Trading Cost Decomposition during FOMC Announcement

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Abstract

This study investigates the behavior of bid-ask spread components around the Federal Open Market Committee (FOMC) meetings for Canadian stocks traded in Canada and in the U.S. We find that for the Canadian market, information asymmetry component increases significantly during Fed Funds Rate announcements, indicating an increase in differential interpretations as to how the news would affect firms' performance. The order persistence components, on the other hand, increases significantly in the U.S., indicating a faster consensus among U.S. market participants with regard to the interpretation of news, and trades occurring in the same direction. Overall, our results suggest that the U.S. market has better information processing capacity than its Canadian counterpart, and are consistent with the literature on the informational benefit of stock cross-listing.

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1 Introduction

Trading securities incur transaction costs (Demsetz, 1968; Tinic, 1972; Aitken and Ferris, 1991). These costs arise as compensation for liquidity providers when matching buyers and sellers. To provide immediacy, a liquidity provider posts two different prices; the price at which he wants to buy (bid price), and the price at which he wants to sell (ask price), creating a positive difference between the two prices called the spread. As new information enters the market, the bid and ask prices will be revised, leading to a change in spread.

One important source of information is the prescheduled macroeconomic news announcements, which studies have shown to affect the behavior of the bid-ask spread (see Copeland and Galai, 1983; Balduzzi et al., 2001; Fleming and Remolona, 1999; Frino and Hill, 2001). The general findings seem to be that bid-ask spreads start to widen before announcement and remain wide for some period after announcement. The majority of these studies, however, concentrate on the behavior of the total bid-ask spread rather than its components. As such, existing studies have different interpretations on the widening in spreads with microstructure theories and report mixed results in explaining the behavior of traders in the market.[1]

This study intends to fill that gap in the literature by assessing the various components of bid-ask spread during macroeconomic news announcements. Particularly, we argue that the temporary information advantages that are present in the market can be assessed through the behavior of the components of bid-ask spread. Given that quotes are revised following market activities, the changes in spreads can be seen as the result of trade activities by various market participants, including those with superior information. In this regard, spread decomposition models can be used to explain the behavior of traders in the market. Furthermore, this study extends the literature by assessing the spread components in two different, but fully-synchronised and cointegrated markets.[2] By

[1] For example, Copeland and Galai (1983) and Ho and Stoll (1981) explain that bid-ask spread acts as an "option to trade" offered by market makers to traders. As volatility increases because of the announcement, the value of the option increases, leading to a widening of the spread. Balduzzi et al. (2001) argue that bid-ask spreads widen due to asymmetric information as traders may have differing ability to process information from macroeconomic news. Fleming and Remolona (1999) attribute the widening in spreads to dealers controlling inventory risk at a time of extreme price volatility. Given the "lock-up" conditions imposed by government agencies, asymmetric information is improbable.

[2] Existing studies only assess spread in a single market. For example, Fleming and Remolona (1999) assess the response of US Treasury market total bid-ask spread to macroeconomic news announcement. Balduzzi et. al., (2001)

comparing how the spread components in different markets respond to news arrival, we can assess the information processing capacity of those markets. Such analysis may shed light on why some markets are more informationally efficient than others.

We employ the model of Lin, Sanger and Booth (1995) to decompose spread into three important components to reflect information asymmetry, order persistence, and order processing costs. Our empirical procedure and sample selection distinguish this study from other microstructure studies in several ways. First, the information asymmetry component reflects the portion of spread that is attributed to asymmetric information processed by market participants, while order persistence reflects the portion of spread that is attributed to order flow in the market. If a market is informationally efficient, information asymmetry decreases during news announcements and order persistence increases with the increase in order flow. Therefore, the extent of information asymmetry and order persistence components should capture the information processing capacity of a market. Second, we study bid-ask spread during Fed Funds Rate announcements. These announcements have been shown to convey price-relevant information and their timing is largely predictable. One key feature of these announcements is the "lock-up" conditions imposed by the Federal Reserve Bank which prevents information leakage prior to the scheduled release to ensure that traders do not have unfair advantage. Therefore, it works as a natural filter to classify traders into either liquidity traders or superior information processors (henceforth, superior traders). Hence, we can narrow down our definition of a market with better information processing capacity as the one with more superior traders.

For this study, we use a sample of Canadian stocks which are listed and traded in Canada and in the U.S. from January 2004 to January 2011. Comparing spread components during Fed Funds Rate announcement and during non-announcement periods, we document several interesting findings. First, consistent with the literature, bid-ask spreads in both markets increase significantly during the announcement time. This finding confirms a strong relationship between stock prices and macroeconomic news - businesses are concerned about economic fundamentals conveyed in macroeconomic variables (McQueen and Roley, 1993). Second, we find that information asymme-

investigate the effects of macroeconomic announcements on the spreads of various US government bonds. Frino and Hill (2001) examine intraday futures market behavior such as trading volume and quoted bid-ask spreads around major scheduled macroeconomic announcements on the Sydney Futures Exchange.

try increases more in Canada, suggesting that the Canadian public is divided as to how the news would affect firms' performance Third, we observe that order persistence component increases significantly in the U.S. during announcement times. This suggests that traders in the U.S. seem to be in consensus as to how the news would affect firms' performance, and trade in the same direction. Our findings are consistent with the literature of stock cross-listing. In particular, we find that cross-listing is related to a reduction in information asymmetry and an improvement in a stock's information environment.

Our study has implications for market design and market quality because the extent to which information processing capacity affects the cost of trading that traders incur especially during news announcement. For investors, our findings show that participants in the host market seem to have better understanding of the implication of news. This could be due to stringent disclosure requirement in the host market which leads to equal dissemination of information and reduction in information asymmetry between corporate managers and investors. In this respect, the U.S. market provides such informational benefit for investors. Furthermore, our findings indicate why some markets leads in terms of price discovery. For instance, Frijns et al. (2015) show that a market's contribution to price discovery is not determined by the geographical origin of news, but rather the information processing capacity of a market relative to others. The U.S. market experiences an increase in price discovery relative to the Canadian market during macroeconomic news announcements because it is better at processing of market-wide information than the Canadian market.

The remainder of this paper is structured as follows. Section 2 discusses related literature and the hypotheses we test in this paper. Section 3 explains the methodology. Section 4 describes the data used in this study. Section 5 reports our empirical findings and interpretations. Finally, Section 6 concludes.

2 Literature and Hypotheses

The main objective of this study is to examine the impact of macroeconomic news announcements on the components of the bid-ask spread for cross-listed stocks. As such, we start this section with a discussion on the various components of spread. We then explain how these components may change during news announcement times. Furthermore, we discuss the literature on informational advantage of stock cross-listing. These discussions form the bases for the hypotheses tested in our study.

There is an extensive literature on the components of bid-ask spread. Generally, spread can be decomposed into three components: order processing (Benston and Hagerman, 1974; Stoll, 1978), information asymmetry (Copeland and Galai, 1983; Glosten and Milgrom, 1985), and inventory holding costs (Amihud and Mendelson, 1980). The order processing cost component represents the fixed expense in trading (such as labour, communication, clearing and record keeping). The asymmetric information cost component represents a reward to market makers for taking on the risk of dealing with traders who may possess superior information. As such, this component reflects the differential information possessed by market participants. The inventory holding cost component compensates market makers for maintaining an orderly market by holding inventory that may deviate from the desired level. Among these three components, there is a lack of evidence of inventory effects, especially in the short-run (Hasbrouck, 1988; Madhavan and Smidt, 1991; and Hasbrouck and Sofianos, 1993). Given that most trade data display a high probability of order persistence (buys followed by buys or sells followed by sells), Barclay and Hendershott (2004) explain that it is more sensible to estimate the portion of spread which reflects order flow persistence rather than inventory holding costs.

Several empirical studies have investigated the components of spread during the release of public information. For example, Krinsky and Lee (1996) investigate the behavior of bid-ask spread components around earnings announcements. They find that information asymmetry cost component significantly increases surrounding the announcements, while the inventory holding and order processing components significantly decline during the same periods. They conclude that earnings announcements may have insignificant impact on the total bid-ask spread, even when they result in increased information asymmetry. Ascioglu, McInish and Wood (2002) assess the impact of merger announcements on the components of the bid-ask spread for stocks of firms traded in the U.S. They do not observe any widening of bid-ask spread before the announcement day. However, they find evidence of a significantly narrowing spread and a significantly lower information asymmetry component of the bid-ask spread that persists after the announcement. They conclude that trading after the merger announcement is liquidity motivated.

