

## **Research on HFTs in the Canadian Venture Market**

### **Background**

In recent years, BC and Alberta participants in the Canadian equity markets have expressed concerns that high-frequency traders (HFTs) negatively affect venture securities trading, particularly securities listed on the TSX Venture Exchange (TSXV). In particular, we heard that:

- trading by HFTs increases volatility in TSXV listed securities
- short-selling by HFTs limits price increases of TSXV securities following news releases

### **Introduction**

In early 2012, venture market participants began reporting factors that in their view, were adversely affecting secondary trading in Canada's venture markets. After some initial meetings with some market participants, BCSC, ASC, IIROC, and TSXV staff consulted more deliberately to understand venture market participant concerns.

Market participants told us that high frequency trading was increasing general venture market volatility. They also told us that HFTs were entering short sale orders after positive news and muting the naturally positive effects of positive news on share price.

Staff gathered relevant data to analyse whether:

- share prices of frequently HFT traded securities are more volatile than other share prices
- HFTs more frequently sell short, or try to sell short, on a downtick following news than other market participants

### ***Not a cause-and-effect study***

Many factors contribute to share price changes and market movements. This study does not seek to prove a causal relationship between:

- HFT trading and share price volatility
- share price movements following news

Rather, this study seeks to determine whether there is evidence to verify the experiences reported by venture market participants.

## **Methodology**

### **Trading years in this study**

We compared trading data from:

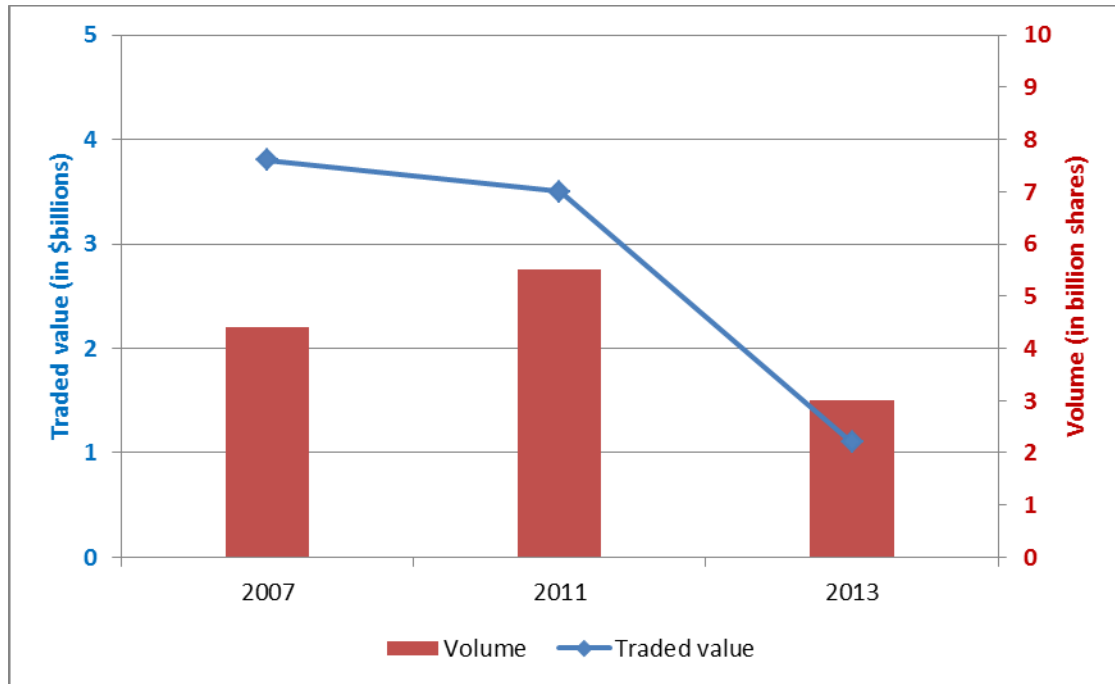
- 2007, when HFTs were not active in the venture market
- 2011, when HFT activity was at its peak

- 2013, after the short sale rule was amended to permit short-selling on a downtick and to introduce the short-marking exempt (SME) identifier<sup>1</sup>

The three study periods were different market environments for trading in TSXV-listed securities.

**Figure 1** shows the average monthly trading levels during the three study periods.

**Figure 1: Average monthly trading levels during 2007, 2011, and 2013**



In 2007, the TSXV composite index was above 2500 for the entire year (over 3300 in the first half of the year). Trading volume averaged 4.4 billion shares per month. The value of trading averaged \$3.8 billion per month.

In 2011, the TSXV composite index never fell below 1400 and was over 2000 more than half of the year. Trading volumes averaged more than 5.5 billion shares per month. The value of trading in 2011 averaged \$3.5 billion per month.

The trading environment for TSXV-listed securities was very different in 2013. In April, the composite index dropped below 1000 and stayed there for the rest of the year. Compared to 2011, trading volumes fell by almost 50%, to an average of 3 billion shares per month. The value of shares traded in 2013 fell by two-thirds, averaging \$1.1 billion per month.

<sup>1</sup> 2007 data is from TSXV only, as only TSXV was trading venture securities; 2011 and 2013 data is from all Canadian marketplaces that traded TSXV securities during those years.

### Sample securities in this study

We selected sample securities for this study by:

1. identifying trader IDs that exhibited HFT-like trading activity in 2011 and 2013
2. selecting a sample of TSXV listed securities for all three study periods

### ***Step one: identify HFTs in 2011 and 2013***

First, staff identified trader IDs exhibiting HFT-like trading activity. Registrants assign trader IDs to an account or a group of accounts - client, staff/pro, or house/proprietary. A trader ID does not necessarily represent one client or one account.

There is no generally accepted definition of HFT. In this study, we chose indicators associated with HFT trading by market participants, third-party researchers, and IOSCO (*Regulatory Issues Raised by the Impact of Technological Changes on Market Integrity and Efficiency*, July 2011.)

The indicators are:

- using low latency (high speed) technology to manage order flow
- trading to avoid taking a position that would expose the trader to market volatility risk (i.e. flat at the end of a trading day)
- executing a large number of trades
- executing a large number of small trades
- sending heavy message traffic to the marketplaces, including a large number of messages associated with each trade executed
- frequently cancelling orders shortly after posting them

We used trading and message<sup>2</sup> data to assess whether certain trader IDs are engaged in HFT-like activities. In particular, we focused on five data elements of 1500 trader IDs active in June 2013. Characteristics of these five data elements that correspond to indicators of “HFT” are:

- a large number of trades
- a large number of messages
- a large message per trade ratio
- use of the short-marking exempt (SME) identifier
- a small average trade size

We then established a threshold for each data element. We aimed to capture approximately the top 20% of traders for each data element, but the actual percentages of trader IDs that met each threshold were different.

**Table 1 outlines** the data elements, their thresholds, and the actual percentage of trader IDs that met the thresholds.

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<sup>2</sup> Messages included all messages received include orders, order amendments and order cancellations.

**Table 1: Thresholds for data elements**

Data Element	Threshold	% of trader IDs
Number of trades	Greater than 500 trades per day	19.6%
Number of messages	Greater than 20,000 messages per day	16.5%
Messages per Trade	Greater than 5 messages per trade	20.3%
SME marker	Any use	11.6%
Average trade size	Less than 300 shares with more than 60 trades/day	24.8%

If a trader ID met the thresholds for at least three of the five data elements, we deemed it to be HFT because:

- We wanted to capture a broad range of market participants that displayed HFT-like activities. By requiring that they meet the thresholds for a majority of data elements (rather than all data elements), we expected to capture all market participants that use HFT trading strategies but exclude those that are clearly not HFTs.
- When tested, we saw that requiring three of five did not cast the net too widely. For more than 5000 trader IDs active in 2011 and 2013, just under 10% of all trader IDs active during each of those years were deemed to be HFT. This ratio is consistent with the 11% of trader IDs deemed to be HFT in IIROC's HOT study, published in December 2012.
- We tested whether well-known HFT traders (Getco, Virtu, Citadel, Knight, and Rothar Analytics) were captured by applying a three-of-five threshold, and they were. If we had required they meet the threshold for all five data elements, not all would have been captured.
- We also tested whether trader IDs of firms that were not commonly known to facilitate HFT trades (GMP, Haywood, Odlum, Peters, Edward Jones, Wolverton) were captured. Only one trader ID associated with these firms was captured in 2011 and no trader IDs associated with these firms was captured in 2013.

Although most trader IDs identified as HFTs in this study are not well-known high frequency traders, each trader ID demonstrated, through its trading activity, a profile that we think is a reasonable proxy for HFT.

