# The Impact of Cross-listing on High-Frequency Trading

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PRELIMINARY DRAFT. PLEASE DO NOT CITE OR CIRCULATE.

**ABSTRACT**

We empirically examine the impact of US cross-listing on high-frequency trading (HFT) of Canadian stocks during the period 2005–2017. We document that Canadian stocks cross-listed on the NYSE have higher levels of HFT in their home market compared their non-cross-listed counterparts. We also find a significant increase in HFT of Canadian cross-listed stocks in the home market following the cross-listing event. In contrast, the introduction of HFT tax in Canada in April 2012 has a significant negative impact on HFT of Canadian cross-listed stocks. Finally, we test potential channels of the documented increase in HFT after cross-listing. We document a significant increase in HFT of cross-listed stocks around US news announcements. We also test cross-market arbitrage channel and find that HFT in the US market significantly increases HFT in Canadian market. However, we find no evidence that HFT activity is related to the level of mispricing between the US and Canadian markets.

KEYWORDS: High-Frequency Trading, Cross-Listing, Cross-Market Arbitrage, Financial Markets

JEL classifications: G12, G14, G15, G23

## 1. Introduction

By the end of 2017, 496 non-US stocks from 46 countries were listed on the NYSE, including 134 Canadian stocks.[1] Empirical evidence has shown that non-US firms that cross-list in the US benefit from greater stock liquidity, lower cost of capital, higher market valuation, lower information asymmetry risk, and greater efficiency of stock prices.[2] In markets populated by high-frequency traders (HFTs), however, cross-listing in the US could have some other outcomes that are not yet understood. The aim of this study is to contribute to the understanding of consequences of the decision of non-US companies to cross-list their stocks in the US markets in the last decade, specifically, in terms of high-frequency trading (HFT) activity. We examine whether a cross-listing in the US is associated with an increase in HFT in the stock's home market and examine potential channels of the changes in HFT after US cross-listing.

HFT refers to the use of ultra-fast computer algorithms and low latency technology for proprietary trading. HFTs engage in heterogeneous strategies including market-marking, cross-venue latency arbitrage, and directional speculation (e.g., Boehmer, Li, and Saar, 2018), the success of which rely on speed of execution. Despite being a relatively recent phenomenon, HFT is responsible for most of the liquidity supply, message traffic, and trading activity in financial markets all around the world (e.g., O'Hara, 2015). The literature on HFT is already quite extensive.[3] However, to the best of our knowledge, no study has examined the role of international cross-listing for HFT.

We find opposing arguments regarding the potential impact that cross-listing may have on HFT activity in the domestic market. On the one hand, cross-listing in the US improves the information environment and information efficiency of stock prices in the home market (Dodd

[1] Data source: the NYSE web-site https://www.nyse.com/
[2] See, for example, Diamond and Verrecchia (1991), Easley and O'Hara (2004), Chemmanur and Fulghieri (2006), and Dodd and Gilbert (2016).
[3] See Biais and Woolley (2011), Jones (2013), Biais and Foucault (2014), Goldstein, Kumar, and Graves (2014), SEC (2014), O'Hara (2015), and Menkveld (2016) for literature reviews.

and Gilbert, 2016), which results from stricter disclosure rules, greater visibility, and greater analyst coverage in the US. More informative prices would result in reduced inefficiencies and mispricing for the HFTs to exploit (e.g., Hendershott and Jones, 2005; Comerton-Forde and Putniņš, 2015). If cross-listing dampens the profitability of the HFT strategies in the domestic market, it could lead to a decrease in HFT.

On the other hand, cross-listing could lead to an increase in HFT by creating a more favorable trading environment for HFTs, increasing the sensitivity of the cross-listed stock prices to US news, and opening an avenue for cross-border latency arbitrage. This is because HFTs concentrate their activity on frequently traded and liquid stocks, and cross-listing in the US offers greater liquidity and lower transaction costs for the cross-listed stocks in the home market (Foerster and Karolyi, 1998, Moulton and Wei, 2009). Therefore, cross-listing creates conditions that make non-US cross-listed stocks more attractive to HFTs. Furthemore, cross-listing in the US creates profitable opportunities for HFTs around US news announcements that they can exploit due to their relative speed advantage. This is because cross-listing in the US leads to an increase in returns co-movement with the US market and stronger reactions to US news announcements, increasing the number of news events the cross-listed stock's price will be responsive to (Frijns, Indriawan and Tourani-Rad, 2015). Finally, cross-listing in the US opens an additional trading avenue creating fragmentation in liquidity and opportunities for HFTs to exploit any mispricing that occur between the US and home markets (e.g. Gagnon and Karolyi, 2010). The above arguments suggest that cross-listing in the US would lead to an increase in HFT of cross-listed stocks.

In this paper, we empirically examine the impact of US cross-listing on HFT. We compare HFT activity of cross-listed stocks and non-cross-listed stocks and examine the changes in HFT before vs. after the cross-listing in the US. We use a sample of 112 Canadian stocks cross-listed on the NYSE during the period 2005–2017 and focus on HFT activity in the home

(Canadian) market. Canadian stocks are listed in the U.S. as ordinary shares, unlike securities from other countries, which are usually listed as ADRs (e.g., Eun and Sabherwal, 2003). As a result, US-listed Canadian stocks are identical to the ones traded in Canada. If cross-listing enhances HFT, we expect cross-listed stocks to have higher levels of HFT activity relative to comparable (in terms of price level, trading volume and spreads) non-cross-listed (NCL) Canadian stocks, and we also expect to observe a significant increase in the HFT activity following the cross-listing.

The empirical findings provide support to the argument that cross-listing in the US increases HFT of non-US stocks in their home market. First, we document that cross-sectionally Canadian cross-listed stocks have significantly greater levels of HFT than comparable NCL stocks, based on four estimated measures of HFT (AT proxy, quote-intensity-to-trade ratio, limit order duration, and average trade size). In multivariate framework, Fama-MacBeth regressions show that HFT activity is greater for cross-listed stocks compared to NCL stocks, controlling for the differences in firm characteristics. Second, we evaluate the changes in HFT around the cross-listing event for a sample of 62 cross-listing events that took place in 2005–2017. Using diff-in-diff univariate and multivariate analysis (with a sample of matched NCL stocks), we document a significant increase in HFT in the home market following the cross-listing event for cross-listed stocks.

To address the issue of potential endogeneity, that is the causality between the cross-listing status and the level of HFT activity, we use the introduction of HFT tax in Canada in April 2012 as an exogenous shock to HFT that is independent of the cross-listing event. We find that HFT of Canadian stocks decreases following the tax introduction event, and HFT of cross-listed stocks decrease more significantly than that of NCL stocks.

Finally, we test empirical validity of two potential channels of the documented increase in HFT after cross-listing: (1) increase in HFT around US public news announcements and (2) increase in cross-market arbitrage. To test the first channel, we examine the changes in HFT around the US macroeconomic news announcements. Using diff-in-diff analysis, we compare HFT of CL and NCL stocks during two-hour period surrounding Federal Open Market Committee (FOMC) announcements to HFT of CL and NCL stocks on non-announcement days. We find a significant increase in HFT activity for CL stocks relative to NCL stocks around the US around the US news announcements This provides a supportive evidence for the first channel. To test the second channel, we examine HFT activity in relation to mispricing between the US and home market. If HFT strategies rely on arbitrage opportunity between the two markets, then HFT activity would increase when cross-market mispricing is high. We use 1-minute interval intraday prices in two markets to estimate daily measures of mispricing and apply a structural VAR (SVAR) model using an Identification through Heteroskedasticity approach of Rigobon (2003) to examine the contemporaneous relationship between mispricing and HFT activity. Estimation results do not yield a significant relationship between mispricing and HFT in Canadian or US markets, however, we do find that an increase in HFT in the US (Canadian) market is associated with an increase in HFT in Canadian (the US market), with HFT in the US market having a greater impact. This finding suggests that HFT activity in Canadian market is greatly influenced by HFT activity in the US market.

We contribute to the literature in following ways. To the best of our knowledge, this is the first study to examine the changes in HFT around international cross-listings and the consequences of cross-listing in the presence of HFTs. Therefore, we contribute to the literature on the consequences of US cross-listings and to the literature on the determinants of HFT activity.

The rest of the paper is organized as follows. In section 2 we provide a discussion on consequences of US cross-listings and potential impact of US cross-listing on HFT of cross-listed stocks and provide arguments to support our hypotheses. In section 3 we discuss our measures of HFT. In section 4 we discuss how we have constructed the sample and provide sample description. In section 5 we discuss the estimation results and in section 6 we conclude.