Contrary to firm-specific announcements, macroeconomic news announcements may have different impacts on the components of spreads for several reasons. First, the timing for macroeconomic news announcements is largely predictable. Therefore, traders can set up a position prior to the news release. In such a case, bid-ask spreads can widen around announcements because the spreads act as an "option to trade" offered by the market maker to traders (see, for example, Copeland and Galai, 1983 and Ho and Stoll, 1981). As volatility increases because of the announcement, the value of the option (the bid-ask spread) increases, leading to a widening of the spread. Second, vital macroeconomic information is not disclosed until the scheduled release time. In the case of the Federal Funds Rate announcements, the Federal Reserve Bank provides accredited news outlets with pre-release access to the information under embargo agreements. The accredited journalists receive the data prior to the public release (typically in press lockup facilities) to allow time for clarifying questions and preparing reports, but unable to relay the information to the public until the official release time. This lockup practices prevent information leakage that would give some traders an unfair advantage. As a consequence, there are typically two types of traders during Fed Funds Rate announcement period: liquidity traders and superior information processors. The former trade for liquidity reasons while the latter trade because they have gathered and interpreted information which they believe is not currently reflected in prices.

Given the presence of the above traders, we conjecture that the proportion of bid-ask spread components may change during prescheduled announcement times for the following reasons. First, there is the asymmetric information argument which predicts a widening of the spread because of the fear on the part of market makers that traders may be better informed (Glosten and Milgrom, 1985 and Glosten, 1987). Since there should be no leakage of information before announcements are made, and since information relevant to the stock market is quickly disseminated in a widespread manner, asymmetry arises not because different information is received by traders, but because traders may have differing ability to process information. Therefore, if the public is divided as to how the news would affect firms' performance, the typical information asymmetry model (e.g., Copeland and Galai, 1983 and Glosten and Milgrom, 1985) predicts that the spread, and in particular the information asymmetry component of the spread, should widen. Since the period during Fed Funds Rate announcements is typically represented with unusually high number of trades, and given the differential information processing capacity among market participants, the asymmetric information component of spread will increase during announcement times. This leads to our first hypothesis.

Hypothesis 1: Information asymmetry cost component increases during Fed Funds Rate announcements due to different public interpretations on the impact of news on firms' performance.

Second, the widening of spread during announcement times can be attributed to an increase in order flow (a buy order following a buy order, or a sell order following a sell order). Kyle (1985) explains that because liquidity providers cannot distinguish the individual quantities traded by the liquidity traders nor by those with superior information, they set prices based on the observations of the current and past aggregate quantities traded by both traders combined. The extent of order persistence component affecting spread is dependent on which side of the market has traders been trading on. High order persistence could be caused by several factors including traders splitting large orders into smaller orders, or by more traders interpret news the same way and share the view that the stock will continue to move further in one direction. Hence, we may observe that the order persistence component increases during Fed Funds Rate announcements. Thus, our second hypothesis.

Hypothesis 2: Order persistence cost component increases during Fed Funds Rate announcements due to more trades occurring on one side of the market.

Third, the order processing cost component also influences the impact of Fed Funds Rate announcements on the bid-ask spread. Copeland and Stoll (1990) argue that the average order processing cost per share should decrease as trading volume increases because the order costs represent the clerical fixed costs of carrying out a transaction. An increase in trading volume will create economies of scale where the fixed costs incurred by the market makers are spread over more shares. Therefore, order processing cost will decrease during announcement times. This issue will be empirically addressed in this paper.

Since our study focuses on cross-listed stocks, we decompose spreads in two markets separately. This partitioning allows us to explore the possibility of any systematic variations in spread components of stocks traded in those markets. In this regard, we recognize that the extent information asymmetry cost components respond to news announcements may differ between markets. The stock cross-listing literature suggests that cross-listing is associated with additional mandatory disclosure requirements of the foreign market and an increase in investor recognition. First, the information disclosure theory suggests that cross-listing is generally associated with meeting mandatory disclosure requirements of the foreign host exchange, in addition to the existing disclosure at the home market. This, in turn, disseminates more information and reduces information asymmetry between corporate managers and investors and also among different groups of investors (Huddart et al., 1999, and Chemmanur and Fulghieri, 2006). Consequently, there will be a reduction in divergence of public interpretation on how news would affect firms' performance. Second, the investor recognition theory developed by Merton (1987) suggests that cross-listing makes a stock more appealing to investors in the foreign market and facilitates widening of the investor base of the cross-listed firm. Such exposure will lead to a higher recognition, especially for firms which are less known by investors.[3] These evidence indicate that cross-listing may be associated with a decrease in information asymmetry. We relate our findings in this paper with the above theories in order to shed light on the characteristic differences between markets.

3 Methodology

We decompose trading costs into asymmetric information, order processing, and order persistence components using the effective spread decomposition model of Lin et al. (1995) for several reasons. First, spread decomposition models typically assume that there is zero or negative serial correlation in trades.[4] In contrast to those models, Lin et al. (1995) model does not require high probability of order reversal to provide sensible estimates of the spread components. Thus, this model can

[3] Empirical evidence has shown that investors tend to invest in foreign stocks that cross-list in the investors' home market over the foreign stocks that do not (Aggarwal et al., 2005; Ferreira and Matos, 2008; Ammer et al., 2012).

[4] Existing inventory models (Amihud and Mendelson, 1980; Huang and Stoll, 1997) assume that trade data exhibit strong order reversal (probability of a trade reversal is greater than 0.5) to separate the inventory component from the information asymmetry component of the spread. Since trade data display a high probability of order persistence rather than order reversals, estimating inventory and asymmetric information components of the spread becomes problematic and results in negative information asymmetry estimates.

be estimated trade by trade while accounting for positive order persistence. Second, this model does not require a constant effective spread, and therefore is more versatile when studying bid-ask spread surrounding public news announcement periods.

Madhavan et al. (1997) provide an alternate approach to decomposing the spread when orders are persistent. Their model provides similar estimate of the information asymmetry component of the spread of Lin et al. (1995). The difference between the two models arises in the fixed component of the spread. The model of Madhavan et al. (1997) attributes the non-information asymmetry component of the spread to market makers' cost per share of providing liquidity, fixed, inventory, and risk bearing costs, along with dealers' profits. By comparison, Lin et al. (1995) three-way decomposition allows the fixed and dealer profit component to be estimated separately.[5]

Before estimating the spread decomposition, we briefly explain the underlying model. Let A_t and B_t be the bid and ask quotes at time t, and let ρ be the probability of of order persistence (a sell order followed by another sell order, vice versa). The expected future market price conditioned on the trade at time $t+1$ can be written as:

$$E_t(P_{t+1}) = \rho B_{t+1} + (1-\rho)A_{t+1}, \tag{1}$$

where P_t is the transaction price at time t, and $(1-\rho)$ is the probability of order reversal. Given this definition, and conditional on a sell order at time t such that $P_t = B_t$, a market maker's expected gross profit at $t+1$ is:

$$E_t(P_{t+1}) - P_t = \rho(B_{t+1}) + (1-\rho)(A_{t+1}) - B_t. \tag{2}$$

Let $Q_t = (A_t + B_t)/2$ be the quote midpoint at time t and let $z_t = P_t - Q_t$ be the effective half-spread. To reflect possible asymmetric information revealed by a trade at time t, quote revisions are assumed to be $B_{t+1} = B_t + \lambda z_t$ and $A_{t+1} = A_t + \lambda z_t$, where $0 < \lambda < 1$ reflects the quote revision in response to a trade as a fraction of the effective spread. A market maker's gross profit for a sell order at time t is then related to the effective spread by the following relation:

[5] See also Barclay and Hendershott (2004) for a discussion of Lin et al. (1995) versus Madhavan et al. (1997) and other spread decomposition models.

$$\begin{aligned} E_t(P_{t+1}) - P_t &= \rho(B_{t+1}) + (1-\rho)(A_{t+1}) - P_t \\ &= \lambda z_t + (1-2\rho)(Q_t - B_t) + Q_t - P_t \\ &= -(1-\lambda-\theta)z_t, \end{aligned} \tag{3}$$

where $\theta = 2\rho - 1$, and $(1-\lambda-\theta)z_t$ is the liquidity supplier's expected profit. A liquidity supplier's gross profit for a buy order at time t can be obtained in similar fashion. The λ in Equation (3) is the proportion of spread due to asymmetric information, and θ is the proportion of spread due to order persistence. These parameters can be estimated using the following regressions:

$$\Delta Q_{t+1} = \lambda z_t + e_{t+1}, \tag{4}$$

$$z_{t+1} = \theta z_t + \eta_{t+1}. \tag{5}$$

where e_{t+1} and η_{t+1} are the disturbance terms, assumed to be uncorrelated. Given that $z_{t+1} = P_{t+1} - Q_{t+1}$, the order processing costs for the trade at time t is related to the effective spread, z_t by the following equation:

$$\begin{aligned} P_{t+1} - P_t &= (Q_{t+1} - Q_t) + z_{t+1} - z_t \\ \Delta P_{t+1} &= -\gamma z_t + u_{t+1}, \end{aligned} \tag{6}$$

where $u_{t+1} = e_{t+1} + \eta_{t+1}$ and the estimate γ is the order processing cost component of the spread.

