Forming an orderly line — How queue-jumping drives market fragmentation

This version: May 2021

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ABSTRACT

We identify queue-jumping as a key mechanism that causes trading activity to fragment. We use the introduction (and partial removal) of the Order Protection Rule, which enforces strict inter-venue price (but not time) priority and encourages market fragmentation. We show fragmentation occurs because liquidity providers increasingly apportion their activities across alternative venues, attempting to jump long queues on larger venues by increasing submissions to venues with short (or empty) queues. Such activity reduces adverse selection costs on the alternative venues. Our findings help explain the acceleration of fragmentation in markets with trade-through prohibitions, as compared to best execution requirements, providing clear policy considerations for the evolving structure of global marketplaces.

Keywords: Liquidity; Fragmentation; Trade-Through Prohibition; Segmentation; Connectivity

JEL Codes: G10; G20

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When the SEC approved Regulation NMS in 2005, it could not have envisioned that 14 years later there would be 13 active equity exchanges, with a 14th recently approved, and two more rumored in the works, as well as more than 30 alternative trading systems.

- SIFMA Market Structure conference 2019[1]

1. Introduction

Fragmentation is perhaps the most prominent structural change to occur in equity markets over the past decade, with the number of trading venues in the U.S. alone increasing from 26 in 2002 to more than 80 in 2019.[2] In particular, there has been a proliferation of 'micro-exchanges' in North America, trading venues which execute less than 2% of total market volume, with about 10% of exchange traded volume in the US in 2019 occurring in such venues. The existence of excess fragmentation has raised concerns for both market quality and fairness; creating a cost burden through excessive fees for end users; and heightened concerns amongst regulators. SEC Chairman Mary Jo White, for example, identified 'excess fragmentation' as a major concern in modern market structure.[3]

Many studies have considered the impacts of fragmentation, with more recent empirical evidence suggesting that fragmentation does not harm market quality, rather more fragmented stocks experience improved market efficiency but suffer higher short term volatility (O'Hara and Ye, 2011). Related literature has also argued that both regulation and trader preferences may drive fragmentation (e.g. Madhavan, 1995, Chao, Chen, and Ye, 2018). Many cite Reg NMS as having facilitated fragmentation. Most recently, SEC Commissioner Elad Roisman suggested that the Order Protection Rule should be revisited in light of the rapid growth in the number of exchanges.[4]

The Order Protection Rule, or OPR (also known as the 'trade-through rule'), specifically Reg NMS Rule 611 in the U.S. and the Order Protection Rule in Canada,[5] eliminates the potential for orders on different markets to trade at suboptimal prices. This forces market centres to route trades to alternate venues if better prices exist, no matter how small the quoted quantity.[6] However, the

[1] `https://www.sec.gov/news/speech/roisman-remarks-sifma-equity-market-structure-conference-091919`

[2] `https://business.nasdaq.com/media/Nasdaq_TotalMarkets_2019_tcm5044-69828.pdf`

[3] `https://www.sec.gov/news/speech/2014-spch060514mjw`

[4] `https://tabbforum.com/opinions/exchange-landscape-gearing-up-for-expansion-in-2020/`

[5] The trade-through prohibition was introduced with the purpose of linking the markets together to create virtual consolidation (O'Hara and Ye, 2011), but the industry and literature also recognized fragmentation as an unintended consequence of this rule.

[6] The SEC recently re-opened the discussion around the trade-through rule in a meeting of the Equity Market Structure Advisory Committee in 2017 Committee (2017), citing concerns of market fragmentation. In the recent TotalMarkets release by NASDAQ in April 2019, to stem costs of fragmentation it was proposed that venues that do not trade adequate volume be removed from the protection of the trade-through prohibition. This step was taken

mechanism by which this occurs, or how traders go about fragmenting markets remains unexplained. We show that a key reason markets fragment is the desire of traders to jump long queues on primary exchanges. We further show that such orders experience reduced transaction costs and adverse selection. This is consistent with Degryse and Karagiannis' (2018) model of order preferencing and execution probability. While queue jumping may arise endogenously, the trade-through rule increases the likelihood of execution, as even small orders on alternate venues cannot be 'ignored' by traders. As market orders can be either pro-rata or randomly distributed across exchanges at a certain limit order price, the submission of limit orders at the front of an alternate venue now have a strictly higher probability of execution. If a large market order arrives, they will now be executed in either case, while if a smart order router chooses the alternate exchange, they execute before the long line on the primary exchange. The reduction in transaction costs for the queue jumpers is to the detriment of the orders at the back of the queue on the primary exchange, which experience increased costs, as measured by effective spreads.[7]

The queue-jumping mechanism was first identified by Foucault and Menkveld (2008), where absent time priority across venues, liquidity providers jumped long queues on primary exchanges by submitting limit orders to alternative venues with shorter queues. However, the extent, drivers and impacts of such queue-jumping have not been empirically documented. Further, the extant literature mostly considers that order preferencing occurs because different trading venues provide differentiated services, seeking to serve certain classes of market participants (see for example Foucault and Menkveld, 2008 and Menkveld, 2013). We also differentiate from this literature in showing that the queue-jumping incentive does *not* rely on heterogeneity across venues, whereby even a new venue entrant that is an exact replica of the incumbent can still attract significant market activity because of traders' queue-jumping incentives.

To explore whether queue-jumping is a mechanism by which fragmentation occurs, one needs to overcome three challenges. First, it is necessary to exploit a setting where we can observe fragmentation occurring. The introduction of new trading venues or smart order routers, while facilitating potential fragmentation, in isolation do not necessarily cause traders to fragment their orders. Rather, an exogenous event needs to be identified following which traders move orders to alternative venues. Foucault and Menkveld (2008) identify this as a 'chicken and egg' problem in their use of smart order router introductions to proxy for reductions in trade-throughs, pointing out that

by the Canadian regulator (CSA) in 2016 when the market share threshold was set at 2.5%, providing a test case for EMSAC. Securities Industry and Financial Markets Association (SIFMA) has also submitted to the EMSAC, suggesting an order volume threshold be implemented for the trade-through prohibition.

[7]It is important to clarify here that while the proliferation of exchanges facilitates fragmentation, it does not cause fragmentation per se. Fragmentation of trades only occurs *when* traders elect to *provide* liquidity at other trading venues, rather than when new venues simply become available.

introducing smart routers will not result in their use unless an adequate number of counterparties are already using them. This can act as a barrier to entry for new venues. Consistent with Degryse and Karagiannis (2018), empty queues at alternative venues were less likely to attract liquidity providers until after the introduction of the trade-through rule, which provided queue jumpers with ex-ante expectations of higher execution probability, as market orders are forced to execute at the best price at all venues prior to moving to the next best price at any venue. Second, regulatory events that cause fragmentation may be introduced simultaneously with other regulatory initiatives. For example, Reg NMS 611 was introduced in the U.S. alongside changes to other rules, including the access rule, sub-penny rule etc, likely contaminating any analysis of fragmentation around that event. Third, to observe brokers routing decisions (particularly to non-central markets) one needs detailed order level data across trading venues, at high frequency, and at the broker level. Such data has been typically unavailable for U.S. markets.

In this paper, we address these three challenges by examining the extent of quote matching on Canadian equity trading venues around the introduction (and subsequent partial removal) of the trade-through rule. The trade-through rule has been recognised by regulators and academics alike as a possible cause of fragmentation (O'Hara and Ye, 2011). We exploit the introduction of the trade-through rule in Canada, both because its introduction did not coincide with any other regulatory initiatives, and because Canada experienced both the introduction and partial removal of the trade-through rule, allowing us to also study trader behaviour around its removal from a small venue. The Canadian market is structurally similar to U.S. markets, particularly with respect to the Order Protection Rule, the growth in fragmentation, and fee structures (see for example, Malinova and Park, 2015). Crucially, Canadian broker identified transaction-level data allows us to observe transactions by individual brokers around the introduction of the trade-through rule.

Given this setting, our empirical analysis proceeds in four steps. First we provide evidence that the introduction of the trade-through rule caused the fragmentation of trading. After the introduction of the trade-through rule, trading activities on alternative venues increased significantly and our measure of trade dispersion across venues also significantly increased. Second, we examine the impact of the trade-through rule on Canadian market quality, and find results consistent with evidence from the U.S. markets (e.g. Hendershott and Jones, 2005 and Battalio, Hatch, and Jennings, 2004); we find that NBBO depth improves, while quoted spreads and transaction costs decrease for the market as a whole. We also provide new evidence that this effect is the strongest for smaller venues. Using pre-period measures of quote length, we find that the observed effects are strongest for stock-venues with shorter existing queues or fewer connected brokers, particularly venues with little or no queue, where the top of queue position is the most valuable. While alternative venues were already being used before the introduction of trade-through prohibition as a means of jumping queues at the primary venue, the trade-through rule increases the probability of queue jumping, and also results in queue jumping even when queues at the primary venue are relatively short. Third, the removal of the trade-through prohibition from certain venues in 2016 provides the opportunity to examine the opposite test to that of the introduction. We find the impact of the reversal on both the affected venue and at the NBBO level are marginally significant, suggesting that most liquidity remains on smaller venues once brokers are connected to the fragmented venues, implying a fixed cost to connectivity. Finally, we demonstrate the mechanism by which brokers routing behaviour fragments markets. We consider situations when each venue joins the queue at the NBBO level, computing a variety of novel metrics each time a new 'NBBO queue' is created. We find that venues with the shortest existing queues more frequently join the NBBO queue and do so more quickly after the introduction of the trade-through rule.

Although the trade-through prohibition facilitates liquidity providers to jump the NBBO queue, it does not force them to use the shorter queues. Therefore marginal benefits must be attributed from utilizing those queues. We examine the motivation for queue-jumping, documenting execution costs faced by individual brokers as a result of queue-jumping. We find that brokers that queue-jump most frequently under the trade-through rule reduce both adverse selection and execution costs i.e. effective spreads. We show that limit orders resting at the back of short queues on alternative venues face lower adverse selection costs when compared to orders at the back of long queues on the primary exchange. This also implies that orders at the back of the queue on the primary exchange were disadvantaged by the queue-jumpers, incurring greater overall adverse selection costs. We find that liquidity providers increasing their usage of the short queues on alternative venues experience about five times greater reduction in adverse selection costs. This finding is consistent with Van Kervel (2015), where price impact is linearly increasing in the size of incoming market orders. It is also comparable to the "soft-competition" modelled in Degryse and Karagiannis (2018), where placing a limit order at the front of the queue on an alternative venue is weakly preffered to posting at the back of the queue on the primary venue.

Our key contribution, both to the literature and policy debates, is that we provide compelling evidence that queue-jumping is a mechanism which promotes fragmentation. We show that fragmentation can result from an increase in queue jumping driven by exogenous regulation, rather than being driven by differentiated services offered by new venues. We also establish that the introduction of the trade-through prohibition tends to improve market quality, particularly for smaller venues. Further, we show that once a fragmented market structure exists, the removal of such protection has a dampened impact, due to existing broker connectivity. By way of queue-jumping, we seek to answer the question posed by Stoll (2001) on whether price priority across venues alone would entice liquidity onto smaller venues. Additionally, from a policy perspective, while a trade-through rule tends to benefit liquidity in the short-term, an unintended consequence over the long-term is the proliferation of small venues, particularly when brokers are forced to 'check' liquidity on increasing numbers of smaller venues prior to trading, especially when this requires brokers to consume costly data fees from these exchanges. This coincides with anecdotal evidence of an increasing influence of micro-exchanges from countries with trade-through prohibitions such as the U.S. and Canada, whereas this is not the case for jurisdictions where trade occurs according to "best execution" rules, such as Europe, Australia and Asia. In addition, we find that introducing trade-through rule thresholds, once established, is generally not detrimental to overall market quality. This implies that policy initiatives such as trade-through prohibitions might be used as a temporary solution to introduce competition into the market. If we view the competitive market consisting of multiple exchanges and a monopoly exchange as two potential equilibriums in a coordination game, this policy helps the market to reach the competitive equilibrium. Our findings provide valuable evidence in the current regulatory debate surrounding the future of the trade-through prohibition in the U.S. and document that there are limits to the beneficial impact of additional trading venues, with incremental benefits diminishing as additional venues are added.