## 2. Background and Hypotheses

### *2.1 US cross-listing and HFT*

Non-US firms that cross-list on US exchanges are subject to the US laws and regulations. US cross-listing involves registration and compliance with the listing requirements of the US Securities and Exchange Commission (SEC) that entail additional mandatory information disclosure (Coffee, 2002; Leuz, 2003). This leads to non-US firms cross-listed in the US having higher levels of disclosure compared to firms that do not cross-list (Khanna, Palepu and Srinivasan, 2004). In addition to mandatory additional disclosure, cross-listed firms benefit from greater visibility and analysts' coverage that facilitates production, dissemination and accuracy of information after the cross-listing (Baker et al., 2002; Lang, Lins, and Miller, 2003; Eaton et al., 2007; and Lee and Valero, 2010), and greater monitoring by institutional investors (Ferreira and Matos, 2008).

The additional information created and disseminated after the cross-listing should reduce the adverse selection costs of trading cross-listed stocks (Brennan and Subrahmanyan, 1995). Fernandes and Ferreira (2008) find that for firms from developed markets US cross-listing improves price informativeness. Dodd and Gilbert (2016) report an improvement in the stock's information environment (lower effective spread, adverse selection costs' spread component, and price impact) and stock price efficiency (reduced autocorrelation in intraday returns) in the home market after cross-listing in the US. The above evidence points towards a reduction in inefficiencies in trading and a reduction in mispricing of cross-listed stocks, which in turn, could reduce profitable opportunities and incentives for HFTs.

On the other hand, US cross-listing creates conditions that make non-US stocks cross-listed in the US more attractive to HFTs. When a single security is traded on multiple venues, as it happens as a result of international cross-listing, liquidity becomes fragmented across these venues, creating the opportunity for HFTs to exploit pricing inefficiencies across venues. HFTs' arbitrage activity across trading venues keeps prices aligned (e.g., Brogaard, Hendershott, and Riordan, 2014). Canadian stocks are listed in the U.S. as ordinary shares, unlike securities from other countries which are usually listed as American Depository Receipts; this means Canadian stocks traded in the US are identical to the one traded in Canada, with no trading or ownership restrictions and no additional conversion fees (Eun and Sabherwal, 2003; Gagnon and Karolyi, 2010). However, these stocks are not fully fungible because US trading and dividends distribution takes place in US dollars, the trades are cleared and settled in the US (through the Depository Trust Company) while in Canada trading takes place in Canadian dollars and the trades are cleared and settled through the Canadian Depository for Securities).[4] This fragmentation may increase the activity by HFTs.[5]

Moreover, HFTs are attracted to stocks with high liquidity and low trading costs. The cross-listing literature provides evidence that cross-listing in the US enhances liquidity and reduces costs of trading. Smith and Sofianos (1997) report a 42% (24%) increase in the combined

[4]Gagnon and Karolyi (2010) list the conditions that a US-listed security that is fully fungible with the corresponding home-market security must satisfy: (a) the certificates traded in the two markets are identical; (b) there is no legal constraint on cross-border ownership and trading; (c) investors can seamlessly trade between the US and the home market; (d) there are no conversion fees; (e) investors can hold the securities and receive dividends in US dollars or in the home currency regardless of where they were obtained. According to this set of conditions, Canadian certificates would not be fully fungible as they fail to satisfy condition (e). Specifically, "investors buying the shares on the US must hold them in U.S. dollar accounts and must receive U.S. dollar dividends. If a U.S. investor buys a Canadian stock in the U.S., the trade is cleared and settled through the Depository Trust Company (DTC); a trade by a Canadian investor in that stock will clear and settle with the Canadian Depository for Securities (CDS) Limited. These transfer arrangements might induce a potential home-market trading preference" (p. 56).

[5]HFT is shown to increase in venues with trade-through protection where market orders must be routed to the market displaying the best price (REF). This is because HFT firms often use electronic market-making strategies which require that the limit orders they post in displayed markets are protected when they are at the best prices. Regulation National Market System (Reg. NMS) in the US, which was adopted in stages between 2006 and 2007, provides trade-through protection known as the Order Protection Rule (OPR). This rule contributes to the high level of HFT activity in the US. In Canada, the OPR was introduced in February 2011.

trading volume in the NYSE and the home market (in the home market trading volume) after cross-listing.[6] For Canadian companies, Foerster and Karolyi (1993) report an increase of 62% (26%) in total (domestic) trading volume after cross-listing, while You et al. (2012) report a decrease in trading volume after delisting. Regarding transaction costs, Foerster and Karolyi (1998) find a decrease in both quoted and effective spreads in the Canadian market after cross-listing that they attribute to intensified competition between market makers. For domestic stocks that do not trade synchronously with their US-listed counterparts, trading concentrates during the overlapping trading hours (e.g., Werner and Kleidon, 1996; Howe and Ragan, 2002), traders split orders across markets (e.g., Menkveld, 2008), and spreads and depth improve (e.g. Moulton and Wei, 2009) after cross-listing.[7]

HFTs need to trade in and out of positions quickly and constantly, as they hold short-lived open positions and zero inventory overnight (e.g., SEC, 2010). Moreover, profit margins from HFT strategies are marginal (e.g. Menkveld, 2013; Carrion, 2013). Therefore, high levels of turnover are necessary to generate a sizable profit. Finally, trading in liquid stocks incurs much lesser market making costs, as it is easier to manage inventory and adverse selection risk (e.g., Aït-Sahalia and Saglam, 2017; Hoffmann, 2014). In summary, HFT strategies benefit from liquid trading environments. This explains why HFTs focus their trading activity on highly liquid stocks (e.g., Brogaard et al., 2014). Cross-listing to the NYSE offers greater liquidity and lower transaction costs for Canadian stocks, which should therefore enhance HFT activity.

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[6]For emerging markets, however, Domowitz et al. (1998) and Silva and Chavez (2008) report a reduction in trading activity in the home market after cross-listing in the US as a result of migration of order flows to the US market. The lack of transparency and insider trading in the emerging market explains order flow migration (Levine and Schmukler, 2006).

[7] Transaction costs in the US for non-US cross-listed stocks are, however, higher than those of US stocks (Bacidore and Sofianos, 2002). Bacidore and Sofianos (2002) report lower specialist end-of-day inventory positions, higher specialist participation and stabilization rates, wider spreads, and less depth for non-US stocks. They conclude that liquidity providers demand greater compensation for trading non-US stocks to offset the higher adverse selection risk.

Although cross-listing in the US improves the stock's information environment and price efficiency, it also improves stock liquidity and costs of trading, and creates fragmentation in liquidity between the US and home market, providing profitable opportunities to HFTs. Therefore, our main hypothesis is that cross-listing in the US leads to an increase in HFT activity.

Furthermore, we propose that the increase in HFT after US cross-listing occurs via two channels: (1) by increasing profitable opportunities for HFTs around US news announcements; (2) by opening an avenue for cross-market arbitrage. We discuss these two potential channels next.

*HFT around US news announcements*

The first channel is related to the relative speed advantage of HFTs around price sensitive public news announcements. Hu, Pan, and Wang (2016) show that when Thomson Reuters released a key reading of the US consumer confidence to some fee-paying HFTs two seconds before the official announcement time, most of the price discovery on the ES occurred within 200 milliseconds after the HFTs' early peek. Scholtus, van Dijk, and Frijns (2014) show that speed matters for event-based trading profitability, as a delay of 300 microseconds or more significantly reduces returns around US macro news announcements. Regarding cross-listed stocks, cross-listing in the US leads to an increased returns co-movement with the US market and stronger reactions to US news announcements. Frijns et al. (2015) report that US macroeconomic news announcements affect trading of Canadian stocks cross-listed in the US. Since after cross-listing in the US there will be more news events the cross-listed stock's price will be responsive to, and thus more profit opportunities for HFTs, we expect HFT of cross-listed stocks to increase around US news announcements, leading to an overall increase in HFT after cross-listing.

*Cross-market arbitrage*

The second channel is that US cross-listing opens an additional trading avenue creating opportunities for HFTs to exploit any mispricing that occur between the prices in two markets using cross-border arbitrage.[8] Several studied provide evidence of price discrepancies and arbitrage opportunities in cross-listed stocks (Suarez, 2005; Alsayed and McGroarty, 2012; Ghadhab and Hellara, 2015). The most comprehensive study by Gagnon and Karolyi (2010) compare prices and quotes of cross-listed shares in the US with synchronous prices of their home-market shares on a currency-adjusted basis. They find that while, on average, deviations from price parity are economically small, they are volatile and can reach large extremes; price parity deviations are positively related to proxies for holding costs that can limit arbitrage.