We considered whether we could use fewer data elements as a proxy for HFT. After reviewing the five data elements for 1500 traders, we could not find a significant correlation between the data elements, as shown in Table 31 in Appendix F. We concluded that selecting a single data element as a proxy for the others would not be effective and would put us at risk of failing to identify HFT-like activity.

We did not apply the three-of-five data elements to 2007 trading data as HFTs were not yet trading TSXV securities in that time frame.

***Step two: select sample of TSXV issuer securities with HFT trading activities***

2007 pre-dates HFT activity in the venture market.<sup>3</sup> We reviewed trading in 2007, nonetheless, because it provides a baseline for short-selling activity on market news against which the 2011 and 2013 activity – which included HFT activity – can be compared.

To select our 2007 sample, we obtained a list of the 200 most active venture securities, by volume, from Bloomberg, then selected a random sample of 40 from these securities. We determined the sample data dates by reviewing the issuers' SEDAR filings and selecting a period when there was a news release (other than a release about a shareholder meeting).

To select our 2011 and 2013 samples, we applied these criteria to TSXV-listed securities:

- the issuer was Tier-1 or Tier-2 at the end of 2013<sup>4</sup>
- the security had above average trading (by number of trades and volume) in a month when the issuer put out at least one news release, when compared to the security's annual monthly average trading activities in all three periods under study
- the security was relatively liquid, with more than 5000 trades in 2011 and 2500 trades in 2013<sup>5</sup>
- the security was traded by trader IDs we identified as HFTs

We categorized each security as infrequently, moderately, or frequently traded by HFT.

While having the same securities for both 2011 and 2013 would seem to make results between the two years more comparable, we found that profiles of securities and their issuers often differed between 2011 and 2013 and it is not common to find a security that fit into the same category for both years. This is consistent with the dynamic nature of the venture market. As such, our sample securities for 2011 and 2013 are made up of different securities that as a group are more comparable from one year to the other.

**Table 2 shows** the thresholds we used to determine frequency of HFT trading in a security. We used different thresholds for 2011 and 2013. In 2013, more securities had a high percentage of activities by trader IDs identified as HFTs. Increasing the threshold for 2013 allowed us to have a comparable ratio of securities in each year's sample. This

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<sup>3</sup> There is anecdotal evidence suggesting that HFT activity levels began to increase substantially in 2008 when: (1) TMX Group offered colocation services (2) marketplaces competing with the TSXV increased their market shares (3) HFT activity materially increased - globally. The anecdotal evidence is consistent with analysis about HFT ascendancy in the appendix to "High Frequency Trading and End-of-Day Manipulation" (by Cumming, Zhan and Aitken, January 2013). This paper suggests that the best measure of the start time of HFTs' influence on a market is the conclusion of a four-month period when average trade sizes declined during each month. Using this test, the start time of HFT influence on TSXV was in the second quarter of 2009.

<sup>4</sup> We excluded NEX issuers because they were likely to have limited activities in 2013. We restricted the sample to more liquid securities, as we think that HFTs would be inactive in illiquid securities.

<sup>5</sup> We established these thresholds after reviewing 771 TSXV listed securities that met the other criteria. We wanted to select relatively liquid securities based on the trading activity levels in the two years.

allowed us to compare securities with more HFT activity to securities with comparatively less activity.

**Table 2: Categories based on level of trading by HFT in a security**

Category	Criteria	
	2011	2013
Infrequently HFT traded	< 10% HFT	< 22.5% HFT
Moderately HFT traded	10 – 20% HFT	22.5 – 30% HFT
Frequently HFT traded	> 20 % HFT	> 30% HFT

Further, to study the impact of news on HFT trading levels, we identified securities whose number of trades by HFTs increased by at least 75% following a news release (a material increase). In most cases, this increase coincided with a large increase in an increased number of trades generally. We did not classify each news release as positive or negative. Although venture-supporting dealers reported seeing diminished increases in share price after positive news, we wanted to avoid injecting our subjective judgments into how the news should affect the value of a security and let the market demonstrate its reactions.

From the frequently and infrequently HFT traded securities, we randomly selected a set of securities.

**Table 3 shows** how many securities were in each category, for each period.

**Table 3: Number of securities in our sample for the three study periods**

Period	Category	Number of securities
2007	With news releases <sup>6</sup>	19
	No news releases	20
2011	Infrequently HFT traded	30
	Frequently HFT traded	40
	HFT trading increased after material news releases	40
2013	Infrequently HFT traded <sup>7</sup>	29
	Frequently HFT traded	40
	HFT trading increased after material news releases	40

For each security, we requested trade-by-trade data for 15 trading days. For each security that displayed increased HFT trading following a news release, we reviewed trading data the five trading days before news and the 10 trading days after. For example, if a news release was issued on January 10, we analysed trading data from January 3 to 24.

<sup>6</sup> The original sample size was 20 securities, but we removed one security due to data issues.

<sup>7</sup> The original sample size was 30 securities, but we removed one security due to data issues.

Similarly, for our 2007 sample securities we manually selected securities with news releases and experienced a material increase in trading volume (75%) during the week following the news release when compared with the security's average trade volumes. We selected the sample data periods for non-news release securities to match the same sample periods for the new release securities to ensure that differences between the sample groups did not result from changes that affected TSXV broadly.<sup>8</sup>

We reviewed five days of trading data prior to each news release because in our review of trading activity during the sample selection process, we observed there is often an increase of trading activities even before news releases. We included data for the 10 trading days after the news release to ensure we have trading data that covers a sufficient length of time before other events overtake the effect of the news releases.

## **Analysis and results**

### **Volatility and HFT**

The first hypothesis we tested was that security prices of frequently HFT traded securities are more volatile than those for infrequently HFT traded securities.

Volatility is a measure of changes in a security's price over time. To compare whether volatility was higher for frequently HFT traded securities, we chose three measures<sup>9</sup>:

- Weighted average standard deviation in the security's price of the security<sup>10</sup>
- Average difference between the high and low price as a percentage of close price each day
- Average price change, by percentage, of each trade of the security

While standard deviation of share prices is the most widely used way of measuring volatility, we also used the average difference between each trading day's high and low price to measure volatility over the course of a single trading day, and the average change in price of a security for each trade executed to measure intraday volatility as a percentage of the value of the security.

If HFT activity increased share price volatility as reported by the venture supporting dealer community, we would expect that frequently HFT traded securities should have a higher:

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<sup>8</sup> Each of the non-news release securities was matched with a news release security and we obtained data for identical trading periods. Where a security that was a non-release security did have a news release that resulted in a material change in trading volumes during the sample period we matched it with a different security to ensure that none of the non-news release securities were impacted by material news during the sample periods.

<sup>9</sup> We selected standard deviation of price and average price change as a percentage of price as separate measures of volatility, in part, to ensure that we are assessing price volatility as both an absolute amount and as a percentage of the price of the security.

<sup>10</sup> "Standard deviation" measures the dispersion of trade prices around the average trade price for a security. A volatile stock will have a high standard deviation, while stable blue-chip stock will have a lower standard deviation.

- average standard deviation of security prices when compared to infrequently HFT traded securities
- average difference between their daily high and daily low price as a percentage of close price when compared to infrequently HFT traded securities
- average price change per trade than infrequently HFT traded securities

***Volatility: Infrequently HFT traded vs. frequently HFT traded securities***

For 2011 and 2013, we determined whether the differences in volatility measures were statistically significant<sup>11</sup> between infrequently HFT traded and frequently HFT traded securities.

**Table 4 shows** the results for 2011 and 2013, respectively. The complete results are in Appendix A.

We did not make similar comparisons for 2007 because there was minimal HFT activity during that time period.

**Table 4: Volatility comparison between infrequently HFT traded and frequently HFT traded securities**

2011	
Standard deviation	<i>Frequently HFT traded higher than Infrequently HFT traded</i>
High-low difference	<i>Frequently HFT traded higher than Infrequently HFT traded</i>
Price change	<i>Frequently HFT traded lower than Infrequently HFT traded</i>
2013	
Standard deviation	<i>Frequently HFT traded lower than Infrequently HFT traded *</i>
High-low difference	<i>Frequently HFT traded lower than Infrequently HFT traded</i>
Price change	<i>Frequently HFT traded higher than Infrequently HFT traded *</i>

\* indicates a significance level of 0.05

For 2011:

- The average standard deviation of prices for frequently HFT traded securities was higher than for infrequently HFT traded securities. This is consistent with the hypothesis, but the difference was not statistically significant.
- The average differences between daily high and low prices was higher for frequently HFT traded securities than for infrequently HFT traded securities. This is consistent with the hypothesis, but the difference was not statistically significant.
- The average percentage price change per trade for infrequently HFT traded securities was higher than for frequently HFT traded securities. This does not support the hypothesis, but the difference was not statistically significant either.

