Internet Appendix to
How Is Earnings News Transmitted to Stock Prices?

Intended for online publication.

Vincent Grégoire and Charles Martineau

This Internet Appendix reports results that are discussed but not reported in the main manuscript.

1Grégoire: HEC Montréal, 3000, chemin de la Côte-Sainte-Catherine, Montréal QC, Canada H3T 2A7 (vincent.3.gregoire@hec.ca). Martineau: Rotman School of Management and UTSC Management, University of Toronto, 105 St-George, Toronto ON, Canada, M5S 3E6 (charles.martineau@rotman.utoronto.ca).
IA1. Additional Details on TRTH, TAQ, and NASDAQ Data

IA1.1. Thomson Reuters Tick History

This note contains details about the Thomson Reuters Tick History (TRTH) dataset. This dataset has been rebranded Refinitiv Tick History following the name change of Thomson Reuters Financial & Risk business to Refinitiv in July 2018. We refer to the old name TRTH in the paper since it was the name at the time we accessed the data.

For each trade for our sample of stocks, we extract the price, quantity, execution venue, and trade qualifiers. We exclude any trade that is reported late or out-of-sequence. In addition to trades, we also obtain the prevailing national best bid and offer across all exchanges (NBBO), with quote qualifiers.

TRTH provides two timestamps, \textit{Time} and \textit{Exch Time} (for trades) or \textit{Quote Time}. \textit{Time} corresponds to the time at which the information was recorded by Thomson Reuters’ servers with microsecond precision. \textit{Exch Time} and \textit{Quote Time} have millisecond precision and correspond to the consolidated tape timestamp. We use \textit{Exch Time} and \textit{Quote Time}, and fill in any missing values using the \textit{Time} field.

Trade qualifiers provide valuable information, including whether a trade is at the opening or closing auction, if it has been reported late or out-of-sequence, or if it is meant for next day settlement, or if it is a “Form T” trade. Brokers have to file a “Form T” with the Financial Industry Regulatory Authority (FINRA) to report trades executed outside of normal market hours. In our analysis of price discovery in the after-hours markets, we focus only on trades that are reported to FINRA and marked “Form T.” Each exchange is also uniquely identified, while trades reported by dark pools, automated display facilities, and broker internalization systems to Trade Reporting Facilities are grouped under the same \textit{ADF} identifier.

IA1.2. NYSE Trade and Quote (TAQ)

While TRTH is more comprehensive, the NYSE Trade and Quote (TAQ) dataset is more commonly used in academic research. Because our study focuses on trades and NBBO quotes, both products can be used interchangeably to produce our results. Indeed, TRTH sources SIP data (the consolidated feed used to reconstruct the NBBO) from the NYSE. We have manually verified a few events and confirmed that trades and quotes updates are a perfect match. One aspect on which they differ is in the ease of use for researchers. While TRTH provides the NBBO in a simple dataset, the NBBO must be constructed manually from TAQ data by properly merging the quote and nbbo tables.

To use TAQ in order to replicate our methodology, we recommend using the sample code from Holden and Jacobsen [2014] available on Professor Craig Holden’s personal website \url{https://kelley.iu.edu/cholden/} and Professor Stacey Jacobsen’s website \url{https://www.smu.edu/cox/Our-People-and-Community/Faculty/Stacey-Jacobsen}. However, because that code was designed to work for regular hours, changes must be made. Researchers must change the valid time range to include after-hours trades and quotes which are excluded by default and apply the following changes to the sample code:

**Trades** Exclude trades that have one of the following conditions under the field name \texttt{tr_scon}:

- ‘L’: Sold Last (Late Reporting)

\footnote{The NBBO quotes are protected from “trade-throughs” under USSEC Rule 611 during regular trading hours only.}
Quotes  The main issue in dealing with quotes in the after-hours market is that liquidity is very limited, spreads are wide and there are often no quotes at all. The sample code from Holden and Jacobsen [2014], which was designed for regular market hours, treats most of these conditions as errors and removes problematic quote updates. This is not appropriate in the after-hours because by removing quote updates we are assuming that the old quotes are still valid, which inflates the available liquidity. In our context, it is thus better to keep potentially problematic quote updates than to discard them.