4 Data and Sample Description

Our sample consists of Canadian stocks which are listed on the TSX and on the NYSE for the period January 1, 2004 to January 31, 2011.[6] The end of the sample is chosen to avoid confounding

[6] We choose to study Canadian stocks listed in the U.S. for several reasons. First, Canada and the U.S. are highly integrated markets. This enables easy access for firms to list and also for investors to trade actively in both markets.

effects from the new Order Protection Rule in Canada which became effective on February 1, 2011 (see Clark, 2011). We obtain tick data (to the nearest millisecond) for prices, quotes and trading volume from Thomson Reuters Tick History (TRTH). For the U.S. market, we use the national best bid and ask quotes for stocks with the NYSE as primary listings and for the Canadian market, we use quotes posted at the TSX. We select stocks which are traded in both markets throughout the sample period, had no stock splits, and of which data is available from TRTH. Furthermore, we exclude thinly traded stocks (i.e. stocks with fewer than 100 daily trades on average). Our final sample consists of 36 cross-listed stock pairs.[7]

We sometimes observe trades executed at different prices but at the same time stamp. In such cases, we treat them as one trade. We assign the appropriate price of the trade using value-weighted average and as for the volume, we aggregate the volume from multiple trades, attribute it to the first trade, and then remove the other trades from the sample. We omit the first and the last 5 min of the trading day. To ensure the comparability of prices between the two markets, we obtain intraday Canadian–U.S. Dollar exchange rate quotes from TRTH and use the midpoint to convert the Canadian prices into the U.S. dollar.[8]

Our sample period covers days with U.S. Fed Funds Rate announcements and days with no prescheduled macroeconomic news announcements.[9] Federal Funds Rates are announced every 6-week at 2:15PM (EST) of which the date and time of announcements are obtained from the Federal Reserve Bank website. There are 57 days with Fed Funds Rate announcements and 430 days with no announcements, leading to a total of 487 trading days considered during January 2004 to January 2011 period.

Table 1 contains summary statistics for the stocks in our sample. It reports the name of the company, the identification symbol (RIC), Market Capitalization (in $million, as of 31 January

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Second, their trading hours are synchronised and overlap completely. Regular trading hours for both markets are from 9:30 AM to 4:00 PM (EST). This is important for conducting intraday analysis since we need prices observed at the same time in the two markets. Third, Canadian securities are listed in the U.S. as ordinary shares, unlike securities from other countries which are usually listed as American Depositary Receipts (ADRs). Canadian stocks trading in the U.S. and Canada are therefore fully fungible, and are likely to move more closely to each other than the prices of ADRs from other countries and their home-market securities.

[7] In comparison, Eun and Sabherwal (2003) and Frijns et al. (2015) analyze 38 TSX–NYSE pairs from 2 February to 31 July 1998 and 1 January 2004 to 31 January 2011, respectively.

[8] We also conducted analyses in Canadian dollars and found no significant difference in results.

[9] Prescheduled macroeconomic news announcements include 10 Canadian news releases and 22 U.S. news releases. Refer to Frijns et al. (2015) for a full list of Canadian and U.S. announcements.

2011), the average daily price, the average daily trading volume, average daily trade, and the average daily percentage effective spread for each stock in both the U.S. and Canada. Our sample covers a broad set of firms with market capitalization ranging from a minimum of $889 million to a maximum of $66 billion. Average daily prices are comparable in the U.S. and Canada with $37.35 and $37.12, respectively. The average trading volume in both markets are also comparable, with 1,354,000 stocks and 1,357,000 stocks traded daily in the U.S. and Canada, respectively. The average daily trade, on the other hand, is higher in the U.S. with 6,887 trades as compared to 4,221 trades in Canada, which suggest that average trade size in the U.S. is smaller than average trade size in Canada. The average daily effective spread in the U.S. and Canada is 7.30 bps and 8.79 bps, respectively, suggesting that cost of trading, on average, is higher in Canada than in the U.S.

INSERT TABLE 1 HERE

Figure 1 illustrates the intraday effective bid-ask spreads from 9:35am to 3:55pm for the U.S. and Canadian markets. We plot the abnormal spread, which is the difference between spread during Fed Funds Rate announcement and during non-announcement days. The differences in spreads are then averaged across firms. The figure shows that abnormal spreads are comparable in both markets. We observe that abnormal spreads are relatively constant throughout the trading day except during the period surrounding Fed Funds Rate announcement. Specifically, spreads start to widen prior to the news release and peaks at precisely 2:15pm when the announcement is made. Following the announcement, spreads decline gradually until trading closes for the day.

INSERT FIGURE 1 HERE.

In Table 2, we report the summary statistics for several microstructure variables during the 150 minute trading period surrounding Fed Funds Rate announcement days (60 minute prior and 90 minute after) and of the same period during non-announcement days. The reported values are computed by averaging over the sample period across firms.

INSERT TABLE 2 HERE.

Consistent with previous studies (e.g. McInish and Wood, 1992; Fleming and Remolona, 1999; Frino and Hill, 2001; Flemming and Piazzesi, 2005), we find that effective spreads (both in level and in percentage) increase significantly during Fed Funds Rate announcements. For the U.S. market, the average effective spread during non-announcement days is 6.74 bps and 7.23 bps during announcement times. For the Canadian market, average spread increases from 8.20 bps to 8.63 bps. Both daily trading volume and number of trades increase significantly in either markets during the same period. While trading volume are comparable in size in both markets, the daily number of trades are noticeably smaller in Canada than in the U.S., suggesting that trade size in the U.S. tends to be smaller than in Canada. To assess whether traders "slice and dice" large orders into smaller pieces during announcement periods, we calculate the volume per trade. However, we do not observe a significant change in the figure. Finally, we assess the autocorrelation of order flow (the probability of buy orders followed buy orders, and vice versa). While our data indicates higher positive serial correlation in the direction of trades for the Canadian than the U.S. market (0.547 as opposed to 0.398), we only observe a significant increase in autocorrelation in the U.S. This observation indicates presence of increased order persistence in the U.S. market during announcement times. Overall, Table 2 suggests that there are significant revision in various market variables as Fed Funds Rate news is released. To assess asymmetry between markets, we examine the responses of various spread components to news announcements. This will be discussed in the next section.

5 Empirical Findings

5.1 Spread Components during Fed Funds Rate Announcements

To test the hypotheses in Section 2, we estimate Equation (4), (5), and (6) for each of the 36 stocks in both markets. As previously explained, the extent of information asymmetry and order persistence components should capture the information processing capacity of a market. The market with superior information processing capacity should exhibit lower information asymmetry and higher order persistence.

Table 3 reports the difference in the various components of spreads during Fed Funds Rate announcement and non-announcement days. We report decomposition in both markets separately. The figures presented are the relative proportion of the various components of spread, as well as the difference in means and the related t-statistics. A quick glimpse of the table shows that the U.S. and Canadian markets have different characteristics. Specifically, information asymmetry accounts for about 17% of total spread in the U.S., but about 22% in Canada. These figures suggest that on average, there is less information asymmetry among traders in the U.S. compared to Canada. Order persistence accounts for 41% of the total spread in the U.S. and 55% in Canada. This is due to the fact that autocorrelation of order flow is higher in Canada than in the U.S. (see Table 2), which leads to higher proportion of spread attributed to order persistence. Order processing component is almost double in the U.S. than in Canada. This indicates that trading in the U.S. involves a higher fixed cost and a positive premium relative to trading in Canada, which is consistent with Chen and Choi (2012).

INSERT TABLE 3 HERE.

Panel A reports our results for the 150 minutes period surrounding the announcements. The first row of the panel shows that during announcement times, information asymmetry stays unchanged in the U.S., but increases significantly by 0.70% in Canada. This finding is consistent with our Hypothesis 1. In particular, information asymmetry cost component increases during Fed Funds Rate announcements due to different public interpretations on the impact of news on firms' performance. This finding is also in line with the cross-listing literature. In particular, cross-listing reduces information asymmetry and improves a stock's information environment.[10] The second row of panel A shows that during the period surrounding news release, order persistence component increases significantly in the U.S. by 0.80%, but is unchanged in Canada. This is consistent with Hypothesis 2 that order persistence cost component increases during Fed Funds Rate announcements due to trades occurring on one side of the market. In addition, both markets experience a decrease in

[10] Several studies provide empirical evidence on the issue. For example, Khanna et al. (2004) report that firms cross-listed in the USA have significantly higher levels of disclosure (measured by the S&P's Transparency and Disclosure scores) relative to firms that do not cross-list. Eaton et al. (2007) distinguish between three types of information disclosure around cross-listing: exchange disclosure requirements, improvement in accounting standards and increase in financial analysts' coverage, and show that all three types of disclosure have significant implications for firms cross-listing in the USA.

the order processing component, which are in line with the literature that suggests processing fees decrease following an increase in trading activity (Copeland and Stoll, 1990). With higher volume, market makers have economies of scale such that the bid-ask spread can be tighter in percentage terms.