For 2013:

<sup>11</sup> We tested based on a significance level of both 0.05 and 0.01. This paper uses 0.05 as the base level but we have noted where the outcome would be different at a 0.01 level. 0.05 is a common standard for measuring statistical significance.



- The average standard deviation of prices for frequently HFT traded securities was lower than for infrequently HFT traded securities. The difference was **statistically significant**, and this does not support the hypothesis.
- The average difference between high and low prices was lower for frequently HFT traded securities than for infrequently HFT traded securities. This does not support the hypothesis, but the difference was not statistically significant either.
- The average percentage price change per trade was higher for frequently HFT traded securities than for infrequently HFT traded securities. The difference was **statistically significant**, and supports the hypothesis.

### ***Volatility and news releases***

For 2011 and 2013, we determined whether the differences in volatility measures were statistically significant between the infrequently HFT traded securities that experienced increased HFT-trading following news and the frequently HFT traded securities that experienced increased HFT-trading following news.

**Table 5 shows** the results for the comparison of securities that experienced increased HFT-trading after news, between infrequently HFT-traded and frequently HFT-traded securities for 2011 and 2013. The complete results are in Appendix A.

**Table 5: Volatility comparison between infrequently HFT traded and frequently HFT traded securities, when both experienced increased HFT trading activity with news releases**

Note: all securities in this comparison experienced increased HFT trading activity with news releases

2011	
Standard deviation	<i>Frequently</i> HFT traded <b>higher</b> than <i>infrequently</i> HFT traded *
High-low difference	<i>Frequently</i> HFT traded <b>lower</b> than <i>infrequently</i> HFT traded
Price change	<i>Frequently</i> HFT traded <b>lower</b> than <i>infrequently</i> HFT traded *
2013	
Standard deviation	<i>Frequently</i> HFT traded <b>lower</b> than <i>infrequently</i> HFT traded
High-low difference	<i>Frequently</i> HFT traded <b>lower</b> than <i>infrequently</i> HFT traded
Price change	<i>Frequently</i> HFT traded <b>lower</b> than <i>infrequently</i> HFT traded

\* indicates a significance level of 0.05

For 2011, for securities that experienced increased HFT trading around news releases:

- The average standard deviation of prices of frequently HFT traded securities was higher than for infrequently HFT traded securities. This is consistent with the hypothesis, and the difference was **statistically significant**.
- The average difference between daily high and low prices for frequently HFT traded securities was lower than for infrequently HFT traded securities. This does not support the hypothesis, but the difference was not statistically significant either.

- The average percentage price change per trade for frequently HFT traded securities was lower than for infrequently HFT traded securities. The difference was **statistically significant**, and this does not support the hypothesis.

For 2013, for securities that experienced increased HFT trading around news releases:

- The average standard deviation for frequently HFT traded securities was lower than for infrequently HFT traded securities. This does not support the hypothesis, but the difference was not statistically significant either.
- The average difference between daily high and low prices for frequently HFT traded securities was higher than for infrequently HFT traded securities. This does not support the hypothesis, but the difference was not statistically significant either.
- The average percentage price change per trade for frequently HFT traded securities was lower than for infrequently HFT traded securities. This does not support the hypothesis, but the difference was not statistically significant either.

### ***Key observations from volatility and HFT analysis***

#### **Infrequently HFT traded securities vs. frequently HFT traded securities**

The data did not include any statistically significant findings or clearly indicate whether frequently HFT traded securities suffer from increased volatility when compared to infrequently HFT traded securities in 2011. However, the data contained two statistically significant findings for 2013 that are not consistent; one supports our hypothesis while the other does not. While the average standard deviation was higher for frequently HFT traded securities, the average percentage price change per trade was lower for frequently HFT traded securities.

#### **Infrequently HFT traded securities after news vs. frequently HFT traded securities after news**

In 2011, the three volatility measures showed mixed results. When we looked at the impact of HFT activity on volatility around news, we found that frequently HFT traded securities had higher standard deviation, but lower price changes than infrequently HFT traded securities. In each of these cases, the differences were statistically significant. In terms of the average difference in the daily high and low prices, our data showed that frequently HFT traded securities were less volatile than infrequently HFT traded securities, but the difference was not statistically significant.

In 2013, during the period after news, all three volatility measurements showed that infrequently HFT traded securities were more volatile than frequently HFT traded securities. In each case, the difference was not statistically significant.

It is possible that the data showing increased volatility around press releases in 2013 (but not 2011) could result from the reduction in trading volumes in 2013, compared with 2011, making ordinary price changes around news seem like increased volatility. A conclusive finding would require additional analysis around volatility in periods around the publication of news.

Our analysis of volatility does not support the hypothesis that HFT trading increases the price volatility of TSXV securities.

### **Short-selling and HFTs**

The second hypothesis we tested was whether short-selling activity by HFTs limits price increases of securities following positive news.

To test this hypothesis, we used our sample of 40 securities from each of 2011<sup>12</sup> and 2013<sup>13</sup> that experienced increased trading activity after news as well as our 2007 sample of securities that provided us with data in the period around their news<sup>14</sup>.

Using these sample securities, we undertook four analyses:

1. We used the data to determine how long news had an impact on the price of a security. This analysis will tell us which trading days we should examine when testing our hypothesis.
2. We reviewed the average price changes of securities around news to determine whether securities frequently traded by HFTs experienced a smaller percentage increase in their stock prices following positive news compared with securities infrequently traded by HFTs.
3. We reviewed the aggregate short-selling activity of HFTs on the key trading days following news to determine whether HFTs increased their percentage of short-selling activity when compared with other trading days.
4. We reviewed the impact of short-selling on specific venture securities to determine whether HFTs orders to sell short exhibited different patterns after trades that were upticks, downticks or flatticks or when no trades had been recently executed.

The following sections describe the results of each of these analyses.

#### ***Time period when news affects securities prices***

To assess the impact of HFTs on the price of a security after a news event we need to determine how long a news event has a significant impact on the change in the price of a security. Figure 6 through Figure 8 in Appendix B show the average percentage rate of change of the volume weighted average price (VWAP) on each trading day compared to

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<sup>12</sup> Of these 40 securities from 2011:

- 19 were frequently HFT traded securities
- 20 were infrequently HFT traded securities
- one was a less liquid security that was not identified as either a frequently or infrequently HFT traded security

<sup>13</sup> Of these 40 securities from 2013:

- 25 were frequently HFT traded securities
- 12 were infrequently HFT traded securities
- three were less liquid securities that were not identified as either frequently or infrequently HFT traded securities

<sup>14</sup> As stated earlier we do not believe that HFTs were active in the TSXV during 2007 so all 2007 are infrequently HFT traded. In addition, all 2007 securities were liquid.

the VWAP price on the day before the news release. These changes are cumulative from day-to-day.<sup>15</sup>

We separated the securities into two groups, based on the direction of the average price change between the day prior to the news and the day of the news: those that increased in price on day of the news, and those that decreased in price on day of the news. Where a security saw an initial increase in price we deemed the news to be positive and if the price fell we deemed the news to be negative.

The price movement patterns following positive and negative news are generally mirror images. There is, in most cases, an identifiable typical pattern of market participant behaviour when news is released. The market's reaction is immediate, and the reaction to the news continues, with diminishing impact, until the movement of the price of the security changes. After that, the impact of the news release is negligible and securities' prices find a new level. This pattern is between 2007 and 2013. In our sample, the average day when the direction of the securities price changes is 1.8 days after the close of trading on the day that the news is published.<sup>16</sup> For the purpose of our analysis, we deemed that the impact of a news release ends at the close of trading on the second day after publication of news. These three trading days will be referred to as the "news period".

#### ***Average price changes in securities after news releases***

One method to assess whether HFTs adversely impact the price of TSXV securities during the news period is to determine whether securities frequently traded by HFTs had smaller percentage price increases in their price during the news period than securities that were infrequently traded by HFTs. We looked at the change in average price<sup>17</sup> between the day prior to news release and each day of the news period. If short-selling activities by HFTs were limiting price increases following news, we would expect the change in average price to increase by a lesser degree, or even change direction, for securities that saw an initial positive price change.

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<sup>15</sup> For example, in Figure 2 the price increased, on average, about 5.5% on the first day of the news period, another 0.5% on the second and third days and then fell about 3% to end the fourth day with a price increase of more than 3% compared to the trading day before the news period. Each percentage is a percentage of the price at the end of the trading day before the news period, not a percentage of the previous day's price.