- Add ‘C’ (closing) to the list of quotes condition under the field name **qu_cond**.
- In step 2, do not remove entries for which there are no quotes. This is important because “empty” quotes are common in the after-hours market. Thus, it is important to remove the following lines (lines 155–159) from Holden’s sample code:

```c
if both ask and bid are set to 0 or . then delete */
  if Best_Ask le 0 and Best_Bid le 0 then delete;
  if Best_Ask siz le 0 and Best_Bid siz le 0 then delete;
  if Best_Ask = . and Best_Bid = . then delete;
  if Best_Ask siz = . and Best_Bid siz = . then delete;
```
- Skip step 3 in the sample code. We do not want to exclude wide bid-ask spreads at this stage (we do exclude them from some tests). Wide spreads is the norm in the after-hours market and so should not be automatically flagged as “erroneous”.
- In step 5, do not delete crossed markets, do not delete abnormal spreads, and do no delete withdrawn quotes. Therefore, remove the following lines (lines 250–264) in the code provided by Holden and Jacobsen [2014]:

```c
/* Delete if abnormal crossed markets */
if Bid>Ask then delete;

/* Delete abnormal spreads*/
if Spread>5 then delete;

/* Delete withdrawn Quotes. This is
  when an exchange temporarily has no quote, as indicated by quotes
  with price or depth fields containing values less than or equal to 0
  or equal to '. '. See discussion in Holden and Jacobsen (2014),
  page 11. */
```
IA1.3. Institutional details on hidden orders in NASDAQ TotalView-ITCH

This note contains details about hidden orders in NASDAQ TotalView-ITCH (ITCH). NASDAQ has a program for academics that offers free-of-charge access to their historical data. We have made our code for processing ITCH data publicly available (although the documentation still needs to be improved) at https://meatpy.readthedocs.io/en/latest/.

In ITCH data, we do not observe hidden orders submitted by liquidity providers. Before July 14, 2014, trades against a hidden order would display a Buy/Sell Indicator, which indicates whether the trade is buyer- or seller-initiated [see appendix in NASDAQ, 2016]. Since July 14, 2014 all trades against hidden orders display “B” for buy as a Buy/Sell Indicator.

This change imposes challenges to empiricists who wish to understand the dynamics surrounding the use of hidden orders versus displayed orders and the impact of hidden orders on stock prices, trade volume, etc. For example, in this paper, when we study the impact of market-initiated trade imbalance (i.e., order flow imbalance) on stock returns, we must end our sample on July 13, 2014 because we do not have the Buy/Sell Indicators on trades against hidden orders after that date. The reason why this field is not populated after that date is because many in the industry complained to NASDAQ that providing in real-time whether a trade was executed against a buy or sell hidden limit order revealed too much information to market participants and helped high-frequency traders figure out market directions. The objective of using hidden orders is not to provide other traders the ability to infer their strategies and potentially private information.

NASDAQ has a program for academics that offers free-of-charge access to their historical data. We have made our code for processing ITCH data publicly available at https://meatpy.readthedocs.io/en/latest/.

IA2. Market Fragmentation in the After-Hours Market

Market fragmentation during regular trading hours and after hours varies greatly. Panel A of figure IA1 shows that 30% of trading volume occurs on dark venues but Panel B shows that it increases to approximately 80% after hours. Panel C shows, however, that the share of volume executed on dark venues falls to 20% when there is an earnings announcement. This is consistent with theoretical predictions of Menkveld, Yueshen, and Zhu [2017] that indicate trading will occur on lit venues following public news because of the need for immediacy by traders. Recent studies by Balakrishnan and Taori [2017] and Gkougkousi and Landsman [2017] find an increase in relative trading on dark pools in the week of earnings announcements. We find a decline in after-hours trading executed on dark pools on announcement days, consistent with the theoretical predictions in Menkveld et al. [2017].
IA3. Additional Results: After-Hours Price Discovery for Micro-cap Stocks