The above studies do not consider intraday deviations from price parity that present low latency arbitrage opportunities for HFTs. Latency arbitrage exploits extremely short-lived deviations from parity for prices of identical or related securities across venues.[9] Latency arbitrage is facilitated by the current highly fragmented trading landscape (e.g., O'Hara and Ye, 2011). Budish, Crampton, and Shim (2015) estimate an average US$75 million per year at stake in latency arbitrage between the S&P500 exchange traded fund (SPY) and the S&P500 E-mini futures contract (ES). Wah (2016) estimates a potential profit resulting from latency arbitrage in S&P500 stocks of US$3.03 billion in 2014. Due to their ultra-fast algorithms, high-speed connectivity, and direct access to data feeds, HFTs are particularly well suited to exploit fleeting arbitrage opportunities (e.g., Biais and Foucault, 2014). Chaboud et al. (2014), Baron et al. (2018) and Boehmer et al. (2018) provide empirical evidence that HFTs engage in cross-market latency

[8] Hegde (2010) report an increase in aggregate trading volume and a decrease in bid-ask spreads for dual listed stocks (NYSE-listed stocks that concurrently list on Nasdaq), in line with an increase in cross-market arbitrage.

[9] Examples of low latency arbitrage opportunities include locked and crossed markets (e.g., Shkilko, Van Ness, and Van Ness, 2008), and triangular arbitrage opportunities in currency markets (e.g., Foucault, Kozhan, and Tham, 2012).

arbitrage. If international cross-listing increases the profits at stake in latency arbitrage, we can expect HFT to increase after cross-listing both in the home and in the US market.

## 3. Measures of High-Frequency Trading

We estimate four measures of HFT. For our first *AT proxy (AT)*, we use Hendershott et al. (2011) measure which is the negative trading volume in hundreds of dollars divided by the total message traffic number (the sum of the number of trade observations and quote changes), i.e. (-*$Volume*/100) ÷ *Total_Messages*. This ratio represents the negative dollar volume associated with each trade or quote update. An increase in this measure reflects an increase in high-frequency trading activity. The second proxy that we use is based on the idea that HFT activities have contributed to a huge increase order traffic relative to trade executions. As such, we measure the *Quote-intensity-to-trade ratio (QIT)* (see, e.g. Conrad et al., 2015; Chakrabarty et al., 2017), where quote intensity is defined as the number of changes in either price or depth at the best quotes of the limit order book. QIT is the ratio of the quote intensity to the number of trades that day. Third, we consider the *limit order duration (QD)*, i.e. the time difference between consecutive limit orders (Hagströmer and Nordén, 2013; Subrahmanyam and Zheng, 2016). An increase in AT activity will decrease the duration between subsequent quote changes. Finally, we use the *average trade size (ATS)*, which is a ratio of trading volume (in 100 shares) to the number of trades (Angel, Harris, and Spatt, 2011; Chung and Lee, 2016; Weller, 2017).

## 4. Data

To examine HFT activity of cross-listed stocks, we collect a sample of Canadian stocks that traded on the Toronto Stock Exchange (TSX) and the New York Stock Exchange (NYSE) during our sample period 2005 – 2017. Data on Canadian cross-listed stocks (company name and date of cross-listing) is obtained from the NYSE web-site. Since we examine HFT of stocks in their home market (Canada), we exclude direct foreign IPOs, i.e. stocks that do not trade in Canada. We also exclude stocks without coverage in Datastream, our data source for firm-level variables. Next, we obtain intraday trading data from Thompson Reuters Tick history (TRTH) database maintained by Securities Industry Research Centre of Asia-Pacific (SIRCA). These data contain all message traffic at the top of the limit order book, including transactions, volume and revisions in bid and ask prices and depths, time-stamped to the nearest millisecond. After applying the above sample selection criteria, we obtain a sample of 112 Canadian stocks that cross-list on the NYSE, including 62 stocks that cross-list during the sample period 2005 – 2017.

In addition to cross-listed stocks, our sample includes matched domestic or non-cross-listed (NCL) stocks. For each cross-listed stock, we identify a matching NCL stock from the same home market (Canada) for each year. Domestic stocks are stocks that have not been listed on any US exchanges (NYSE, Nasdaq, Amex). We use propensity scores estimated for each year to find the closest match based on price level, trading volume and bid-ask spread. Again, matched sample selection criteria include data availability in Datastream and TRTH databases.

Table 1 reports the distribution of the sample stocks and cross-listing event by year. The largest number of stocks in the sample are in 2017 (total 182 stocks) and 2013 (total 174 stocks); the largest number of cross-listing events is in 2017 (12 events) and in 2012 (9 events).

INSERT TABLE 1 HERE

## 5. Results

### *5.1 Comparing HFT activity between cross-listed (CL) and non-cross-listed (NCL) stocks*

In Figure 1 we plot various measures of HFT activity for CL and NCL stocks over time. For both groups, we can see clear trends of increasing HFT activity over the period 2005 to 2017. For instance, the AT measure in Figure 1A becomes less negative over the years, suggesting that high-frequency trading activity has been increasing over the years. In addition, CL stocks tend to have higher AT compared to NCL stocks. Figure 1B shows that Quote-intensity-to-trade (QIT) has increased over the sample period with the peak being in 2013. Similarly, CL stocks tend to have higher QIT than NCL stocks, suggesting that the former group has more limit order revisions (price or depth) per trade.

INSERT FIGURE 1 HERE

Figure 1C and 1D plot the Quote Duration (QD) and Average trade size (ATS), respectively. We observe that both QD and ATS decrease over time, indicating that the time between consecutive limit orders and the average volume per transaction have decreased, i.e. trades become smaller but executed more quickly. Overall, we observe increasing trends in HFT of Canadian stocks, both cross-listed and non-cross-listed. However, the CL group seems to have stronger HFT presence, as shown by the magnitude of the above proxies. This highlights the importance of controlling for time effects.

In Table 2, we report average values for HFT proxies and firm characteristics for cross-listed and non-cross-listed stocks, and the differences in means and medians. Panel A suggests that for all four HFT proxies, cross-listed stocks have significantly higher levels of HFT activity, i.e. AT and QIT are higher, while QD and ATS are lower. Both the mean and median differences are statistically significant at the 1% level. These results confirm the plots in Figure 1 that show stronger HFT presence for CL stocks.

INSERT TABLE 2 HERE

Panel B of Table 2 reports the differences in firm level variables between CL and NCL stocks. We observe that trading activity (number of trades) is higher for CL stocks, but lower in terms of size, indicating that CL stocks attract more but smaller-sized trades. Bid-ask spreads (both quoted and effective spreads) are lower, indicating lower costs of trading. Realized volatility in returns is also much lower for the CL stocks. In terms of limit order depths (in dollar), CL stocks seem to have greater supply. Finally, the order imbalance is significantly higher for the CL stocks, indicating that there are more trades executed on the buy-side of the order book.

Changes in HFT activity could be due to various factors, including changes in liquidity and volatility that occur after stocks are cross-listed abroad. To control for these factors, we conduct Fama-MacBeth multivariate regression analysis. For each year, we estimate a cross-sectional regression using daily observations for cross-listed and non-cross-listed stocks, controlling for differences in firm characteristics . The main explanatory variable is a cross-listing dummy variable that equals one for cross-listed stocks after the cross-listing event and zero otherwise. We include a number of control variables, including trading volume, inverse stock price (1/price), quoted spread, and realized volatility.

Table 3 reports the estimation results of the Fama-MacBeth regressions. Based on the estimated coefficients of the cross-listing dummy *CL*, cross-listed stocks have significantly higher levels of HFT activity for all four HFT proxies. Specifically, the *CL* coefficients for both AT and QIT are positive (3.81 and 27.24, respectively), while for QD and ATS are negative (-40.89 and -6.95, respectively). All coefficients are statistically significant at the 1%

level. These results suggest that cross-listed stocks indeed have higher level of HFT activity even after controlling for factors such as liquidity and volatility.

INSERT TABLE 3 HERE

*5.2 Analysis of HFT activity before and after the cross-listing event*

In this section, we test whether cross-listing event triggers more HFT activity for Canadian cross-listed stocks. Particularly, we compare the difference between HFT activity of CL and NCL stocks before and after the cross-listing event, that is we conduct a diff-in-diff analysis. We consider HFT activity three months before and after the cross-listing events.[10] The results of this analysis are reported in Table 4.

Panel A reports the means and the differences in HFT proxies between CL and NCL stocks during the three months period before the cross-listing event. We observe that *AT*, *QIT* and *ATS* are comparable and not significantly different for CL and NCL stocks. We do notice that in terms of quote duration *QD*, the CL group tends to have lower limit order duration than the NCL group. Panel B of Table 4 reports the HFT proxies for the three months period following the cross-listing event. Here, we observe more prominent differences between the two groups. QD and ATS are significantly lower for CL compared to NCL stocks, indicating that following the cross-listing event, limit order duration and average trade size for the CL stocks are considerably smaller relative to NCL stocks. We also observe that the difference in AT and QIT are positive, albeit statistically insignificant, indicating that potentially HFT activities for the first group are stronger.