<sup>16</sup> Where news is published after the close of trading we have deemed the news to be published on the following trading day.

<sup>17</sup> We calculated volume-weighted average price for each security.

Figure 2: Change in VWAP for 2007

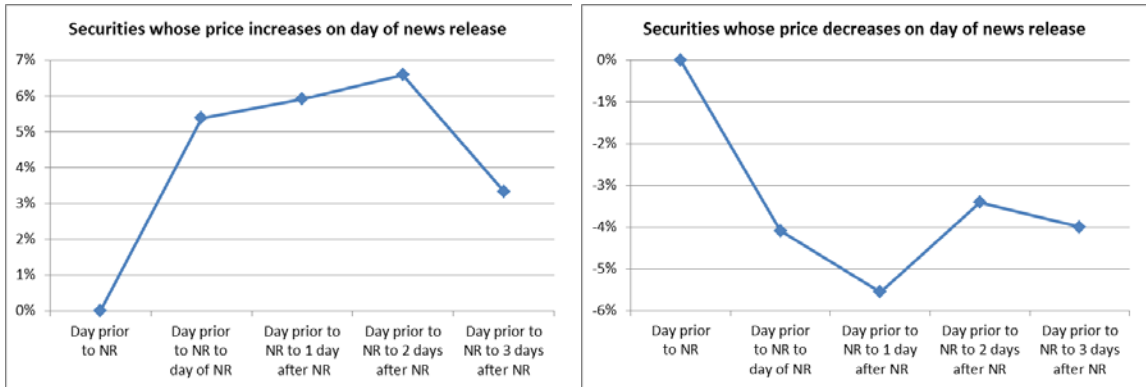


Figure 3: Change in VWAP for 2011

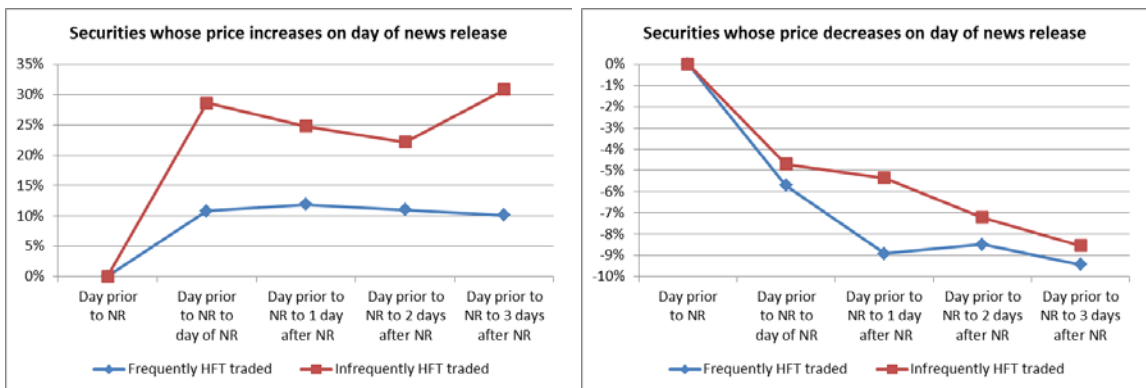
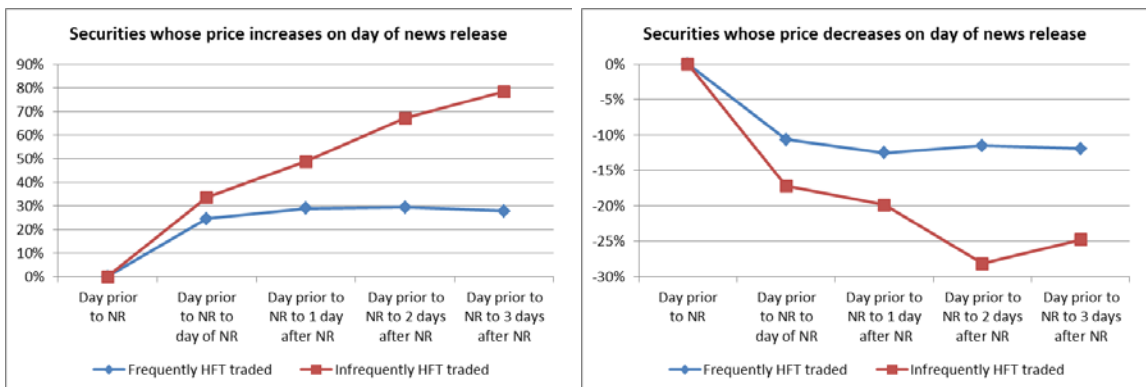


Figure 4: Change in VWAP for 2013



Our analysis shows some interesting results. In 2007, we see that positive news resulted in an average peak increase in the price of the sample securities of almost 7%. Negative news resulted in a decrease in the average price of securities of about 5.5%.

In 2011 and 2013, we placed our sample securities in two categories: securities frequently traded by HFTs and securities that were infrequently traded by HFTs. In both of the years, we saw that after positive news securities' average prices increased more than they increased in 2007. Average prices also decreased more after negative news. This

occurred whether the securities were frequently traded by HFTs or not. We also saw that in both 2011 and 2013, securities frequently traded by HFTs experienced a smaller percentage increase in price after positive news than securities that were infrequently traded by HFTs. The differences between securities frequently traded by HFTs and those infrequently traded by HFTs were interesting however conclusions cannot be drawn as they were not statistically significant.

When we compared the impact of positive news and negative news in 2011 and 2013, we see different results. In 2013, the impact of negative news mirrored the results after positive news. Securities infrequently traded by HFTs experienced a larger percentage decrease in price than securities frequently traded by HFTs. In 2011, we see different results. During the news period after negative news, securities frequently traded by HFTs experienced a larger percentage decrease than those infrequently traded by HFTs. This is not the mirror image that we would expect to see and that we did see in 2013. In both cases the differences between the sample group was not statistically significant.

This trends we observed matched the venture market dealer's belief that HFTs negatively impact venture issuers and their investors by short-selling after positive news. However, the differences were not conclusive as they were not statistically significant.

We considered whether the higher percentage increase in the price of securities infrequently traded by HFTs could be explained by those securities having more price volatility than securities frequently traded by HFTs. The 2013 data appears to support this as securities that are infrequently traded by HFTs experienced a larger percentage decrease in price than securities frequently traded by HFTs. The 2011 data, however does not support this. Securities frequently traded by HFTs experienced a large percentage decrease than securities infrequently traded by HFTs.

Our analysis does not result in a clear conclusion. The average percentage increase in securities' prices following positive news was, in both 2011 and 2013, larger than the average price increase in 2007 when HFTs were not active on TSXV. This does not support the hypothesis that HFTs short-selling adversely impacts the price of TSXV securities after positive news. Our analysis compares the average price change in securities that were frequently traded by HFTs with those that were infrequently traded by HFTs. The data indicated that securities frequently traded by HFTs had a lower average percentage increase in price after positive news in both 2011 and 2013. While consistent with the hypothesis that HFTs short-selling adversely impacts the price of TSXV securities after positive news for each period, the differences in the sample were not statistically significant. This suggests that HFT activity has been a largely neutral factor in venture market trading for these sample years in these sample securities but data suggesting that securities frequently traded by HFTs have smaller price increase than securities infrequently traded by HFTs does raise an issue that may warrant additional analysis in the future.

***Aggregate percentage of HFT short sales during the news period***

The aggregate short-selling trading activity by HFTs could, as a result of its overall size, negatively impact a security's price. For example persons identified as HFTs could enter a large number of orders to sell short that result in trades that negatively impact the price of the security during the news period.

To determine whether there was an increase in short-selling activity during the news period, we compared the ratio of short-selling by HFTs, by both number of trades and volume, to the ratio of short-selling by HFTs during other trading days for sample securities that had positive news in both 2011 and 2013. Because trades marked with SME generally are not also marked short, in 2013, we assumed that half of all SME trading activity, by volume and number of trades, was from short positions. As HFTs that mark their trades as SME do not trade to take positions, they should be equally likely to be selling from a short position as a long position.

In 2011, the sample data indicates that short-selling activity by HFTs increased during the news period when compared to the other trading days. We cannot conclude that this proves an increase in the activity as the difference during these two time periods was not statistically significant. In reviewing the difference, we found that the difference is attributable to a single, heavily traded security (security 7 in Table 12 in Appendix C).<sup>18</sup> The results are shown in Table 10 in Appendix C. If this security is removed, the ratio of HFT selling for the rest of the sample securities is lower during the news period compared to the other trading days.

