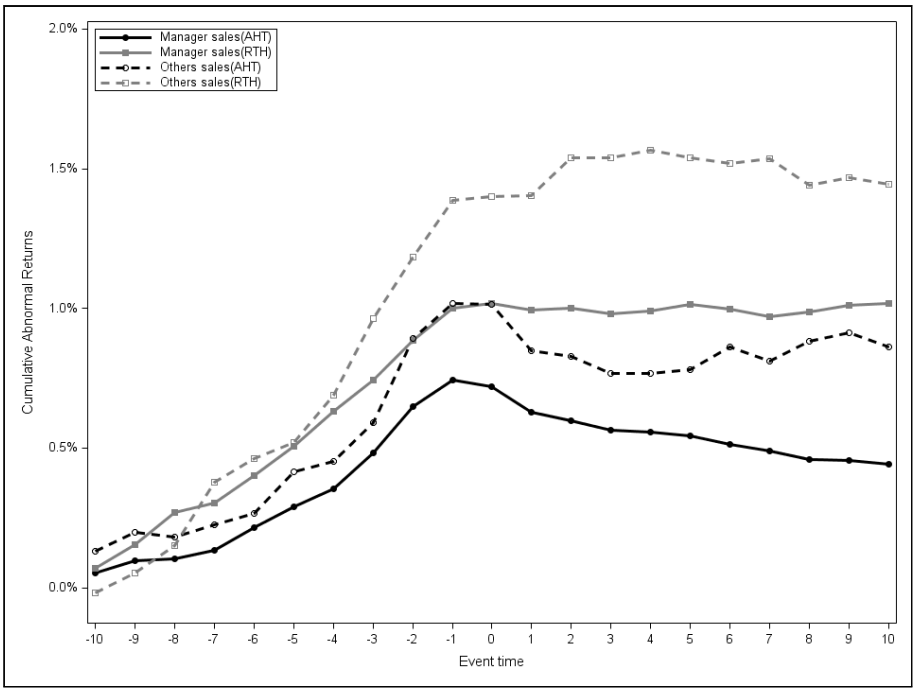
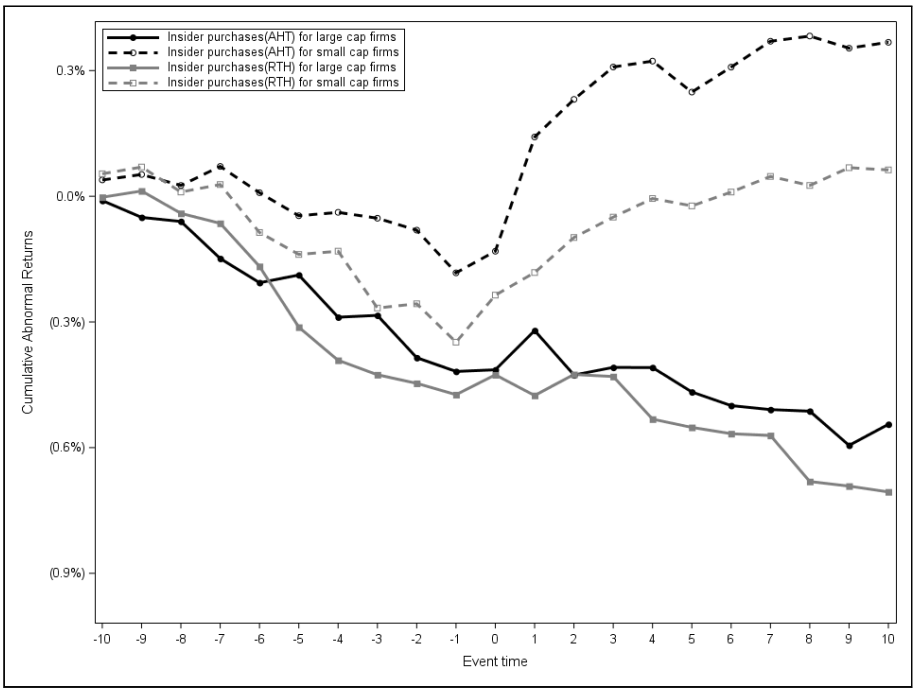


Figure 10. CAR for insider trading announcements: large cap vs. small cap firms

This figure shows the cumulative abnormal return on a -10/+10 window for insider purchases announcements (Panel A) and insider sales announcements (Panel B) during RTH and AHT for S&P500 stocks. Firms are categorized into large vs. small cap firms based on market capitalization 11 days before the announcements. Large cap firm is defined as a firm whose market capitalization is larger than the median of market capitalization for particular announcement group, i.e., insider purchases (AHT), insider sales (AHT), insider purchases (RTH) and insider sales (RTH). Event time zero indicates that insider purchases and sales are announced during 09:30 a.m. to 04:00 p.m. EST. and 04:00 p.m. to 08:00 p.m. EST for RTH and AHT respectively on trading date t. Cumulative abnormal return (CAR) is the close-to-close return taking into account the 4-factor model. The sample period is from December 9, 2013 to June 30, 2016.

(a) Insider trading purchases



(b) Insider trading sales

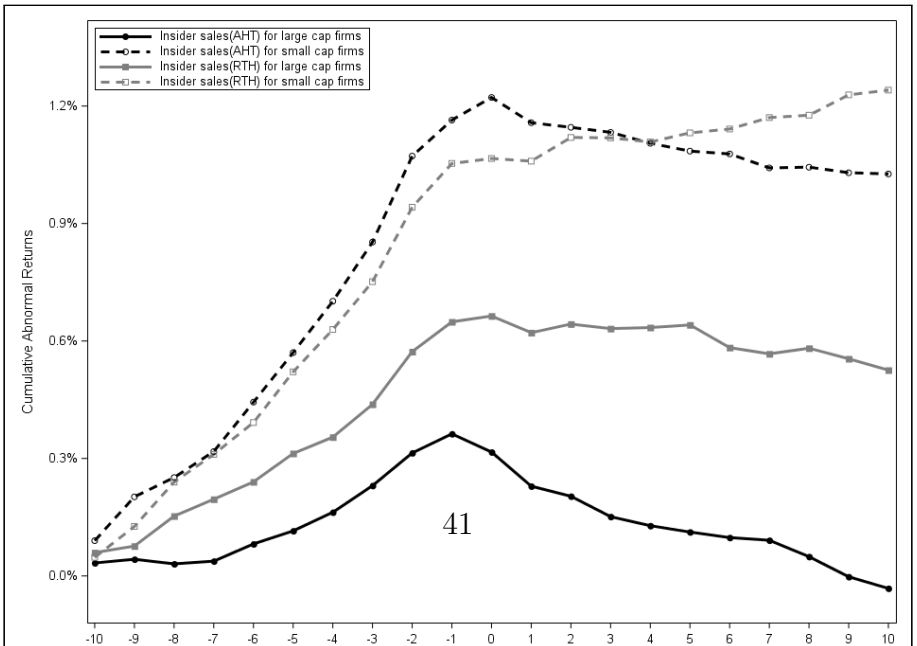


Table I List of news by categories

The table lists the top twenty news categories covered by Ravenpack for S&P500 stocks, during the period December 09, 2013 to June 30, 2016. We define *Good News* (*Bad News*) if the Ravenpack news sentiment scores during 4:00 p.m. to 8:00 p.m. takes value 0 to 50 (50 to 100). A score of 50 represents a neutral sentiment. Regular trading hours (RTH) refers to trading session during 09:30 a.m. to 04:00 p.m. EST. After-hours trading (AHT) refers to trading session during 04:00 p.m. to 08:00 p.m. EST.