We show that our findings are also generalizable to microcap stocks. Our analysis primarily focuses on S&P 1500 stocks because active liquidity provision by liquidity providers in the after-hours market is required to highlight the price discovery differences of using quote and trade prices. Liquidity providers do not have an obligation to participate in the after-hours market. They will, therefore, be more active after hours if they anticipate some potential trading activity. Nonetheless, it is worthwhile to investigate whether our findings are generalizable to microcap stocks.

As in Hou, Xue, and Zhang [2020], we define microcap stocks as those smaller than the NYSE 20th percentile (based on a firm’s market value of equity). We then select microcap stocks with at least one earnings forecast in the 90 days before an earnings announcement from I/B/E/S for a total of 13,308 earnings announcements and 1,799 microcap stocks. We find that the median number of trades in the two hours following an earnings announcement for a microcap stock is just one (zero and nine trades at the 25th and 75th percentile, respectively). Such limited trading activity is indicative of wide bid-ask spreads around earnings announcements.

Figure IA3 presents cumulative returns around earnings announcements using midquote and trade prices. Similar to Figure 3, we find substantial differences between the cumulative returns in trades and midquotes, with trade returns lagging midquote returns. In contrast to S&P 1500 stocks, however, the adjustment in midquote occurs more slowly. To better understand the dynamics in quotes, we plot in Figure IA6 the bid and ask price adjustment. At the announcement, we find that bid and ask prices adjust immediately with no opportunity for liquidity takers to profit from the slow adjustment in midquote. What is causing the slower adjustment in midquotes for microcap stocks is that the other side of the quote adjusts much more slowly to news than for S&P 1500 stocks.
**Figure IA1. Trade Volume and Fragmentation in the After-Hours Market**

Panel A shows the monthly market share of total volume executed on dark and lit venues. Panel B shows the monthly market share of after-hours volume executed on dark and lit venues. Panel C shows the monthly market share of after-hours volume following earnings announcements executed on dark and lit venues. The sample period is January 1, 2011 to December 31, 2015.
This figure shows the buy-and-hold cumulative abnormal returns (BHAR) from 9:40 a.m. on the trading days preceding after-hours sessions with earnings announcements until 4 p.m. on the following trading days. The BHAR values for the full sample, S&P 500, S&P MidCap 400, and S&P SmallCap 600 stocks are presented in Panels A to D, respectively. We define BHAR for stock-earnings announcement \( i \) from time \( \tau \) to \( T \) as

\[
BHAR[i; \tau, T] = \sum_{t=\tau}^{T} r_{i,t} - \sum_{t=\tau}^{T} r_{m,t},
\]

where \( r_{i,t} \) is the stock log return and \( r_{m,t} \) is the log return of the stock market using the SPDR S&P 500 ETF on interval \( t \). We use midquotes (mid-point between the best bid and best ask price) to calculate log returns at 5-minute intervals. We condense stock returns in the after-hours trading session to a single point, which includes the opening auction and the first 10 minutes of trading, calculated using the closing price at 4 p.m. and the midquote at 9:40 a.m. on the following trading day. Each line represents a different quintile sort for earnings surprises. The shaded areas represent pointwise 95% confidence bands around the average BHAR. The sample period is January 1, 2011 to December 31, 2015.
**Figure IA3.** Cumulative Returns Following Earnings Announcements in the After-Hours Market for Microcap stocks

