Online Appendix

Regulating Dark Trading: Order Flow Segmentation and Market Quality

Carole Comerton-Forde[a], Katya Malinova[b] and Andreas Park[c]

[a] *Department of Finance, University of Melbourne*

[b] *University of Toronto*

[c] *University of Toronto Mississauga and Rotman School of Management*

This internet appendix comprises five sections. Section A1 provides a detailed reconciliation of our paper with two recent papers which also examine the introduction of the minimum price improvement rule (MPIR) in Canada. Section A2 provides supplementary information about the institutional detail of the Canadian marketplaces. Section A3 provides a detailed description of the method used to classify trader types. Section A4 provides comprehensive summary statistics for each of these trader types and robustness results for a subset of tick-constrained stocks. Section A5 provides robustness tests for the analysis of winners and losers.

OA.1. Reconciling our results with other research examining the introduction of the MPIR

OA1.1. Overview

There are two other studies that examine the introduction of the MPIR in Canada. The first is Foley and Putnins (2016) and the second is an Investment Industry Regulatory Organization of Canada (IIROC) staff study, Devani, Anderson and Zhang (2015). All three studies report that the MPIR led to a significant drop in the level of dark trading. Other than this result, the main findings of the Foley and Putnins paper conflict with the results reported in our paper and in Devani et al. Foley and Putnins report that the MPIR had a detrimental impact on aggregate Canadian market liquidity and informational efficiency. Our paper and Devani et. al. report that the MPIR rule had no impact on aggregate liquidity. Devani et al. also report there is

no change in informational efficiency. Devani et al. and our paper document that the changes in dark liquidity occur largely on a single trading venue, where almost all marketable flow came from retail investors. Both our paper and Devani et al. use trader-level data to demonstrate that the impact of the MPIR is not uniform across all trader types, and that this has important implications for understanding the results. Foley and Putnins consider the impact of the MPIR for the aggregate market using public data and therefore cannot identify the differential impact of the rule by trader-type.

Given that these papers have far-reaching implications for future policy decisions in many major world markets, it is critical to understand the drivers of the differences. In this section we briefly compare how we reach our respective conclusions, and we highlight some key differences in our respective works. Given the consistency of our results with those presented in Devani et al. we do not provide any further comparison of their paper with ours.

OA.1.2. Identification of the main impact: retail order flow

Both our paper and Devani et al. document that the main observable change in behavior after the MPIR is a significant drop in volume on market Ad. Other venues are largely unaffected. Foley and Putnins do not discuss the differences in results across markets in their paper (although Table 1 in their paper shows this result). An important institutional feature of market Ad is that almost 100% of all marketable orders on this market were from retail traders. After the MPIR, one of the main changes in behavior is that the retail flow that formerly cleared in market Ad is directed to the public, lit market. This detail is critical when drawing conclusions about the impact of MPIR and dark trading in general.

OA.1.3. Classification of one- vs. two-sided dark liquidity

Foley and Putnins' analysis separates dark trading into one- and two-sided dark liquidity. They do not provide a formal definition of one- and two-sided dark liquidity but instead focus on

a data-driven classification. Specifically, they classify dark liquidity as one-sided when trades occur at the midpoint and classify liquidity as two-sided when the trade executes at fractional prices. They argue that one-sided liquidity describes a situation when only buyers or sellers are present in the market at any point in time (for if there were both buyers and sellers, they would trade at the midpoint), whereas two-sided liquidity describes a situation when both buyers and sellers can be in the market at the same time. They further argue that two-sided liquidity can only exist when traders can post limit orders at different prices (for if buyers and sellers post the same price, they would trade). The hypotheses that they develop and test require a correct classification of these types of liquidity.

However, this data-driven classification becomes problematic in light of the institutional features of market Ad. By design, after the MPIR, all trades in dark markets trade at the midpoint and Foley and Putnins therefore classify all trades in Ad as one-sided. However, many of these trades in Ad involve two-sided liquidity. Liquidity providers can and commonly do restrict their passive midpoint orders to trade only against "seek-dark-liquidity" orders, which are exclusively available to retail traders. Therefore at any point, liquidity providing buy and sell orders can sit at the midpoint at the same moment in time, and in market Ad, almost 100% of trades thus involve two-sided liquidity in the spirit of their description, before and after MPIR.