	AHT				RTH				All			
News Group	N	Frequency	*Bad/Good*	*Bad/All*	N	Frequency	*Bad/Good*	*Bad/All*	N	Frequency	*Bad/Good*	*Bad/All*
Products Services	40,867	12.09	0.14	0.12	105,916	18.07	0.10	0.09	146,783	15.88	0.11	0.10
Technical Analysis	11,176	3.31	1.01	0.48	128,796	21.97	1.12	0.47	139,972	15.14	1.11	0.47
Earnings	63,613	18.82	0.37	0.16	40,033	6.83	0.54	0.21	103,646	11.21	0.44	0.18
Stock Prices	23,801	7.04	0.86	0.46	53,714	9.16	0.87	0.46	77,515	8.39	0.87	0.46
Labor Issues	29,192	8.64	0.64	0.39	41,783	7.13	0.46	0.31	70,975	7.68	0.53	0.34
Insider Trading	41,700	12.34	2.61	0.67	23,032	3.93	2.17	0.50	64,732	7	2.46	0.61
Acquisitions Mergers	22,323	6.6	1.40	0.58	39,481	6.73	1.38	0.58	61,804	6.69	1.39	0.58
Marketing	16,117	4.77	0.01	0.01	17,278	2.95	0.02	0.01	33,395	3.61	0.01	0.01
Legal	11,261	3.33	2.54	0.72	19,462	3.32	3.15	0.76	30,723	3.32	2.91	0.74
Revenues	18,486	5.47	0.65	0.26	11,182	1.91	0.79	0.36	29,668	3.21	0.70	0.30
Partnerships	7,328	2.17	0.03	0.03	21,029	3.59	0.02	0.02	28,357	3.07	0.02	0.02
Dividends	13,894	4.11	0.04	0.01	12,739	2.17	0.06	0.01	26,633	2.88	0.05	0.01
Credit Ratings	6,860	2.03	0.28	0.20	15,768	2.69	0.27	0.19	22,628	2.45	0.27	0.19
Investor Relations	9,120	2.70	0	0	10,823	1.85	0.00	0.00	19,943	2.16	0.00	0.00
Equity Actions	8,073	2.39	0.53	0.33	11,614	1.98	0.55	0.35	19,687	2.13	0.54	0.34
Assets	5,836	1.73	0.43	0.29	12,549	2.14	0.27	0.20	18,385	1.99	0.32	0.23
Analyst Ratings	1,641	0.49	0.56	0.36	10,052	1.71	0.72	0.42	11,693	1.27	0.70	0.41
Credit	3,734	1.10	0.03	0.03	2,618	0.45	0.06	0.06	6,352	0.69	0.04	0.04
Regulatory	1,251	0.37	62.38	0.80	2,485	0.42	179.62	0.94	3,736	0.40	114.93	0.89
Price Targets	169	0.05	0.30	0.22	2,636	0.45	0.51	0.33	2,805	0.30	0.50	0.32
All	336,442	100			582,990	100			919,432	100		

Table II Market reaction to AHT news

The table contains the results of average AHT trading activities and next trading day returns based on AHT news sentiment.At the end of each trading date t, we compute $\$Volume_t^{AHT}$, as well as the equally weighted average raw return R_{t+1}^{RTH}, Fama-French market adjusted return $R_{mkt,t+1}^{RTH}$, Fama-French benchmark adjusted return $R_{FF6,t+1}^{RTH}$, which adjusted return as the raw daily return minus the daily value-weighted return on a portfolio of firms with similar size and book-to-market, daily abnormal return as the raw return minus the daily value-weighted return on a portfolio of firms with similar size, book-to-market and momentum $R_{DGTW,t+1}^{RTH}$. We also conduct a two-sided t-test to evaluate the significance of the difference between good after-hour news sentiment $GoodNews_t^{AHT}$ and bad after-hour news sentiment $BadNews_t^{AHT}$. We define *Good News* (*Bad News*) if the adjusted Ravenpack news sentiment scores during 4:00 p.m. to 8:00 p.m. takes value 0 to 50 (50 to 100). A score of 50 represents a neutral sentiment.. *No News* refers to no news announcements in AHT. *,** and *** indicate significance at the 10%, 5% and 1% levels, respectively. Regular trading hours (RTH) refers to trading session during 09:30 a.m. to 04:00 p.m. EST. After-hours trading (AHT) refers to trading session during 04:00 p.m. to 08:00 p.m. EST.

	1	2	3	4	5	6
Variables	$Goodnews_t^{AHT}$	$Badnews_t^{AHT}$	$Nonews_t^{AHT}$	$GoodNews_t^{AHT}$ - $BadNews_t^{AHT}$	$GoodNews_t^{AHT}$ - $NoNews_t^{AHT}$	$BadNews_t^{AHT}$ - $NoNews_t^{AHT}$
$\$Volume_t^{AHT}$	13.441	9.759	5.089	3.682***	8.352***	4.670***
R_{t+1}^{RTH}	0.121%	-0.050%	0.030%	0.171%***	0.091%***	-0.080%***
$R_{mkt,t+1}^{RTH}$	0.082%	-0.087%	0.004%	0.168%***	0.078%***	-0.090%***
$R_{FF6,t+1}^{RTH}$	0.080%	-0.089%	0.003%	0.169%***	0.077%***	-0.092%***
$R_{DGTW,t+1}^{RTH}$	0.069%	-0.081%	0.002%	0.150%***	0.067%***	-0.083%***

Table III Trading volume by reporting venue (TAQ reporting facilitates)
The table presents the consolidated dollar trading volumes of S&P500 stocks by reporting venue. Sample period is from December 09, 2013 to June 30, 2016. Regular trading hours (RTH) refers to trading session during 09:30 a.m. to 04:00 p.m. EST. After-hours trading (AHT) refers to trading session during 04:00 p.m. to 08:00 p.m. EST.

Trading venue		ATH		RTH	
		Volume ($ billions)	Volume (%)	Volume ($ trillions)	Volume (%)
	Consolidated volume	2052.16	100	71668.85	100
A	NYSE MKT Stock Exchange	0	0	0.07	<0.01
B	NASDAQ OMX BX Stock Exchange	1.29	0.063	1696.15	2.37
C	National Stock Exchange	<0.01	<0.01	34.26	0.05
D	FINRA	1869.64	91.11	23111.56	32.25
J	Direct Edge A Stock Exchange	1.00	0.05	1782.13	2.49
K	Direct Edge X Stock Exchange	40.90	1.99	4818.53	6.72
M	Chicago Stock Exchange	13.03	0.63	403.62	0.56
N	New York Stock Exchange	0	0	9675.91	13.50
P	NYSE Arca SM	67.15	3.27	6978.28	9.74
Q	NASDAQ Stock Exchange (In Tape C)	46.60	2.27	6582.80	9.19
T	NASDAQ Stock Exchange (In Tape A, B)	9.91	0.48	8178.39	11.41
W	CBOE Stock Exchange	0.06	<0.01	16.85	0.02
X	NASDAQ OMX PSX Stock Exchange	0.10	<0.01	601.11	0.84
Y	BATS Y-Exchange	0.26	0.01	2407.78	3.36
Z	BATS Z-Exchange	2.21	0.11	5381.42	7.51

Table IV Descriptive statistics

The table presents the descriptive statistics for S&P500 stocks. Panel A reports the market quality measures for the longer period Sep 2003 - Jun 2016. Panel B shows the statistics for the recent sample, Dec 2013 - Jun 2016, including the number of scheduled and unscheduled corporate events.