Changes in HFT short-selling between the two time periods varied greatly for our sample securities. Table 12 in Appendix C lists the percentage change in number of trades during the two periods for each sample security.

In some securities, the ratio of HFT selling from a short position decreased during the news period while other securities saw substantial increases in the ratio. There was no clear pattern of a systemic increase in the ratio of short-selling by HFTs in the news period.

We did, however, see an increase in the ratio of HFT selling from a short position for slightly more than half (12 of 21) of our sample securities that had positive new releases. Of these, half increased more than 40% (including security 7 in Table 12). While this is not evidence of a widespread trend, it could indicate some HFTs may be entering short sale orders that may have a negative impact on the price of some securities. We will discuss the specific impact of HFT short sale orders on these securities in the section entitled "Impact of HFT Short Order Entry" below.

For 2013, the results were very different. We did not see an increase in the ratio of short-selling activity by HFTs in the news period compared to the other trading days.

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<sup>18</sup> During news periods in 2011, the short-selling volume increased 43% and the number of trades increased by 15%.

Table 11 in Appendix C compares the percentage of short sale activity by HFTs, by number of trades and volume, respectively, between the news period and the other trading days. The majority of our sample securities (18 of 26) did not experience an increase in the ratio of short-selling activity during the news period. Only two of the 26 sample securities experienced an increase of more than 40%.

Table 13 in Appendix C lists the percentage change in number of trades during the two periods for each sample security. We will also discuss the specific impact of HFT trading on these securities in the section entitled “Impact of HFT short-selling orders on specific venture securities” below.

In conclusion, we could find no evidence that HFTs increased the ratio of sales from short positions during the news period in 2013. In 2011, there was an increase in the ratio of short-selling activity during these days, but it was not statistically significant<sup>19</sup> and the results were largely attributable to price movements in a single security.

***Impact of HFT short-selling orders on specific venture securities***

While the data does not appear to show that HFTs generally adversely impact the price of securities after positive news releases, we did want to see whether there was any evidence of short-selling having an adverse impact on the price of any of our sample securities from 2011 and 2013. In particular, we wanted to determine whether there was any evidence of short-selling orders having a negative impact on securities during the news period.

HFTs could have an adverse impact during the news period where they enter short sales that, as a result of the sales’ timing or size. In particular, orders entered at key times during the trading day, such as immediately after an uptick or downtick. These orders may have a negative impact on investor confidence. This, in turn, may have a negative impact on the security’s price. For example, a person identified as an HFT could enter orders to sell short at a price lower than the last sale price every time that there is an uptick in the stock price in an effort to reduce upward price momentum.

For the purpose of this analysis, we did not consider typical HFT activity of buying and selling securities as adversely affecting the market. Instead, we considered whether HFTs exhibited a pattern of activity around certain key points that may indicate they were using short sales to limit a security’s price increase or to lower a securities price. To do this, we looked at when HFTs entered orders to sell short securities that had positive news.

We expected HFTs, like other market participants, would have entered more orders after a trade, particularly a trade that changed the price. For the purpose of this analysis, we assumed that HFTs would have entered their orders in reaction to a price-changing trade within 10 seconds. We expected the ratio of orders entered to be as follows:

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<sup>19</sup> We tested based on a significance level of both 0.05. The increase was not statistically significant at either level.



**Table 6: Expected ratio of orders entered relative to trades**

Timing of order entry relative to trades	Expected ratio of orders entered
No trade in previous 10 seconds	Low
A trade in the previous 10 seconds that do not change the price	Medium
A trade in the previous 10 seconds that upticks or downticks the price	High

The results of our analysis are provided in Appendix D.

In both 2011 and 2013 (see Figure 5), for most of the securities, the majority of orders were entered when trades had not been executed in the previous 10-second period. For all sample securities, a minority of trades are entered after upticks and downticks.

**Figure 5: Breakdown of orders entered within 10 seconds of an uptick, a downtick, a flattick, and when there was no trade in the previous 10 seconds**

However, when we break down this information by trade executed we see a different outcome. In both 2011 and 2013 we see that HFTs enter about three times as many orders after an uptick or downtick trade as they do after a trade that occurs at the same price as the previous trade (a flattick) (see Appendix D, Table 14 and Table 15). The average number of HFT orders (both buy and sell) entered after a downtick (8.52 in 2011 and 6.24 in 2013) are similar to the average number of orders entered after an uptick (8.37 in 2011 and 5.89 in 2013).

Non-HFT participants showed similar order patterns. Non-HFTs actually enter a larger proportion of their order in the 10-second period after an uptick or a downtick when compared to the number of orders after a flattick, almost four times more orders (see Appendix D, Table 16 and Table 17). Like HFTs, non-HFTs' average number of orders entered after a downtick (5.50 in 2011 and 3.74 in 2013) are similar to the average number of orders entered after an uptick (5.33 in 2011 and 3.50 in 2013).

Both HFTs and non-HFTs were more likely to enter sell orders after downticks than upticks and to enter buy orders after upticks. In 2011, we see that HFTs entered an average of 4.46 buy orders after an uptick and 3.50 buy orders after an downtick while

entering an average of 3.91 sell orders after an uptick and 5.02 sell orders after a downtick. Non-HFTs entered an average of 3.19 buy orders after an uptick and 2.44 buy orders after a downtick while entering an average of 2.14 sell orders after an uptick and 3.06 sell orders after a downtick. HFTs exhibited the same behaviour in 2013. They entered an average of 3.49 buy orders after an uptick and 2.72 buy orders after a downtick while entering an average of 2.40 sell orders after an uptick and 3.52 sell orders after a downtick.

When breaking down the activity for each of our sample securities in 2011, we found:

- more than 80% (17 of 21) entered more orders to sell short after a downtick than after an uptick
- more than 85% (18 of 21) entered more orders to sell from a long position after a downtick than after an uptick
- more than 80% (17 of 21) entered more orders to buy after an uptick than after a downtick

We also compared order entry activity when an order is being sold short and when they are being sold from a long position after downtick, uptick, and flattick (see Appendix D, Table 14 through Table 17). We found:

- In both 2011 and 2013, HFTs entered more sale orders, on average, after a downtick than an uptick regardless of whether they were selling from a short or a long position.
- In both 2011 and 2013, on average, HFTs entered the most number of long sale orders after downtick, and the least number of long sale orders after flattick. This pattern was the same for short sale orders.
- In 2011, HFTs entered more orders to sell short than to sell long whenever there was a trade in the previous 10-second period regardless of whether the trade was an uptick, downtick, or flattick. In contrast, in 2013, HFTs entered more orders to sell long than to sell short in the 10-second period after any trade regardless of the tick.
- Orders entered by non-HFTs showed similar patterns. They entered more sell orders after a downtick and more buy orders after an uptick. In both 2011 and 2013, non-HFTs entered more orders to sell long than to sell short in the 10-second period after any trade regardless of the tick.

HFT behaviour was largely consistent whether they were selling from a long position or a short position, with the few notable exception that HFTs entered substantially more order to sell from a short position than a long position in 2011. While this in isolation may indicate a potential red flag, we would also note that HFTs also entered proportionately more orders to sell on an uptick, downtick, and flattick. These total volume of orders were not substantially greater than the number of orders that these HFTs entered to purchase the sample securities. When comparing HFT order entry activity to order entry activity of non-HFTs we see that HFTs do enter more orders of all types when compared to non-HFTs. In sample securities in both 2011 and 2013, HFTs enter between two-thirds and three-quarters of orders while they represent about 10% of trader IDs. This is consistent with what we would expect of HFTs.

While they do enter a disproportionate number of orders, their pattern of order entry is remarkably similar to order entry patterns by non-HFTs. They enter more buy orders after upticks, more sell orders after downticks and fewer overall orders after flatticks.

We also tested for evidence of unusual order patterns for the sample securities that saw an increase in short-selling activity during the news period. Appendix E provides a breakdown of order activity for each sample security that saw at least a 40% increase in short-selling activity during the news period. When we compared each of the securities from both 2011 and 2013, we found:

- Each of the securities experienced a higher ratio of orders to sell from a long position than to sell from a short position in the 10-second period following a downtick trade.
- Each of the securities experienced a higher ratio of orders to sell from a short position than to sell from a long position in the 10-second period following an uptick trade.

The second point is an issue to consider. The sample securities, as a group, also experienced a greater percentage of orders to sell short after an uptick than orders to sell long during the same period (see Appendix E, Table 26 and Table 29). With the exception of one security, each of the securities that experienced increases in short-selling activity during the news period of more than 40% experienced a higher percentage of sell trades from short positions after an uptick when compared with the other securities in the example (see Appendix E, Table 30).