OA.1.4. Sample selection

Although Foley and Putnins' headline results state that dark trading is beneficial to market quality, their internet appendix makes it clear that these results are due to the inclusion of non-liquid securities in their sample. Specifically, in their internet appendix they compare their work to ours and state that "[t]he results also show that [...] imposing the highly-liquid requirement does [change our main conclusions]." Of the 248 securities in the TSX Composite Index (the Foley and Putnins sample consists of 242 of these), 236 (95%) are frequently traded. Foley and Putnins' conclusions therefore are driven by six to 12, relatively illiquid stocks, rather than the full sample of 242 securities.

OA.1.5. Measuring proportional spreads in declining markets

There is one additional piece of information that we want to bring to the readers' attention: spreads measured in basis points of the prevailing midpoint are very sensitive to price changes. When we plot the time series of spreads in cents over our sample period, there is no discernable change. When plotting average quoted spreads in bps, on the other hand, one could argue that post MPIR, there was a (small but visible) increase in spreads. However, in November 2012, Canadian stock prices experienced a very substantial price drop. To illustrate the possible impact of this price drop, consider Figure OA.1. It plots the average quoted spreads in bps against the inverse of the average midpoint price. It is clear from this figure that the two series move in almost perfect lockstep. In our analysis, we control for this price effect by including returns from a U.S. commodity price index as a control variable.[1] In our regressions, this variable absorbs the variation in quoted spreads in bps.

OA.1.6. Other Differences

Foley and Putnins' sample consists of 242 of the 248 TSX Composite securities. We use 92 securities that are cross-listed in the U.S. and "highly liquid" as defined by IIROC (most of these are also in the TSX Composite Index). We exclude non-cross-listed securities because these were subject to a major regulatory change that happened at the same time as the introduction of the MPIR. Namely, on the same day, IIROC repealed short-selling restrictions for non-cross-listed securities, which could arguably put downward price pressure on non-crosslisted securities. The second structural difference in our studies is the sample horizon: they consider trading from August 15 to December 15, and we consider trading from August 27 to November 30. We end our sample before December 1, because the main exchange, the TSX, implemented a major technological change on December 1. This change involved a speed upgrade of the kind

[1] The Canadian economy and its equity markets are strongly linked to the commodities sector, which justifies using this non-causally linked index.

studied by Brogaard, Hagstroemer, Norden and Riordan (2015); following their work, this change had the capacity to affect behavior significantly. Foley and Putnins provide a short discussion of the different time horizons and of the restriction to cross-listed securities in their Internet Appendix, arguing that these differences do not affect their results.

OA.2. The institutional setting

OA.2.1. Additional details on the rules governing trading in Canada

The Toronto Stock Exchange (TSX) is the primary listing venue for large companies in Canada. Like other major markets around the world, trading in TSX-listed stocks is fragmented across multiple exchanges and Alternative Trading Systems (ATS). Securities trading and the activities of market participants in Canada are regulated by the Investment Industry Regulatory Organization of Canada (IIROC) [2] and are governed by the Universal Market Integrity Rules (UMIR).

Most of the core elements of the UMIR are similar to those governing trading in the U.S. equities markets. Brokers and marketplaces are required to respect the order protection rule, which mandates that orders must be routed to the marketplace with the best-priced orders available on lit markets. Brokers are also subject to obligations regarding best execution for client orders. [3]

In the context of our study, there are three critical differences between trading rules in the U.S and Canada. First, the order protection rule in Canada applies to the whole-of-book rather than the top-of-book as is the case in the US. Second, Canada also imposes a strict version of an order *exposure* rule,[4] with few exceptions. This rule requires that client orders below a certain

[2] IIROC is a self-regulatory organization that oversees dealers and trading activities and performs real-time market surveillance.

[3] National Instrument 23-101 formulates the order-protection rule; UMIR 5.1 outlines the framework for best execution practices. The order-protection rule differs slightly from its U.S. counterpart, but we believe that the differences are immaterial for our analysis.

[4] See UMIR 6.3 and related guidance notes.

size be immediately sent to a marketplace that publicly displays prices. This rule severely limits the practice of broker internalization, which occurs when a broker trades against their customer's order instead of sending the order to a public marketplace, and the practice of selling retail orders to market makers.[5] Third, unlike the US, Canadian marketplaces are allowed to offer broker-preferencing on the market's order book. This practice allows incoming orders to a marketplace to match with other orders from the same broker-dealer ahead of similarly priced orders from other broker-dealers, without regard to time priority. To take advantage of broker-preferencing, brokers must elect to publicly display broker IDs when submitting their orders. [6]

Dark trading in Canada is subject to restrictions that are similar to rules in other jurisdictions. First, consistent with the principles set out by the International Organization of Securities Commissions (IOSCO), dark orders have lower execution priority than visible orders at the same price.[7] All trades in Canada, including dark trades, are subject to full and immediate post-trade transparency.