The rest of the paper is organised as follows. Section 2 explains the queue-jumping mechanism and develops testable hypotheses. Section 3 provides the methodology and description of the sample. Section 4 presents our findings, while section 5 concludes the paper, exploring future research directions and policy implications.

2. OPR, Queue-Jumping, and Hypotheses

2.1. Current Fragmentation in the Marketplace

The current level of fragmentation has evolved over the course of more than 10 years in both the U.S. and Canada. Anecdotally, the establishment of new venues accelerated after the 2006 implementation of Reg NMS the U.S. and the Canadian trade-through rule in 2011. Fig.1 shows the number of small venues, being those with market shares below 2.5%, whilst Fig. 2 shows the growth of the total market share attributable to these small venues.

[Insert Fig 1A here]

The number of venues with market share at or below 2.5% also grew significantly in recent years.

[Insert Fig 1B here]

The early literature argued that liquidity naturally consolidates as 'liquidity begets liquidity'. Paradoxically, fragmentation has been a long-existing feature of the modern market. Numerous reasons have been suggested as potential causes. Harris (1993) argues that traders might prefer different venues depending on their level of sophistication and trading motives. Pagano's (1989) model shows that a stable equilibrium does not exist when trading venues offer differentiated liquidity and trading costs, while Degryse, Van Achter, and Wuyts (2021) show that fees and execution probability can also drive such fragmentation. In Chowdhry and Nanda (1991), when investors are allowed to split trades between venues, fragmentation can exist. Speed (and its acquisition) can also drive fragmentation, according to Huang and Yueshen (2020). In Parlour and Seppi (2003), multiple venues co-exist when liquidity providers have heterogeneous costs. Stoll (2001) and Bessembinder (2003) held the view that when price priority and time priority are enforced, it contributes to fragmentation because orders need to be sent to small markets with low liquidity if better prices are quoted.

The role of regulation in the fragmentation of markets is also unclear. Madhavan (1995) argues that fragmentation would occur if trade disclosure rules were not mandatory but would remain consolidated otherwise. Chao, Chen, and Ye (2018) suggest discrete tick sizes may cause fragmentation and Kwan, Masulis, and McInish (2015) considered Reg NMS Rule 612 on tick sizes as a cause for the growth of dark trading venues. O'Hara and Ye (2011) have pointed to OPR impacting the fragmentation of equity trading, while Blume (2007) argues that such a rule might concentrate liquidity back towards the primary exchange. Pagnotta and Philippon (2018) conjectured that price protection could lead to excessive fragmentation in equity market, but from a speed competition point of view.

Regarding whether fragmentation impacts market quality, findings have been mixed. Earlier theoretical papers including Amihud and Mendelson (1987) suggest markets may benefit from fragmentation, while Pagano (1989), Chowdhry and Nanda (1991), Madhavan (1995), and Brolley (2020) propose the opposite. Empirically, Gajewski and Gresse (2007) and Amihud, Lauterbach, and Mendelson (2003) suggest consolidated markets benefit market quality, and Menkveld and Yueshen (2019) show that fragmentation can increase crash risk in markets. Several empirical studies have found that fragmentation improves market quality, including Battalio (1997), Boehmer and Boehmer (2003) and Foucault and Menkveld (2008). Chen and Duffie (2021) conjectures that fragmentation can improve welfare by encouraging informed traders to become more aggressive, increasing price informativeness across virtually consolidated venues.[8] Babus and Parlatore (2021) show that a fragmented market structure is an equilibrium when disagreement among investors is low and that only dealers and not investors may benefit from fragmentation in dealer markets, which is not inconsistent with only limit order providers benefiting from fragmentation in order driven markets as described in this paper. For reviews on this topic, see for example Gomber, Sagade, Theissen, Weber, and Westheide (2017), and Abergel, Bouchaud, Foucault, Lehalle, and Rosenbaum (2012).

[8] Trade-through prohibition does not eliminate cross-exchange latency in our context.

However, in recent years, we have witnessed the proliferation of new small venues. While the initial increase in competition brought benefits to the market as a whole, we find the marginal benefit for overall market quality of an additional venue to be diminishing in the level of competition, at least in the Canadian context.

[Insert Fig 2 here]

The grey bar in Fig.2 indicates the decrease in NBBO quoted spreads for the TSX60 after each venue launch (the venues are ordered in time sequence over the last 10 years. As we can see, the improvement in spreads becomes smaller and less statistically significant with every additional venue launched, with the fifth new venue (TMX's launch in 2011) actually increasing NBBO quoted spread. In addition, the change in quoted spread is not mechanical, as it does not necessarily coincide with any changes in primary exchange fees.[9]

2.2. The Trade-Through Rule

In a review of U.S. market structure, O'Hara and Ye (2011) considered the current equity marketplace as one which is 'virtually consolidated' with each exchange representing an additional point of entry. This was one of the motivations for introducing the trade-through prohibition in the U.S. (Reg NMS 611). This rule in the U.S. coincided with the beginning of fragmentation in the Canadian marketplace. As of 2010, several alternative venues were already established in Canada and trading TSX-listed securities, including Pure Trading (GO), Alpha, and Omega. The Canadian trade-through rule was introduced on the 1st February, 2011 to 'promote linkages across venues and to ensure fairness and efficiency in the market'. Before that, all dealers were bound by the best execution obligations imposed by the Investment Industry Regulatory Organization of Canada (IIROC). The trade-through rule formalized price priority as an obligation for both traders and exchanges, where exchanges receiving market orders were required to re-route those orders to exchanges with better prices if they could not be executed at the NBBO. The rule came with a few exceptions, including Intermarket Sweep Orders (examined in Chakravarty, Jain, Upson, and Wood, 2012), odd-lots, and unintentionally locked or crossed markets.[10] One of the unique features of the Canadian rule is that it offers protection to the whole orderbook, beyond the top level.

In responding to recent debates on the trade-through rule, the Canadian Securities Commission has removed several venues from trade-through protection since the 1st of October 2016. The removal is purely based on traded value market share, with the threshold set at 2.5% of total

[9] Please see the Appendix for the evolution of primary exchange make and take fees during the period.

[10] Locked and crossed markets are evaluated in Shkilko, Van Ness, and Van Ness (2008). See Battalio, Hatch, and Jennings (2004) for an explanation of orderbook ”drilling”.

market volume. This threshold is revised every six months. In the first revision, Pure Trading (GO) was the only venue to be removed.[11]

2.3. The Impact of the Trade-Through Rule on Market Quality

Via the mechanism of queue-jumping, Foucault and Menkveld (2008) argue that trade-through prohibitions would encourage liquidity provision, enhancing depth for the whole market. However, the literature has not reached consensus as to how the trade-through rule impacts overall market quality. Stoll (2001) suggests that a strict enforcement of time and price priority across venues encourages the posting of price-improving quotes. Although, the absence of time-priority across venues might not be enough to attract liquidity onto smaller venues due to low execution probability. O'Hara and Ye (2011) also raise concerns that the lack of time priority across venues might cause quotes on small venues to be ignored.

The empirical evidence is also mixed. Battalio, Hatch, and Jennings (2004) find that prior to 2000, trade-throughs were mainly caused by the inability to obtain data on the NBBO, but trade-throughs after that are due to payment for order flow and the dominance of large existing venues. Hendershott and Jones (2005) examine the exemption from the trade through prohibition of three ETFs in the U.S., and find no significant impact on market quality or price discovery. O'Hara (2015) identifies that the trade through prohibition could have various unintended effects, such as increasing internalization.

Van Kervel (2015) models a scenario where algorithmic market makers with unique speed advantage duplicate quotes on multiple venues to take the top-of-the-queue position and subsequently cancel upon execution on any one of the venues. This way, overall quoted depth improves following the rule change, but the actual transaction costs for participants might not change.

HYPOTHESIS 1: With trade-through prohibition, there is a decrease in transaction costs measured by quoted spread and effective spreads and an increase in NBBO depth on the smaller venues. When a venue becomes unprotected, its transaction costs increase, depth decreases and price impact increases.

2.4. Queue-jumping mechanism and testable hypotheses

Existing levels of fragmentation require that brokers decide where to route orders. For market orders, the concern is not solely price, but also the availability of depth, timeliness, and information leakages. This can cause the limit orders resting on the smaller venues to be ignored.

Consider the following scenario (Fig 3A). Prior to the introduction of the trade-through prohibition, even though Pure Trading has a slightly better price compared with TSX and Alpha,

[11] Also included in our sample, Alpha exchange was excluded from the protection in September 2015 due to the introduction of a speed bump (Chen, Foley, Goldstein, and Ruf, 2017).

there is not enough existing depth to execute the whole order in its entirity. Therefore, routing the market order to Pure increases the potential execution time, risking the larger quotes fading on other venues and information leakage. In order to obtain 'best execution', it is reasonable for brokers to route solely to the larger exchanges, ignoring the existing depth on Pure Trading. However, such routing would constitute a 'trade-through' under the new regulations and would therefore be prohibited.

[Insert Fig 3A here]

Given that limit orders at the top of the book on smaller venues are less likely to be overlooked, liquidity providers can take advantage of the lack of time-priority across venues and effectively queue-jump the large venues. Consider the following scenario (Fig 3B). With respect to limit orders, if routed to the larger primary venue (TSX) with large existing depth, the time-priority rule requires that the order waits behind the existing queue prior to being executed. Alternatively, the limit order can be routed to a small venue with little or no existing queue at that same price level and be positioned at the top of the queue. This is comparable to the model by Degryse and Karagiannis (2018), where participants have a chance of gaining priorities by submitting to those empty queues, which have a non-zero probability of being executed if an order is routed to the smaller exchange. Therefore, empty queues create opportunities for 'soft competition'.

[Insert Fig 3B here]

In this way, we expect the queue-jumping activities to increase the most where the existing queues are shortest. The practical channel for small venues to survive is by having more brokers connected. Therefore we expect more brokers to connect to the smaller venues in order to take advantage of the shortest queues after the introduction of the trade through prohibition.

HYPOTHESIS 2: The improvement in liquidity is largest for shorter existing queues and more frequently empty NBBO queues.

It is important to note that the enforcement of price priority across venues itself does not force brokers to utilize less liquid venues, for brokers to queue-jump there has to be positive marginal benefit. Therefore we expect limit orders posted on smaller venues in order to queue-jump also face lower adverse selection and incur lower transaction costs for the queue-jumping brokers.

HYPOTHESIS 3: Queue-jumpers enjoy lower transaction costs and reduced adverse selection.

3. Methodology and Data

3.1. Data

We use data from Thomson Reuters Tick History (TRTH), supplied by the Securities Industry Research Centre of Asia Pacific (SIRCA). The data is millisecond-timestamped, and provides the broker ID associated with trades, as well as trade and quote price and volume data. We analyze the constituents of the TSX Composite index. We only examine stocks that continuously remained in the index during our sample period.