[10] We also conduct the analyses using 6-month and 9-month event windows and find similar results. These results are available from the authors upon request.

INSERT TABLE 4 HERE

Panel C reports the diff-in-diff results. Based on the results reported in the first column, all four HFT proxies improve after cross-listing. The NCL stocks (results reported in the second column), however, do not seem to react to the cross-listing event. For instance, *QIT*, *QD* and *ATS* do not significantly differ following the cross-listing event. Only the change in *AT* proxy is positive and significant at 10% level. Finally, the third column reports the diff-in-diff estimates. After controlling for the matched stocks, we still observe significant changes in all four HFT proxies for the CL stocks. Overall, Table 4 suggests that HFT activity has increased following cross-listing to the U.S.

Figure 2 plots HFT proxies for the CL stocks around (up to a year before and after) the cross-listing event.[11] The figure shows increasing HFT activity around the cross-listing event for all four HFT proxies. We can observe profound changes in HFT proxies around the cross-listing event. Limit order duration and Average trade size decrease, while AT proxy and Quote-intensity-to-trade ratio increase – all indicating an increase in HFT after the cross-listing event.

INSERT FIGURE 2 HERE

We further test the robustness of our results using multivariate regression analysis. Specifically, we conduct a pooled regression to assess the marginal impact of cross-listing event for the CL stocks. The variable of interest is *CLPost*, which is an indicator variable for

[11]To fit the plots into one graph, the variables are normalized to have 0 mean and 1 standard deviation.

the period following the cross-listing event for the CL group. We use the normalized values of HFT proxies (with mean 0 and 1 standard deviation). We also control for analyst coverage, *Analysts* and the U.S. stock market volatility using *VIX*. We find that the coefficients are positive and significant for AT (0.4364) and QIT (0.3759), suggesting that the period after cross-listing is accompanied with higher HFT activity for the CL stocks. In terms of quote duration and average trade size, we observe that the coefficients are negative and significant (-0.4354 for *QD*, and -0.6262 for *ATS*), indicating that both the duration between limit orders and the average trade size decreased following cross-listing, i.e. HFT became more active.

INSERT TABLE 5 HERE

Figure 3 plots the estimated incremental variation between the CL and the NCL stocks (with respect to its mean, measured in standard deviations) for each HFT proxy and its 95% confidence interval. It shows patterns of increasing HFT activity around the cross-listing event for all four HFT proxies for cross-listed stocks.

INSERT FIGURE 3 HERE

*5.3. Endogeneity test*

To address a potential endogeneity, endogeneity, that is the causality between the cross-listing status and the level of HFT activity, we evaluate the changes in HFT activity of cross-listed stocks around an exogenous shock to the market. In particular, we consider the introduction of a tax on the number of market messages (e.g. trades, order submissions, cancellations and modifications) in Canada on April 1, 2012 (Malinova et al., 2018) (HFT tax hereafter). This tax was imposed by the Investment Industry Regulatory Organization of Canada (IIROC) to cope with the increasing IT costs for real-time market surveillance. As such, the IIROC assumes the position that those who generate the most costs should bear the brunt of the cost recovery fees, which in this case are the HF traders. This fee may therefore have a negative impact on HFT in Canada, making high-frequency trading in Canada and cross-market arbitrage in cross-listed stocks less lucrative. This potentially resulted in a reduction of HFT activity of Canadian cross-listed stocks.

We conduct a multivariate regression analysis using diff-in-diff model around the implementation of HFT tax on 1 April 2012. Specifically, we run pooled regressions with year fixed effects using the normalized HFT proxies. We consider the period 3 months before 1 April 2012, and 3 months after 1 May 2012. This is because even though the tax was in force since April, HFTs were only charged from May onwards (Malinova et al., 2018). The results from this analysis are reported in Table 6. Based on the coefficient estimates for Post variable (negative for QIT and positive for QD and ATS), all Canadian stocks, cross-listed and non-cross-listed experience a reduction in HFT activity following the implementation of the new tax. Based on estimates for our main variable of interest, CLPost, cross-listed stocks experience a more significant reduction in HFT than non-cross-listed stocks. In particular, the *CLPost* coefficient on *AT* is negative and statistically significant, suggesting that in the first three months after the new tax, HFT activity has decreased. Similarly, the impact on *QIT* is negative albeit statistically insignificant. Finally, the impact of *QD* and *ATS* are positive and significant, indicating that quote duration and average trade size have increased, i.e. lower HFT activity. These results provide evidence to support a causal relationship between cross-listing and HFT activity.

INSERT TABLE 6 HERE

*5.4. HFT and cross-listing channels*

So far we have shown that cross-listing is associated with an increase in HFT. In this section, we examine two potential channels of the documented increase in HFT after cross-listing: (1) increase in HFT around US news announcements and (2) increase in cross-market arbitrage. To test the first channel, we examine HFT activity around the Federal Open Market Committee (FOMC) announcements. The idea is to test whether HFT strategies rely on fast processing of news. If that is the case, then we would expect HFT activity to be higher for CL compared to NCL stocks during the FOMC announcements.

We conduct a diff-in-diff analysis between CL and NCL stocks on announcement and non-announcement days. We collect the date and time of FOMC announcements from Bloomberg. For non-announcement days, we consider two days before and two days after each FOMC release dates. We focus on the two-hour period around the news release (one hour before and another hour after).[12]

Table 7 reports the results from the diff-in-diff analysis. Panel A shows that on non-announcement days HFT activity for the CL stocks is higher than for NCL stocks. These results confirm our previous finding that HFTs are more active in the former group. Panel B reports the difference in HFT activity during FOMC announcement days. Similarly, we observe HFT activity is higher for CL stocks. Panel C reports the diff-in-diff estimates. As reported in the first column, AT, QIT and QD for CL stocks significantly differ during announcement relative to non-announcement days. These findings suggest that for CL stocks there is an increase in HFT activity during the two-hour period surrounding the FOMC announcements. In contrast, there is no significant change in HFT activity for the NCL stocks during the same period as shown in the

[12] Prior to 2013, time of these announcements vary between 12:30pm and 14:15pm (EST). Since then, these announcements are released at 14:00pm (EST).

second column. The final column reports the differences in the changes in HFT for CL and NCL stocks - positive and significant differences in AT and QIT, suggesting that cross-listed stocks experience a more significant increase in HFT activity relative to NCL stocks around the FOMC releases. This finding provides an empirical support for the first channel.

INSERT TABLE 7 HERE

The second channel we assess is the cross-market arbitrage. In particular, we test whether mispricing between the Canadian and U.S. markets lead to greater HFT activity. Menkveld (2013) examines whether HFTs' arbitrage activity across trading venues keeps prices aligned and prevents investors from observing that the same asset is being priced differently on different trading venues. If HFT strategies indeed rely on arbitrage opportunity between the two markets, then we can expect HFT activity to increase when cross-market mispricing is high.

We define stock mispricing as the sum squared (log) difference between prices in Canada and the U.S. The process goes as follows. First, we use intraday data at 1-min interval and match prices in Canada and the U.S. We use mid-quote in Canadian dollar to ensure comparability between the two prices.[13] Second, we compute the (log) difference in prices between the two price series. Third, we square these differences and aggregate them for the day. This mispricing variable is calculated for each stock pair each day.

Given that mispricing and HFT activity may have contemporaneous effects on each other, and assuming these variables exhibit persistence, their relationship can be expressed by the following SVAR:

[13] Intraday (1-min interval) CAD/USD exchange rate is obtained from TRTH.

$$AY_t = c + \sum_{l=1}^{L} \Pi_l \cdot Y_{t-l} + \varepsilon_t, \quad (1)$$

where $Y_t$ is the (3×1) vector of the stock mispricing $m_t$ and the HFT proxy for Canada and the U.S., i.e. $Y_t = (Misp_t, HFT_t^{CAN}, HFT_t^{US})'$, $\Pi_l$ is a (3×3) matrix of coefficients for the autoregressive terms for lag $l$, and $\varepsilon_t$ is a vector of error terms. Matrix $A$ captures the structural parameters and is normalized such that all diagonal elements are equal to 1, and its off-diagonal elements capture the contemporaneous interactions between the variables, i.e.,

$$A = \begin{pmatrix} 1 & a_{12} & a_{13} \\ a_{21} & 1 & a_{23} \\ a_{31} & a_{32} & 1 \end{pmatrix}.$$

The off-diagonal elements capture the interactions among the variables. For instance, $a_{12}, a_{13}$ represent the contemporaneous impact of $HFT_t^{CAN}$ and $HFT_t^{US}$ on $Misp_t$, while $a_{21}, a_{31}$ represent the contemporaneous impact of $Misp_t$ on $HFT_t^{CAN}$ and $HFT_t^{US}$.