The most liquid security, Security 7 in 2011, experienced a lower than average ratio of sell orders from a short position when selling after an uptick. It was exceptional among the group.

The evidence does not show any obvious efforts on the part of HFTs to negatively impact the price of securities during the period that news releases have an impact on the trading price of our sample securities.

HFTs do have a tendency to enter a higher proportion of sell orders, including both sales from a short position as well as sales from a long position, during the period after a downtick in the price of a security. This mirrors a tendency to enter orders to purchase a security in the 10-second period after an uptick in the price of a security. It would appear that HFT selling activity largely mirror HFT buying activity. Non-HFTs follow a similar pattern of order activity.

When comparing HFTs' entry of orders to sell short and to sell long, we see that HFTs entered a higher proportion of orders to sell from a short position than orders to sell from a long position in the 10-second period after a security experiences a trade that upticks the securities price in both 2011 and 2013 (see Appendix D, Table 18 and Table 19). The higher proportion is also there for all of the securities that experienced more than a 40% increase ratio of sales that are short sales during the news period.

Our review of order entry activity did not provide any evidence to indicate that HFTs were entering short sale orders during news periods in a way that would adversely affect the price of our sample securities. Their pattern of entering orders to sell short was similar to the entry of order to sell from a long position and represented a mirror image of their buy order patterns. In addition, their pattern of order entry was remarkably similar with the way that non-HFTs entered their orders. When examining short sale orders on individual securities during news periods, we found no indication that HFTs had conducted their order activity in a way that would indicate that they were making an effort to reduce the increase in the price of the securities.

## **Conclusions**

We conducted analysis of sample data to test two hypotheses:

- that share prices of securities frequently targeted by HFTs are more volatile than those less or not targeted by HFTs
- that short-selling activities by HFTs after news releases were more prevalent on downtick than uptick, compared to short-selling activities by non-HFTs

We did not find any evidence to support the first hypothesis. In general, securities frequently traded by HFTs did not experience more volatility than securities infrequently traded by HFTs in either 2011 or 2013. This finding applies for periods when there was no news and for periods immediately following news that resulted in increased HFT trading activity.

It is plausible that the increased volatility in periods after new releases that was more evident in 2013 may be the result of ordinary volatility resulting from material news when trading volumes were lower. A conclusive finding would require additional analysis around volatility in period around publication of news.

We conducted three types of analysis to test the second hypothesis.

The first type of analysis was to determine whether securities frequently traded by HFTs experience smaller percentage increases in share price after positive news than securities that were infrequently traded by HFTs. We used two sample groups to represent securities infrequently traded by HFTs: (1) securities traded in 2007 before HFTs were active in TSXV, and (2) securities infrequently traded by HFTs in 2011 and 2013.

The results of the comparison between percentage change in price between securities traded in 2007 and securities frequently traded by HFTs in 2011 and 2013 do not support the hypothesis. On average, securities frequently traded by HFTs in 2011 and 2013 experienced a larger percentage increase in price than securities in 2007.

When comparing securities that were frequently traded by HFTs with securities infrequently traded by HFTs, we found that in both 2011 and 2013, securities infrequently traded by HFTs experienced a larger percentage increase on average. To test

whether this difference could be explained because securities infrequently traded by HFTs may be more volatile in general, we compared it against the average price changes after negative news. This analysis was inconclusive. The data does raise an issue that may warrant additional analysis in the future.

The second type of analysis was to determine whether HFTs may increase short-selling activity after news. We looked at the ratio of short selling activities by HFT during the news period and other trading days. We found that in both 2011 and 2013, HFTs decreased their percentage of short sale trading activity during the news period when compared with the other trading days. This finding does not support short selling hypothesis.

The third type of analysis was to determine whether orders by HFTs exhibit different or abnormal patterns at different key times of a day (i.e. on uptick, downtick, flattick, or when there were no recent trades) that could negatively impact security prices following news. In both 2011 and 2013, we found that HFTs had similar patterns of order activity whether they were selling from a short position or from a long position. There was no evidence that they were using a different trading strategy when selling short. Furthermore, both HFTs and non-HFTs were more likely to enter sell orders after downticks than upticks, and to enter buy orders after upticks. There was no evidence that the two groups of traders had different order entry patterns. These findings did not support the short selling hypothesis.

## Appendix A

**Table 7: Weighted average standard deviation of the price of the security**

Period	Category	Average Standard Deviation
2007	With news releases	0.0589
	No news releases	0.0608
2011	Infrequently HFT traded	0.0350
	Frequently HFT traded	0.0533
	HFT trading increased after material news releases – Infrequently HFT traded	0.0438
	HFT trading increased after material news releases – Frequently HFT traded	0.1197
2013	Infrequently HFT traded	0.0418
	Frequently HFT traded	0.0191
	HFT trading increased after material news releases – Infrequently HFT traded	0.1099
	HFT trading increased after material news releases – Frequently HFT traded	0.0528

**Table 8: Average difference between the daily high price and low price as a percentage of close price**

Period	Category	Average Difference between Daily High and Low Price
2007	With news releases	11.20%
	No news releases	10.14%
2011	Infrequently HFT traded	5.44%
	Frequently HFT traded	5.44%
	HFT trading increased after material news releases – Infrequently HFT traded	6.41%
	HFT trading increased after material news releases – Frequently HFT traded	6.28%
2013	Infrequently HFT traded	4.60%
	Frequently HFT traded	4.42%
	HFT trading increased after material news releases – Infrequently HFT traded	7.97%
	HFT trading increased after material news releases – Frequently HFT traded	6.35%

**Table 9: Average price change for each trade**

Period	Category	Average Price Change per Trade
2007	With news releases	0.54%
	No news releases	0.50%
2011	Infrequently HFT traded	0.90%
	Frequently HFT traded	0.19%
	HFT trading increased after material news releases – Infrequently HFT traded	0.61%
	HFT trading increased after material news releases – Frequently HFT traded	0.21%
2013	Infrequently HFT traded	0.53%
	Frequently HFT traded	0.59%
	HFT trading increased after material news releases – Infrequently HFT traded	0.58%
	HFT trading increased after material news releases – Frequently HFT traded	0.52%