When examining the implementation of the trade-through prohibition, we use data from January 1, 2011 to March 1, 2011, including one month before and after the event date.[12] We include all activity at the Toronto Stock Exchange (TSX), Alpha (ALP), Pure Trading (GO), and Chi-X (CXC).[13] For the second event, the removal of the trade-through prohibition from Pure Trading, we similarly consider data one month either side of the event date, October 1, 2016 (being September 1, 2016 to November 1, 2016). The exchanges included in the sample are the Toronto Stock Exchange (TSX), Alpha (ALP), Pure Trading (GO), Chi-X (CXC), Chi-X2 (CX2) and Omega (OMG). Data for the remaining lit venues, including Lynx, Aequitas Lit and Aequitas NEO are not provided in TRTH, and therefore excluded from the analysis. However, the market share of these venues collectively is about 2.5%, meaning we capture the vast majority of market activity.[14]

In the current study, only trades and quotes from the continuous trading period are included, which differs for different exchanges. For consistency and to minimize the impact of opening and closing auctions, the first and last 15 minutes are excluded to minimize any impact from the auctions.

We use several filters to exclude potentially erroneous trades and quotes. We exclude trades and quotes when the market is locked or crossed, as locking and crossing a market is prohibited in Canada and such situations are likely to be caused by timestamp error and latency and are deemed 'economically nonsensical' (Holden and Jacobsen, 2014). Second, if a bid or ask is 0 in the data and the depth is also 0, we assume that indicates there is no available liquidity on that venue and we treat such 0 price as missing. We further exclude quotes where one or both sides of the BBO is missing when calculating spreads.

Trade direction is assigned according to the original sequence in the exchange-level database. If

[12] The 2-month sample window was chosen with the following trade-off: if the sample window is too narrow, we might not capture the change in broker behavior and the results might lack statistical power; if the sample window is too wide, the results are likely to be influenced by other factors. We also control for any influence of uncontrolled factors using a difference-in-difference setting in 2016. The impact of the rule change was literally overnight, 2 months therefore appears sufficient to capture the impact of the change.

[13] After filtering by stocks that existed and quoted both at the beginning and end of the sample period, we are left with 227 stocks in 2011.

[14] `iiroc.ca` (Accessed 6 May 2018)

a trade was executed at a price equal to or lower than the best bid of that venue it is assumed to be seller initiated and if a trade was executed at or higher than the best ask on that venue it is assumed to be a buyer initiated (O'Hara, 2015). We include instances where a trade price is outside the best bid and ask on that venue because a trade can consume multiple levels of liquidity on a venue, executing a portion at prices inferior to the best prevailing price. Normally the order book does not update until the whole trade series is executed in this case. Trades at the mid-point are excluded as they are likely to be dark-midpoint trades.[15]

3.2. Metrics

We utilize standard market microstructure metrics as well as new, customized metrics. The standard microstructure metrics include liquidity measures and market share measures.

Liquidity measures used include *Quoted Spread*, *Effective Spread*, *Realized Spread*, *Price Impact*, *Depth at NBBO*, *Depth at NBBO Levels 2 and 3*. Market share measures include *Value Share*, *NBBO Depth share* and *NBBO Time Share*. In Table 1A, we compare the mean for these metrics before and after the event. All spreads are reported in bps, attained by dividing the spread by the prevailing quote midpoint.[16]

The quantity is multiplied by the prevailing bid or ask price to arrive at the dollar value of quoted depth. The measure is averaged across alternative venues in the table. In Table 1A we also include value, volatility and price which are used as control variables.

In addition, we have calculated the following customized metrics. The descriptive statistics for these metrics before and after the introduction event are provided in Table 1B.

NBBO Depth Share measures the percentage of NBBO depth offered on each venue, where all venues sum to 100%. In our sample, the TSX provides about 62% of all depth quoted at the NBBO while the alternative venues combined share the remaining 38%. *NBBO Time Share* measures the percentage of time during a trading day that a venue quotes at the NBBO. When several venues are all at the NBBO, they are all counted, as such the sum across all venues can exceed 100%. *NBBO Depth Share* measures the distribution of the queue length at NBBO across venues, while *NBBO Time Share* measures how long the NBBO queue is being used or remains empty on each venue.

Percent Time Stale Quote measures the percentage of time during a day the best bid or best ask of a venue is more than three ticks away from the NBBO. This metric seeks to capture the cases where the queue is empty for the first three levels on a venue. This ratio is only about 1% on

[15] Results not displayed show the results are robust to the inclusion of these dark trades. For more information on dark trading in Canada see Foley and Putniņš (2016).

[16] For depth, the database records shares in board lots. For securities priced above $1 board lots are 100 shares, otherwise it represents 500 shares (there was no security priced under $0.1 in our sample).

TSX, but on the alternative venues it averages 25%.

Central to this paper is a novel measure of queue-usage to examine queue-jumping behaviour on each venue. To measure queue jumping we need to develop metrics that capture the tendency of limit order submitters to utilize alternative venues. To do this we first observe every 'new queue at NBBO', which is calculated every time a new NBBO price is created. For each of these instances, we then observe whether each venue joins the new queue (*%Match NBBO*), how long it takes before they join the queue (*%Wait Duration*) as a fraction of the time the quote remains at the best,[17] and the prevailing quoted spread on that venue when they join. *%Match NBBO* is calculated as a percentage of all NBBO quote updates for a stock-venue-day.

To capture queue-jumping behaviour when participants post liquidity of one board lot at the best bid or ask on a venue, we compute *One Lot Percentage*, which measures, for each broker's passive trades, what percentage is executed when the prevailing depth on the passive side (queue length) is a single board lot.

In conducting the broker connectivity analysis, we compute the number of brokers trading each stock on each venue, which is obtained by examining the number of unique broker IDs associated with trades. We calculate this measure for each venue, stock, and day. For each broker, we have computed the prevailing effective spread and price impact for each trade when a broker is acting as the liquidity provider. Price impact has been used extensively as a measure of 'informed trading' or adverse selection cost (see for example, Conrad, Wahal, and Xiang, 2015).

The final metric. *Back of Queue* captures situations when a trade has depleted the liquidity available at that price level. This is characterized by two features: a quote update with a less favourable price (higher for ask and lower for bid), and when the volume of the executed trade consumes the entire current depth level. We consider the price impact on the "last" orders to determine if they face differential adverse selection, over the time horizons of one second, 30 seconds and 1 minute.

4. Findings

Our empirical analysis is divided into three main sections. Section 1 examines the impact of the trade-through prohibitions introduction and subsequent removal on market quality for each venue, and at the aggregate market level. This examines not only market quality (transactions costs and depth) but also the level of trading fragmentation in the market. Section 2 provides direct evidence on what drives the queue-jumping mechanism by sub-grouping the stock-venues into quintiles based on prevailing queue length and broker connectivity before OPR introduction, demonstrating when

[17] Wait duration only considers the cases where the NBBO is improved, to avoid capturing NBBO updates caused by large orders exhausting all liquidity at the best NBBO level.

queue-jumping is most likely to occur. Section 3 provides evidence on the economic impact of the trade-through prohibition on broker transaction costs and price impact, when individual brokers are acting as liquidity providers. This importantly provides the economic intuition that underpins the queue-jumping mechanism.

4.1. Market quality impacts of OPR introduction and removal

The difference-in-means test for the standard market quality metrics pre and post both the trade-through prohibition introduction and partial removal events are provided in Table 1A.

After the introduction event in 2011, quoted spread, effective spread and price impact all decreased significantly on all venues. Depth in all first three levels saw a significant increase after the introduction. The change on the alternative venues is more significant than those on the primary venue (TSX). Similarly, trading value increased more significantly on the alternative venues post the introduction, which supports the notion that the level of fragmentation has increased. The increase in depth for the first three levels is consistent with prior literature (see Foucault and Menkveld, 2008 and Van Kervel, 2015). The narrowing of spread and increase in depth is also significant at the NBBO level, consistent with the notion that prohibiting trade-through encourages limit order submissions and improves liquidity on the marketplace as a whole.

[Insert Table 1A here]

Table 1B presents the difference in means test for our novel NBBO metrics. Both NBBO depth share and time share increased significantly on the alternative venues after the introduction of the trade-through rule, meaning both the queue length and the utilization of empty queues increased on those venues on average. For NBBO depth share, the computation of such metrics mechanically requires all venues to add to 100%, where we see TSX's percentage decrease commensurate with alternative venues' increase. This means that, for liquidity provision, the level of fragmentation among venues has increased, with liquidity provision more evenly distributed between primary and alternative venues.

NBBO time share increases significantly on alternative venues, implying the filling of previously empty queues. Meanwhile, the primary venue did not see a decrease in time share, implying increases in queue utilization on the alternative venues occur when the NBBO queue on the primary exchange has already been utilized, with the quote being matched on the alternative venues.

The proportion of stale quotes decreases by 7% on the alternative venues, which corresponds to the economically significant decrease in quoted spreads on the alternative venues of 3.9 bps on average. The increase in %Match NBBO and decrease in %Wait NBBO are also statistically and economically significant on the alternative venues, meaning those quotes are matching the NBBO more frequently and are posted more rapidly. Overall, this provides strong support for Hypothesis

1, with trade-through prohibition leading to improvements in market quality, both at the venue and NBBO level.

[Insert Table 1B here]

4.1.1. Impact of OPR introduction for alternative exchanges

These univariate findings are confirmed in the regressions in Table 2. The regression allows for an event effect and differential impacts on the primary and alternative venues. All regressions control for price, volume and volatility for that stock, as well as incorporating venue and stock fixed effects.

$$Metric_{i,v,t} = \alpha_{i,v,t} + \beta_1 Alternative_{i,v,t} \cdot OPR_{i,v,t} + Controls_{i,v,t} + \delta + \theta + \varepsilon_{i,v,t} \quad (1)$$

where α is the intercept, δ is stock fixed-effects, and θ is venue fixed-effects.

Table II shows our variable of interest (the interaction term between alternative venue and the OPR event dummy) is negative and significant at the 1% level for quoted, effective and realized spread. In economic terms, the reduction in quoted (effective) spread of 3.85(4.13)bps represents a significant reduction of 13.8(18.9)% on the pre-period means for alternative venues, reducing transactions costs significantly on these venues. These reductions in transactions costs are met with similar significant increases in quoted depth and trading activity on alternate venues. Alternative venues quote 2.71% more of the aggregate NBBO depth, are present at the NBBO 2.99% more frequently, significantly increase the dollar value of depth quoted both at the best and top three levels, have stale quotes 7.90% less frequently and attract over 2.34% more of traded volume. All differences are statistically significant at the 1% level.

[Insert Table 2 here]

4.1.2. Impact of OPR removal for one alternative exchange

In 2016, amid industry concerns about increasing data fees for exchanges with less than 1% market share, the regulator removed order protection for a single venue (GO). This event provides an opportunity to test the exogenous impact of the removal of the order protection rule from a single exchange using a difference-in-differences setting, using the removed venue as the treatment group, with the remaining venues serving as controls. The regression specification below is similar to equation (1):

$$Metric_{i,v,t} = \alpha_{i,v,t} + \beta_1 Removal_{i,v,t} + \beta_2 GO_{i,v,t} + \beta_3 Removal_{i,v,t} \cdot GO_{i,v,t} + Controls_{i,v,t} + \delta + \theta + \varepsilon_{i,v,t} \quad (2)$$

where α is the intercept, δ is stock fixed-effects, and θ is venue fixed-effects.