Panel A. Summary statistics for RTH and AHT, Sep 2003 - Jun 2016							
Variable/RTH	Mean	Std.Dev.	Min	p25	Median	p75	Max
Trades (thousands)	18.175	21.308	0.393	4.289	11.552	23.531	171.023
$Volume (millions)	152.760	202.023	3.740	41.250	86.967	176.623	2002.939
Trade size	11.527	9.448	1.456	5.595	8.566	13.699	67.445
Quoted spread (b.p.)	5.300	3.467	1.385	3.214	4.364	6.162	31.014
Effective spread (b.p.)	4.250	2.892	1.238	2.610	3.466	4.858	28.424
Realized spread (b.p.)	0.678	1.721	-5.078	-0.274	0.474	1.417	11.530
Price impact (b.p.)	3.488	2.537	-0.417	1.875	2.826	4.235	20.953
Depth	4.632	11.211	0.308	0.778	1.491	3.476	145.485
OTR	13.972	8.302	3.081	7.857	11.854	17.760	57.420
Variable/AHT	Mean	Std.Dev.	Min	p25	Median	p75	Max
Trades	18.528	36.081	1	5	10	19	580
$Volume(millions)	3.300	7.350	0.003	0.263	0.968	2.980	94.338
Trade size	213.986	410.253	2.165	35.498	89.423	214.375	5144.827
Quoted spread (b.p.)	224.536	229.321	1.720	67.916	145.356	307.705	1605.590
Effective spread (b.p.)	80.296	91.988	0.880	24.902	49.468	98.109	724.832
Realized spread (b.p.)	70.853	95.145	-116.538	16.937	40.077	87.047	721.231
Price impact (b.p.)	11.027	36.738	-168.219	0	2.191	14.390	305.042
Depth	1.244	1.777	0.199	0.424	0.705	1.299	20.302
OTR	33.300	47.682	0.167	5.500	16.714	40.667	423.600
Panel B. Trading summary for RTH and AHT, Dec 2013 - Jun 2016							
Variable/RTH	Mean	Std.Dev.	Min	p25	Median	p75	Max
Trades (thousands)	21.054	19.378	2.427	8.994	15.078	25.617	163.224
$Volume (millions)	194.851	216.636	16.426	72.433	124.363	227.815	2,317.140
OLtrade	29.549	12.160	0	20.466	28.078	37.008	93.674
OLvol	10.072	5.773	0	5.878	9.071	13.189	66.907
OLbuy	50.417	4.877	8.576	47.425	50.399	53.393	100
Variable/AHT	Mean	Std.Dev.	Min	p25	Median	p75	Max
Trades	22.483	33.341	2	10	14	23	566
$Volume(millions)	5.009	9.933	0.014	0.664	1.742	4.763	112.391
OLtrade	25.412	17.238	0	12.500	22.222	34.483	100
OLvol	1.790	6.925	0	0.087	0.346	1.176	100
OLbuy	50.779	38.021	0	11.111	50	100	100

Variable	# of events
$Purchases_{AHT}$	2,515
$Sales_{AHT}$	10,363
EA_{AHT}	1,839
$EA_{outsideAHT}$	3,236
M&A	1,297
SEOs	37
Repurchases	365
Dividend initiation	4,124
Stock splits	15

Table V Trading activity by firm characteristics

The table presents the trading information based on price and market capitalization groups for S&P500 stocks. Sample period is from December 09, 2013 to June 30, 2016. We report all of these measures for a 5×1 scheme of portfolios where stocks are partitioned each day into quartile by the level of price or market capitalization. For every portfolio, we first compute the mean value of each measure across firms every day, and then average these cross-sectional means across all days in the sample. *,** and *** indicate significance at the 10%, 5% and 1% levels, respectively. The t-statistics are based on the Newey-West (1987) adjusted standard errors of the time-series means. Regular trading hours (RTH) refers to trading session during 09:30 a.m. to 04:00 p.m. EST. After-hours trading (AHT) refers to trading session during 04:00 p.m. to 08:00 p.m. EST.

Panel A. By price				
	1	2	3	4
Price/RTH	*OLtrade*	*OLbuy*	*Trades ('000)*	*$Volume*
Low	17.281	50.687	32.471	179.385
p2	24.418	50.324	24.421	184.234
p3	29.216	50.313	20.934	194.955
p4	33.288	50.386	19.250	233.209
High	43.569	50.385	16.177	327.936
High-Low	26.288***	-0.302***	-16.294***	148.551***
Price/AHT	*OLtrade*	*OLbuy*	*Trades*	*$Volume*
Low	17.886	49.921	39.934	4.853
p2	22.132	50.421	32.537	5.415
p3	24.105	50.911	35.212	5.633
p4	26.423	50.854	38.071	6.868
High	36.525	51.484	66.343	9.433
High-Low	18.640***	1.563***	26.409***	4.580***
Panel B. By market capitalization				
	1	2	3	4
Mktcap/RTH	*OLtrade*	*OLbuy*	*Trades* ('000)	*$Volume*
Low	27.330	50.332	14.508	73.652
p2	30.353	50.168	15.531	109.482
p3	30.580	50.330	16.971	141.271
p4	30.920	50.469	22.216	217.801
High	28.510	50.798	44.175	578.659
High-Low	1.179***	0.466***	29.667***	505.007***
Mktcap/AHT	*OLtrade*	*OLbuy*	*Trades*	*$Volume*
Low	29.372	51.077	18.645	1.750
p2	27.905	51.368	22.549	2.732
p3	25.067	50.951	24.314	3.644
p4	22.204	50.296	34.404	6.016
High	22.449	49.887	112.411	18.098
High-Low	-6.923***	-1.190***	93.766***	16.348***

Table VI Trading activity by investor attention

The table presents the trading information based on attention measures: RTH's $OTC^{Vol}_{t,RTH}$ and RTH's $DHL^{Vol}_{t,RTH}$ for S&P500 stocks. For each day, we control for firm price by initially sorting all firms into price quartiles, based on the firms mean price over the previous 20 trading days. Then, within each price quartile, we form 5 finer portfolios by independently sorting based on each proxy for attention. For every portfolio, we first compute the mean value of each measure across firms every day, and then average these cross-sectional means across all days in the sample. *,** and *** indicate significance at the 10%, 5% and 1% levels, respectively. The t-statistics are based on the Newey-West (1987) adjusted standard errors of the time-series means. Regular trading hours (RTH) refers to trading session during 09:30 a.m. to 04:00 p.m. EST. After-hours trading (AHT) refers to trading session during 04:00 p.m. to 08:00 p.m. EST.

Panel A. By $OTC^{Vol}_{t,RTH}$				
	1	2	3	4
$OTC^{Vol}_{t,RTH}$/RTH	*OLtrade*	*OLbuy*	*Trades ('000)*	*$Volume*
Low	29.549	50.417	20.950	207.435
p2	29.777	50.471	21.212	208.733
p3	29.728	50.430	21.857	215.668
p4	29.544	50.422	22.898	226.740
High	29.091	50.357	26.429	261.082
High-Low	-0.459***	-0.060	5.479***	53.647***
$OTC^{Vol}_{t,RTH}$/ATH	*OLtrade*	*OLbuy*	*Trades*	*$Volume*
Low	24.775	50.369	39.532	6.432
p2	24.926	50.445	39.082	6.367
p3	24.935	50.811	38.065	6.395
p4	25.518	50.834	39.152	6.518
High	26.875	51.146	56.387	6.476
High-Low	2.101***	0.777***	16.855***	0.044
Panel B. By $DHL^{Vol}_{t,RTH}$				
	1	2	3	4
$DHL^{Vol}_{t,RTH}$/RTH	*OLtrade*	*OLbuy*	*Trades('000)*	*$Volume*
Low	29.689	50.651	19.586	196.189
p2	30.005	50.481	20.438	202.600
p3	29.754	50.397	21.333	210.234
p4	29.446	50.313	23.220	228.828
High	28.792	50.253	28.793	282.005
High-Low	-0.897***	-0.397***	9.207***	85.817***
$DHL^{Vol}_{t,RTH}$/AHT	*OLtrade*	*OLbuy*	*Trades*	*$Volume*
Low	23.931	50.750	25.528	6.294
p2	24.641	50.669	35.611	6.484
p3	25.238	50.632	41.437	6.532
p4	26.011	50.405	48.755	6.568
High	27.220	51.138	60.999	6.308
High-Low	3.288***	0.388*	35.471***	0.014