Panel B reports the results for the 60 minutes period prior to the announcements. The panel shows that in the U.S., information asymmetry decreases significantly by 0.39% while order persistence increases significantly by 0.82% prior to the Fed Funds Rate announcements. These figures indicate that there is a decline in differential public interpretation of the upcoming news, and an increase of trades occurring on one side of the market. We interpret these findings as U.S. investors having more consensus on what the impact of the Fed Funds Rate announcements would be for the stocks and react to that information. In Canada, on the other hand, the various spread components do not change prior to the announcement time, suggesting that there is no specific change in trading behavior by market participants.

Panel C reports our results for the 90 minutes period following the announcements. For the U.S. market, the increase in order persistence component is more pronounced at 1.02%. At the same time, we also observe an increase in information asymmetry component by 0.86%. We attribute this finding to the increase in information-driven trades after the announcement is made.[11] For the Canadian market, we observe that the information asymmetry component increases significantly by 1.59%, but the order persistence component does not. These findings again indicate that there is an increase in differential public interpretation following the announcement as Canadian investors seem to be divided as to how the news would affect the stocks. Furthermore, we observe that order processing component decreases significantly by 1.91% and 1.81% in the U.S. and Canada, respectively.

Overall, the findings in Table 3 suggest that the U.S. market has a higher information processing capacity than the Canadian market. These results are also in line with Frijns et al. (2015) who show that the U.S. market price discovery increases relative to Canada during macroeconomic news

[11] Kim and Verrechia (1994) explain that some market participants are inherently more informed (e.g. large shareholders, financial analysts, etc.) than others. Information asymmetry may arise following FOMC announcements because those informed market participants are now able to produce better assessments on a firm's performance on the basis of the newly-released Fed Funds Rate relative to other traders in the market.

announcements, which can be attributed to the superior information-processing capacity of the U.S. relative to the Canadian market.

In addition to providing estimates of the proportional components of the spread, we also calculate the dollar value of each component of the spread. Given that estimates of the costs show exactly how much each spread component contribute to trading costs, these estimates can be more intuitive for investors. Table 4 presents the difference in value measured in cents, of the three components of the spread. These values are computed for each stock by multiplying each of the proportional components with the effective spread. We then compute the average of these values across firms.

INSERT TABLE 4 HERE.

Panel A of Table 4 reports the spread components during the 150 minutes period surrounding the announcements. As expected, effective spreads increase significantly in both markets. However, the increase is higher in the U.S. (0.176 cents) than in Canada (0.128 cents). With regard to the economic magnitude of our results, information asymmetry cost for an average stock in the U.S. with the price of $37.35 during non-announcement days (see Table 1) increases by 0.034 cents, while order persistence and order processing accounts increase by 0.091 and 0.051 cents, respectively. These findings suggest that a big part of spread increase in the U.S. is contributed by the noninformation-asymmetry component of the spread which accounts for market makers' cost per share of providing liquidity, fixed, inventory, and risk bearing costs, along with dealers' profits. In Canada, information asymmetry components accounts for 0.046 cents of the spread increase, while the remaining 0.082 cents are contributed by the increase in order persistence and order processing component, respectively. From an investor's perspective, these figures are economically important because they indicate an increase in spread is mainly caused by the transitory component of spread, rather than by the asymmetry that announcements cause to the market, especially in the U.S. market.

Panel B reports the spread components in the 60 minutes period prior to the announcements. During this time, the increase is spread in the U.S. is double of the increase in Canada (0.144 against 0.071 cents). A majority of that increase is caused by the order persistence component

(0.079 cents) which accounts for 55% of the overall increase in spread. These findings suggest that spread revisions occur predominantly in the U.S. than in Canada prior to news announcement times. Panel C shows the increase in trading costs in the 90 minutes period following the announcements. During this period, effective spreads increase the highest. Of the 0.340 cents increase in the U.S., 0.077 cents is caused by information asymmetry, which accounts for 23% of the increase while the remaining can be attributed to order persistence and order processing. In Canada, however, 0.110 of the 0.304 cents increase in spread is caused by information asymmetry, thus accounting for 36% of the overall increase.

Overall, Table 4 shows that information asymmetry component increases more in Canada than in the U.S. while order persistence component increases more in the U.S. than in Canada. As a robustness test, we estimate the spread components using the methodology of Madhavan et al. (1997). We obtain similar findings, which we report in Appendix 1.

5.2 Intraday Variations of Spread Components

We also assess the intraday variations of the various cost components using a rolling-sample analysis. Specifically, we estimate Equation (4), (5), and (6) using a 30-minute sample. We roll the estimation forward one observation at a time and obtain a series of coefficients which are then averaged to the nearest minute. We then compute the abnormal information asymmetry, the order persistence and the order processing cost components of the effective bid-ask spread. Each abnormal components are obtained by subtracting the component during non-announcement from the announcement days.

We first evaluate the breakpoint when the abnormal spread components depart from the stable state. We detect this timing of departure in order to examine the time when market participants start to react to news announcement. We utilize the structural breakpoint identification framework suggested in Bai (1997) and Bai and Perron (1998, 2003).[12] The employed method enables us to estimate the unknown breakpoint and to provide associated confidence interval. The procedure is accompanied by F statistic tests. The estimation results are reported in Table 5.

[12] For the detailed description of the method, please refer to Appendix 2.

INSERT TABLE 5 HERE.

Table 5 reports the break points for each of the spread components. The F statistics indicate the strong statistical significance of the existence of the structural break for all the abnormal spread components series. In Panel A, we observe that information asymmetry starts to deviate from stable state at around the same time in the U.S. and Canada (13:56 and 14:00). In Panel B, we observe that the order persistence component starts to depart from the stable state earlier than in Canada (13:50 against 14:02), suggesting that trade order flow has started to increase in the U.S. earlier than in Canada. Finally, Panel C suggests that the order processing components also changed prior to news announcements.

Overall, Table 5 shows that the spread components depart from the stable state in the vicinity of the announcement. The table further reports the direction of the change. The sixth and seventh columns respectively reports the trend coefficient before and after the detected break point.[13] We observe a significant increasing trend in abnormal spread components in case for information asymmetry and order persistence after the break, indicated by the siginificant positive trend coefficients for both U.S. and Canada. In contrast for the order processing component, a decreasing trend is observed after the break.

In order to provide a visual confirmation of the tests, Figures 2-4, respectively, plot the abnormal information asymmetry, the order persistence and the order processing cost components of the effective bid-ask spread throughout the day. In general, besides the hours around the announcement timing, the components are relatively stable and mean reverting.

INSERT FIGURE 2 HERE.

Figure 2 shows that abnormal information asymmetry component is relatively constant during the day, except during the period surrounding Fed Funds Rate announcements. For the U.S. market, abnormal information asymmetry component decreases prior to the announcement time.

[13] We run linear regression involving linear trend term before and after the detected break point. The estimated linear model is specified in Appendix 2.

We attribute this finding to traders setting up position in one side of the market, leading to a decrease in information asymmetry. The break test result reported in Table 5 shows that from 1:56pm information asymmetry increases, presumably due the increase in information-driven trades, especially by those who are better informed. For the Canadian market, we observe the surge in abnormal information asymmetry starting from 2:00pm. It continues to increase following the announcement and peaks at 2:32pm, which is 17 minutes after the announcement is made, before it declines afterward. The 95% confidence intervals implies that the starting point of the increase of the abnormal information asymmetry is significantly earlier in U.S. than in Canada. Both abnormal components remain high until trading closes for the day. We interpret these findings as Fed Funds Rate announcements induce differential public interpretation among market participants regarding the effect of the news, especially in Canada. Therefore, we observe an increase in information asymmetry component, which is consistent with Hypothesis 1 in Section 2.

INSERT FIGURE 3 HERE.