Table 3 presents the results of our difference-in-differences regression. The variable of interest is the interaction term between treatment exchange GO and the removal event. While quoted spreads do not significantly change, transactions costs paid by liquidity demanders on GO (effective spread) increases significantly by just under 1bps, or 10%. This coincides with a significant increase in price impact of 1.64bps (28%) and a reduction in realized spread (the reward for liquidity provision) of 0.67bps (20%). These results indicate that whilst the average reward demanded by liquidity providers does not increase significantly, after it's removal from OPR traders choose to come to GO only as an exchange of last resort, likely when they are otherwise 'clearing' a price level. This would generate near instantaneous adverse selection, resulting in increased price impact and reduced realized spread. Commensurate with this increased adverse selection, GO quotes at the NBBO 2.46% less often, with a significantly smaller share of the overall available depth and in absolute lower values across all top three levels. These reductions in the attractiveness of quoted liquidity reduces overall volume share by 0.68% as a result of the OPR removal. While these results indicate a significant deterioration in liquidity on the venue whose orders are no loner protected, the magnitude of these effects are significantly smaller than those observed for the introduction of OPR.

[Insert Table 3 here]

This supports the notion that once brokers are connected to a venue, it remains 'sticky' to the routing table, suggesting that fragmentation is not easily 'reversible'. This is consistent with fixed connectivity costs being seen as "sunk-costs" - once participants establish connections to a venue, infrastructure is not discarded simply because the venue is no longer protected.

After the removal of order protection, we observe that the number of brokers that have no liquidity-providing activity on the unprotected venue increased significantly. This is consistent with our expectation that the incentive to use unprotected venues for queue-jumping is weaker, as posting on these venues no longer means that an order necessarily joins the NBBO queue. If the order is ignored, its probability of execution is significantly diminished. However, such ex-ante expectation does not necessarily remove the need for brokers to remain connected to the smaller venues — particularly as they still need to satisfy their best-execution obligations should a better price be observed on the unprotected venue. Indeed, anecdotal evidence from brokers indicates that trading through a better price may still entail a breach of these 'best execution' requirements.

4.1.3. Impact of OPR introduction on market wide fragmentation and liquidity

We next examine changes in the aggregate (market-wide) level impacts of the OPR introduction on two key aspects: the fragmentation of trading activity, and the level of liquidity and transactions costs. This analysis uses the regression specification documented in Equation (3) below:

$$metric_{i,t} = \alpha_{i,t} + \beta_1 OPR_{i,t} + Controls_{i,t} + \delta_{i,t} + \varepsilon_{i,t} \tag{3}$$

where α is the intercept, δ represents stock fixed-effects.

We first analyze the impact of the OPR on the overall level of fragmentation - both in quoted liquidity and executed volume. We measure fragmentation using the Herfindahl index (*HHI*), which ranges from 0 (perfect competition) to 10,000 (monopoly). We calculate the overall market share of each venue in three ways: how frequently each venue quotes at the NBBO best prices (*Time Share*), the proportion of depth quoted at the best NBBO prices (*Depth Share*) and the share of total traded dollar volume (*Traded Value*).

Table 4 presents the results of our analysis. Across all three fragmentation measures, we observe a significant reduction in the *HHI*, suggesting OPR encourages increased trading fragmentation (or competition) amongst venues.

We next turn our attention to the impact of the OPR on market-wide liquidity and transactions costs, in order to understand potential benefits to traders. If liquidity becomes more fragmented as a result of the OPR regulations, but this comes at the expense of increases in market-wide transactions costs, it would be difficult to argue this increase in competition was beneficial.

Our NBBO estimates confirm the findings of our descriptive tables. Overall transaction costs decline significantly, with quoted and effective spreads declining 0.40bps and 0.34bps respectively. These are significant economically, representing reductions compared to the pre-period mean of 3.2-3.7%. Consistent with the predictions of Foucault and Menkveld (2008), we also observe a significant increase in NBBO quoted depth, as competition between venues at the best prices intensifies. It is interesting to note that the one-second price impact also decreases market-wide, which is likely attributable to the improvement in depth for the whole market, making it harder to exhaust NBBO liquidity which reduces immediate price impact. We note here that the increase in depth does not contradict the predictions of Van Kervel (2015)'s model, as the trade-through prohibition does not make everyone a 'fast' trader, providing evidence that market makers have ex-ante expectations of some non-zero latency across venues. In the setting of the rule, 'fast' trading might be viewed as Direct Action Orders (equivalent to U.S. ISO orders), where participants direct orders to trade on several venues at the same time, avoiding exchange-level checks for potential violations of the trade-through prohibition.

Taken together, it appears that the introduction of the trade through prohibitions has encouraged liquidity suppliers to migrate their limit orders from primary to alternative exchanges. This migration not only improves liquidity and transactions costs at those venues, but also provides tangible benefits of increased depth, reduced price impact and reduced transactions costs for all traders across the entire market. We next seek to understand the mechanism which underpins these results — examining when and why liquidity providers choose to adopt these alternative exchanges in response to this exogenous regulatory change.

[Insert Table 4 here]

4.2. Understanding the queue-jumping mechanism

In this section, we provide direct evidence on the queue-jumping mechanism that causes the improvement in liquidity on the alternative venues. To better understand where new queues form, we first compare the endogenous utilization of alternative venues prior to the introduction of OPR, then examine the impact of the OPR regulation on liquidity provision in venues experiencing differing levels of queue utilization. Finally, we seek to understand the determinants of queue utilization on alternate venues.

In order to understand the distribution of 'queues' on different venues prior to the introduction of OPR, a variable we will use to condition alternative venue queue utilization, Fig. 4 presents the histograms of NBBO time shares in the pre-introduction period (1 month prior to 2011-02-01). Each individual observation represents a single stock-venue-day.

[Insert Fig 4 here]

Fig.4 shows that prior to the introduction of trade-through prohibition, for most stock-days the TSX quoted at the NBBO almost 100% of the time, while smaller venues quoted at the NBBO far less frequently. In the pre-period, we see that the queue was most empty on Pure (GO), the smallest venue, while Chi-X and Alpha experienced empty queues in a significant portion of stock-days. These empty queues represent opportunities for liquidity providers to queue-jump directly to the front of these alternative venues, and indicate that there was some endogenous utilization of these alternative venues to quote at the NBBO. In a small set of securities, the alternative venues were able to endogenously quote at the best prices almost 100% of the day. These represent the securities with the longest existing queues on the TSX, for which queue jumping was beneficial even prior to the introduction of the trade through prohibition.

We expect that if OPR encourages liquidity providers to utilize empty queues, the benefits of increased quoting and trading behaviour should be concentrated in those scenarious where alternative venues were previously poorly utilized. To examine this mechanism, we partition our sample into quintiles based on the average pre-period venue-stock trading characteristics. We consider two classification variables: the percentage time for which a venue-stock quoted at the NBBO, as well as the average number of brokers trading on a given venue-stock combination.

Having divided our sample into quintiles based on the above classifications, we then run the following regression specification:

$$Metric_{i,v,t} = \alpha_{i,v,t} + \beta_1 OPR_{i,v,t} + \beta_2 Controls_{i,v,t} + \delta + \theta + \varepsilon_{i,v,t} \tag{4}$$

where α is the intercept, δ is stock fixed-effects, and θ is venue fixed-effects. For ease of exposition, only the coefficients for the OPR event variable are presented.

The left-hand-side of Table 5 presents the results of an event study regression for 5 quintiles, classified according to the stock-venue's pre-period average NBBO time share. Stock-venues in the lowest NBBO time share quintiles have queues which were previously predominantly empty, while stock-venues where the NBBO queue is mostly full are captured in the highest NBBO time share quintile. If the benefits of the trade-through prohibition are driven by the increased utilization of empty queues, we expect to see our improvements concentrated in the "Low Queue" (Quartile 1), with limited impact observed for queues which were previously full (i.e. the primary venue).

The right hand side of Table 5 presents similar results for quintiles based on broker connectivity. If our results are driven by an increase in the number of brokers trading on alternative exchanges, we would expect to see improvements concentrated in those venue-stocks which were "Least Connected" (Quintile 1) in the pre-period.

In both our queue length and broker connectivity groupings, the benefits of the introduction of OPR are concentrated in the lowest quintile, with occasional benefits accruing to Quintile 3. We rarely observe any significant effects for the largest existing queues. Panel A considers the impacts of OPR on measures of trade and quote activity. The observed benefits include increases in both the share of quoted depth (1.6-1.7%) and the absolute dollar value of depth, as well as more frequent quotation at the NBBO (8.8-9.8%). This increased quoting activity leads to increases in the share of traded value (0.64-0.68%), as well as improvements in effective spreads (-14.7-14.8 bps) and price impacts (-11-12 bps), conditional on trades occurring.

Panel B of Table 5 presents results which speak to the way in which changes in quoting behavior brings about these improvements. Alternative venue queues which were poorly utilized prior to the regulation (either in matching the NBBO or broker connectivity) now match new NBBO prices 11.8-12.6% more frequently. These best-price matching quotes occur 9.8-10.4% more quickly, when compared to the life of the new best quote. Executions on alternative venues tend to be dominated by single board-lot trades, increasing to 60-76% of all executions post OPR, and increasing significantly in absolute frequency also. This increase in activity at the best quotes significantly reduces the proportion of time for which these venues quote stale prices (more than 3 ticks away from the NBBO), reducing 29-32%. These improvements result in quoted spreads reducing on average by

1.4-1.6 ticks.

In this way, liquidity shifts from being primarily consolidated on a single venue, to being present in most venues, particularly where liquidity was absent before the rule. This evidence strongly supports the hypothesis that queue-jumping is the mechanism behind the improvement of market quality and is the driver of increased trading fragmentation. The observed improvements for those stock-venues with the least number of brokers connected in the pre-period demonstrates that broker connectivity represents another channel driving trade fragmentation, and is consistent with the theoretical findings of Duffie, Malamud, and Manso (2014) that increased market connectivity by some brokers will encourage an equilibrium in which all brokers seek increased connectivity. This may be especially important in settings where brokers face fixed costs to connectivity which, once paid, yield continuous variable benefits in reduced trading costs for their clients.

[Insert Table 5 here]

Consistent with Foucault and Menkveld (2008) we observe endogenous queue jumping prior to the introduction of the OPR regulation. However, our evidence suggests that the introduction of this regulation significantly increases the likelihood of execution on alternative venues, accelerating queue jumping activity, particularly across empty queues. To test this conjecture, we examine the determinants of queue utilization. To measure this, we define a dummy variable as 1 when the venue, stock, day observation exceeds a threshold of matching the NBBO quotes. These thresholds chosen include 10, 25, 50, 75 and 90% of the day, to capture a broad range of liquidity provision.

Table 6 presents evidence on the likelihood of observing queues forming in the alternative venues based on the length of existing queues on the primary venue.

$$QueueDummy_{i,v,t} = Intercept_{i,v,t} + \beta_1 \, TSXQueue_{i,v,t} + \beta_2 \, OPR_{i,v,t} + \beta_3 \, TSXQueue * OPR_{i,v,t} + Controls_{i,v,t} + \varepsilon_{i,v,t} \quad (5)$$

The dependent variable is a dummy of how frequently a best-price quote exists on alternative venues. We use high *NBBO Time Share* to represent quote existence, and the five columns represent different thresholds, (10, 25, 50, 75 and 90%) above which we code the dependent variable as 1, and 0 otherwise. The independent variable *TSX Queue* measures the time-weighted depth on the primary venue (TSX) and *OPR* is a dummy variable for OPR implementation. Our three key coefficients are *TSX Queue, OPR* and the interaction term between these two variables.