Table VII Determinants of AHT activity

This table reports results of the variation in AHT and odd-lot trades. We run fixed-effect regression on the panel of total trades and odd-lot trades during AHT for each stock on each day. $Trades_t^{AHT}$ and $\$Volume_t^{AHT}$ are logarithm of number of trades and trading volume for all trades happened during AHT. $OLTrade_t^{AHT}$ is the percentage of odd-lot trades and $OLbuy_{t,AHT}$ is the buyer initiated of odd lot trades, $logprc_t$ is the logarithm of price level; $spread_t$ is the percent effective spread (in basis point); OTC_t^{Vol} and DHL_t^{Vol} is the RTH squared close-to-open return (in basis point) and RTH high-low ratio; $Purchases_{t,AHT}$, $Sales_{t,AHT}$, $EA_{t,nonAHT}$, $EA_{t,AHT}$, $dividend_t$, $stocksplit_t$, $M\&A_t$ and SEO_t are dummy variables which indicate insider purchases announcements, insider sales announcements, earnings announcements happened outside AHT, earnings announcements happened during AHT, dividend initiation (regular quarterly cash dividends and special cash dividends), stock splits and M&A activity on that day, respectively. VIX, the Chicago Board Options Exchange S&P 500 implied volatility index, is normalized to a daily volatility measure by dividing it by $\sqrt{250}$. Year, month and weekday of date fixed effect and firm fixed effect are included. The sample period is trading days from December 09, 2013 to June 30, 2016 for S&P500 stocks and t-statistics are presented in parentheses. ***,**, and * indicate significance at the 1%,5%,and 10% level, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	$Trades_t^{AHT}$	$\$Volume_t^{AHT}$	$OLtrade_t^{AHT}$	$OLbuy_t^{AHT}$	$Trades_t^{AHT}$	$\$Volume_t^{AHT}$	$OLtrade_t^{AHT}$	$OLbuy_t^{AHT}$
OTC_t^{Vol}	-0.017	-0.259**	2.391*	-0.796				
	(-0.307)	(-2.225)	(1.730)	(-0.208)				
DHL_t^{Vol}					0.015***	0.016***	0.058***	0.042
					(31.736)	(16.777)	(5.191)	(1.325)
$Logprc_t$	0.072***	0.595***	5.613***	2.833***	0.087***	0.611***	5.670***	2.876***
	(12.419)	(49.869)	(39.715)	(7.198)	(14.899)	(51.062)	(39.998)	(7.282)
$Spread_t$	0.004***	-0.048***	0.489***	0.253***	-0.002	-0.054***	0.466***	0.236***
	(3.622)	(-19.089)	(16.508)	(3.072)	(-1.342)	(-21.495)	(15.524)	(2.827)
$Purchases_{t,AHT}$	0.041***	0.040*	-0.913***	-1.142	0.042***	0.040*	-0.912***	-1.141
	(3.570)	(1.680)	(-3.251)	(-1.448)	(3.607)	(1.700)	(-3.249)	(-1.447)
$Sales_{t,AHT}$	0.011*	0.023*	-0.406***	0.133	0.011*	0.023*	-0.407***	0.132
	(1.914)	(1.939)	(-2.854)	(0.334)	(1.842)	(1.896)	(-2.862)	(0.331)
$EA_{t,outsideAHT}$	0.316***	0.323***	1.147***	0.718	0.288***	0.292***	1.039***	0.638
	(30.642)	(15.287)	(4.580)	(1.029)	(27.887)	(13.801)	(4.134)	(0.911)
$EA_{t,AHT}$	2.179***	1.208***	0.277	-0.630	2.173***	1.202***	0.254	-0.647
	(160.838)	(43.471)	(0.840)	(-0.696)	(160.635)	(43.247)	(0.771)	(-0.715)
$Dividend_t$	0.039***	0.010	0.413*	0.653	0.038***	0.009	0.411*	0.651
	(4.288)	(0.537)	(1.871)	(1.053)	(4.238)	(0.508)	(1.860)	(1.051)
$Stocksplit_t$	0.497***	0.319	12.635***	10.962	0.489***	0.310	12.601***	10.939
	(3.358)	(1.052)	(3.512)	(1.118)	(3.307)	(1.023)	(3.502)	(1.116)
$M\&A_t$	0.121***	0.125***	-0.106	1.764	0.114***	0.117***	-0.126	1.743
	(7.537)	(3.806)	(-0.273)	(1.622)	(7.140)	(3.572)	(-0.323)	(1.602)
$Repurchase_t$	0.577***	0.258***	0.949	0.162	0.574***	0.255***	0.934	0.153
	(19.161)	(4.179)	(1.295)	(0.079)	(19.082)	(4.125)	(1.275)	(0.075)
SEO_t	0.435***	0.300	-0.680	-5.523	0.434***	0.299	-0.684	-5.524
	(4.620)	(1.553)	(-0.297)	(-0.886)	(4.620)	(1.550)	(-0.299)	(-0.886)
$Reconstitution_t$	0.939***	2.202***	-3.068***	2.845***	0.938***	2.201***	-3.072***	2.843***
	(61.266)	(70.054)	(-8.235)	(2.790)	(61.296)	(70.050)	(-8.249)	(2.787)
VIX_t	0.271***	0.426***	-0.831***	-6.761***	0.252***	0.406***	-0.906***	-6.815***
	(48.923)	(37.571)	(-6.177)	(-18.042)	(45.314)	(35.572)	(-6.699)	(-18.080)
Observations	318,194	318,194	318,194	298,907	318,194	318,194	318,194	298,907
Adjusted R-squared	0.557	0.461	0.349	0.007	0.558	0.462	0.349	0.007
Year, Month and Weekday FE	YES	YES	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES	YES	YES

Table VIII AHT insider trading sales announcements returns

The table provides cross-sectional OLS regression results of cumulative abnormal returns (CAR) on insider sales announcements during AHT dummy. $\$Volume_t^{AHT}$ and $OLtrade_t^{AHT}$ are the standardized dollar trading volume and odd-lot trades during AHT on the AHT insider trading announcement dates. CAR[0,0],CAR[-1,1], CAR[-2,2] and CAR[-5,5] are the cumulative abnormal returns from day 0 (the first trading day after announcements), from day -1 to day 1, from day -2 to day 2 and day -5 to 5, taking into account the 4-factor model . After-hours trading (AHT) refers to trading session during 04:00 p.m. to 08:00 p.m. EST. Year, month and weekday of date fixed effect and firm fixed effect are included. The sample period is trading days from December 09, 2013 to June 30, 2016 for S&P500 stocks and t-statistics are presented in parentheses. ***,**, and * indicate significance at the 1%,5%,and 10% level, respectively.