Figure 3 plots the intraday variation in the abnormal order persistence components. The figure shows that abnormal order persistence is more volatile throughout the trading day in either market, indicating trade clustering at different periods of the day. Table 5 shows that for the U.S. market, abnormal order persistence component starts increasing significantly at 1:50pm, 25 minutes prior to the announcement. It stays high for another 30 minutes before it gradually declines. This plot illustrates an increase in trading activity on one side of the market prior to the news release, consistent with Hypothesis 2. For the Canadian market, we observe a drop in abnormal order persistence prior to the announcement, and starts increasing from 2:02pm. While it took around 30 minutes to reach the positive territory. These observations suggest that Canadian market participants only reach a consensus and trade in the same direction 30 minutes after the news is released, implying that convergence in news interpretation comes at a delay. The 95% confidence interval confirms that the timing is statistically significant. Unlike the information asymmetry, the abnormal order persistence component reverts to the pre-break point level.

INSERT FIGURE 4 HERE.

Figure 4 plots the intraday variation in the abnormal order processing components. Table 5 reports that for the U.S. market abnormal component starts decline significantly 14 minutes prior to the announcement, at 2:01pm while for the Canadian market it is 41 minutes prior at 1:34pm. The difference of the timing is statistically significant. Order processing costs decrease further following the announcement before it gradually returns to the normal level. These findings further confirm that order processing costs decrease following an increase in trading activity especially during Fed Funds Rate news announcements.

5.3 Spread Components Pre- and Post-Regulation NMS

As a further test, we assess the impact of regulatory changes in the U.S. market. Reg NMS was prompted by the Securities and Exchange Commission's concern that the increased fragmentations of trading and quoting across venues may reduce liquidity.[14] The order protection rule (OPR), in particular, is designed to prevent the execution of trades at prices inferior to protected quotations displayed by other trading centers. The SEC believes that the protection of public limit orders provided by OPR would help reward liquidity suppliers and encourage competition among traders, thus increasing market liquidity and reducing trading costs. There are, however, some concerns about these new rules. Hendelman and Rowley (2010) and Mehta (2010) argue that OPR will reduce market liquidity because it reduces the role of NYSE specialists and floor brokers as liquidity providers and information intermediaries. Furthermore, Chung and Chuwonganant (2012) examine the liquidity of the U.S. stock markets one month before and after the adoption of Reg NMS and find that liquidity was reduced in the form of increased quoted and effective spreads, as well as decreased quoted dollar depth. These evidence suggest that there may be an impact of Reg NMS on the bid-ask spreads.

In this section, we examine the impact of the Regulation NMS on the various components of spreads. Specifically, we test whether these components are affected by news announcements. Such a test provides further robustness to our findings in the previous section. Empirically, we split our data into two sub-periods based on the completion date of the Reg NMS on 8 October 2007. The

[14]Today, US equity trading venues includes primary and regional exchanges, crossing networks, Electronic Communication Networks (ECNs), and dark pools.

first sub-period is from 2 January 2004 to 5 October 2007 as the pre-NMS period. The second sub-period is from 8 October 2007 to 31 January 2011 as the post-NMS period. We report our results in Table 6.

INSERT TABLE 6 HERE.

Panel A of Table 6 reports the spread components prior to the adoption of the Reg NMS. During this period, information asymmetry accounts for 21% (21%) of the spread in the U.S. (Canada), while order persistence and order processing account for 32% (50%) and 48% (29%), respectively. During announcement time, order persistence increases by 0.74% in the U.S., while information asymmetry increases by 0.58% in Canada. During the same period, order processing component decreases in both markets. All figures are statistically significant at 1% level.

Panel B reports the spread components after the adoption of the Reg NMS. During this sub-period, information asymmetry component decreases in the U.S., but not in Canada. Information asymmetry in the U.S. now accounts for 15% of total spread as compared to 21% prior to the adoption of Reg NMS. Order persistence components increase in both markets, presumably due to the automation of trading, and due to traders slicing large orders into multiple smaller orders. Order processing components also decrease with the increase in trading activity. In terms of the changes, information asymmetry increases during announcement times in both markets. However, the increase is greater in Canada than in the U.S. (0.90% compared to 0.47%). Order persistence in the U.S. increases significantly during news release, but no significant change is observed in Canada. As expected, order processing components decrease with the news release, which is consistent with our findings thus far.

Panel C reports the change in the various spread components before and after the Reg NMS. First, we observe significant decrease in information asymmetry component of spread in the U.S., indicating a reduction in differential interpretation of news. This could be attributed to the access rule (AR) which complements OPR as it helps protect the best displayed quotes against trade-through by allowing broker-dealers and trading centers to access those quotes easily and cheaply. In Canada, however, information asymmetry increases post Reg NMS. This is because there is no imposing rule which ensures that all Canadian market participants have fair access to best displayed quotes, similar to the AR in the U.S. Given the unprecedented increase in automated trading systems, lack of access to best quotes may lead to increased information asymmetry. Second, We observe a significant increase in order persistence in both markets which implies that Reg NMS leads to an increase in trading on one side of the market, presumably due to softwares that automates the process of executing trades against multiple market participants simultaneously or in rapid succession. Third, we find that order processing component decreases in either market, which can be attributed to the increased trading activity in the second sub-period.

Overall, Table 6 emphasizes the importance of regulatory structures to ensure the efficiency of tradings in the market. Despite these changes, we still observe that order persistence is more dominant in the U.S., while information asymmetry is more dominant in Canada during news announcements. These findings further confirm that the U.S. has better information processing capacity than Canada.

6 Conclusion

In this paper, we study the components of bid-ask spread for a sample of Canadian cross-listed stocks in the U.S. from January 2004 to January 2011. We decompose effective bid-ask spread into information asymmetry, order persistence, and order processing components using the methodology of Lin et al. (1995). How these components change during public news announcements reflect changes in trading behavior among market participants.

Our analyses lead to several interesting findings. First, we show that information asymmetry component increases significantly in Canada during Fed Funds Rate announcements, indicating an increase in differential interpretations as to how the news would affect firms' performance. Second, we find that order persistence component increases significantly in the U.S., indicating a consensus among U.S. market participants with regard to the interpretation of news, leading to trades occurring in the same direction. Overall, our findings are consistent with the literature of stock cross-listing which documents that cross-listing reduces information asymmetry and improves a stock's information environment.

Appendix 1: Decomposition Results Using Madhavan et al. (1997) Methodology

Appendix 1. Spread components (in US cents)

This table reports the spread components (in US cents) computed using the methodology of Madhavan et al. (1997). The model decomposes bid-ask spread into information asymmetry and non-information asymmetry components. Panel A reports the estimates for the full 150-minute period surrounding the announcement time (1:15pm to 3:45pm). Panel B reports the estimates for the 60-minute period prior to the announcement time (1.15pm to 2.15pm). Panel C reports the estimates for the 90-minute period following the announcement time (2.15pm to 3.45pm). Figures in parantheses are the t-statistics. ***, and ** denote statistical significance at 1% and 5% levels, respectively.

	US				CAN			
	NA	A	Diff	(t-stat)	NA	A	Diff	(t-stat)
Panel A: Full 150min period								
Effective Spread	1.31	1.53	0.218***	(6.28)	1.50	1.66	0.167***	(5.06)
Information Asymmetry Component	0.15	0.21	0.059***	(6.16)	0.92	1.11	0.185***	(7.50)
Non-Information Asymmetry Component	1.16	1.32	0.158***	(4.76)	0.58	0.56	-0.018	(-0.79)
Panel B: 60min pre-announcement								
Effective Spread	1.33	1.57	0.240***	(8.15)	1.44	1.62	0.176***	(5.04)
Information Asymmetry Component	0.16	0.19	0.031***	(4.86)	0.89	0.94	0.049**	(2.23)
Non-Information Asymmetry Component	1.17	1.37	0.208***	(7.52)	0.55	0.68	0.128***	(3.97)
Panel C: 90min post-announcement								
Effective Spread	1.30	1.57	0.270***	(6.30)	1.42	1.63	0.206***	(5.30)
Information Asymmetry Component	0.15	0.23	0.083***	(5.88)	0.88	1.12	0.247***	(9.87)
Non-Information Asymmetry Component	1.15	1.34	0.187***	(4.57)	0.54	0.50	-0.041	(-1.62)

Appendix 2: Break Point Estimation and Testing Procedure

First we set a sample period to be used for the breakpoint test. The peak (trough) of abnormal information asymmetry and order persistence components (order processing component) is identified by detecting the maximum (minimum) during the whole trading hours. The end of the sample period is then set to the timing when the peak (trough) is identified in the previous step. Then the point which is two hours before the peak (trough) is defined as the starting point of the sample period. Finally we apply the breakpoint test to the defined sample period following the procedure suggested by Bai (1997) and Bai and Perron (1998, 2003).