The positive coefficient of *TSX Queue* indicates a higher probability of queues forming in alternative venues, given longer queues on the primary venue. The significance and size of these coefficients increases monotonically when the threshold of a queue forming on alternative venues increases, consistent with longer queues on the primary venue driving liquidity towards alternative venues. After OPR is implemented, the probability of observing queues on the alternative venue increases significantly, especially in cases where the existing alternative venue queue is short, as represented by low NBBO time share thresholds. Finally, we observe that the interaction variable between *TSX Queue* and OPR has a consistently negative coefficient, indicating that the implementation of OPR reduces the importance of the size of the TSX queue, encouraging participants to fill all queues equally.

Combined, these results clearly demonstrate that while prior to the implementation of OPR the alternative venues were being used to queue-jump long queues on the primary venue, following the introduction of OPR queues formed on alternative venues with significantly increased frequency – irrespective of the length of the queue on the primary venue.

[Insert Table 6 here]

4.3. Economic benefits of queue jumping

In this section we provide direct evidence of the trade-through prohibition's impact on the adverse selection experienced by liquidity providers using two methods. The first uses six classifications to split our sample into two based on variables related to queue-jumping, and then analyzes the impact of OPR's introduction on adverse selection. The second analysis examines how the adverse selection experienced by trades which are at the 'back of the queue' on the primary and alternative exchanges changes as a result of the trade through prohibition.

In order to better understand the changes in adverse selection for each trade, we identify the liquidity-providing side, and compute the price impact (adverse selection) at three horizons (one second, one minute and five minute) for those liquidity providers. Similar to our previous subsample analysis, we identify six classification variables, and split broker-stock-venue-day observations by these variables. We then compute the below regression, using our measure of price impact (value-weighted by broker-stock-venue-day) as our dependent variable:

$$PriceImpact_{i,v,n,t} = \alpha_{i,v,n,t} + \beta_1 OPR_{i,v,n,t} + Controls_{i,v,n,t} + \delta + \theta + \phi + \varepsilon_{i,v,n,t} \tag{6}$$

where α is the intercept, δ is stock fixed-effects, θ is venue fixed-effects, and ϕ is broker fixed-effects.

The evidence in Table 7 indicates that the trade-through prohibition primarily benefits liquidity providers who, post OPR, utilize the shorter queues offered by alternative venues more frequently, experiencing a reduction in adverse selection costs. In Table 7, six classifications methods are presented, each one representing a different way to identify utilization of queue-jumping strategies. For all classifications, the first reported group represents brokers who increased their usage of short queues on the alternative venues (or decreased the usage of long queues on the primary venue), while the second group represents brokers who decreased their usage of short queues (or increased their usage of the primary venue).

For all measures of price impact, we observe larger reductions in adverse selection for: brokers who used passive orders on the alternative venues less before the regulation (leaving more room for improvement post OPR); brokers who increased their usage of passive trading on alternative venues after OPR; brokers (and stocks) that decreased their utilization of passive orders on the primary venue (likely in favour of passive orders on alternative venues); stocks which exhibited an increase in one-lot queues (i.e. queue-jumping orders); and brokers who submit orders which generate one-lot queues (i.e. queue-jumping orders). These results support the notion that the adverse selection faced by an order at the top of the queue on the alternative venue is lower than a comparable order at the back of the queue on the primary venue, as that back of queue order would only be transacted once all available depth on the primary venue is depleted.

[Insert Table 7 here]

To directly test the economic benefit of quoting on the alternative exchange, we specifically examine the "back of queue" orders, i.e. the immediate adverse selection (price impact) for trades that deplete the entire level of liquidity on the primary or alternative exchanges. We test this using the following regression framework:

$$PriceImpact_{i,v,t} = \alpha_{i,v,t} + \beta_1 OPR_{i,v,t} \cdot BackofQueue_{i,v,t} + Controls_{i,v,t} + \delta + \theta + \phi + \varepsilon_{i,v,t} \quad (7)$$

where *Back of Queue* takes a value of 1 when the trade has depleted the liquidity available at that price level on that venue, and 0 otherwise (that is for middle of queue executions). All other variables are as defined in Equation 6.

Table 8 shows that orders at the back of queue on the alternative venues experienced larger, more significant reductions in adverse selection as a result of the trade-through prohibition than orders on the primary exchange. Such improvements come from the lack of time-priority across venues, which enables orders in the short queues on alternative venues to be traded ahead of the orders at the back of queue on the primary exchange. This evidence supports the view that traders prefer to post limit orders to alternative venues after the introduction of the trade-through prohibition due to the significant reduction in adverse selection faced by those orders. Such reductions in adverse selection will be welcomed by liquidity providers, as they represent one of the primary components of a liquidity providers costs.

[Insert Table 8 here]

5. Conclusion

We provide compelling evidence that the trade-through prohibition increases fragmentation via queue-jumping. We utilize two natural experiments, the introduction of the trade-through prohibition and its subsequent removal from a single venue in Canada. The trade-through prohibition protects quotes at all venues which is particularly valuable for the previously less-liquid venues i.e. the ‘empty queues’, which liquidity providers can now use to jump the longer queues on the primary exchange. We are the first to directly document the queue-jumping mechanism, first suggested by Foucault and Menkveld (2008), and show its relevance to the excessive fragmentation predominately observed in North American markets. Further, while the existence of empty order books provides an opportunity for traders to form new queues, the motivation for such behaviour has also not been previously explored. In this paper, we provide evidence that queue-jumpers are motivated by improved transaction costs and decreased adverse selection costs when orders execute in these ’shorter’ queues.

We begin by confirming the findings of the prior literature, that trade through prohibitions benefit market quality by encouraging limit order submissions, narrowing spreads and improving depth on the market as a whole. We show this benefit to be most pronounced on the smaller, less liquid venues. Our findings suggest that such a rule may have the unintended consequence of further fragmenting liquidity towards empty queues, potentially creating an excessive level of fragmentation.

We provide policy suggestions on the current debate surrounding the existence of trade-through prohibition in the U.S. and potential introduction in Europe. On the one hand, given the high fixed costs of starting an exchange, such a rule reduces barriers to entry and can effectively initiate competition between exchanges by ensuring better prices at smaller venues are not ignored. Trade-through prohibitions have been applauded for migrating markets from monopolies towards perfect competition. On the other hand, this encourages the creation of new ’empty queues’ through time, which can increase data and connection fees, which are ultimately borne by end investors. Universally protecting empty queues market-wide can also result in ’too much’ competition. We document a diminishing benefit to additional exchange entry beyond the fourth trading venue in Canada, despite charging additional data and connection fees. When compared to the significant number of venues in both the US and Canada, this may be indicative of ’excessive’ competition. Data fees charged to market participants now constitute a major part of exchange revenue, representing a direct cost for brokers, which is eventually passed on to end investors. Protecting an exchange’s quotes often forces brokers to pay for that exchange’s data. The fact that 12 of the 13 major U.S. lit exchanges are owned by three operators (NYSE, NASDAQ and CBOE) means that they are able to charge higher fees than if these exchanges were consolidated.

In the 2019 SIFMA conference, various proposals have been brought to the SEC for imposing a market share threshold with order protection, similar to the mechanism implemented in Canada in 2018. In this paper, we show that the removal of protection from a single small venue worsens liquidity on that venue, but not as significantly as the introduction improves liquidity. This is likely due to the 'stickiness' of brokers connectivity and smart order router technology.

Applying a value share threshold allows brokers to evaluate exchanges based on a trade-off between available liquidity and fixed connectivity costs. Striking a balance between sufficient and excessive competition is a difficult task faced by the regulators. We observe an immediate shock to the liquidity provision activities on the unprotected venues after they were removed. It appears that the 2% trading threshold to be considered for order protection has halted the fragmentation of liquidity in Canada, with no new venues added since the thresholds introduction, despite a number of new venues having been introduced in the U.S. in the same time period. This suggests that such thresholds may be effective in curbing the further fragmentation of liquidity in similar settings, such as the U.S.

However, we find that the simple removal of order protection for small venues may not be sufficient to address excessive data feed connection fees created by such excessive fragmentation, as the interaction of best-execution and trade-through regulations may require brokers to remain connected to unprotected venues in order to satisfy their best execution requirements for market orders should better prices appear. Such evidence provides clear guidance to regulators considering the removal of such rules - such removals must be considered in the overall context of the existing regulatory framework - including the obligations imposed on the order routing choices of brokers.

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Figure 1A: Number of micro-venues in the U.S. and Canada

This plot illustrates the number of micro-venues (those with less than 2.5% of traded value) at each point in time. The metric is calculated on two sample stocks: GE and Citigroup in the U.S., and TD and RBC in Canada.

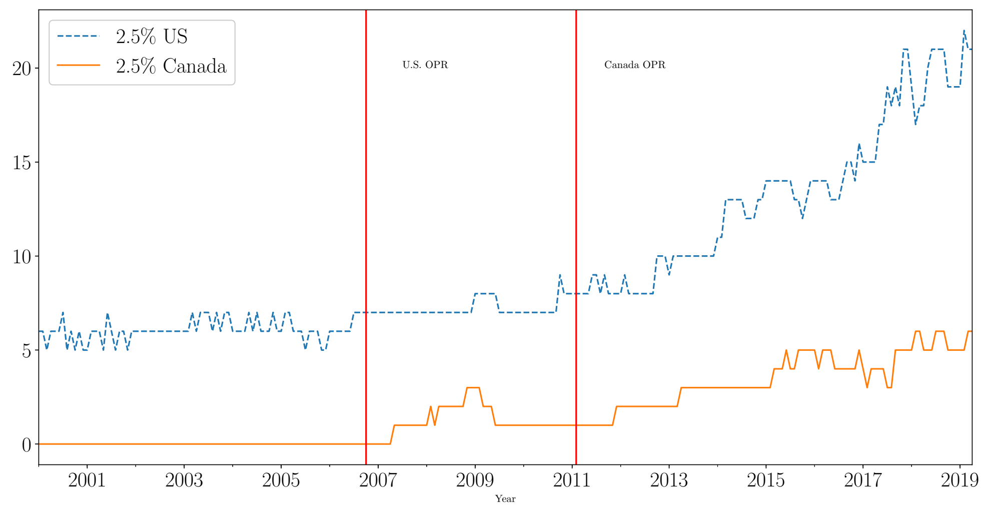

Figure 1B: Total market share of micro-venues in the U.S. and Canada

This plot illustrates the sum of trade value share undertaken by micro-venues (those with less than 2.5% trade value share) at each point in time. The metric is calculated on two sample stocks: GE and Citigroup in the U.S., and TD and RBC in Canada.

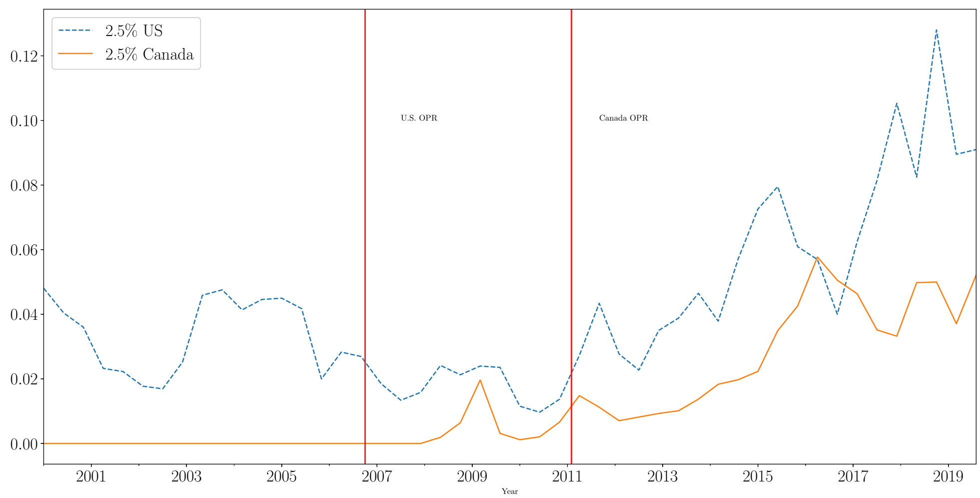

Figure 2: Change in quoted spread (bps) after successive venue introducitons in Canada

The following plot computes the change in NBBO quoted spreads around the introduction of new Canadian equity venues. We use data 20 trading days before and after the launch date of each included venue. Our results are value-weighted across stocks and time-weighted during each day. We use all TSX60 stocks at the time of the venue launch for our representative sample. The light bar indicates the difference ($post - pre$).while the dark bar indicates the corresponding t-statistic for each change.