Since the contemporaneous relations among the VAR variables are not equal, $A$ is asymmetric. Consequently, the parameters in $A$ cannot be obtained using OLS. Hence, we estimate Equation (1) using the identification through heteroskedasticity methodology of Rigobon (2003). This approach starts with transforming Equation (1) into its reduced-form below:

$$Y_t = A^{-1}c + A^{-1} \sum_{l=1}^{L} \Pi_l \cdot Y_{t-l} + A^{-1}\varepsilon_t,$$

$$Y_t = \tilde{c} + \sum_{l=1}^{L} \tilde{\Pi}_l \cdot Y_{t-l} + \tilde{\varepsilon}_t, \quad (2)$$

where the residuals $\tilde{\varepsilon}_t$ from the reduced-form VAR are related to the residuals $\varepsilon_t$ from the SVAR through the inverse of $A$. Since Equation (2) can be estimated by OLS, it serves as the basis for the heteroskedasticity identification scheme. In particular, the residuals $\tilde{\varepsilon}_t$ from Equation (2) are split into different subsamples, such that the covariance matrices under these subsamples are not proportional to each other.[14] Once the different heteroskedastic regimes have been identified, we can increase the number of available moment conditions and use them to estimate the parameters in $A$.

The SVAR results are reported in Table 8. Panel A shows the results of using $AT$ as the HFT proxy. The left-most column represents the explanatory variable while the top-most row represents the dependent variable. Turning first to the first row, we do not find $Misp_t$ to significantly affect $HFT_t^{CAN}$ and $HFT_t^{US}$ although the coefficients are positive. This indicates that mispricing between the two markets do not attract HFT activity in either markets. On the second row, we observe that an increase in $HFT_t^{CAN}$ leads to a contemporaneous increase in $HFT_t^{US}$ while on the third row, we find that an increase in $HFT_t^{US}$ leads to a contemporaneous increase in $HFT_t^{CAN}$. The impact of $HFT_t^{US}$ on $HFT_t^{CAN}$ is greater than the inverse, suggesting that HFT activity in Canada is greatly influenced by the HFT activity in the U.S. We do not observe that HFT activity in either market leads to mispricing.

INSERT TABLE 8 HERE

Panels B to D show similar results. There is evidence of contemporaneous interaction between HFT activity in Canada and the U.S., but they are not triggered by mispricing, nor do they lead to more mispricing. Similar to Panel A, we find HFT in the US has greater influence on HFT in Canada.

[14] Rigobon (2003) suggests that at least two distinct variance regimes for the error terms are required in order for the identification scheme to work.

While we do not find evidence that mispricing is related to HFT activity, we find that HFT activity in Canadian market is greatly influenced by HFT activity in the US market. Overall, the results for the cross-market arbitrage channel are inconclusive.

## 6. Conclusion

This is the first study to examine HFT activity of non-US stocks cross-listed in the US, using a significant case of Canadian stocks cross-listed on the NYSE. We use intraday trading data to estimate four measures of HFT, firm level variables and the measure of mispricing between the US and Canadian markets. We employ cross-sectional analysis, event study and diff-in-diff methodologies to provide robust evidence that cross-listing in the US leads to a significant increase in HFT in the home market. We address the issue of potential endogeneity by examining HFT of cross-listed stocks relative to non-cross-listed stocks around the introduction of HFT tax. Finally, we test empirical validity of two potential channels of the documented increase in HFT after the cross-listing. We provide evidence of a significant increase in HFT of cross-listed stocks around US news announcements. We also test cross-market arbitrage channel and find that HFT in the US market significantly increases HFT in Canadian market. However, we find no evidence that HFT activity is related to the level of mispricing between the US and Canadian markets.

The findings of this study have important implications for non-US companies that cross-list in the US or considering a cross-listing in the US; for market regulators that need to understand the extend and consequences of HFT; and for stock exchanges that compete for order flow of stocks traded in multiple markets.

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**Figure 1. HFT activity of cross-listed (CL) and matched (NCL) stocks over time**

This figure plots the average AT activity of Canadian cross-listed stocks and their (domestic) matched counterparts.