Dep. Variables	CAR[0,0]		CAR[-1,1]		CAR[-2,2]		CAR[-5,5]	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$Volume_t^{AHT}$	0.025*		0.056**		0.075**		0.130***	
	(1.934)		(2.397)		(2.467)		(2.785)	
$OLtrade_t^{AHT}$		0.002		0.003		-0.041		-0.026
		(0.152)		(0.153)		(-1.372)		(-0.570)
Constant	-0.118	-0.133	-0.266	-0.297	-0.228	-0.282	-0.000	-0.083
	(-0.964)	(-1.081)	(-1.230)	(-1.375)	(-0.806)	(-1.001)	(-0.000)	(-0.190)
Observations	10,252	10,250	10,251	10,249	10,251	10,249	10,251	10,249
R-squared	0.054	0.054	0.050	0.049	0.069	0.068	0.076	0.075
Time FE	YES	YES	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES	YES	YES

Dep. Variables	CAR[0,0]				CAR[-1,1]				CAR[-2,2]				CAR[-5,5]			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
	Large cap		Small cap		Large cap		Small cap		Large cap		Small cap		Large cap		*Small cap*	
$Volume_t^{AHT}$	0.058***	-0.004			0.068**	0.046			0.101**	0.050			0.126**	0.130*		
	(3.192)	(-0.203)			(2.133)	(1.376)			(2.469)	(1.125)			(2.078)	(1.845)		
$OLtrade_t^{AHT}$			-0.023	0.028			-0.022	0.036			-0.059	-0.019			-0.108*	0.043
			(-1.313)	(1.496)			(-0.718)	(1.077)			(-1.488)	(-0.430)			(-1.825)	(0.608)
Constant	-0.190	-0.129	-0.217	-0.115	-0.733**	0.141	-0.765**	0.125	-1.288***	0.624	-1.339***	0.582	-1.671***	1.007	-1.737***	0.936
	(-1.067)	(-0.745)	(-1.221)	(-0.665)	(-2.352)	(0.462)	(-2.455)	(0.409)	(-3.249)	(1.542)	(-3.377)	(1.441)	(-2.843)	(1.571)	(-2.958)	(1.462)
Observations	5,123	5,110	5,121	5,108	5,123	5,110	5,121	5,108	5,123	5,110	5,121	5,108	5,123	5,110	5,121	5,108
R-squared	0.056	0.068	0.054	0.068	0.058	0.076	0.057	0.075	0.069	0.105	0.068	0.105	0.085	0.116	0.084	0.116
Time FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES

Appendix A. Data Construction

In the appendix, we describe the detailed steps we follow and filters we apply to construct variables we use in this study.

Filters to clean trade and quotations data in DTAQ

First, we exclude nonnormal trade conditions (U,X,and Z) and nonnormal quote conditions (A,B,H,O,R,and W). Second, for each exchange or market maker, we delete cases in which the bid of one exchange or market maker is greater than or equal to the ask of the same exchange or market maker. Third, We exclude the quote if the quoted spread is greater than \$5.00 or 30% of the midpoint quote and the bid (ask) price is less (greater) than the previous midpoint -\$2.50 (previous midpoint +\$2.50). Fourth, we delete bid (ask) quotes that have a bid (ask) price or bid (ask) size that is set to be zero or a missing value.

To alleviate the outliers, we exclude extreme volatile trading dates, for example, September 29, 2008, which was the largest one-day point-drop of the Dow in history,as well as May 6, 2010 and May 7, 2010, which was known as the 2010 Flash Crash.

Appendix B. Variable description

Variable	Description(unit)
Trades	*# of trades*
Volume	*dollar trading volume ($million)*
Trade size	*share size per transaction*
Quoted spread	*time-weighted average of the difference between the National Best Ask and the National Best Bid divided by the prevailing quoted midpoint using the TAQ NBBO data*
Effective spread	*time-weighted average of twice the absolute value of the difference between the transaction price and the prevailing quoted midpoint using the TAQ NBBO data and then is divided by the midpoint*
Depth	*time-weighted average of the share amount available at the best quote from the exchange or market maker with the largest size quoted at that price*
Realized spread	*two times of the absolute difference between transaction price and the prevailing midpoint five minutes later and then is divided by the prevailing midpoint*
Price impact	*two times of (Lee and Ready, 1991) liquidity-demander "buy" indicator and the difference between midpoint five minutes later and the prevailing midpoint, and then is divided by the prevailing midpoint*
OTR	*the ratio of number of quotes over number of trades*
OLTrade	*ratio of number of odd lot trades over number of total trades*
OLVol	*ratio of dollar trading volumes of odd lot trades over total dollar trading volumes of all trades*
OLBuy	*ratio of number of (Lee and Ready, 1991) liquidity-demander "buy" odd lot trades over number of all odd lot trades*

Appendix C. List of TAQ Reporting Facilities

The table displays the market canters contained in the NYSE TAQ database. The list is from the "Daily TAQ Client Specification" document version 2.2, dated 6 July 2016.

Code	Description
A	NYSE MKT Stock Exchange
B	NASDAQ OMX BX Stock Exchange
C	National Stock Exchange
D	FINRA
I	International Securities Exchange
J	Direct Edge A Stock Exchange
K	Direct Edge X Stock Exchange
M	Chicago Stock Exchange
N	New York Stock Exchange
P	NYSE Arca SM
S	Consolidated Tape System
T	NASDAQ Stock Exchange (In Tape A, B)
Q	NASDAQ Stock Exchange (In Tape C)
V	The Investments Exchange
W	CBOE Stock Exchange
X	NASDAQ OMX PSX Stock Exchange
Y	BATS Y-Exchange
Z	BATS Exchange

Appendix D. Early or Late After Hours: Robustness checks

In this section we look into different types of M&A activity measures. In Table IX, we show the determinants of AHT activity during the early after-hour period (4:00-4:45pm). In Table X, we show the determinants of AHT activity during the early after-hour period (4:45-5:30pm).

Table IX Determinants of AHT activity for early after-hour period (4:00-4:45pm)

This table reports results of the variation in AHT and odd-lot trades for early after-hour period (4:00-4:45pm). We run fixed-effect regression on the panel of total trades and odd-lot trades during AHT for each stock on each day. $Trades_t^{AHT}$ and $\$Volume_t^{AHT}$ are logarithm of number of trades and dollar trading volume for all trades happened during AHT. $OLTrade_t^{AHT}$ is the percentage of odd-lot trades and $OLbuy_{t,AHT}$ is the buyer initiated of odd lot trades, $logprc_t$ is the logarithm of price level; $spread_t$ is the percent effective spread (in basis point); OTC_t^{Vol} and DHL_t^{Vol} is the RTH squared close-to-open return (in basis point) and RTH high-low ratio; $Purchases_{t,EarlyAHT}$, $Sales_{t,EarlyAHT}$, $EA_{t,EarlyAHT}$, $EA_{t,nonAHT}$, $dividend_t$, $stocksplit_t$, $M\&A_t$ and SEO_t are dummy variables which indicate insider purchases, insider sales, earnings announcements happened during early AHT, earnings announcement happened outside AHT, dividend initiation (regular quarterly cash dividends and special cash dividends), stock splits and M&A activity on that day, respectively. VIX, the Chicago Board Options Exchange S&P 500 implied volatility index, is normalized to a daily volatility measure by dividing it by $\sqrt{250}$. Year, month and weekday of date fixed effect and firm fixed effect are included. The sample period is trading days from December 09, 2013 to June 30, 2016 for S&P500 stocks and t-statistics are presented in parentheses. ***,**, and * indicate significance at the 1%,5%,and 10% level, respectively