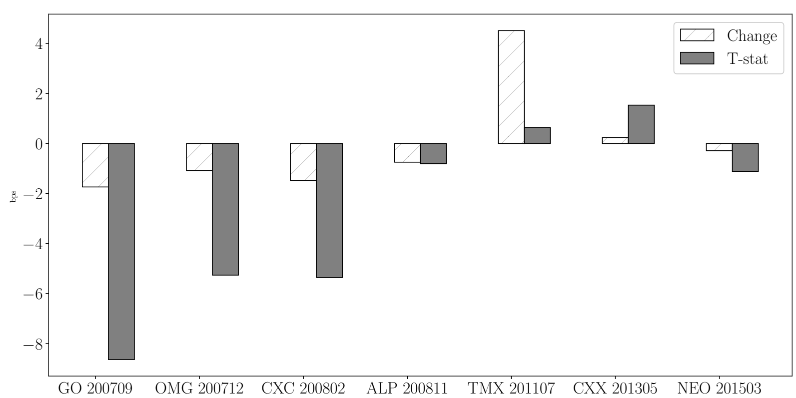

Figure 3A: Routing a marketable buy order

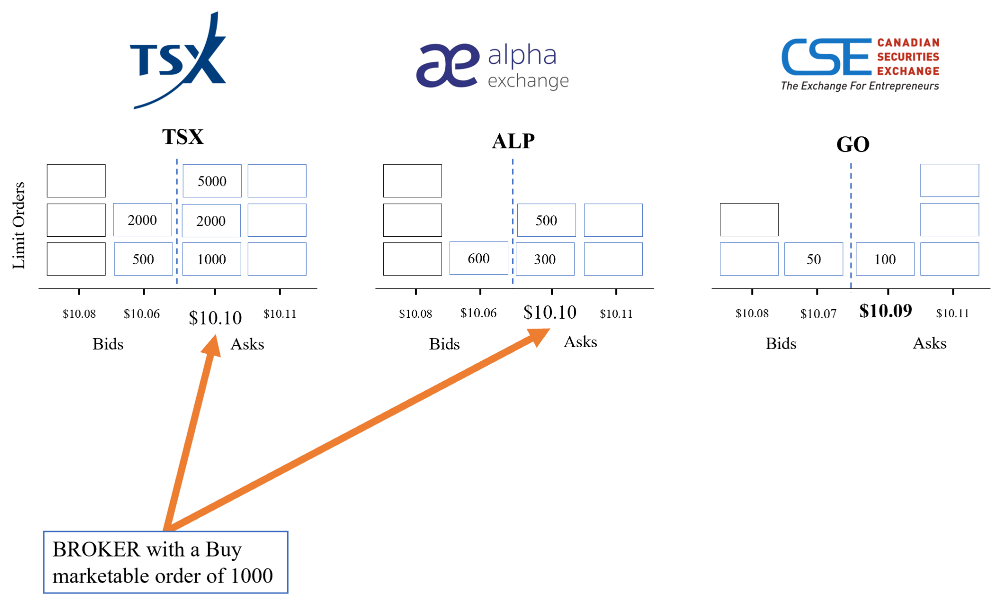

Figure 3B: Routing a limit buy order

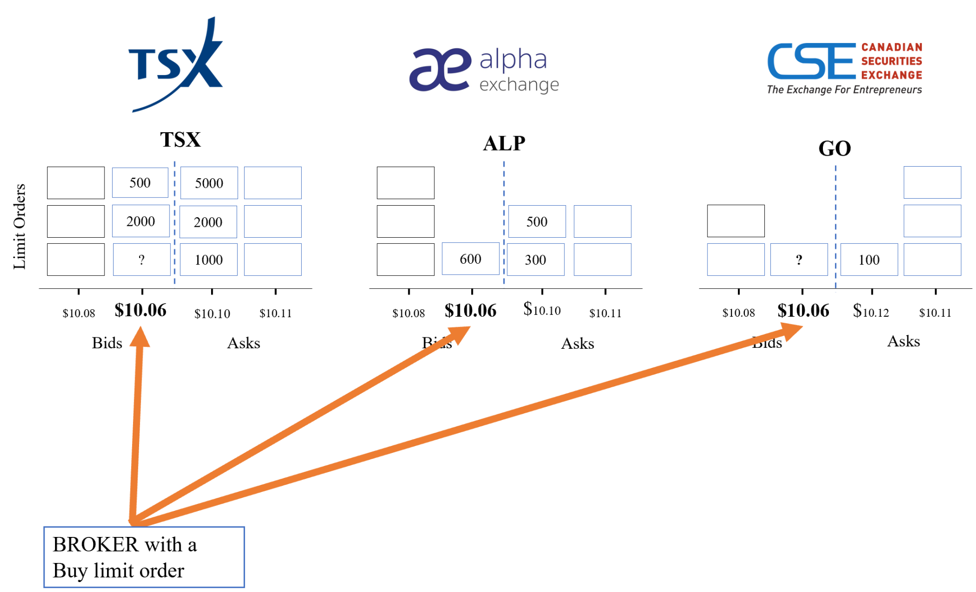

Figure 4: Venue NBBO Time Share Prior to OPR

This figure presents the per-stock per-day NBBO time share histograms for each venue prior to the introduction of the trade-through prohibition (2011-01-01 to 2011-01-31). NBBO time share is calculated as the percentage of time during a day the venue bid or ask is at NBBO. The x axis is the NBBO time share (in percentage of a day) while the y axis is the % frequency of each observation.

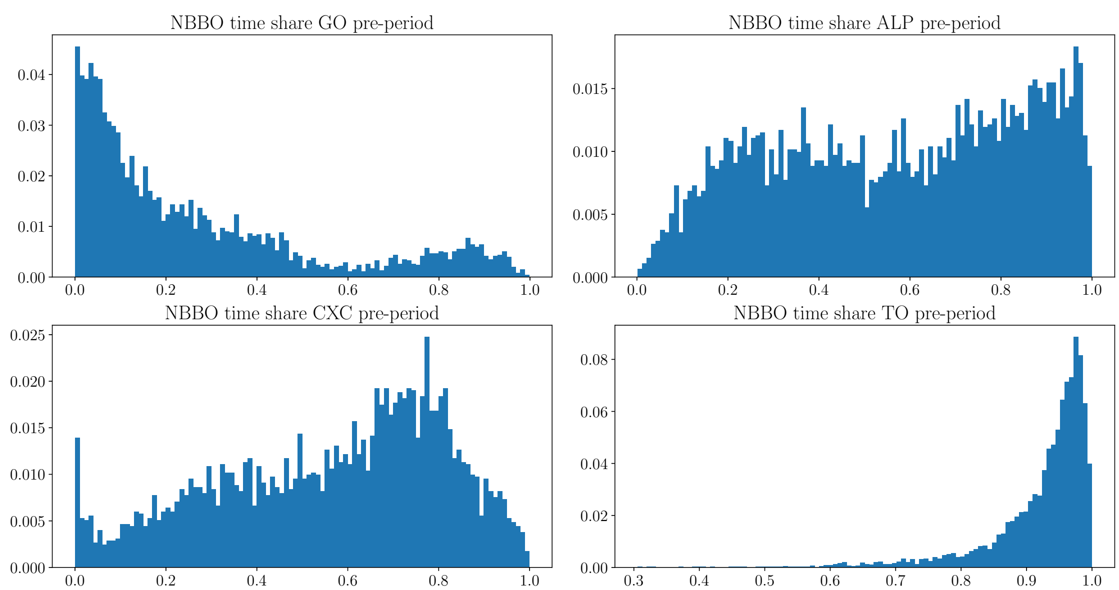

Table 1A: Descriptive Statistics

This table provides the summary statistics for the TSX Composite constituents before and after the introduction (and partial removal) of OPR. *Quoted Spread* is calculated as the difference between each venues Best Offer - Best Bid, which is then time-weighted. *Effective Spread* is the signed difference between trade price and the prevailing Midpoint of the venue. *Realized Spread* is calculated as the signed difference between the trade Price and the venue midpoint one second after the trade. *Price Impact* is calculated as the difference between *Effective Spread* and *Realized Spread*. *Effective Spread*, *Realized Spread* and *Price Impact* are all value-weighted across each stock-day. All spread measures are divided by the prevailing midpoint to provide a measure in bps. Daily Trade Value (*Value*) sums total dollar volume on a venue, in millions of dollars. The above measures are averaged across the one month window before and after OPR introduction (1st Feb 2011) on the left-hand-side and OPR removal on the right-hand-side (1st Oct 2016). Primary venue refers to TSX and alternative venues include all other venues for which data is available(GO, CXC, ALP in 2011; GO, CXC,ALP,OMG and CXX in 2016) $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$; Diff = Post − Pre.

		OPR Introduction				OPR Removal			
		Pre	Post	Diff		Pre	Post	Diff	
Metric	Venues	Mean	Mean	Mean		Mean	Mean	Mean	
Quoted Spread (bps)	Primary	11.14	10.62	-0.52	***	11.04	11.00	-0.03	
	Alternative	27.80	23.92	-3.89	***	10.50	10.49	-0.01	
	NBBO	10.79	10.31	-0.25	***	10.69	10.74	0.05	
Effective Spread (bps)	Primary	10.96	10.51	-0.45	***	7.51	7.29	-0.22	*
	Alternative	21.81	17.63	-4.17	***	9.04	8.94	-0.10	
	NBBO	10.36	10.04	-0.32	*	7.54	7.36	-0.18	
Realized Spread 1s (bps)	Primary	0.71	0.70	-0.01		-1.31	-1.35	-0.05	
	Alternative	0.76	-0.35	-1.11	***	3.34	3.22	-0.12	*
	NBBO	1.44	1.41	-0.03		-0.18	-0.19	-0.01	
Price Impact 1s (bps)	Primary	10.25	9.81	-0.44	***	8.82	8.65	-0.17	
	Alternative	21.05	17.98	-3.06	***	5.71	5.72	0.01	
	NBBO	8.92	8.62	-0.30	**	7.72	7.55	-0.17	
NBBO Depth ($000)	Primary	81.49	126.44	44.95	***	54.67	55.46	0.79	
	Alternative	19.46	26.05	6.59	***	11.20	11.94	0.74	***
	NBBO	135.26	197.91	62.65	***	110.83	115.33	4.5	
NBBO Depth Level 3 ($000)	Primary	290.26	402.56	112.30	***	51.80	52.67	0.86	
	Alternative	75.41	89.38	13.97	***	10.91	11.16	0.25	
	NBBO	499.63	648.24	148.61	***	355.18	370.11	14.92	
Value ($M)	Primary	3129.29	3265.18	135.89		3828.30	3661.11	-167.19	
	Alternative	1470.85	1558.04	87.19		2285.82	2276.80	-9.02	
	NBBO	4600.14	4823.22	223.08	*	6114.12	5937.91	-176.21	
Price	Primary	26.83	27.20	0.37		34.55	34.52	-0.03	
	Alternative	26.88	27.17	0.29		34.46	34.37	-0.08	
	NBBO	26.85	27.18	0.33		34.51	34.45	-0.06	
Volatility	Primary	2.50	2.37	-0.12		2.39	2.34	-0.05	
	Alternative	2.19	2.13	-0.05		2.13	2.09	-0.04	
	NBBO	2.52	2.40	-0.12		2.26	2.22	-0.04	