In the test, a standard linear regression model

$$comp_t = \beta_0 + \beta_1 trend + \beta_2 comp_{t-1} + u_t \qquad (t = 1, ..., T)\,, \tag{A.1}$$

is considered, where at time t, $comp_t$ is the abnormal component, *trend* is the linear trend, and β are the regression coefficients, which may vary over time. As indicated in Figures 2-4, there is apparently a breakpoint preceding the announcement, where the coefficients, especially one for the linear trend, shift from one stable regression relationship to a different one. In other words, there are two structures in which the model parameters are time invariant. Thus the model can be written in such a form as

$$comp_t = \beta_{i,0} + \beta_{i,1} trend_t + \beta_{i,2} comp_{t-1} + u_t \qquad (t = t_{i-1} + 1, ..., t_i, \quad i = 1, 2) \tag{A.2}$$

where i denotes the index for the two different model structures. Thus t_1 is the breakpoint,τ, while $t_0 = 0$, and $t_2 = T$. We estimate the breakpoint by minimizing the residual sum of squares of the equation (A.2). For the computation of the confidence intervals of the estimated breakpoints, the distribution in Bai (1997) is utilized.[15]

Further we test the hypothesis that the regression coefficients remain constant

$$H_0 : \qquad \beta_{1,0} = \beta_{2,0}, \beta_{1,1} = \beta_{2,1}, \ and \ \beta_{1,2} = \beta_{2,2} \tag{A.3}$$

[15] Please refer Zeileis et al. (2003) for the ideas behind the implementation. The breakpoint estimation are obtained by utilizing the `strucchange` package for statistical software R provided by the authors.

against the alternative that at least one coefficient varies over time, i.e. a structural break. The test rests on a series of F statistics for a break at time τ. The OLS residuals $\widehat{u}(\tau)$ from a regression (A.2) are compared to the residuals $\widehat{u}$ from regression (A.1) via

$$F_\tau = \frac{\widehat{u}'\widehat{u} - \widehat{u}(\tau)'\,\widehat{u}(\tau)}{\widehat{u}(\tau)'\,\widehat{u}(\tau)\,/\,(T - 2\times 3)}. \tag{A.4}$$

These F statistics are then computed for $\tau = \underline{\tau}, ..., \overline{\tau}$. The sequence of F statistics can be aggregated in three alternative ways, suggested by Andrews (1993) and Andrews and Ploberger (1994). The three statistics are supremum, average and exp functional of the F statistics:

$$\begin{aligned}
\sup F &= \sup_{T_0 \leq \tau \leq \overline{\tau}} F_\tau, \\
\text{ave } F &= \frac{1}{\overline{\tau} - \underline{\tau} + 1} \sum\nolimits_{\tau=\underline{\tau}}^{\overline{\tau}} F_\tau \\
\exp F &= \log\left(\frac{1}{\overline{\tau} - \underline{\tau} + 1}\right) \sum\nolimits_{\tau=\underline{\tau}}^{\overline{\tau}} \exp\left(0.5 \times F_\tau\right).
\end{aligned}$$

The corresonding p values are then computed based on Hansen (1997).

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Table 1: Summary statistics

This table provides summary statistics of the 36 stocks in our sample. It reports the company name, symbol, and market capitalization. It also reports the average daily price, the average daily trading volume('000), the average daily trade, and the average daily percentage effective spread (in bps) in the US and Canada.

	January 2004 - January 2011	**Market Cap**	**US**				**CAN**			
No.	**Company**	**($mil)**	**Price**	**Volume**	**Trade**	**Espread**	**Price**	**Volume**	**Trade**	**Espread**
1	Barrick Gold	34,904	32.81	5,951	27,948	3.95	32.81	2,588	8,922	5.35
2	Agnico-Eagle Mines Limited	7,122	40.34	2,032	11,123	5.74	40.31	690	3,264	8.49
3	Agrium Inc.	8,784	41.32	1,732	10,672	5.49	41.31	765	3,872	8.49
4	BCE Inc.	27,213	27.72	550	2,911	5.02	27.73	2,955	5,304	5.37
5	Bank of Montreal	31,497	50.75	298	1,994	5.63	50.77	1,537	5,259	4.64
6	Bank of Nova Scotia	49,846	41.72	249	1,672	7.02	41.40	1,935	6,033	4.73
7	Brookfield Office	7,793	24.00	1,384	6,730	7.63	23.84	327	1,354	11.60
8	Cameco Corp.	11,372	40.24	1,794	9,083	5.84	39.82	1,165	4,480	7.66
9	Celestica Inc.	1,826	9.75	1,063	3,396	12.57	9.75	784	1,506	15.37
10	Canadian Imperial Bank Communication	27,844	66.19	211	1,497	5.98	66.20	1,194	4,359	4.80
11	Canadian National Railway Company	27,396	52.84	937	5,519	3.58	52.65	937	3,966	5.04
12	Canadian Natural Resources Ltd.	34,037	54.28	1,734	10,136	4.57	54.20	1,702	6,626	5.77
13	COTT Corp.	889	13.36	421	1,587	16.14	13.32	248	634	22.17
14	Canadian Pacific	9,967	48.27	457	2,859	5.29	48.28	593	2,415	7.10
15	Encana Corp.	31,810	49.86	2,467	12,293	3.56	49.65	2,226	7,491	4.82
16	Enbridge Inc.	19,012	38.80	198	1,245	6.96	38.80	628	2,382	7.07
17	Enerplus Corp.	4,834	35.36	535	2,404	7.46	35.39	287	1,267	10.46
18	Goldcorp Inc.	24,539	28.29	5,585	25,604	5.04	28.28	2,626	8,819	6.65
19	CGI Group	3,738	9.40	116	558	18.81	9.40	983	1,440	16.04
20	Gildan Activewear Inc.	3,060	33.13	426	2,596	9.39	33.00	318	1,292	12.81
21	Kinross Gold Corp.	10,759	13.40	3,786	16,518	9.87	13.39	3,405	6,792	10.89
22	Manulife Financial Corp.	40,305	34.23	1,256	6,448	4.93	34.19	3,063	7,170	5.75
23	Nexen Inc.	12,615	35.80	1,413	8,256	6.52	35.65	1,597	5,429	7.59
24	Precision Drilling Trust	2,307	27.00	871	3,689	10.04	27.05	672	1,775	12.18
25	Pengrowth Energy Corp.	3,156	16.03	888	2,818	10.60	14.75	434	1,192	15.13
26	Potash Corporation of Saskatchewan Inc.	28,774	109.00	3,849	23,278	4.14	108.17	698	4,947	5.87
27	Ritchie Brothers Auctioneers	2,262	39.35	198	1,108	10.54	39.10	45	242	20.56
28	Rogers Communication Inc.	16,220	37.63	421	2,158	5.25	34.26	1,289	3,633	7.98
29	Royal Bank of Canada	66,555	51.39	509	3,388	4.70	50.81	2,383	7,548	4.38
30	Shaw Communications Inc.	7,803	22.34	165	859	8.85	22.29	738	1,850	11.06
31	Sun Life Financial	20,867	35.17	297	1,882	6.20	35.19	1,154	3,666	6.81
32	Suncor Energy Incorporated	42,305	52.84	3,806	19,598	4.05	52.73	2,501	9,485	5.18
33	TransAlta Corp.	4,865	21.02	32	188	14.58	21.02	611	1,559	10.70
34	Toronto-Dominion Bank	52,833	54.56	602	3,936	4.53	54.56	1,823	6,614	4.36
35	Talisman Energy Inc.	17,131	25.80	2,277	10,668	6.47	25.56	2,763	6,006	7.67
36	TransCanada Corp.	23,358	30.74	228	1,324	5.96	30.75	1,172	3,376	5.78
	Mean		37.35	1,354	6,887	7.30	37.12	1,357	4,221	8.79

Table 2. Statistics during announcement and non-announcement days

This table provides summary statistics during the 150min period surrounding Fed Funds Rate announcements (60min prior to and 90min after 2.15PM). The *mean* values are computed by averaging over the sample period across firms. *stdev* is the standard deviation from firms' average values. *Min* and *Max* values are the lowest and highest of the firm averages. Figures in parantheses are the t-statistics. *** denotes statistical significance at 1% level.