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	$Trades_t^{AHT}$	$\$Volume_t^{AHT}$	$OLtrade_t^{AHT}$	$OLbuy_t^{AHT}$	$Trades_t^{AHT}$	$\$Volume_t^{AHT}$	$OLtrade_t^{AHT}$	$OLbuy_t^{AHT}$
OTC_t^{Vol}	-0.035	-0.245**	1.95	-0.778				
	(-0.633)	(-2.052)	(1.379)	(-0.204)				
DHL_t^{Vol}					0.010***	0.013***	0.016	0.042
					(22.753)	(13.457)	(1.383)	(1.324)
$Logprc_t$	0.088***	0.545***	4.805***	2.847***	0.098***	0.558***	4.820***	2.889***
	(15.580)	(44.708)	(33.239)	(7.232)	(17.336)	(45.646)	(33.241)	(7.315)
$Spread_t$	-0.005***	-0.053***	0.495***	0.250***	-0.010***	-0.058***	0.488***	0.233***
	(-4.507)	(-20.601)	(16.320)	(3.040)	(-7.990)	(-22.467)	(15.925)	(2.795)
$Purchases_{t,AHT}$	0.060***	0.082**	-1.049**	-1.364	0.060***	0.082**	-1.050**	-1.365
	(3.354)	(2.121)	(-2.279)	(-1.077)	(3.341)	(2.114)	(-2.281)	(-1.077)
$Sales_{t,AHT}$	-0.001	-0.003	-0.338	-0.646	-0.001	-0.003	-0.338	-0.647
	(-0.164)	(-0.139)	(-1.477)	(-1.028)	(-0.167)	(-0.142)	(-1.477)	(-1.028)
$EA_{t,outsideAHT}$	0.215***	0.284***	-0.159	0.8	0.196***	0.258***	-0.187	0.719
	(21.410)	(13.080)	(-0.617)	(1.141)	(19.410)	(11.878)	(-0.724)	(1.023)
$EA_{t,AHT}$	2.288***	1.219***	1.429***	-1.187	2.284***	1.214***	1.424***	-1.203
	(160.289)	(39.618)	(3.919)	(-1.214)	(160.142)	(39.466)	(3.904)	(-1.230)
$Dividend_t$	0.026***	0.007	0.118	0.683	0.026***	0.007	0.117	0.682
	(2.989)	(0.392)	(0.524)	(1.103)	(2.945)	(0.365)	(0.521)	(1.100)
$Stocksplit_t$	0.162	0.235	10.770***	10.978	0.156	0.228	10.760***	10.953
	(1.124)	(0.758)	(2.926)	(1.120)	(1.082)	(0.734)	(2.924)	(1.118)
$M\&A_t$	0.077***	0.097***	-0.397	1.77	0.072***	0.091***	-0.399	1.749
	(4.934)	(2.898)	(-0.996)	(1.627)	(4.641)	(2.708)	(-1.001)	(1.608)
$Repurchase_t$	0.427***	0.216***	0.28	0.189	0.425***	0.213***	0.276	0.18
	(14.564)	(3.417)	(0.374)	(0.092)	(14.497)	(3.373)	(0.368)	(0.088)
SEO_t	0.401***	0.267	-0.59	-5.492	0.400***	0.266	-0.592	-5.493
	(4.369)	(1.351)	(-0.252)	(-0.880)	(4.367)	(1.348)	(-0.253)	(-0.881)
$Reconstitution_t$	0.939***	2.269***	-1.803***	2.874***	0.938***	2.268***	-1.805***	2.872***
	(62.920)	(70.595)	(-4.733)	(2.818)	(62.922)	(70.587)	(-4.737)	(2.816)
VIX_t	0.228***	0.337***	-0.313**	-6.759***	0.215***	0.320***	-0.334**	-6.812***
	(42.395)	(28.998)	(-2.277)	(-18.037)	(39.744)	(27.395)	(-2.413)	(-18.074)
Observations	318,309	318,309	318,309	298,852	318,309	318,309	318,309	298,852
Adjusted R-squared	0.475	0.44	0.354	0.007	0.476	0.441	0.354	0.007
Year, month and weekday FE	YES	YES	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES	YES	YES

Table X Determinants of AHT activity for late after-hour period (4:45-5:30pm)

This table reports results of the variation in AHT and odd-lot trades for late after-hour period (4:45-6:00pm). We run fixed-effect regression on the panel of total trades and odd-lot trades during AHT for each stock on each day. $Trades_t^{AHT}$ and $\$Volume_t^{AHT}$ are logarithm of number of trades and trading volume for all trades happened during AHT; $OLTrade_t^{AHT}$ and $OLbuy_{t,AHT}$ are the percentage of odd-lot trades and the buyer initiated of odd lot trades; $logprc_t$ is the logarithm of price level; $spread_t$ is the percent effective spread (in basis point); OTC_t^{Vol} and DHL_t^{Vol} is the RTH squared close-to-open return (in basis point) and RTH high-low ratio; $Purchases_{t,AHT}$, $Sales_{t,AHT}$, $EA_{t,AHT}$, $EA_{t,nonAHT}$, $dividend_t$, $stocksplit_t$, $M\&A_t$ and SEO_t are dummy variables which indicate insider purchases, insider sales, earnings announcements happened during AHT, earnings announcements happened outside AHT, dividend initiation (regular quarterly cash dividends and special cash dividends), stock splits and M&A activity on that day, respectively. VIX, the Chicago Board Options Exchange S&P 500 implied volatility index, is normalized to a daily volatility measure by dividing it by $\sqrt{250}$. Year, month and weekday of date fixed effect and firm fixed effect are included. The sample period is trading days from December 09, 2013 to June 30, 2016 for S&P500 stocks and t-statistics are presented in parentheses. ***,**, and * indicate significance at the 1%,5%,and 10% level, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	$Trades_t^{AHT}$	$\$Volume_t^{AHT}$	$OLtrade_t^{AHT}$	$OLbuy_t^{AHT}$	$Trades_t^{AHT}$	$\$Volume_t^{AHT}$	$OLtrade_t^{AHT}$	$OLbuy_t^{AHT}$
OTC_t^{Vol}	0.652***	0.129	15.592*	-2.231				
	(3.467)	(0.231)	(1.814)	(-0.256)				
DHL_t^{Vol}					0.039***	0.041***	0.158***	0.153***
					(36.214)	(12.851)	(3.228)	(3.119)
$Logprc_t$	-0.092***	0.686***	7.488***	2.186***	-0.057***	0.724***	7.631***	2.328***
	(-8.769)	(21.974)	(15.632)	(4.583)	(-5.393)	(23.089)	(15.862)	(4.859)
$Spread_t$	0.028***	-0.022***	0.563***	0.444***	0.012***	-0.040***	0.498***	0.377***
	(12.949)	(-3.431)	(5.669)	(4.496)	(5.200)	(-6.043)	(4.903)	(3.732)
$Purchases_{t,EarlyAHT}$	0.047	-0.127	1.674	-0.972	0.047	-0.127	1.672	-0.972
	(1.366)	(-1.231)	(1.060)	(-0.617)	(1.360)	(-1.235)	(1.058)	(-0.617)
$Purchases_{t,LateAHT}$	0.089**	0.206*	-3.243*	0.088	0.089**	0.206*	-3.244*	0.091
	(2.332)	(1.808)	(-1.857)	(0.050)	(2.347)	(1.812)	(-1.858)	(0.052)
$Sales_{t,EarlyAHT}$	0.005	0.077	-0.784	-0.622	0.005	0.077	-0.782	-0.622
	(0.296)	(1.455)	(-0.963)	(-0.764)	(0.307)	(1.458)	(-0.961)	(-0.763)
$Sales_{t,LateAHT}$	0.001	0.03	-1.557	0.257	0	0.03	-1.559	0.257
	(0.027)	(0.478)	(-1.622)	(0.268)	(0.021)	(0.477)	(-1.624)	(0.267)
$EA_{t,outsideAHT}$	0.375***	0.381***	1.392*	1.182	0.303***	0.305***	1.113	0.893
	(20.940)	(7.154)	(1.702)	(1.452)	(16.899)	(5.683)	(1.353)	(1.090)
$EA_{t,EarlyAHT}$	3.191***	2.612***	-0.727	-1.245	3.180***	2.600***	-0.772	-1.29
	(146.865)	(40.352)	(-0.733)	(-1.269)	(146.928)	(40.180)	(-0.777)	(-1.314)
$EA_{t,LateAHT}$	1.810***	1.267***	1.281	1.055	1.791***	1.247***	1.203	0.996
	(26.706)	(6.275)	(0.414)	(0.344)	(26.529)	(6.176)	(0.388)	(0.325)
$Dividend_t$	0.065***	-0.068	0.627	0.024	0.063***	-0.07	0.618	0.015
	(3.827)	(-1.340)	(0.812)	(0.030)	(3.718)	(-1.384)	(0.800)	(0.019)
$Stocksplit_t$	1.208***	0.042	26.899**	5.15	1.189***	0.023	26.820**	5.074
	(4.698)	(0.055)	(2.290)	(0.445)	(4.645)	(0.030)	(2.284)	(0.439)
$M\&A_t$	0.177***	0.123	2.220*	1.633	0.166***	0.111	2.173*	1.586
	(6.374)	(1.485)	(1.747)	(1.289)	(5.988)	(1.340)	(1.710)	(1.251)
$Repurchase_t$	0.875***	0.547***	1.45	-0.098	0.865***	0.537***	1.409	-0.133
	(17.537)	(3.683)	(0.636)	(-0.043)	(17.417)	(3.617)	(0.618)	(-0.058)
SEO_t	0.566***	-0.173	4.447	2.155	0.562***	-0.177	4.429	2.144
	(3.446)	(-0.354)	(0.592)	(0.292)	(3.436)	(-0.362)	(0.590)	(0.290)
$Reconstitution_t$	0.607***	1.566***	-16.604***	2.855**	0.604***	1.563***	-16.619***	2.846**
	(24.090)	(20.844)	(-14.411)	(2.507)	(24.070)	(20.814)	(-14.424)	(2.498)
VIX_t	0.234***	0.624***	-3.721***	-5.773***	0.183***	0.569***	-3.931***	-5.977***
	(23.061)	(20.596)	(-8.010)	(-12.464)	(17.897)	(18.620)	(-8.381)	(-12.778)
Observations	157,568	157,568	157,568	151,960	157,568	157,568	157,568	151,960
Adjusted R-squared	0.484	0.187	0.1	0.007	0.488	0.188	0.1	0.007
Year, month and weekday FE	YES	YES	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES	YES	YES