Table 1B: Descriptive Statistics

This table provides the summary statistics for the TSX Composite constituents before and after the introduction of OPR. *NBBO Depth Share* is the shares available at NBBO on a venue divided by the total market-wide number of shares available at the NBBO, time-weighted across each stock-day. *NBBO Time Share* is the proportion of a day that a venue's quote is at the NBBO. If several venues quote are all at the NBBO at the same time, they are all counted. *Stale Quotes %* are counted as the percentage of the trading day that the quoted spread is greater than 3 ticks away from the NBBO. *% Match NBBO* is the percentage of times a venue matches an updated NBBO. *% Wait Duration* is time taken for a venue to join the NBBO queue, as a proportion of the total duration that quote prevails at the NBBO. If it doesn't join, then it equals to 1 for that NBBO update. One lot percentage is the number of single board-lot passive trades executed as a fraction of all passive orders executed by that broker. One lot percentage is computed relative to the liquidity providing brokers total trading activity. All measures are in percentages. The above measures are averaged across the one month window before and after OPR's introduction. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$; Diff = Post − Pre

		Pre	Post	Diff	
Metric	Venues	Mean	Mean	Mean	
NBBO Depth Share %	Primary	63.13	61.22	-1.91	$***$
	Alternative	37.22	38.9	1.68	$***$
NBBO Time Share %	Primary	92.40	92.27	-0.13	
	Alternative	48.09	50.39	2.30	$***$
Stale Quotes %	Primary	1.15	0.79	-0.36	$***$
	Alternative	28.2	20.23	-7.97	$***$
% Match NBBO	Primary	94.98	94.80	-0.18	
	Alternative	63.89	67.28	3.4	$***$
%Wait Duration	Primary	6.82	6.93	0.11	
	Alternative	41.61	38.69	-2.92	$***$
One Lot Percentage	Primary	8.91	9.46	0.55	$***$
	Alternative	4.49	5.05	0.56	$***$

Table 2: Liquidity Change with OPR Introduction

This table examines the impact of OPR's introduction, where $Metric_{i,v,t} = Intercept_{i,v,t} + \beta_1 OPR \cdot Alternative + Controls_{i,v,t} + Stock : VenueFE + DateFE + \varepsilon_{i,v,t}$ for stock i, venue v and day t. Metric includes: *Quoted Spread, Effective Spread, Realized Spread, Price Impact* and log(*DepthatNBBO*), log(*DepthatNBBOLevel2*), and log(*DepthatNBBOLevel3*). *Quoted Spread, Effective Spread, Realized Spread* and *Price Impact* are calculated as in Table 1. *Log(DepthatNBBO* is the natural logarithm of the $ amount of shares offered on each venue at the NBBO price at the best price level, *Log(DepthatNBBOLevel2* and *Log(DepthatNBBOLevel3* reflecting this at the next best price and the following next best price respectively. Value share is that venues share of total traded value. *NBBO Depth Share* is the shares available at NBBO on a venue divided by the total market-wide number of shares available at the NBBO, time-weighted across each stock-day. *NBBO Time Share* is the proportion of a day that a venue's quote is at the NBBO. If several venues quote are all at the NBBO at the same time, they are all counted. Stale quotes are counted as the percentage of the trading day that the quoted spread is greater than 3 ticks away from the NBBO. Controls include stock-venue-day measures of *Price*, *Traded Value* ($ Millions), and *Volatility* (High – Low)/ ((High + Low)/2). *OPR* is a dummy variable that equals 0 before the date of the OPR introduction event, and 1 after. Standard errors are reported in brackets, and are clustered by stock and date. *, **, and *** indicate significance at the 10%, 5%, and 1% levels of signifance, respectively. We include stock-venue and time fixed effects for all regressions. R^2 are adjusted for fixed effects.

	Quoted Spread	*Effective Spread*	*Realized Spread*	*Price Impact*	*NBBO Depth Share*	*NBBO Time Share*	*Value* Share	*Log(NBBO Depth)*	*Log(NBBO Depth Lvl. 3)*	*Stale Quotes %*
Alternative × OPR	-3.85***	-4.13***	-0.44**	-0.13	2.71***	2.99***	2.34***	0.20***	0.25***	-7.93***
	(-6.33)	(-7.55)	(-2.25)	(-0.85)	(3.26)	(4.12)	(3.49)	(4.47)	(5.99)	(-7.31)
Intercept	23.56***	18.81***	3.04***	4.79***	23.79***	62.81***	23.74***	9.06***	10.43***	18.26***
	(40.25)	(41.86)	(8.74)	(8.20)	(41.71)	(37.44)	(64.87)	(86.37)	(113.01)	(10.16)
Price	-0.05**	-0.03**	-0.00	0.01**	0.00	-0.11*	0.00	0.00	-0.00	0.13*
	(-2.44)	(-2.05)	(-0.64)	(1.98)	(0.01)	(-1.84)	(0.02)	(0.85)	(-0.06)	(1.92)
Volatility	0.62***	0.47***	-0.41***	0.79***	0.02	-0.51***	-0.04	-0.03***	-0.02***	-0.11
	(7.12)	(6.14)	(-3.95)	(3.71)	(0.65)	(-6.10)	(-0.92)	(-3.21)	(-2.93)	(-1.02)
Value	-0.03***	-0.02***	0.02***	-0.03***	0.05***	0.06***	0.11***	0.01***	0.01***	-0.01
	(-2.96)	(-2.91)	(4.39)	(-4.56)	(4.39)	(4.07)	(4.94)	(3.69)	(3.51)	(-0.97)
N	33796	33796	33796	33796	33796	33796	33796	33796	33796	33796
Adj. R^2	3%	2%	1%	2%	3%	2%	3%	3%	3%	2%

Table 3: Liquidity Impacts of the Removal of OPR

Table 3 contains the difference-in-difference regression estimated for OPR removal, where $Metric_{i,v,t} = Intercept_{i,v,t} + \beta_1 Removal_{i,v,t} \cdot Removal_{i,v,t} GO_{i,v,t} + Controls_{i,v,t} + stock : venueFE + dateFE + \varepsilon_{i,v,t}$. GO represents Pure Trading, for which OPR was removed in 2016, *Removal* is a dummy variable that takes 0 for dates prior to the removal event and 1 after. The dependent and control variables are as defined in Table 2. Standard errors are reported in brackets, and are clustered by stock and date. *, **, and *** indicate significance at the 10%, 5%, and 1% levels of significance, respectively. We control for both venue-stock and time-fixed effects. R^2 are adjusted for fixed effects.

	Quoted Spread	*Effective Spread*	*Realized Spread*	*Price Impact*	*NBBO Depth Share*	*NBBO Time Share*	*Value Share*	*Log(NBBO Depth)*	*Log(NBBO Depth Lvl 2)*	*Log(NBBO Depth Lvl 3)*
Removal × GO	0.01	0.94***	-0.67**	1.64***	-0.46***	-2.46***	-0.68***	-0.14***	-0.15***	-0.14***
	(0.13)	(3.68)	(-2.32)	(4.88)	(-3.43)	(-6.27)	(-6.10)	(-5.04)	(-5.52)	(-5.37)
Intercept	12.33***	17.03***	2.46***	15.66***	16.66***	62.98***	16.98***	8.85***	9.72***	10.03***
	(23.73)	(16.68)	(4.17)	(17.06)	(22.49)	(31.65)	(30.99)	(65.63)	(83.30)	(85.97)
Price	-0.06***	-0.09***	-0.02	-0.10***	-0.01	-0.29***	-0.02	0.00	0.00	0.00
	(-4.06)	(-2.83)	(-0.96)	(-3.45)	(-0.24)	(-4.80)	(-1.17)	(0.16)	(0.44)	(0.69)
Volatility	0.09***	1.02***	-0.02	1.01***	-0.01	-0.51***	-0.05	-0.03***	-0.02***	-0.02***
	(3.52)	(12.37)	(-0.50)	(11.55)	(-0.66)	(-7.89)	(-1.57)	(-7.41)	(-7.35)	(-7.77)
Value	-0.01***	-0.04***	0.02***	-0.06***	0.08***	0.07***	0.15***	0.01***	0.01***	0.01***
	(-3.23)	(-3.70)	(2.93)	(-3.53)	(3.63)	(3.43)	(3.09)	(3.58)	(3.80)	(3.76)
N	53217	53217	53217	53217	53217	53217	53217	53217	53217	53217
Adj. R^2	3%	2%	1%	2%	2%	1%	1%	2%	2%	2%

Table 4: Effects of OPR Introduction on Market Fragmentation and Liquidity

This table reports the impact of OPR introduction, using an event-study regression, where $Metric_{i,t} = Intercept_{i,t} + \beta_1 OPR_{i,t} + Controls_{i,t} + stockFE + \varepsilon_{i,t}$. Metric represents our dependent variables. Fragmentation is measured with the Herfindahl index. We use three variations, *HHI Time* is computed with *NBBO Time Share* where we rescaled the sum of NBBO time shares across venues for each stock-day to 1. *HHI Depth* is computed with *NBBO Depth Share*. *HHI Value* is computed with *Value Share*.Liquidity is measured using NBBO measures of: *Quoted Spread*; *Effective Spread*; *Realized Spread*; *Price Impact* and $\log(DepthatNBBO)$. *NBBO Quoted Spread* takes the difference between the best (lowest) ask and the best (highest) bid. *NBBO Effective Spread* is calculated by taking the signed difference between trade price and the prevailing NBBO midpoint. *Realized Spread* is calculated by taking the signed difference between the trade price and the NBBO midpoint one second after the trade price. *NBBO Price Impact* is the difference between *NBBO Effective Spread* and *NBBO Realized Spread*. The NBBO spread measures are reported in bps by dividing by the prevailing midpoint. Controls include stock-day measures of *Price*, daily trade value (*Value*), and *Volatility* (High – Low)/ ((High + Low)/2). Standard errors are reported in brackets, and are clustered by stock and date. *, **, and *** indicate significance at the 10%, 5%, and 1% levels of significance, respectively. R^2 adjusted for fixed effects.