Second, the order exposure rule dictates that passive client orders that are below a certain size can only be posted as dark if the client explicitly directs the broker to so do.[8] It is our understanding that during our sample period most brokers did not offer (passive) dark trading as an option to their retail customers; the order exposure rule does not prohibit sending clients' marketable orders to dark venues. The change in dark trading regulations on October 15, 2012,

[5] Battalio, Corwin and Jennings (2016) report that U.S. brokers systematically sell all of their retail marketable orders to market makers (wholesalers). It is our understanding that Canadian broker-dealers did not follow this practice during our sample period, although some entered or considered entering into such arrangements with U.S. wholesalers later. In late 2014, IIROC published a guidance note clarifying that U.S. wholesalers do not satisfy the definition of a regulated public market, effectively banning the practice of selling Canadian retail order flow to the U.S. See also *http://www.osc.gov.on.ca/en/NewsEvents_nr_20141215_concerns-routing-retail-equity-orders.htm* .

[6] Broker-preferencing is subject to several restrictions, e.g., UMIR 5.3 (Client Priority) restricts entering non-client orders at the same or better prices as client orders.

[7] See IOSCO "Principles on Dark Liquidity" http://www.iosco.org/news/pdf/IOSCONEWS210.pdf

[8] The order exposure rule applies to orders that are received by the participant (e.g., the broker). It is the obligation of the participant to ensure compliance with the rule when the received order is at or below 50 standard trading units (for securities in our sample, 5,000 shares); there is also an exemption for orders of more than $100,000 in value.

which we describe in detail below, introduced a price improvement rule, which required that dark orders provide meaningful price improvement over the NBBO to marketable orders that were subject to the order exposure rule.

Finally, trades may be pre-arranged off-exchange, before entering orders on a public marketplace, but these trades must still be executed on a public marketplace, respecting all the applicable rules. Pre-arranged trades thus typically involve orders that are large enough so that they were not subject to the order exposure rule or to the new price improvement rule. We omit such trades from our analysis.

OA.2.2. Additional details on marketplaces unaffected by MPIR

Marketplace B, C, and E to F are unaffected by the rule change. Their institutional arrangements throughout our sample period are as follows:

Marketplace B is a lit market that operates as a public limit order book. Broker preferencing is allowed provided the broker chooses to publicly display its broker ID when submitting the order. Traders may post lit, partially hidden (iceberg), and fully hidden orders. Fully hidden orders may be posted as "mid-point" orders, which are pegged to execute at the floating midpoint of the NBBO, or they may be posted as undisplayed limit orders. Therefore, marketplace B already complied with the dark liquidity rules, before they were introduced. As a result, marketplace B is not directly impacted by the rule change. In principle, this marketplace allows for another form of undisplayed liquidity. Namely, most stocks have a designated market maker or "registered trader" (RT). The RT is in essence a legacy arrangement from the times of floor exchanges, and the RT has some special rights and obligations. For instance, RTs trade against odd-lot (less than 100 share) marketable orders at the currently best-posted prices. They also provide a "minimum guaranteed fill" should liquidity be insufficient and they post liquidity when one side of the order book is empty. One of their rights is the "autofill" functionality, which allows them to trade against marketable orders without posting an order and in violation of time priority. Thus the possibility that the RT has the autofill feature enabled makes it possible that there is additional undisplayed liquidity. This feature is used infrequently: it accounts for

less than .5% of dollar-volume. Moreover, a number of RTs never use the feature, and the feature was not affected by MPIR.

Marketplace C is a lit market that operates as a public limit order book. Like marketplace B, it allows lit, iceberg, and fully hidden orders, which may be pegged to the midpoint. Like marketplace B, marketplace C also complied with the new dark liquidity rules before they were introduced. Marketplace C does not offer broker-preferencing.

Marketplaces E and F operate as public limit order books and **marketplaces G and H** are dark pools. During our sample period, marketplace G is an institutional-only venue, marketplace H offers periodic matching with 1-second random NBBO prices.

Markets A to D operate maker-taker fee models. Different fees apply for lit and dark trades, and fees vary depending on the price of the stock. Details of the fee structure for each market are set out in Table OA.1.