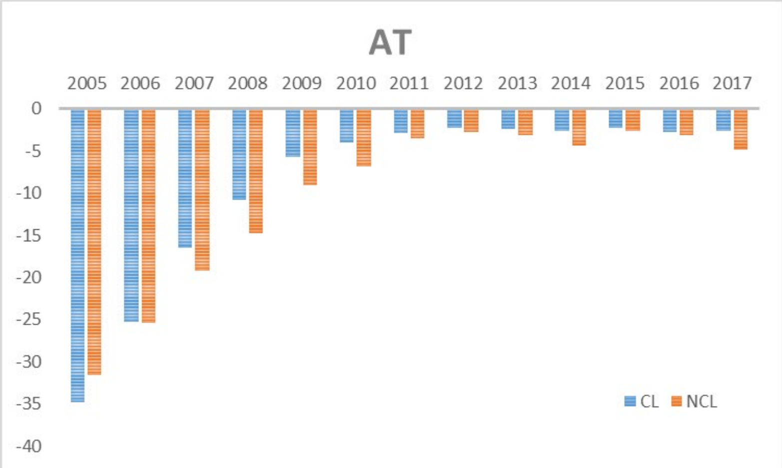



Figure 1A. AT proxy

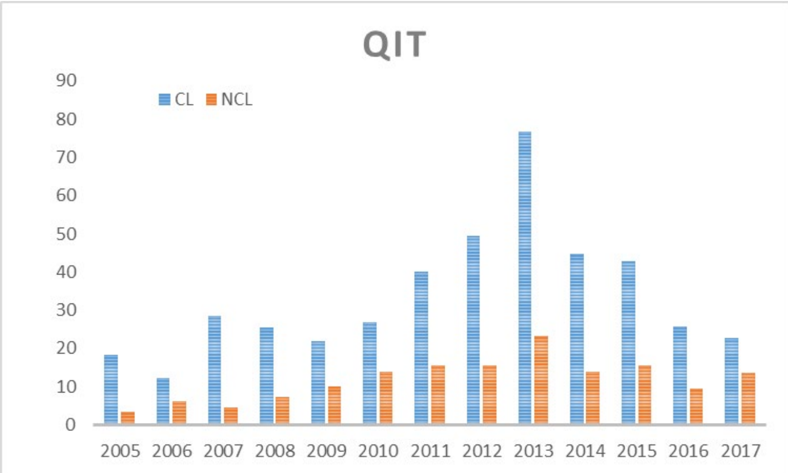



Figure 1B. Quote intensity to trade ratio

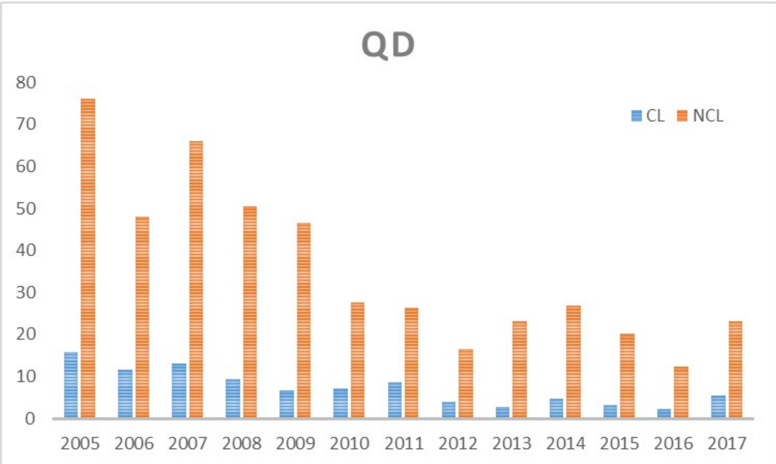



Figure 1C. Limit order duration

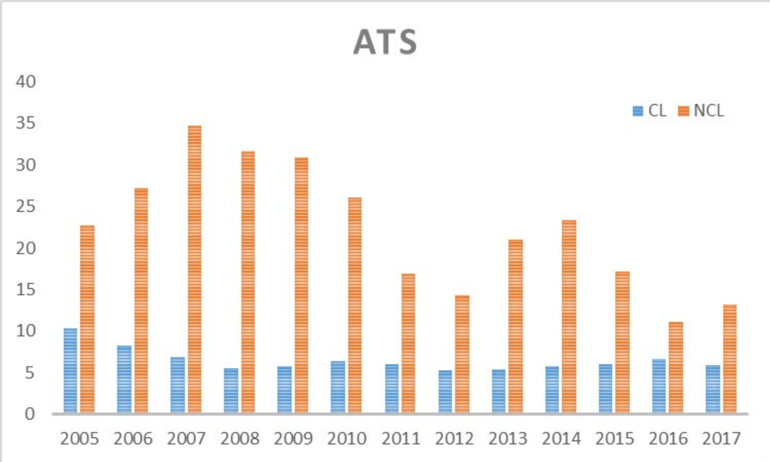
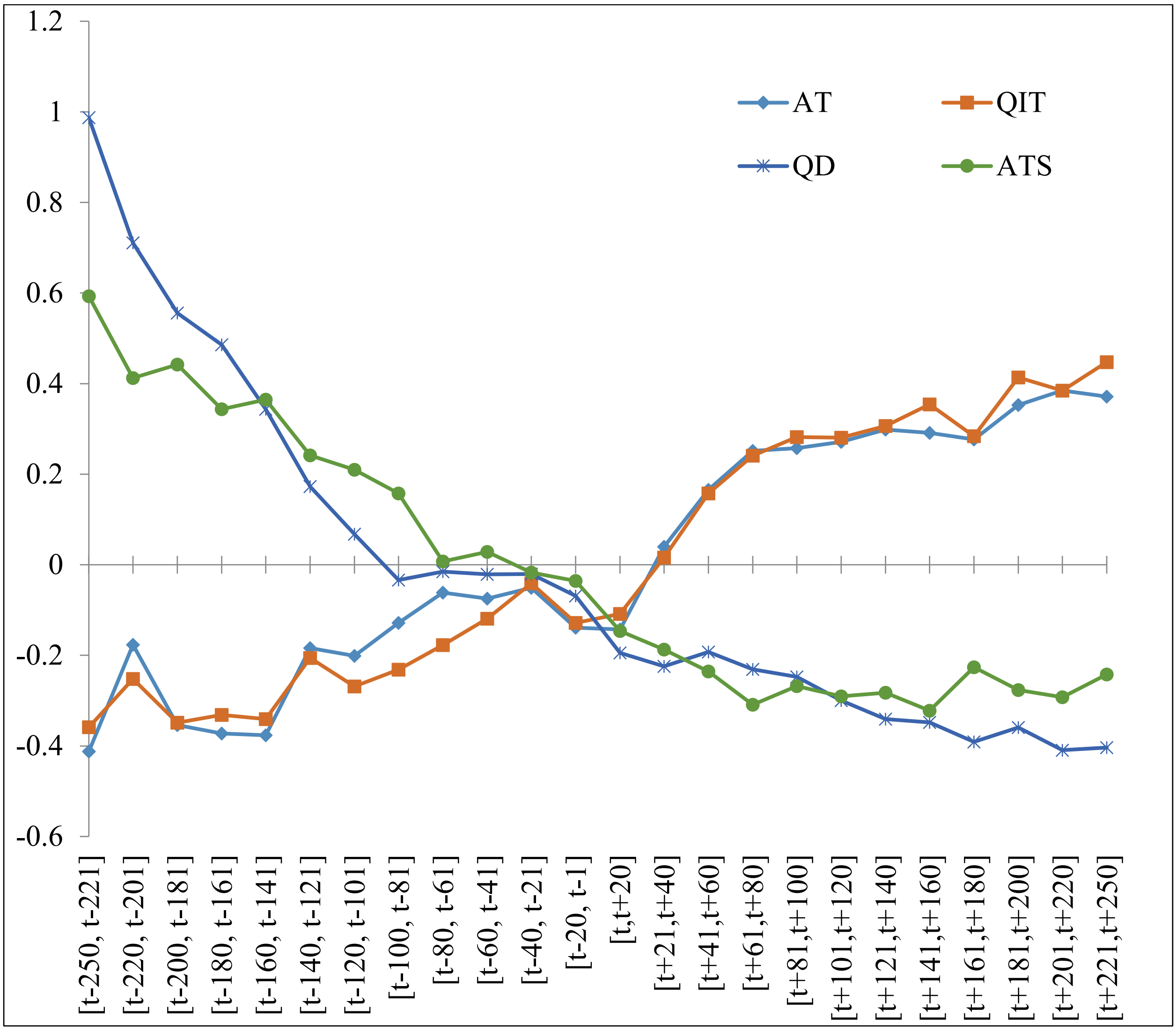


Figure 1D. Average trade size (volume per trade / 100)

**Figure 2. HFT activity of cross-listed (CL) around the cross-listing event.**



## Figure 3. HFT proxies of cross-listed (CL) vs. non-cross-listed (NCL) stocks around the cross-listing event

This figure plots the pooled regression estimates (y-axis) between CL and NCL stocks surrounding the cross-listing date (x-axis). We include the CL stocks that went cross-listed within our sample period and their matched NCL stocks. Explanatory variables are dummies per interval and interactions between those dummies and a CL dummy. We consider intervals of 60 days with an event window of 240 days before and after.