	NBBO Fragmentation			NBBO Liquidity and Transaction Costs				
	HHI Time	*HHI Depth*	*HHI Value*	*Quoted Spread* bps	*Effective Spread* bps	*Realized Spread* bps	*Price Impact* bps	*Quoted Depth*
OPR	-192.66***	-212.12***	-187.71***	-0.40*	-0.34*	-0.09	-0.25*	0.08*
	(-21.37)	(-6.80)	(-5.49)	(-1.87)	(-1.87)	(-0.55)	(-1.65)	(1.78)
Intercept	2674.47***	4323.05***	4607.83***	10.08***	9.81***	2.22***	7.59***	11.12***
	(86.53)	(119.49)	(130.44)	(30.96)	(28.47)	(8.20)	(23.30)	(140.35)
Price	2.42*	-2.99	4.12	-0.00	-0.01	-0.00	-0.00	0.00
	(1.76)	(-0.98)	(1.55)	(-0.28)	(-0.75)	(-0.56)	(-0.55)	(0.16)
Volatility	0.73	-0.50	49.17***	0.28***	0.41***	-0.34***	0.74***	-0.06***
	(0.17)	(-0.06)	(4.53)	(6.83)	(6.22)	(-4.70)	(7.10)	(-3.56)
Value	-0.15	1.22**	1.26**	-0.01***	-0.01***	0.00**	-0.01***	0.00***
	(-0.95)	(2.40)	(2.07)	(-5.20)	(-5.10)	(2.23)	(-5.25)	(3.13)
N	8539	8539	8539	8501	8501	8501	8501	8501
Adj. R^2	2%	2%	2%	3%	3%	2%	3%	3%

Table 5: Queue-Jumping Mechanisms - Queue Length and Broker Connectivity

This table contains condensed regression output for sub-samples classified by the pre-period NBBO time share or broker connectivity. $Metric_{i,v,t} = Intercept_{i,v,t} + \beta_1 OPR_{i,v,t} + Controls_{i,v,t} + stock : venueFE + \varepsilon_{i,v,t}$. for stock i, venue v and date t. Stocks are divided into quintiles 1-5, containing stocks with lowest to highest queue-length/connectivity by pre-period average for each stock-venue pair. Quintile 1 contains stock-venue pairs with the least time share/connectivity, while quintile 5 contains those with the highest. Control variables are the same as in Table 4. *% Match NBBO* is the proportion of NBBO queues joined by each venue. *% Wait Duration* refers to the duration before a venue joins the NBBO queue, divided by the total duration of that NBBO price level. *One Lot Percentage* (frequency) represent the proportion(number) of one-lot passive trades executed by a broker. *Stale Quotes* are counted as the percentage of the trading day that the quoted spread is greater than 3 ticks away from the NBBO. *Quoted Spread* (ticks) measures a venues quoted spread in ticks. *, **, and *** indicate significance at the 10%, 5%, and 1% levels of significance, respectively. All regressions standard errors are clustered by stock and date. Only quintiles 1,3 and 5 are displayed due to space constraints.

	Pre-Period Queue Length Quintiles			Pre-Period Broker Connectivity Quintiles		
	Low Queue (Quintile 1)	Quintile 3	High Queue (Quintile 5)	Least Connected (Q1)	Quintile 3	Most Connected (Q5)
Panel A: Measures of Trade and Quote Activity						
NBBO Depth Share	1.61***	0.79***	-1.62***	1.76***	-0.22	-1.51**
	(5.60)	(3.00)	(-2.78)	(4.57)	(-1.19)	(-2.51)
NBBO Time Share	8.85***	1.21**	-0.06	9.80***	0.84***	-0.54
	(10.42)	(2.51)	(-0.15)	(9.23)	(2.63)	(-0.99)
Log(NBBO Depth)	0.59***	0.14***	0.04	0.62***	0.11***	0.10*
	(8.32)	(6.74)	(0.94)	(7.74)	(6.25)	(1.78)
Value Share	0.68***	0.31	-1.78***	0.64***	-0.42	-1.05*
	(4.45)	(1.03)	(-3.23)	(2.68)	(-1.62)	(-1.77)
Effective Spread (bps)	-14.70***	-0.03	-0.17	-14.81***	-1.11***	-0.24
	(-8.54)	(-0.31)	(-0.92)	(-7.62)	(-5.49)	(-1.38)
Price Impact (bps)	-12.02***	0.20**	-0.43	-11.06***	-0.13	-0.48**
	(-8.10)	(2.17)	(-1.53)	(-7.11)	(-0.94)	(-2.47)
Panel B: Measures of Quoting Behavior						
% Match NBBO	11.85***	0.32	-0.12	12.65***	0.76**	-0.42
	(9.75)	(0.73)	(-0.48)	(8.70)	(2.18)	(-0.97)
% Wait Duration	-9.81***	-0.17	0.13	-10.42***	-0.57	0.52
	(-9.72)	(-0.34)	(0.38)	(-8.58)	(-1.59)	(0.95)
One Lot Percentage	76.78***	0.23**	15.77	60.52***	0.42***	34.18
	(4.15)	(2.14)	(1.07)	(3.41)	(5.30)	(1.48)
One Lot Frequency	10.36***	9.54**	-5.03	8.47***	2.16	25.68
	(4.27)	(2.23)	(-0.37)	(5.31)	(0.67)	(0.82)
Stale Quotes	-29.24***	-2.07***	-0.26	-32.74***	0.29	-0.33
	(-10.40)	(-5.48)	(-1.05)	(-10.66)	(0.78)	(-0.87)
Quoted Spread (ticks)	-1.48***	-0.20***	-0.06**	-1.61***	-0.01	-0.03
	(-8.10)	(-3.24)	(-2.05)	(-7.91)	(-0.33)	(-0.59)
N	4708	2401	5058	3995	4119	3782

Table 6: Determinants of queue formation on alternative venues

This table contains Probit regression output, where $QueueDummy_{i,v,t} = Intercept_{i,v,t} + \beta_1 TSXQueue_{i,v,t} + \beta_2 OPR_{i,v,t} + \beta_1 TSXQueue * OPR_{i,v,t} + Controls_{i,v,t} + \varepsilon_{i,v,t}$. *Queue Dummy* measures how frequently a queue exists on alternative venues. If the NBBO time share for stock i, for venue v on day t exceeds $x\%$, then *Queue Dummy* takes a value of 1, otherwise 0. The header column indicates the threshold percentage. We utilize thresholds ranging from 10% to 90%. TSX Queue measures the average timeweighted $depth on TSX for stock i, on day t, on venue v. *OPR* is the event variable which equals 1 after the OPR implementation and 0 before. $*$, $**$, $***$: 10%, 5%,1%; All regressions standard errors are clustered by stock,date.

	NBBO Time Share				
NBBO Time Threshold	10%	25%	50%	75%	90%
TSX Queue	0.09**	0.17***	0.37***	0.87***	0.69***
	(2.38)	(5.81)	(12.19)	(21.48)	(17.02)
OPR	2.87***	1.21***	1.19***	-0.05	-0.10
	(6.01)	(3.20)	(3.43)	(-0.11)	(-0.15)
TSX Queue × OPR	-0.23***	-0.11***	-0.12***	-0.01	-0.02
	(-4.86)	(-2.88)	(-3.53)	(-0.13)	(-0.28)
Intercept	0.47	-0.47	-2.90***	-8.48***	-7.88***
	(1.21)	(-1.57)	(-9.01)	(-18.31)	(-16.12)
Price	-0.02***	-0.03***	-0.05***	-0.07***	-0.07***
	(-8.31)	(-37.28)	(-33.72)	(-22.19)	(-18.09)
Volatility	-0.06***	-0.11***	-0.12***	-0.17***	-0.13***
	(-3.52)	(-10.65)	(-12.09)	(-10.98)	(-4.79)
Value	0.79***	0.65***	0.31***	0.09***	0.04***
	(8.65)	(18.67)	(14.30)	(7.22)	(11.52)
N	13,247	13,247	13,247	13,247	13,247
Adj. R^2	24%	29%	50%	47%	47%

Table 7: Condensed Broker Evidence on Adverse selection and OPR Introduction

This table contains condensed price impact regressions with various sub-samples. $Metric_{i,v,n,t} = Intercept_{i,v,n,t} + \beta_1 OPR_{i,v,n,t} + Controls_{i,v,n,t} + stock : venue : brokerFE + \varepsilon_{i,v,n,t}$ for each broker-stock-venue-day observation. The specifications differ in their classifications as follows: (1) less vs more pre-period passive trading volume per broker-stock-venue. (2) increase vs decrease in the passive trading volume on alternative venues per broker. (3) decrease vs increase in change in passive trading volume on the primary venue (TSX) per broker. (4) is identical to (3) except calculated at the broker-stock level. (5) stock level increase vs decrease in number of trades where the prevailing queue-length is one-lot per broker in the post vs pre period. (6) is identical to (5), but calculated for each broker. The coefficient of interest (OPR) is reported for each regression. The regression equation utilized is identical to those in Table 7. All regressions control for broker, stock, and venue fixed effects. *, **, and *** indicate significance at the 10%, 5%, and 1% levels of significance, respectively. All regressions standard errors are clustered by stock and date.

Dependent	Alternative venue passive trading		Alternative venue Δ passive trading		Broker Δ primary venue passive		Broker-stock Δ primary venue passive		Stocks number of one-lot queues		Brokers usage of one-lot queues	
	Less	More	Increase	Decrease	Decrease	Increase	Decrease	Increase	Increase	Decrease	Increase	Decrease
Price Impact 1s	-9.78***	-0.86***	-4.27***	-0.97**	-2.56***	-0.59**	-4.00***	-1.73***	-2.73***	-1.84***	-4.13***	-1.78***
Price Impact 30s	-9.87***	-1.38***	-4.55***	-1.53***	-2.84***	-0.71***	-4.36***	-2.26***	-3.18***	-2.24***	-4.59***	-2.21***
Price Impact 1m	-9.55***	-1.39***	-4.34***	-1.58***	-2.89***	-1.31***	-4.22***	-2.22***	-3.09***	-2.25***	-4.41***	-2.22***
N	53,012	235,463	155,482	119,233	218,313	32,664	108,433	77,848	123,464	155,055	86,936	114,188

Table 8: Adverse Selection of 'Back of Queue' Orders

This table computes the price impact of trades at the back of queue on each exchange. $PriceImpact_{i,v,t} = Intercept_{i,v,t} + \beta_1 OPR_{i,v,t} \cdot Backofqueue_{i,v,t} + Controls_{i,v,t} + stock : venueFE + dateFE + \varepsilon_{i,v,t}$. *Back of Queue* takes a value of 1 when the execution depletes the liquidity available at that price level on that venue, and 0 otherwise (i.e. middle of queue orders). NBBO price impacts are defined in the same way as Table 4. They are measured in one second (1s), thirty second (30s) and one minute (1m) intervals. The controls and regression set-ups are identical to those in Table 7. All regressions control for stock and venue fixed effects. *, **, and *** indicate significance at the 10%, 5%, and 1% levels of significance, respectively. All standard errors are clustered by stock and date.

	NBBO Price Impact 1s		*NBBO Price Impact* 30s		*NBBO Price Impact* 1m	
	Alternative	Primary	Alternative	Primary	Alternative	Primary
OPR × *Back of Queue*	-0.26***	-0.20	-0.41***	-0.07	-0.40***	-0.02
	(-3.18)	(-0.89)	(-3.22)	(-0.26)	(-2.81)	(-0.08)
Intercept	4.47***	8.50***	6.07***	9.23***	6.34***	9.21***
	(42.38)	(48.74)	(26.13)	(45.73)	(24.46)	(45.73)
Price	-0.00	-0.01	-0.00	0.00	-0.00	0.01
	(-0.90)	(-1.06)	(-0.27)	(0.69)	(-0.05)	(1.47)
Volatility	0.38***	0.53***	0.73***	1.02***	0.83***	1.17***
	(14.96)	(13.87)	(22.95)	(19.76)	(20.31)	(19.38)
Value	-0.01*	-0.01***	-0.03***	-0.01***	-0.03***	-0.01***
	(-1.72)	(-4.88)	(-3.80)	(-4.72)	(-3.41)	(-4.42)
N	51177	17507	51177	17507	51177	17507
Adj. R^2	51%	71%	47%	65%	44%	61%

Appendix

Figure A1: Make-Take Fee on TSX Across Time

This figure illustrates the make and take fees for an order smaller than $125 million in non-interlisted stocks with prices above $1. Fees are plotted in basis points.