## Appendix B

Figure 6: Change in VWAP for 2007

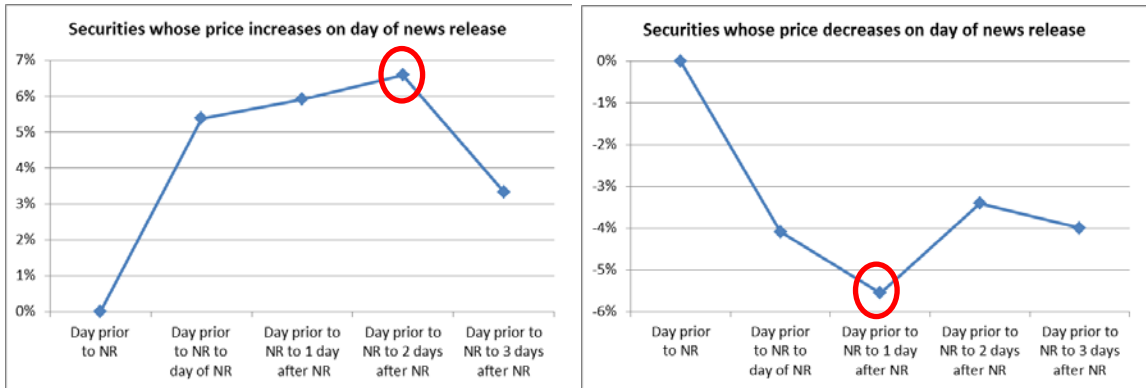


Figure 7: Change in VWAP for 2011

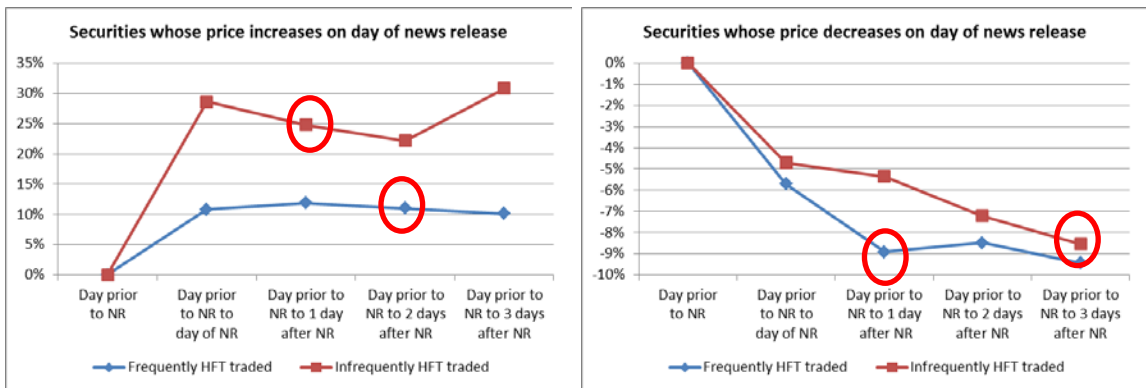
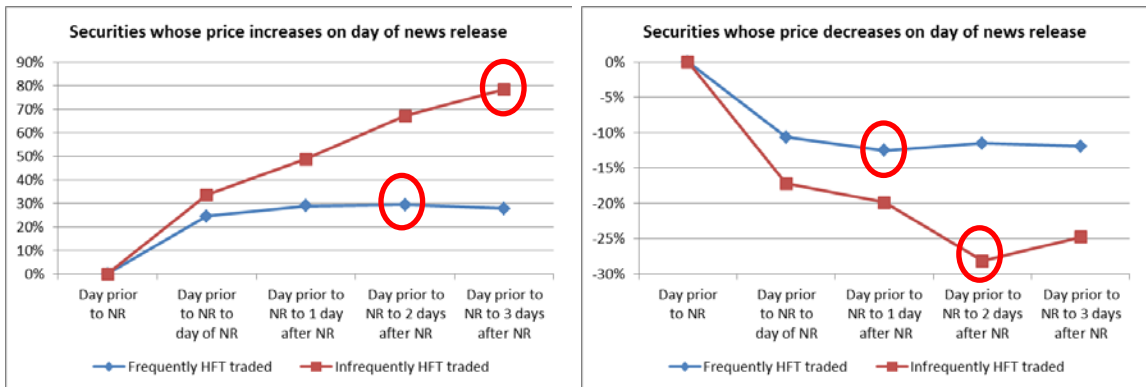


Figure 8: Change in VWAP for 2013



For 2011 and 2013, we did not include results for illiquid securities. There was a low number of them in the sample, resulting in averages that were essentially the results of one security. Also, some of them had no trades in the four days of trading used for this analysis. The red circle represents the trading day on which the closing price change trend that begins after the news is released ends (for example when a security whose



price increases after news has its stock price drop when compared to the previous trading day's closing price).

## Appendix C

**Table 10: Short-selling activity by HFTs during the news period compared to other trading days for securities with positive news release (2011)**

Short sale activity by HFTs (by number of trades)			
News period		Other trading days	
As % of all sales by HFTs	As % of all sales	As % of all sales by HFTs	As % of all sales
56.11%	14.85%	48.79%	14.10%

Short sale activity by HFTs (by trading volume)			
News period		Other trading days	
As % of all sales by HFTs	As % of all sales	As % of all sales by HFTs	As % of all sales
43.52%	4.13%	30.29%	2.97%

**Table 11: Short-selling activity by HFTs during the news period compared to other days for securities with positive news release (2013)**

Short sale activity by HFTs (by number of trades)			
News period		Other trading days	
As % of all sales by HFTs	As % of all sales	As % of all sales by HFTs	As % of all sales
18.12%	6.19%	24.68%	7.47%

Short sale activity by HFTs (by trading volume)			
News period		Other trading days	
As % of all sales by HFTs	As % of all sales	As % of all sales by HFTs	As % of all sales
3.24%	0.78%	4.42%	1.04%

**Table 12: Short-selling activity by HFTs during the news period compared to other sales activity for securities with positive news release, for each sample security (2011)**

Security	News period		Other trading days		% Change in HFTs shorts during the news period
	% HFT sales that are HFT shorts	% of all sales that are HFT shorts	% HFT sales that are HFT shorts	% of all sales that are HFT shorts	
1	32.82%	5.94%	56.86%	17.11%	-42.28%
2	50.35%	9.38%	62.69%	8.68%	-19.69%
3	79.76%	30.31%	64.50%	23.86%	23.65%
4	71.83%	22.32%	69.01%	19.55%	4.09%
5	48.34%	12.03%	44.80%	6.83%	7.91%
6	66.81%	21.57%	65.64%	19.86%	1.79%
7	80.64%	31.80%	55.90%	24.01%	44.27%
8	41.47%	13.16%	25.71%	7.07%	61.27%
9	33.50%	7.22%	34.39%	6.56%	-2.59%
10	45.71%	17.30%	63.16%	10.81%	-27.62%
11	68.87%	21.01%	40.19%	4.84%	71.38%
12	0.00%	0.00%	0.00%	0.00%	0.00%
13	1.34%	0.35%	1.68%	0.18%	-20.33%
14	0.00%	0.00%	2.56%	0.85%	-100.00%
15	4.58%	2.20%	9.24%	3.08%	-50.41%
16	95.24%	15.27%	63.75%	15.60%	49.39%
17	73.81%	9.87%	53.33%	8.00%	38.39%
18	53.89%	1.90%	40.26%	3.09%	33.85%
19	19.54%	7.39%	11.03%	2.95%	77.13%
20	1.05%	0.88%	50.00%	1.97%	-97.89%
21	36.36%	4.71%	11.86%	2.42%	206.49%

**Table 13: Short-selling activity by HFTs during the news period compared to other sales activity for securities with positive news release, for each sample security (2013)**

Security	News period			Other trading days			% Change in HFT/SME shorts during the news period
	% of HFT sales that are HFT shorts	% of SME/HFT sales that are HFT/SME shorts*	% of all sales that are HFT/SME shorts*	% of HFT sales that are HFT shorts	% of SME/HFT sales that are HFT/SME shorts*	% of all sales that are HFT/SME shorts*	
1	0.00%	23.21%	10.00%	0.00%	21.19%	13.06%	-23.43%
2	0.00%	11.21%	1.81%	0.00%	16.32%	5.11%	-64.69%
3	0.00%	16.27%	7.18%	0.00%	12.71%	8.47%	-15.24%
4	0.00%	14.39%	7.69%	0.00%	12.02%	6.47%	18.81%
5	0.00%	4.07%	1.46%	0.00%	11.81%	4.71%	-69.06%
6	0.00%	0.00%	0.00%	6.96%	10.69%	2.38%	-100.00%
7	0.00%	13.27%	6.58%	0.00%	16.13%	6.49%	1.32%
8	0.00%	14.80%	5.13%	0.00%	11.86%	6.69%	-23.29%
9	0.00%	11.45%	4.45%	0.47%	15.34%	7.06%	-36.96%
10	0.00%	7.82%	1.74%	1.52%	10.49%	2.40%	-27.54%
11	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-
12	0.00%	19.15%	7.92%	6.86%	18.10%	10.60%	-25.23%
13	0.00%	3.30%	1.50%	0.00%	4.71%	1.53%	-2.03%
14	0.00%	17.67%	12.62%	0.00%	16.32%	9.25%	36.39%
15	0.00%	15.28%	5.48%	0.00%	14.54%	6.02%	-8.97%
16	0.00%	17.72%	7.04%	0.51%	15.37%	6.90%	1.89%
17	8.17%	18.06%	10.14%	33.82%	38.80%	21.81%	-53.52%
18	0.30%	7.66%	1.71%	1.48%	7.51%	1.35%	27.01%
19	0.22%	2.73%	0.39%	0.80%	1.02%	0.14%	181.34%
20	28.87%	29.29%	4.21%	5.36%	8.84%	1.83%	130.36%
21	0.00%	0.63%	0.34%	0.00%	4.55%	0.58%	-42.23%
22	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-
23	0.00%	0.00%	0.00%	0.00%	3.47%	0.92%	-100.00%
24	0.00%	8.64%	1.68%	5.84%	12.62%	3.68%	-54.34%
25	0.00%	0.64%	0.30%	0.00%	1.42%	0.23%	29.73%
26	0.00%	1.01%	0.41%	0.00%	9.38%	5.94%	-93.10%

\*As SME do not mark trades short, we assumed that half of all SME trades were from short positions. As SMEs do not trade to take positions, SMEs should be equally likely to be selling from a short position as a long position.