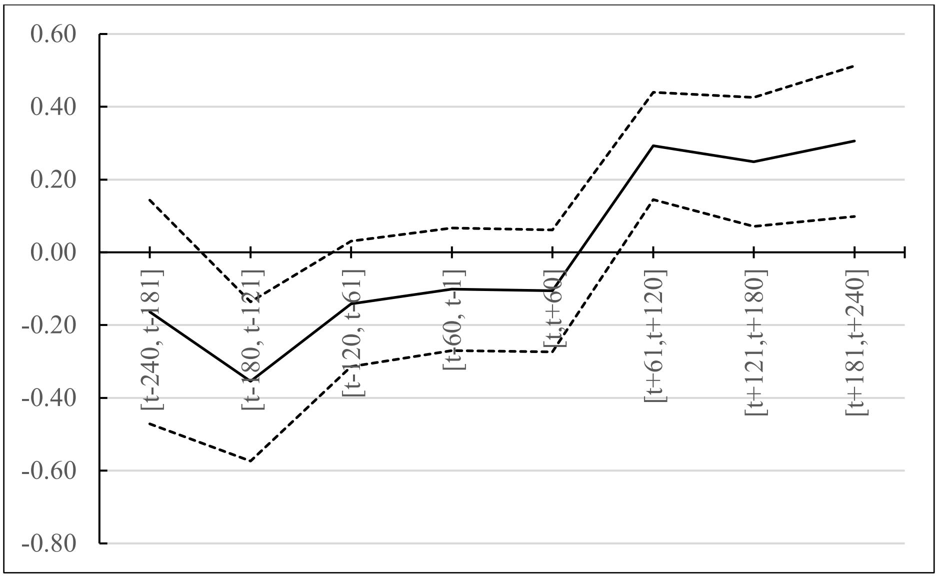



Figure 3A. AT proxy

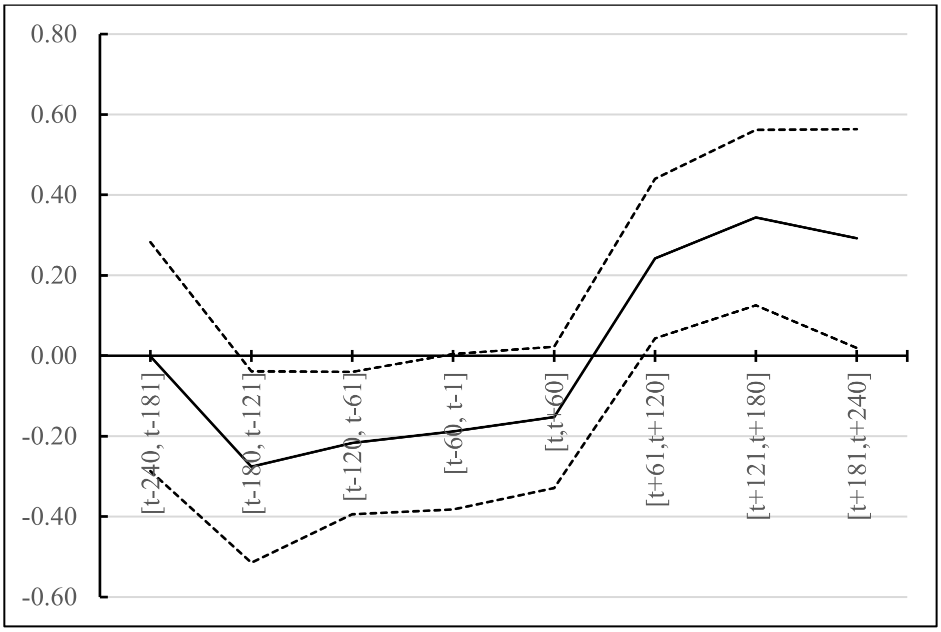



Figure 3B. Quote intensity to trade ratio

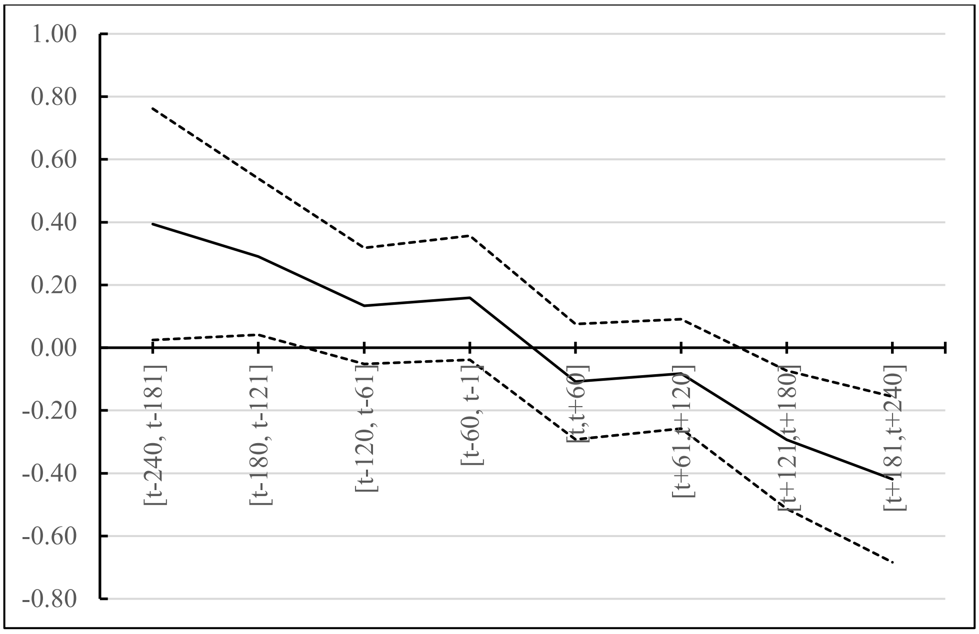



Figure 3C. Limit order duration

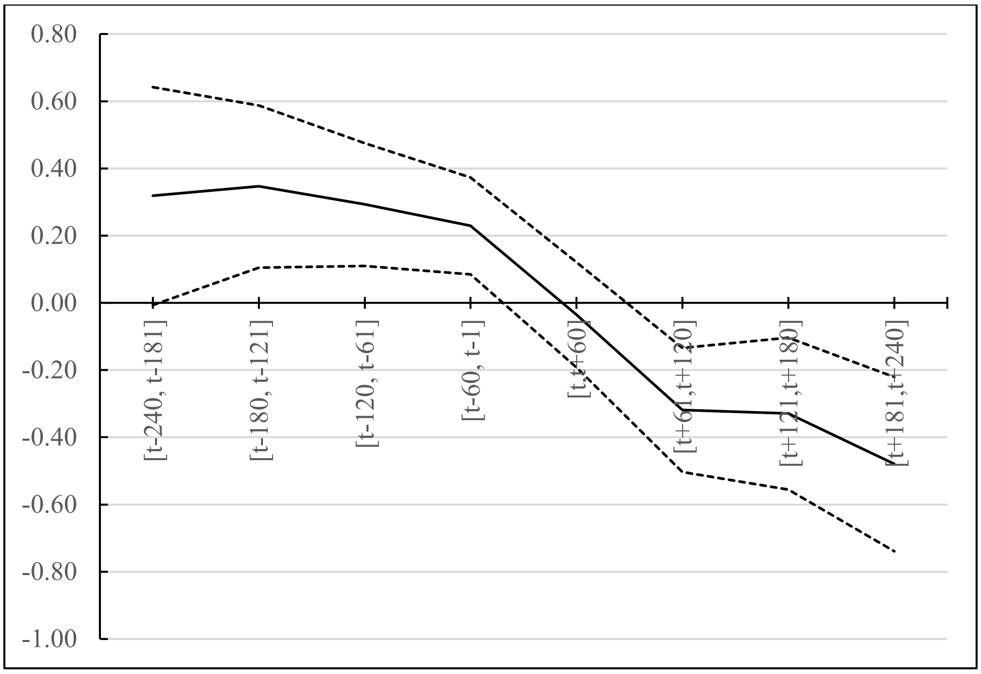



Figure 3D. Average trade size (volume per trade / 100)

**Table 1. Sample description**

This table reports the number of cross-listed and non-cross-listed stocks (NCL), and the number of cross-listing events by year

| Year | *Number of CL stocks* | *Number of NCL stocks* | *Total number of stocks* | *Number of cross-listing events* |
|---|---|---|---|---|
| 2005 | 59 | 59 | 118 | 5 |
| 2006 | 64 | 64 | 128 | 7 |
| 2007 | 65 | 65 | 130 | 4 |
| 2008 | 66 | 66 | 132 | 1 |
| 2009 | 72 | 72 | 144 | 2 |
| 2010 | 76 | 76 | 152 | 4 |
| 2011 | 85 | 85 | 170 | 4 |
| 2012 | 86 | 86 | 172 | 9 |
| 2013 | 87 | 87 | 174 | 3 |
| 2014 | 85 | 85 | 170 | 3 |
| 2015 | 82 | 82 | 164 | 3 |
| 2016 | 81 | 81 | 162 | 5 |
| 2017 | 91 | 91 | 182 | 12 |
| ***Total*** | ***999*** | ***999*** | ***1998*** | ***62*** |

**Table 2. Summary statistics for cross-listed and matched stocks**

This table reports the means for HFT proxies (Panel A) and firm level variables (Panel B) for cross-listed (CL) stocks and the matched non-cross-listed (NCL) stocks. The reported figures are calculated as averages across years and across firms. Also reported are the difference in means and medians. Figures in parenthesis is the t-statistics. ***, **, and * denote statistical significance at the 10%, 5% and 1 % level, respectively.

| | *CL* | *NCL* | *Mean Diff* | *t-stat* | *Median Diff* | *Wilcoxon* |
|---|---|---|---|---|---|---|
| Panel A: AT proxy | | | | | | |
| *AT* | -11.43 | -14.65 | 3.23*** | (5.03) | 2.95*** | (3.20) |
| *QIT* | 33.55 | 11.76 | 21.79*** | (6.17) | 19.93*** | (3.20) |
| *QD* | 15.79 | 107.38 | -91.59*** | (-7.72) | -84.61*** | (-3.16) |
| *ATS* | 6.45 | 22.33 | -15.89*** | (-7.64) | -15.75*** | (-3.16) |
| Panel B: Firm level variables | | | | | | |
| *Volume* | 1,309,671 | 1,522,202 | -212,530*** | (-3.07) | -152,965*** | (-2.67) |
| *Trade* | 2,725 | 1,382 | 1,343*** | (9.41) | 1,306*** | (3.69) |
| *Qspread* | 0.26% | 0.85% | -0.59%*** | (-7.61) | -0.55%*** | (-3.65) |
| *Espread* | 0.25% | 0.88% | -0.63%*** | (-6.01) | -0.58%*** | (-3.65) |
| *RV* | 0.0011 | 0.0020 | -0.0009*** | (-3.13) | -0.0006*** | (-3.16) |

**Table 3. Fama-MacBeth regression results**

This table reports mean coefficients estimates from cross-sectional regressions estimated for each year and the Fama-Macbeth t-statistics. *CL* is a cross-listing dummy variable which equals 1 for cross-listed and 0 for matched non-cross-listed stocks. The control variables are trading volume, 1/price, quoted spread, and realized volatility.

| | *Dependent Variable* | | | |
|---|---|---|---|---|
| | *AT* | *QIT* | *QD* | *ATS* |
| *Constant* | -14.10*** | 11.80*** | 48.91*** | 8.08*** |
| | (-3.48) | (8.07) | (4.79) | (6.19) |
| *CL* | 3.81*** | 27.24*** | -40.89*** | -6.95*** |
| | (5.48) | (5.59) | (-6.57) | (-5.58) |
| *VOLUME* | -0.02** | -0.03*** | -0.08*** | 0.03*** |
| | (-2.44) | (-5.80) | (-4.18) | (4.75) |
| *1/PRICE* | 1.46** | -18.71*** | 38.32*** | 14.87*** |
| | (2.33) | (-3.70) | (3.20) | (9.01) |
| *QSPREAD* | 0.22 | 20.99*** | 57.20*** | 1.13*** |
| | (1.02) | (3.29) | (8.10) | (2.77) |
| *RV* | 0.54** | -2.51 | -35.41*** | 1.11* |
| | (2.50) | (-1.60) | (-2.78) | (1.93) |
| Obs | 37895 | 37895 | 37895 | 37895 |
| Adj. R-squared | 0.06 | 0.01 | 0.32 | 0.31 |
| F-statistic | 446 | 85 | 3657 | 3449 |

**Table 4. HFT measures of cross-listed stocks before and after the cross-listing event**

This table reports the HFT proxies for cross-listed (CL) and the matched non-cross-listed (NCL) stocks 3 months before (Panel A) and after cross-listing (Panel B), and the difference (Panel C). The reported figures are calculated as averages across firms. Also reported are the difference in mean. Figures in parenthesis is the t-statistics. ***, **, and * denote statistical significance at the 10%, 5% and 1 % level, respectively.