	Non-announcement days				Fed Funds Rate announcements				Difference in means	
	Mean	stdev	Min	Max	Mean	stdev	Min	Max	Diff	t-stat
US										
Effective spread (in cents)	1.77	0.55	1.04	3.60	1.95	0.64	1.08	4.17	0.18***	(9.54)
Effective spread (bps)	6.74	3.51	3.15	17.73	7.23	3.49	3.56	18.53	0.49***	(9.66)
Volume ('000)	612	648	17	2,507	815	929	18	3,924	203***	(4.36)
Trades	3,128	3,151	98	11,672	4,280	4,618	112	19,067	1153***	(4.00)
Volume per trade	268	68	178	459	265	74	169	451	-3	(-0.54)
Autocorrelation of order flow	0.398	0.067	0.256	0.540	0.403	0.060	0.292	0.542	0.005*	(1.77)
Canada										
Effective spread (in cents)	2.20	0.80	1.15	5.08	2.33	0.87	1.20	5.63	0.13***	(6.80)
Effective spread (bps)	8.20	4.19	4.02	20.23	8.63	4.35	4.40	21.36	0.43***	(6.89)
Volume ('000)	607	399	21	1,400	752	519	28	2,053	145***	(6.97)
Trades	1,890	1,103	125	4,078	2,456	1,520	159	5,801	566***	(5.95)
Volume per trade	409	147	183	899	411	149	166	862	2	(0.02)
Autocorrelation of order flow	0.547	0.049	0.417	0.642	0.547	0.051	0.423	0.649	-0.001	(-0.39)

Table 3. Spread components surrounding Fed Funds Rate Announcements (in percentages)

This table reports the spread components (in percentages) during Fed Funds Rate announcements (A), non-announcement days (NA), and their differences. Panel A reports the components during the full 150-minute period surrounding the announcement time (1:15pm to 3:45pm). Panel B reports the components during the 60-minute period prior to the announcement time (1.15pm to 2.15pm). Panel C reports the components during the 90-minute period following the announcement time (2.15pm to 3.45pm). Figures in parantheses are the t-statistics. ***, and ** denote statistical significance at 1% and 5% levels, respectively.

	US				**CAN**			
	NA	A	Diff (t-stat)		NA	A	Diff (t-stat)	
Panel A: Full 150min period								
Information Asymmetry Component	17.2%	17.4%	0.13%	(0.96)	21.9%	22.6%	0.70%***	(6.75)
Order Persistence Component	40.6%	41.4%	0.80%***	(3.40)	54.7%	54.8%	0.04%	(0.21)
Order Processing Component	42.2%	41.3%	-0.94%***	(-4.57)	23.4%	22.7%	-0.74%***	(-3.41)
Panel B: 60min pre-announcement								
Information Asymmetry Component	17.6%	17.2%	-0.39%**	(-2.08)	22.0%	22.2%	0.25%	(1.55)
Order Persistence Component	40.4%	41.3%	0.82%***	(2.53)	54.3%	54.2%	-0.13%	(-0.46)
Order Processing Component	42.0%	41.6%	-0.44%	(-1.35)	23.8%	23.6%	-0.12%	(-0.45)
Panel C: 90min post-announcement								
Information Asymmetry Component	16.7%	17.6%	0.86%***	(3.79)	21.4%	23.0%	1.59%***	(9.17)
Order Persistence Component	40.9%	42.0%	1.02%***	(3.79)	55.4%	55.6%	0.23%	(1.07)
Order Processing Component	42.4%	40.4%	-1.91%***	(-5.83)	23.2%	21.3%	-1.81%***	(-6.76)

Table 4. Spread components surrounding Fed Funds Rate Announcements (in US cents)

This table reports the spread components (in US cents) during Fed Funds Rate announcements (A), non-announcement days (NA), and their differences. Panel A reports the components during the full 150-minute period surrounding the announcement time (1:15pm to 3:45pm). Panel B reports the components during the 60-minute period prior to the announcement time (1.15pm to 2.15pm). Panel C reports the components during the 90-minute period following the announcement time (2.15pm to 3.45pm). Figures in parantheses are the t-statistics. ***, **, and * denote statistical significance at 1%, 5% and 10% levels, respectively.

	US				**CAN**			
	NA	A	Diff (t-stat)		NA	A	Diff (t-stat)	
Panel A: Full 150min period								
Effective Spread	1.77	1.95	0.176***	(9.54)	2.20	2.33	0.128***	(6.80)
Information Asymmetry Component	0.31	0.35	0.034***	(9.73)	0.51	0.56	0.046***	(9.16)
Order Persistence Component	0.71	0.80	0.091***	(7.91)	1.18	1.24	0.067***	(6.97)
Order Processing Component	0.75	0.80	0.051***	(7.12)	0.52	0.53	0.015*	(1.75)
Panel B: 60min pre-announcement								
Effective Spread	1.77	1.92	0.144***	(10.23)	2.21	2.28	0.071***	(3.73)
Information Asymmetry Component	0.32	0.34	0.018***	(4.57)	0.51	0.53	0.023***	(4.88)
Order Persistence Component	0.71	0.78	0.079***	(8.08)	1.17	1.20	0.033**	(2.32)
Order Processing Component	0.75	0.80	0.048***	(5.66)	0.53	0.54	0.015*	(1.74)
Panel C: 90min post-announcement								
Effective Spread	1.74	2.08	0.340***	(9.52)	2.18	2.49	0.304***	(8.18)
Information Asymmetry Component	0.30	0.38	0.077***	(9.92)	0.49	0.60	0.110***	(9.49)
Order Persistence Component	0.70	0.86	0.164***	(8.24)	1.18	1.34	0.165***	(9.52)
Order Processing Component	0.74	0.84	0.099***	(7.36)	0.51	0.54	0.029**	(2.40)

Table 5. Breakpoint of the intraday variation of the components

This table reports the estimated break points of the intraday variation of the abnormal spread components, the corresponding 95% confidence intervals and the three F statistics, sup F, ave F and exp F. The sixth and seventh columns respectively reports the OLS coefficient estimates for the linear trend term before and after the detected break point. The reported numbers for the OLS coefficients are multiplied by 10,000 for the sake of lucidity. *** and ** denotes statistical significance at 1% and 5% levels, respectively. The estimation and testing procedure is described in Appendix 2.

	Break Point	95% C.I.	sup F	ave F	exp F	Pre	Post	Sample Period
Panel A: Information Asymmetry Component								
US	13:56	13:52 - 13:57	40.75***	20.63***	16.79***	0.20	4.17***	12:38 - 14:38
Canada	14:00	13:59 - 14:02	44.97***	25.33***	18.74***	-0.34**	2.82**	12:32 - 14:32
Panel B: Order Persistence Component								
US	13:50	13:47 - 13:51	37.97***	19.37***	15.01***	-0.16	13.73**	12:09 - 14:09
Canada	14:02	13:57 - 14:04	32.49***	20.74***	13.49***	0.13	1.42***	12:53 - 14:53
Panel C: Order Processing Component								
US	14:01	13:59 - 14:02	41.89***	16.99***	16.51***	0.24	-6.69***	12:23 - 14:23
Canada	13:34	13:33 - 13:37	68.03***	36.39***	31.25***	3.65***	-1.96***	12:49 - 14:49

Table 6. Spread components Before and After Regulation NMS

This table reports the spread components during the 150-minute period surrounding Fed Funds Rate announcements (1:15pm to 3:45pm). Panel A and B report the components prior to and after the implementation of the Regulation NMS on 8 October 2007, respectively. Panel C reports the difference in difference of those components. Figures in parantheses are the t-statistics. ***, **, and * denote statistical significance at 1%, 5% and 10% levels, respectively.

	US				CAN			
	NA	A	Diff (t-stat)		NA	A	Diff (t-stat)	
Panel A: Full 150min Period (Pre-NMS)								
Information Asymmetry Component	20.8%	20.9%	0.05%	(0.22)	21.3%	21.9%	0.58%***	(4.59)
Order Persistence Component	31.7%	32.4%	0.74%***	(3.14)	50.2%	50.5%	0.34%	(1.23)
Order Processing Component	47.6%	46.8%	-0.80%***	(-2.73)	28.5%	27.5%	-0.92%***	(-3.63)
Panel B: Full 150min Period (Post-NMS)								
Information Asymmetry Component	14.6%	15.1%	0.47%***	(2.56)	22.5%	23.5%	0.90%***	(5.09)
Order Persistence Component	47.3%	47.9%	0.61%*	(1.92)	59.1%	58.8%	-0.37%	(-1.47)
Order Processing Component	38.1%	37.0%	-1.09%***	(-4.40)	18.3%	17.8%	-0.53%**	(-1.98)
Panel C: Difference-in-Difference								
Information Asymmetry Component	-6.2%***	-5.8%***	0.42%		1.2%*	1.5%**	0.32%	
	(-8.84)	(-7.71)	(1.57)		(1.75)	(1.98)	(1.43)	
Order Persistence Component	15.6%***	15.5%***	-0.13%		9.0%***	8.3%***	-0.71%**	
	(12.57)	(13.47)	(-0.34)		(10.95)	(9.52)	(-2.12)	
Order Processing Component	-9.5%***	-9.8%***	-0.29%		-10.2%***	-9.8%***	0.39%	
	(-8.97)	(-9.83)	(-0.84)		(-18.68)	(-17.98)	(1.39)	

Figure 1. Intraday Abnormal Effective Spread

This figure plots the abnormal effective spread (effective spread during Fed Funds Rate announcement less non-announcement days) in the U.S. and Canada. The figures are average spreads for the 36 firms in the sample.