Appendix E. M&A Activity: Robustness checks

In this section we look into different types of M&A activity measures. In Table XI, we show the determinants of AHT activity by separating M&A rumors from M&A surprises. In Table XII, we report separetly M&A target and M&A acquirer cases and differentiate quarterly dividends from special dividend payments.

Table XI Determinants of AHT activity (M&A rumors v.s. M&A surprise)

This table reports results of the variation in AHT and odd-lot trades for after-hour period. We run fixed-effect regression on the panel of total trades and odd-lot trades during AHT for each stock on each day. $Trades_t^{AHT}$ and $\$Volume_t^{AHT}$ are logarithm of number of trades and trading volume for all trades happened during AHT; $OLTrade_t^{AHT}$ and $OLbuy_{t,AHT}$ are the percentage of odd-lot trades and the buyer initiated of odd lot trades; $logprc_t$ is the logarithm of price level; $spread_t$ is the percent effective spread (in basis point); OTC_t^{Vol} and DHL_t^{Vol} is the RTH squared close-to-open return (in basis point) and RTH high-low ratio; $Purchases_{t,AHT}$, $Sales_{t,AHT}$, $EA_{t,AHT}$, $EA_{t,nonAHT}$, $dividend_t$, $stocksplit_t$, $M\&A_t$ and SEO_t are dummy variables which indicate insider purchases, insider sales, earnings announcements happened during AHT, earnings announcements happened outside AHT, dividend initiation (regular quarterly cash dividends and special cash dividends), stock splits and M&A activity on that day, respectively. VIX, the Chicago Board Options Exchange S&P 500 implied volatility index, is normalized to a daily volatility measure by dividing it by $\sqrt{250}$. Year, month and weekday of date fixed effect and firm fixed effect are included. The sample period is trading days from December 09, 2013 to June 30, 2016 for S&P500 stocks and t-statistics are presented in parentheses. ***,**, and * indicate significance at the 1%,5%,and 10% level, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	$Trades_t^{AHT}$	$\$Volume_t^{AHT}$	$OLtrade_t^{AHT}$	$OLbuy_t^{AHT}$	$Trades_t^{AHT}$	$\$Volume_t^{AHT}$	$OLtrade_t^{AHT}$	$OLbuy_t^{AHT}$
OTC_t^{Vol}	-0.018	-0.260**	2.391*	-0.797				
	(-0.314)	(-2.228)	(1.729)	(-0.209)				
DHL_t^{Vol}					0.015***	0.016***	0.058***	0.041
					(31.486)	(16.658)	(5.180)	(1.317)
$Logprc_t$	0.072***	0.594***	5.612***	2.832***	0.086***	0.610***	5.670***	2.875***
	(12.344)	(49.836)	(39.711)	(7.195)	(14.806)	(51.021)	(39.993)	(7.279)
$Spread_t$	0.004***	-0.048***	0.489***	0.252***	-0.002	-0.055***	0.465***	0.235***
	(3.382)	(-19.200)	(16.496)	(3.064)	(-1.535)	(-21.584)	(15.516)	(2.820)
$Purchases_{t,AHT}$	0.041***	0.040*	-0.913***	-1.143	0.041***	0.040*	-0.912***	-1.141
	(3.544)	(1.668)	(-3.253)	(-1.449)	(3.581)	(1.688)	(-3.250)	(-1.448)
$Sales_{t,AHT}$	0.011*	0.023*	-0.406***	0.133	0.011*	0.023*	-0.407***	0.132
	(1.914)	(1.939)	(-2.854)	(0.334)	(1.843)	(1.896)	(-2.862)	(0.331)
$EA_{t,outsideAHT}$	0.315***	0.322***	1.146***	0.717	0.287***	0.292***	1.038***	0.638
	(30.595)	(15.260)	(4.577)	(1.027)	(27.861)	(13.785)	(4.133)	(0.910)
$EA_{t,AHT}$	2.180***	1.209***	0.277	-0.628	2.174***	1.202***	0.255	-0.645
	(160.965)	(43.497)	(0.842)	(-0.694)	(160.760)	(43.275)	(0.773)	(-0.713)
$Dividend_t$	0.039***	0.01	0.413*	0.652	0.038***	0.009	0.410*	0.651
	(4.256)	(0.521)	(1.869)	(1.052)	(4.207)	(0.493)	(1.859)	(1.050)
$Stocksplit_t$	0.499***	0.321	12.636***	10.966	0.490***	0.312	12.602***	10.942
	(3.371)	(1.057)	(3.512)	(1.119)	(3.320)	(1.028)	(3.503)	(1.116)
$M\&A_{t,surprise}$	0.642***	0.604***	0.651	1.317	0.625***	0.585***	0.581	1.267
	(17.626)	(8.077)	(0.734)	(0.545)	(17.174)	(7.825)	(0.656)	(0.524)
$M\&A_{t,rumor}$	0.122***	0.126***	-0.105	1.767	0.115***	0.119***	-0.124	1.746
	(7.627)	(3.846)	(-0.269)	(1.624)	(7.231)	(3.612)	(-0.320)	(1.605)
$Repurchase_t$	0.576***	0.257***	0.947	0.159	0.573***	0.254***	0.933	0.15
	(19.129)	(4.161)	(1.293)	(0.078)	(19.051)	(4.108)	(1.274)	(0.074)
SEO_t	0.435***	0.3	-0.68	-5.523	0.435***	0.3	-0.684	-5.523
	(4.626)	(1.555)	(-0.297)	(-0.885)	(4.625)	(1.552)	(-0.299)	(-0.886)
$Reconstitution_t$	0.939***	2.202***	-3.067***	2.846***	0.938***	2.201***	-3.072***	2.843***
	(61.322)	(70.072)	(-8.234)	(2.790)	(61.349)	(70.068)	(-8.248)	(2.788)
VIX_t	0.271***	0.427***	-0.830***	-6.760***	0.253***	0.407***	-0.905***	-6.813***
	(49.086)	(37.638)	(-6.171)	(-18.037)	(45.497)	(35.648)	(-6.692)	(-18.074)
Observations	318,194	318,194	318,194	298,907	318,194	318,194	318,194	298,907
Adjusted R-squared	0.558	0.462	0.35	0.009	0.559	0.463	0.35	0.009
Year, month and weekday FE	YES	YES	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES	YES	YES