| | *CL* | | *NCL* | | *Mean Diff* | *t-stat* |
|---|---|---|---|---|---|---|
| Panel A: 3-mth before | | | | | | |
| *AT* | -14.04 | | -13.49 | | -0.55 | (-0.21) |
| *QIT* | 8.19 | | 10.29 | | -2.10 | (-1.15) |
| *QD* | 19.08 | | 50.63 | | -31.55** | (-2.01) |
| *ATS* | 5.70 | | 8.32 | | -2.61 | (-1.36)) |
| Panel B: 3-mth after | | | | | | |
| *AT* | -10.29 | | -11.62 | | 2.92 | (1.56) |
| *QIT* | 11.68 | | 11.83 | | 1.32 | (0.45) |
| *QD* | 13.27 | | 53.75 | | -40.48** | (-2.54) |
| *ATS* | 3.62 | | 8.24 | | -4.62*** | (-2.60) |
| Panel C: After less before | | | | | | |
| *AT* | 3.75*** | (2.78) | 1.87* | (1.87) | 1.88* | (1.90) |
| *QIT* | 3.49** | (2.08) | 1.55 | (1.06) | 3.08* | (1.88) |
| *QD* | -5.81* | (-1.75) | 3.11 | (1.06) | -8.81** | (-2.21) |
| *ATS* | -2.08** | (-2.44) | -0.08 | (-0.23) | -2.01** | (-2.03) |

**Table 5. Multivariate analysis of cross-listing events**

This table reports the multivariate regression coefficients surrounding the cross-listing events, for a 360-day event window around the cross-listing event. ***, **, * denote statistical significance at the 1%, 5%, and 10% level respectively

| Coef. | *AT* | | *QIT* | | *QD* | | *ATS* | |
|---|---|---|---|---|---|---|---|---|
| *Intercept* | -0.2325 | * | -0.2305 | | 0.4031 | *** | 0.2168 | |
| *CLPost* | 0.4364 | *** | 0.3759 | ** | -0.4354 | *** | -0.6262 | *** |
| *CL* | -0.2404 | *** | -0.2331 | ** | 0.2988 | *** | 0.3931 | *** |
| *Post* | 0.2057 | * | 0.0943 | | -0.3986 | *** | 0.0658 | |
| *Analysts* | -0.0217 | | 0.0919 | ** | -0.1316 | *** | -0.1485 | *** |
| *VIX* | 0.0107 | *** | 0.0033 | | -0.0037 | | -0.0033 | |
| | | | | | | | | |
| Obs. | 25948 | | 25948 | | 25948 | | 25948 | |
| Adj. R2 | 0.067 | | 0.0386 | | 0.1454 | | 0.0628 | |
| F | 17.4631 | | 6.4024 | | 31.2072 | | 12.8671 | |

**Table 6. Multivariate analysis of HFT Tax (April 1, 2012)**

This table reports the multivariate regression coefficients of diff-in-diff model around the implementation of HFT tax (message fee) on 1 April 2012. We consider the period 3 months before 1 April 2012, and 3 months after 1 May 2012. This is because even though the tax was in force since April, HFTs were only charged from May onwards (Malinova et al., 2018).

| Coef. | *AT* | | *QIT* | | *QD* | | *ATS* | |
|---|---|---|---|---|---|---|---|---|
| *Intercept* | 11.0655 | *** | 6.8471 | *** | 7.9157 | *** | -12.315 | *** |
| *Post* | 0.142 | *** | -0.0459 | ** | 0.1162 | *** | 0.0611 | *** |
| *CLPost* | -0.2348 | *** | -0.0360 | | 0.0931 | *** | 0.1167 | *** |
| *LogVolume* | 0.2595 | *** | -0.1523 | *** | 0.1579 | *** | -0.1827 | *** |
| *RSpread* | -0.8906 | *** | -0.4894 | *** | -0.5910 | *** | 0.9638 | *** |
| *Analysts* | -0.0012 | *** | 0.0008 | ** | -0.0011 | *** | 0.0055 | *** |
| *VIX* | 0.0166 | *** | 0.0034 | | -0.0239 | *** | -0.0205 | *** |
| | | | | | | | | |
| Obs. | 19443 | | 19443 | | 19443 | | 19443 | |
| Adj. R2 | 0.3504 | | 0.0997 | | 0.1801 | | 0.3844 | |
| F | 1774.85 | | 386.10 | | 739.23 | | 2050.39 | |

**Table 7. HFT activity surrounding the FOMC announcements**

This table reports the means of HFT proxies for cross-listed (CL) and the matched non-cross-listed (NCL) stocks during the two hours period on non-announcement days (Panel A), two hours period surrounding the FOMC announcements (Panel B), and their differences (Panel C). The reported figures are calculated as averages across firms. Also reported are the differences in means. Figures in parenthesis is the t-statistics. ***, **, and * denote statistical significance at the 10%, 5% and 1 % level, respectively.

| | *CL* | | *NCL* | | *Mean Diff* | *t-stat* |
|---|---|---|---|---|---|---|
| Panel A: Non-announcement days | | | | | | |
| *AT* | -12.55 | | -15.46 | | 2.91*** | (7.07) |
| *QIT* | 19.00 | | 8.47 | | 10.54*** | (15.53) |
| *QD* | 7.23 | | 38.43 | | -31.20*** | (-14.74) |
| *ATS* | 3.50 | | 10.85 | | -7.36*** | (-15.29) |
| Panel B: Announcement days | | | | | | |
| *AT* | -10.77 | | -15.35 | | 4.57*** | (5.36) |
| *QIT* | 22.87 | | 8.81 | | 14.05*** | (11.23) |
| *QD* | 6.30 | | 38.13 | | -31.83*** | (-13.33) |
| *ATS* | 3.42 | | 10.98 | | -7.57*** | (-11.68) |
| Panel C: Announcement less non-announcement days | | | | | | |
| *AT* | 1.78*** | (3.88) | 0.12 | (0.14) | 1.66* | (1.70) |
| *QIT* | 3.86*** | (3.33) | 0.35 | (1.12) | 3.51*** | (3.01) |
| *QD* | -0.93** | (-2.04) | -0.30 | (-0.18) | -0.63 | (-0.41) |
| *ATS* | -0.08 | (-0.97) | 0.13 | (0.24) | -0.21 | (-0.39) |

**Table 8. Relations between HFT activity and mispricing of stocks**

This table reports the coefficients for the contemporaneous interactions between stock mispricing $m_t$ and HFT activity in Canada and in the U.S. Mispricing is defined as the sum squared (log) difference between prices in Canada and the U.S. computed using data at 1-min frequency. Note that the coefficients in this table have the opposite signs to the coefficients of matrix $A$ because matrix $A$ is on the left-hand side of Eq. (1); when taken to the right-hand side, the effects become the opposite. The column variable is the dependent variable while the row variable is the explanatory variable. Panel A reports the results for *AT*, Panel B reports the results for *QIT*, Panel C reports the results for *QD* and Panel D reports the results for *ATS*. Figures in parentheses are the Newey-West adjusted t-statistics. *, **, and *** denote significance at the 10%, 5% and 1% level, respectively.

| | Dependent Variable | | |
|---|---|---|---|
| | Mispricing | HFT_CAN | HFT_US |
| Panel A: *AT* as HFT proxy | | | |
| $Misp_t$ | -1 | 0.023 | 0.002 |
| | | (1.22) | (0.31) |
| $HFT_t^{CAN}$ | -0.006 | -1 | 0.024** |
| | (-0.19) | | (2.39) |
| $HFT_t^{US}$ | -0.182 | 1.351*** | -1 |
| | (-1.32) | (2.75) | |
| Panel B: *QIT* as HFT proxy | | | |
| $Misp_t$ | -1 | 0.435 | 0.340 |
| | | (0.99) | (1.21) |
| $HFT_t^{CAN}$ | -0.085 | -1 | 0.174*** |
| | (-0.92) | | (2.84) |
| $HFT_t^{US}$ | -0.057 | 1.050*** | -1 |
| | (-0.83) | (3.44) | |
| Panel C: *QD* as HFT proxy | | | |
| $Misp_t$ | -1 | -0.029 | -0.002 |
| | | (-1.21) | (-0.52) |
| $HFT_t^{CAN}$ | 0.043 | -1 | 0.456*** |
| | (0.39) | | (4.87) |
| $HFT_t^{US}$ | 1.255 | 0.476*** | -1 |
| | (0.94) | (5.36) | |
| Panel D: *ATS* as HFT proxy | | | |
| $Misp_t$ | -1 | 0.005 | 0.002 |
| | | (0.82) | (1.59) |
| $HFT_t^{CAN}$ | 0.023 | -1 | 0.008*** |
| | (0.76) | | (3.67) |
| $HFT_t^{US}$ | 0.181 | 0.694** | -1 |
| | (0.64) | (2.46) | |