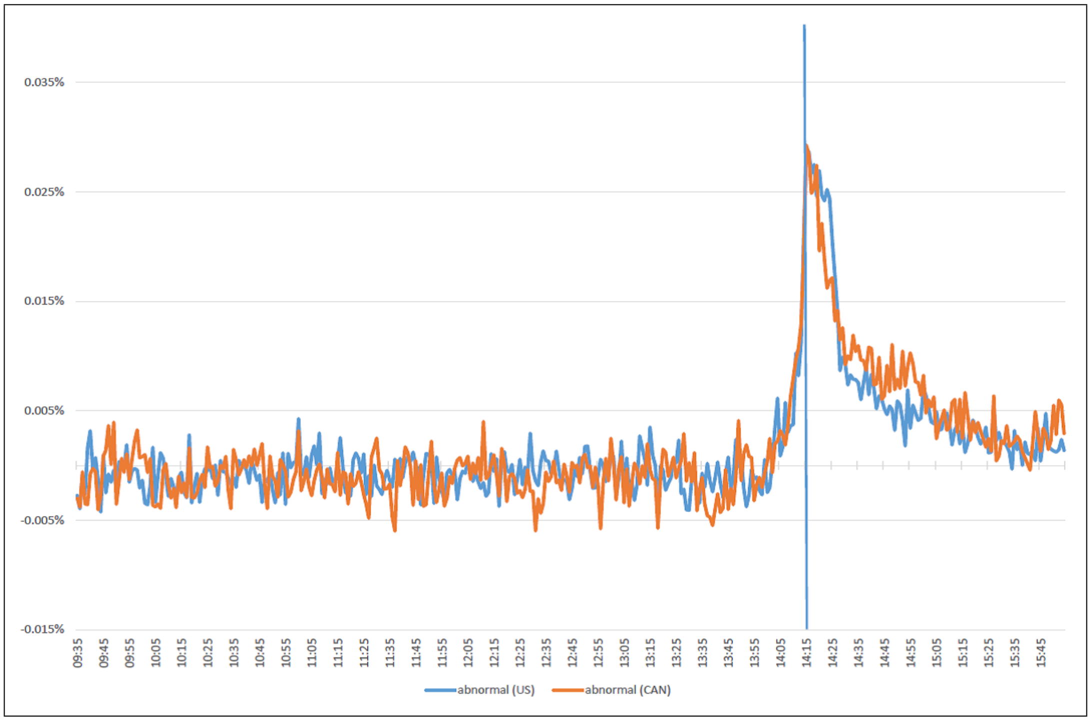

Figure 2. Intraday Abnormal Information Asymmetry Component of Spread

This figure plots the abnormal information asymmetry components of effective bid-ask spread (information asymmetry component during days with Fed Funds Rate announcement less non-announcement days) for the U.S. and Canadian markets. The figures are the 30min centre moving averages computed from the 36 firms in the sample.

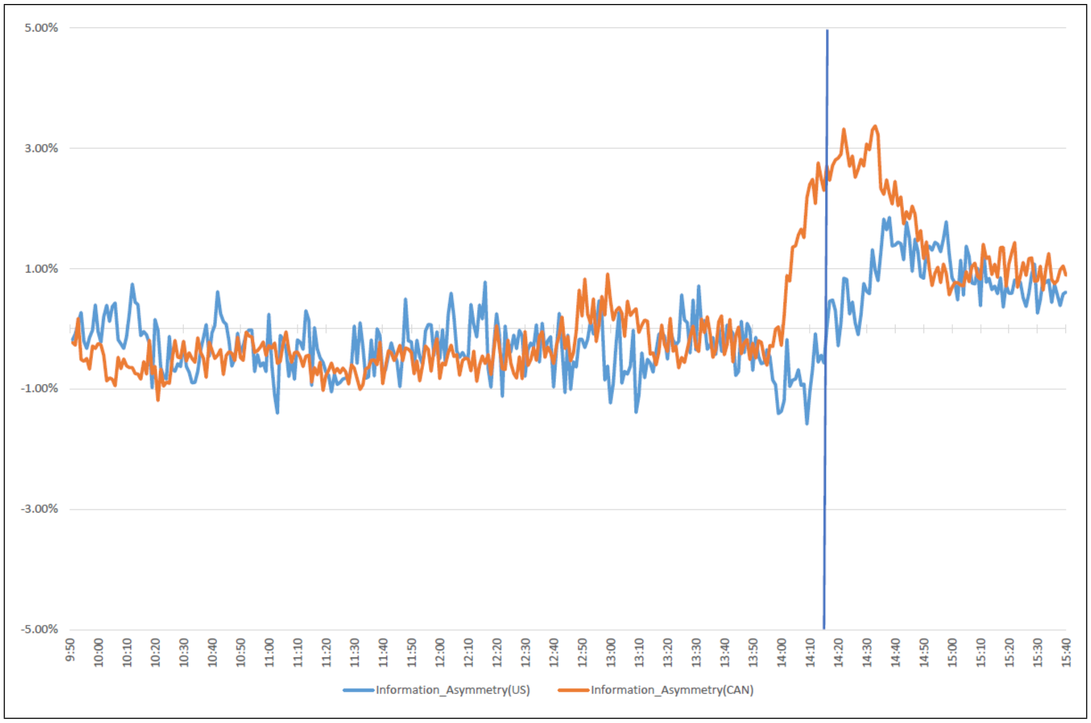

Figure 3. Intraday Abnormal Order Persistence Component of Spread

This figure plots the abnormal order persistence components of effective bid-ask spread (order persistence component during days with Fed Funds Rate announcement less non-announcement days) for the U.S. and Canadian markets. The figures are the 30min centre moving averages computed from the 36 firms in the sample.

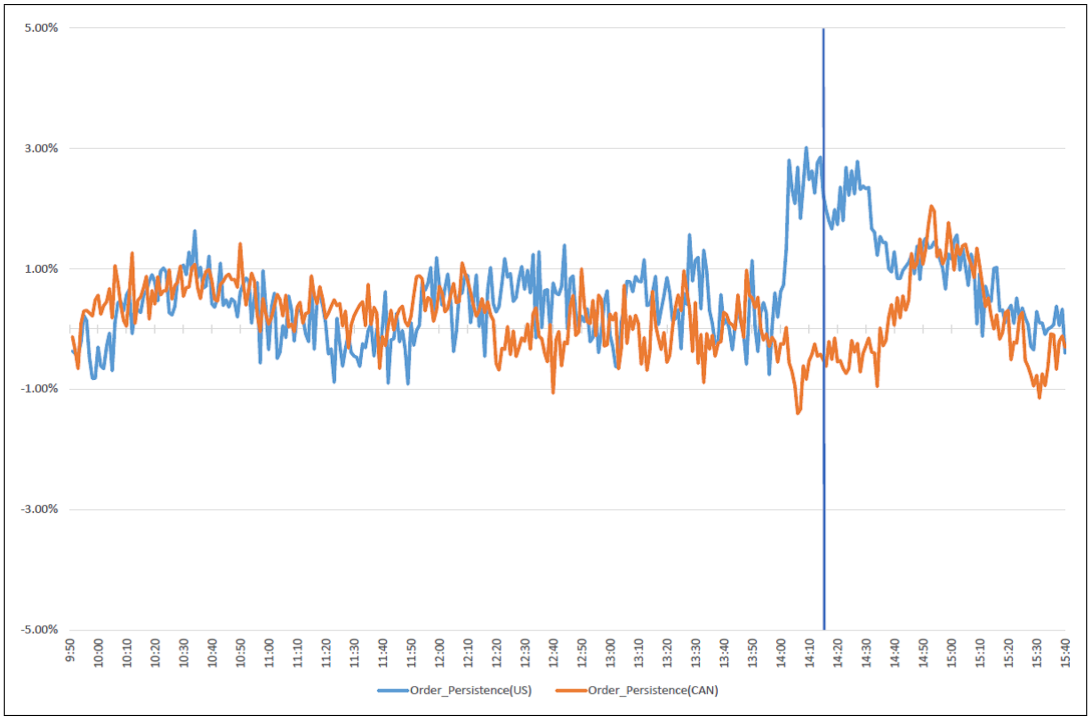

Figure 4. Intraday Abnormal Order Processing Component of Spread

This figure plots the abnormal order processing components of effective bid-ask spread (order processing component during days with Fed Funds Rate announcement less non-announcement days) for the U.S. and Canadian markets. The figures are the 30min centre moving averages computed from the 36 firms in the sample.