Table XII Determinants of AHT activity (Quarterly dividend v.s. Special dividend and M&A as target v.s. M&A as acquiror)

This table reports results of the variation in AHT and odd-lot trades for after-hour period. We run fixed-effect regression on the panel of total trades and odd-lot trades during AHT for each stock on each day. $Trades_t^{AHT}$ and $\$Volume_t^{AHT}$ are logarithm of number of trades and trading volume for all trades happened during AHT; $OLTrade_t^{AHT}$ and $OLbuy_{t,AHT}$ are the percentage of odd-lot trades and the buyer initiated of odd lot trades; $logprc_t$ is the logarithm of price level; $spread_t$ is the percent effective spread (in basis point); OTC_t^{Vol} and DHL_t^{Vol} is the RTH squared close-to-open return (in basis point) and RTH high-low ratio; $Purchases_{t,AHT}$, $Sales_{t,AHT}$, $EA_{t,AHT}$, $EA_{t,nonAHT}$, $dividend_t$, $stocksplit_t$, $M\&A_t$ and SEO_t are dummy variables which indicate insider purchases, insider sales, earnings announcements happened during AHT, earnings announcements happened outside AHT, dividend initiation (regular quarterly cash dividends and special cash dividends), stock splits and M&A activity on that day, respectively. VIX, the Chicago Board Options Exchange S&P 500 implied volatility index, is normalized to a daily volatility measure by dividing it by $\sqrt{250}$. Year, month and weekday of date fixed effect and firm fixed effect are included. The sample period is trading days from December 09, 2013 to June 30, 2016 for S&P500 stocks and t-statistics are presented in parentheses. ***,**, and * indicate significance at the 1%,5%,and 10% level, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	$Trades_t^{AHT}$	$\$Volume_t^{AHT}$	$OLtrade_t^{AHT}$	$OLbuy_t^{AHT}$	$Trades_t^{AHT}$	$\$Volume_t^{AHT}$	$OLtrade_t^{AHT}$	$OLbuy_t^{AHT}$
OTC_t^{Vol}	-0.019	-0.261**	2.388*	-0.796				
	(-0.334)	(-2.237)	(1.727)	(-0.208)				
DHL_t^{Vol}					0.014***	0.016***	0.058***	0.041
					(31.288)	(16.534)	(5.177)	(1.316)
$Logprc_t$	0.071***	0.593***	5.612***	2.833***	0.085***	0.609***	5.669***	2.875***
	(12.161)	(49.739)	(39.704)	(7.197)	(14.612)	(50.915)	(39.986)	(7.280)
$Spread_t$	0.004***	-0.048***	0.489***	0.252***	-0.002*	-0.055***	0.465***	0.235***
	(3.164)	(-19.334)	(16.494)	(3.063)	(-1.717)	(-21.695)	(15.514)	(2.819)
$Purchases_{t,AHT}$	0.040***	0.039*	-0.914***	-1.141	0.041***	0.039*	-0.913***	-1.14
	(3.510)	(1.646)	(-3.255)	(-1.447)	(3.547)	(1.666)	(-3.252)	(-1.445)
$Sales_{t,AHT}$	0.011**	0.024**	-0.406***	0.133	0.011*	0.023*	-0.407***	0.132
	(1.968)	(1.967)	(-2.852)	(0.335)	(1.896)	(1.923)	(-2.861)	(0.332)
$EA_{t,outsideAHT}$	0.315***	0.323***	1.146***	0.718	0.288***	0.293***	1.038***	0.639
	(30.657)	(15.285)	(4.577)	(1.028)	(27.938)	(13.820)	(4.133)	(0.911)
$EA_{t,AHT}$	2.178***	1.207***	0.275	-0.622	2.172***	1.201***	0.252	-0.639
	(160.951)	(43.449)	(0.834)	(-0.688)	(160.748)	(43.229)	(0.766)	(-0.706)
$Dividend_{t,quarterly}$	0.037***	0.008	0.406*	0.641	0.036***	0.007	0.404*	0.639
	(4.037)	(0.427)	(1.837)	(1.032)	(3.989)	(0.400)	(1.827)	(1.030)
$Dividend_{t,special}$	0.263*	0.34	1.732	-5.209	0.263*	0.34	1.731	-5.212
	(1.949)	(1.224)	(0.527)	(-0.565)	(1.951)	(1.224)	(0.526)	(-0.565)
$Stocksplit_t$	0.501***	0.323	12.641***	10.963	0.492***	0.314	12.607***	10.94
	(3.387)	(1.065)	(3.513)	(1.118)	(3.336)	(1.036)	(3.504)	(1.116)
$M\&A_{t,target}$	1.542***	1.664***	0.962	1.492	1.509***	1.628***	0.831	1.396
	(26.249)	(13.796)	(0.673)	(0.381)	(25.717)	(13.497)	(0.581)	(0.356)
$M\&A_{t,acquiror}$	0.111***	0.104***	-0.039	1.751*	0.104***	0.097***	-0.059	1.731*
	(7.315)	(3.363)	(-0.105)	(1.708)	(6.901)	(3.122)	(-0.160)	(1.688)
$Repurchase_t$	0.568***	0.248***	0.931	0.201	0.565***	0.244***	0.917	0.192
	(18.856)	(4.005)	(1.270)	(0.098)	(18.783)	(3.954)	(1.251)	(0.094)
SEO_t	0.436***	0.301	-0.681	-5.523	0.435***	0.3	-0.686	-5.524
	(4.634)	(1.559)	(-0.298)	(-0.885)	(4.633)	(1.556)	(-0.299)	(-0.886)
$Reconstitution_t$	0.939***	2.202***	-3.067***	2.846***	0.938***	2.201***	-3.072***	2.844***
	(61.364)	(70.090)	(-8.234)	(2.791)	(61.391)	(70.086)	(-8.248)	(2.788)
VIX_t	0.271***	0.427***	-0.831***	-6.759***	0.253***	0.407***	-0.906***	-6.812***
	(49.085)	(37.637)	(-6.175)	(-18.035)	(45.516)	(35.660)	(-6.696)	(-18.072)
Observations	318,194	318,194	318,194	298,907	318,194	318,194	318,194	298,907
Adjusted R-squared	0.558	0.462	0.35	0.009	0.56	0.463	0.35	0.009
Year, month and weekday FE	YES	YES	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES	YES	YES