This figure shows the buy-and-hold returns (BHR) in the after-hours market from 5 minutes before to 60 minutes after the earnings announcement by earnings surprise quintiles for microcap stocks. We define BHR for stock-earnings announcement \( i \) from time \( \tau \) to \( T \) as

\[
BHR[\tau, T]_i = \sum_{t=\tau}^{T} r_{i,t},
\]

where \( r_{i,t} \) is the stock log return for the 5-minute interval \( t \). Midquote returns are computed using the mid-point between the best displayed bid and best ask price (solid line), and trade returns (dotted line) are computer using transaction prices. Trade returns are calculated from trade prices and if there is no trade for a minute interval \( t \), we impose a return of 0% for that interval. We define microcap stocks as those smaller than the NYSE 20th percentile based on a firm’s market value of equity. The sample period is January 1, 2011 to December 31, 2015.
**Figure IA4.** Relative Spread Around Earnings Announcements in the After-Hours Market

This figure shows the median 1-minute relative spread 5 minutes before to 60 minutes after earnings announcements in the after-hours market for S&P 500 (red line), S&P MidCap 400 (dashed blue line), and S&P 600 SmallCap (dotted black line) stocks. Relative spread is defined as the difference between the best ask and bid prices divided by the midquote (the midpoint between the ask and bid prices). The earnings announcement occurs at time 0. The sample period is January 1, 2011 to December 31, 2015.
This figure shows the average ask profit (dashed red line), bid profit (dashed-dotted blue line), and midquote profit (solid black line) and their respective 95% confidence intervals by random-walk earnings surprise quintile (columns) and by S&P index (rows) -5 to 60 minutes around earnings announcements in the after-hours market. The profits are calculated from the perspective of a seller. We define the ask profit as \((\text{Ask price}_{i,t} - \text{Closing price}_{i,T})/\text{Ask price}_{i,t}\), the bid profit as \((\text{Bid price}_{i,t} - \text{Closing price}_{i,T})/\text{Bid price}_{i,t}\), and the midquote profit as \((\text{Midquote}_{i,t} - \text{Closing price}_{i,T})/\text{Midquote}_{i,t}\), where \(t < T\). The closing price is the official closing price of the following regular trading hour session at 4 p.m. Random-walk earnings surprises are defined as \((\text{EPS}_{i,q} - \text{EPS}_{i,q-4})/\text{P}_{i,q}\), where \(\text{EPS}_{i,q}\) is primary Earnings Per Share (EPS) before extraordinary items for firm \(i\) in quarter \(q\), and \(\text{P}_{i,q}\) is the price per share for firm \(i\) five days before the earnings announcement. The earnings announcement occurs at time 0. The sample period is January 1, 2011 to December 31, 2015.
**Figure IA6. Profitability Around Earnings Announcements for Displayed Quotes in the After-Hours Market for Microcap stocks**

This figure shows the average ask profit (dashed red line), bid profit (dashed-dotted blue line), and midquote profit (solid black line) and their respective 95% confidence intervals by earnings surprise quintile (columns) -5 to 60 minutes around earnings announcements for microcap stocks (stocks smaller than the NYSE 20th percentile based on a firm’s market value of equity) in the after-hours market by earnings surprise quintiles. The profits are calculated from the perspective of a seller. We define the ask profit as $(\text{Ask price}_{i,t} - \text{Closing price}_{i,T})/\text{Ask price}_{i,t}$, the bid profit as $(\text{Bid price}_{i,t} - \text{Closing price}_{i,T})/\text{Bid price}_{i,t}$, and the midquote profit as $(\text{Midquote}_{i,t} - \text{Closing price}_{i,T})/\text{Midquote}_{i,t}$, where $t < T$. The closing price is the official closing price of the following regular trading hour session at 4 p.m. The gray shaded areas represent the fraction of valid quotes, which is the fraction of stock earnings announcement in our overall sample at each minute with a relative spread, $|(\text{Ask}_{i,t} - \text{Bid}_{i,t})|/\text{Midquote}_{i,t}$, less than or equal to 20%. The earnings announcement occurs at time 0. The sample period is January 1, 2011 to December 31, 2015.
Figure IA7. The Number of Analyst Recommendation Revisions by the Time of Day

This figure shows the number of analyst recommendation revisions per 30-minute interval for S&P 1500 stocks from RavenPack. The sample period is from January 1, 2011 to December 31, 2015.