## Appendix D

**Table 14: Average number of 2011 HFT orders entered within 10 seconds of each uptick trade, downtick trade, and flattick trade**

Type of Order	Number of orders after a downtick (% increase from flat)	Number of orders after an uptick (% increase from flat)	Number of orders after a flattick
Sale from short	3.96 (219.3%)	3.24 (161.2%)	1.24
Sale from long	1.06 (341.6%)	0.67 (179.1%)	0.24
Buy	3.50 (163.1%)	4.46 (235.3%)	1.33
<b>Total</b>	<b>8.52</b>	<b>8.37</b>	<b>2.81</b>

**Table 15: Average number of 2013 HFT orders entered within 10 seconds of each uptick trade, downtick trade, and flattick trade**

Type of Order	Number of orders after a downtick (% increase from flat)	Number of orders after an uptick (% increase from flat)	Number of orders after a flattick
Sale from short	1.62 (252.1%)	1.15 (150.0%)	0.46
Sale from long	1.90 (239.2%)	1.25 (123.2%)	0.56
Buy	2.72 (147.2%)	3.49 (217.2%)	1.10
<b>Total</b>	<b>6.24</b>	<b>5.89</b>	<b>2.12</b>

**Table 16: Average number of 2011 non-HFT orders entered within 10 seconds of each uptick trade, downtick trade, and flattick trade**

Type of Order	Number of orders after a downtick (% increase from flat)	Number of orders after an uptick (% increase from flat)	Number of orders after a flattick
Sale from short	1.23 (355.5%)	0.96 (292.5%)	0.27
Sale from long	1.83 (381.5%)	1.18 (210.5%)	0.38
Buy	2.44 (221.0%)	3.19 (319.7%)	0.76
<b>Total</b>	<b>5.50</b>	<b>5.33</b>	<b>1.41</b>

**Table 17: Average number of 2013 non-HFT orders entered within 10 seconds of each uptick trade, downtick trade, and flattick trade**

Type of Order	Number of orders after a downtick(% increase from flat)	Number of orders after an uptick(% increase from flat)	Number of orders after a flattick
Sale from short	0.84 (320.0%)	0.57 (185.0%)	0.20
Sale from long	1.49 (263.4%)	1.00 (143.9%)	0.41
Buy	1.41 (166.0%)	1.93 (264.1%)	0.53
<b>Total</b>	<b>3.74</b>	<b>3.50</b>	<b>1.14</b>

**Table 18: Percentage of 2011 HFT orders entered within 10 seconds of an uptick trade, a downtick trade, a flattick trade, and when there was no trade in the previous 10 seconds**

Type of Order	% of orders after a downtick	% of orders after an uptick	% of orders after a flattick	% of orders with no trade in previous 10 seconds
Sale from short	11.29%	9.22%	36.91%	42.58%
Sale from long	11.53%	7.27%	27.07%	54.14%
Buy	10.50%	13.36%	41.46%	34.67%

**Table 19: Percentage of 2013 HFT orders entered within 10 seconds of an uptick trade, a downtick trade, a flattick trade, and when there was no trade in the previous 10 seconds**

Type of Order	% of orders after a downtick	% of orders after an uptick	% of orders after a flattick	% of orders with no trade in previous 10 seconds
Sale from short	10.93%	8.07%	26.48%	54.51%
Sale from long	10.80%	7.39%	27.18%	54.62%
Buy	12.41%	16.59%	42.62%	28.38%

## Appendix E

### Order activity for securities in 2011

**Table 20: Order activity for Security 7 in 2011**

Type of Order	% of orders entered within 10 seconds after a downtick	% of orders entered within 10 seconds after an uptick	% of orders entered within 10 seconds after a flattick	% of orders with no trade in previous 10 seconds
Sale from short	23.29%	16.18%	55.57%	4.95%
Sale from long	24.10%	14.64%	55.88%	5.38%
Buy	16.69%	21.18%	56.09%	6.03%

**Table 21: Order activity for Security 8 in 2011**

Type of Order	% of orders entered within 10 seconds after a downtick	% of orders entered within 10 seconds after an uptick	% of orders entered within 10 seconds after a flattick	% of orders with no trade in previous 10 seconds
Sale from short	15.65%	9.42%	57.45%	17.48%
Sale from long	18.76%	4.61%	41.81%	34.82%
Buy	7.17%	12.12%	52.17%	28.54%

**Table 22: Order activity for Security 11 in 2011**

Type of Order	% of orders entered within 10 seconds after a downtick	% of orders entered within 10 seconds after an uptick	% of orders entered within 10 seconds after a flattick	% of orders with no trade in previous 10 seconds
Sale from short	15.03%	5.92%	50.11%	28.93%
Sale from long	25.73%	2.34%	28.07%	43.86%
Buy	11.11%	22.54%	34.12%	32.24%

**Table 23: Order activity for Security 16 in 2011**

Type of Order	% of orders entered within 10 seconds after a downtick	% of orders entered within 10 seconds after an uptick	% of orders entered within 10 seconds after a flattick	% of orders with no trade in previous 10 seconds
Sale from short	2.82%	11.27%	22.54%	63.38%
Sale from long	5.56%	0.00%	22.22%	72.22%
Buy	0.00%	0.00%	13.85%	86.15%

**Table 24: Order activity for Security 19 in 2011**

Type of Order	% of orders entered within 10 seconds after a downtick	% of orders entered within 10 seconds after an uptick	% of orders entered within 10 seconds after a flattick	% of orders with no trade in previous 10 seconds
Sale from short	10.95%	20.15%	49.50%	19.40%
Sale from long	10.36%	7.77%	29.77%	52.10%
Buy	13.16%	11.56%	36.12%	39.17%

**Table 25: Order activity for Security 21 in 2011**

Type of Order	% of orders entered within 10 seconds after a downtick	% of orders entered within 10 seconds after an uptick	% of orders entered within 10 seconds after a flattick	% of orders with no trade in previous 10 seconds
Sale from short	27.43%	17.14%	41.14%	14.29%
Sale from long	11.11%	6.35%	36.51%	46.03%
Buy	8.57%	24.76%	36.67%	30.00%

**Table 26: Order activity for all other sample securities in 2011**

Type of Order	% of orders entered within 10 seconds after a downtick	% of orders entered within 10 seconds after an uptick	% of orders entered within 10 seconds after a flattick	% of orders with no trade in previous 10 seconds
Sale from short	8.11%	7.41%	31.50%	52.98%
Sale from long	9.33%	6.23%	22.11%	62.33%
Buy	8.60%	10.75%	36.26%	44.39%

### Order activity for securities in 2013

**Table 27: Order activity for Security 19 in 2013**

Type of Order	% of orders entered within 10 seconds after a downtick	% of orders entered within 10 seconds after an uptick	% of orders entered within 10 seconds after a flattick	% of orders with no trade in previous 10 seconds
Sale from short	16.89%	20.83%	51.06%	11.23%
Sale from long	9.55%	6.62%	22.42%	61.40%
Buy	13.04%	12.01%	35.39%	39.56%

**Table 28: Order activity for Security 20 in 2013**

Type of Order	% of orders entered within 10 seconds after a downtick	% of orders entered within 10 seconds after an uptick	% of orders entered within 10 seconds after a flattick	% of orders with no trade in previous 10 seconds
Sale from short	8.64%	18.52%	27.16%	45.68%
Sale from long	6.40%	2.43%	21.41%	69.76%
Buy	3.36%	7.24%	10.34%	79.07%

**Table 29: Order activity for all other sample securities in 2013**

Type of Order	% of orders entered within 10 seconds after a downtick	% of orders entered within 10 seconds after an uptick	% of orders entered within 10 seconds after a flattick	% of orders with no trade in previous 10 seconds
Sale from short	15.84%	15.57%	38.95%	29.63%
Sale from long	12.78%	9.15%	36.16%	41.90%
Buy	9.97%	11.67%	30.46%	47.91%



**Table 30: Percentage difference in HFT short-selling order activity compared to long selling order activity after an uptick**

Security	Increase
2011 – Security 7	10.53%
2011 – Security 8	104.34%
2011 – Security 11	152.99%
2011 – Security 16	-*
2011 – Security 19	159.33%
2011 – Security 21	169.92%
2011 – Average of all other sample securities	18.94%
2013 – Security 19	214.65%
2013 – Security 20	675.72%
2013 – Average of all other sample securities	70.16%

\* This security had no orders to sell from short positions in the 10-second period following an uptick during the three-day period.

## Appendix F

**Table 31: Correlation matrix of criteria for HFT proxy**

	SME %	Number of trades	Numbers of messages	Messages per trade	Average trade size
% SME		0.168244785	0.23438398	0.140334131	-0.08527062
Number of trades	0.168244785		0.69558230	-0.00056067	-0.05842036
Numbers of messages	0.23438398	0.69558230		0.07130287	-0.03133747
Messages per trade	0.140334131	-0.00056067	0.07130287		-0.02154844
Average trade size	-0.08527062	-0.05842036	-0.03133747	-0.02154844	

The cells marked in green indicate some statistically significant correlation between the two indicators based on a two-tailed test with a level of alpha of 0.05. The cells marked in red indicate no statistically significant correlation. Overall, correlation between criteria is not high.