OA.3. Trader classifications

Traders are first classified into four trader types: retail, institutional, high frequency and other. Within the high frequency and other trader categories we also further classify traders into those that provide two-sided liquidity and those that do not.

OA.3.1. Retail traders

In Market A, seek-dark-liquidity (SDL) orders are exclusively available to retail traders. The use of SDL orders is the choice of the broker, not the customer, and it is our understanding that brokers have to explicitly seek to be connected to venue Ad to use this order type. We extract all trader IDs that use SDL orders from the complete database (which spans January 1, 2012 to June 30, 2013), and we classify these traders as retail. We know with certainty that these trader IDs are used to trade order flow from retail traders, but there may be other trader IDs that represent order flow from retail traders that are not captured by our classification.

OA.3.2. High Frequency Traders

The critical component of high frequency trading is that trading is automated and that traders have the ability to react quickly to market conditions. Definitions used by various regulators or policy institutions (e.g., BAFin in Germany, the European Commission, or the SEC) often include as a requirement that HFTs use many orders, in particular in relation to their trades. In our opinion, using orders or order-to-trade ratios biases the classification against traders or strategies that use only marketable orders.

We focus on reaction speeds as the main metric to identify HFTs, and we use reaction times that are faster than human reaction times (the average duration of a single blink of a human eye is 100-400 milliseconds, according to the Harvard Database of Useful Biological Numbers[9]). We further require that trader IDs exhibit fast reaction times for long stretches of time, across many trades, and in many securities. We use two criteria to quantify a trader ID's reaction speed.

Our first criterion is the trader ID's median order-to-cancel time. The order-to-cancel time is the time from the submission to cancellation of the same order; for the purpose of this classification, we exclude immediate-or-cancel (IOC) orders, because their order-to-cancel time is determined by the processing speed of the marketplace.

Our second criterion is the number of trade and order messages that a trader ID submits during a short interval after a daily scheduled public information release. We focus on the first 500 milliseconds after 3:40 p.m., which is when the TSX first publishes the imbalance between the buy and sell orders in its market-on-close facility.

The closing price for TSX-listed securities is determined in a multi-stage process. Before 3:40 p.m., traders may submit market buy and sell orders tagged as market-on-close orders. These orders will trade at the 4:00 p.m. closing price. At 3:40 p.m., the TSX publishes the imbalances of buy and sell orders, and traders then have the opportunity to submit priced limit orders to trade at the market-on-close to off-set the market order imbalance. The market-on-close

[9] http://bionumbers.hms.harvard.edu//bionumber.aspx?&id=100706&ver=1

imbalance is indicative of the closing price and may help predict behavior over the last 20 minutes of trading.

In aggregate, there is a significant spike in trades immediately after the publication of the market-on-close imbalance, though this spike may not be visible or pronounced on a stock-by-stock basis. Figure OA.2 plots the by-minute number of trades, aggregated over all securities in our sample over all days in the classification period. The dataset that is provided to us by IIROC does not contain information on the market-on-close announcement. Therefore, we are not able to determine the time between the publication of the market-on-close imbalance and a trader's action at the millisecond level. For this reason, we classify trader IDs as HFTs based on their actions during a relatively long interval of 500 milliseconds after the announcement.

For each trader ID, stock and day we compute the median order-to-cancel speed, and for each trader ID we compute the total number of orders and aggressive trades during the 500 milliseconds after 3:40 p.m. A trader ID is classified as HFT

1. if the median of the traders ID's median stock-day order-to-cancel speeds is below 250 milliseconds, or
2. if the trader ID submits more than 1,000 orders or is involved in more than 500 aggressive transactions in the first 500 milliseconds after the market-on-close publication across all securities in our classification sample during our classification period.

Our HFT group displays the characteristics typically expected of high frequency traders. As a group, they account for 82% of the orders and 83% of order cancellations during our classification period, they account for 53% of all passive trades, and 34% of all aggressive trades. On an average day, the average HFT trades in 136 securities. None of the HFT trader IDs fall into either the retail or institutional investor categories. HFTs are also among the top users of immediate-or-cancel orders, the use of which indicates that the trader is speed sensitive.

OA.3.3. Institutional traders

We conjecture that institutional traders will be involved in large pre-arranged trades and accumulate large inventory positions. We therefore use these two criteria to identify institutions.

First, we extract all trader IDs that involve a client account and that are involved in a so-called "intentional cross". An intentional cross is a trade, usually a large one, that is pre-arranged off-exchange by a brokerage, for instance to match two client orders or take an inventory from a client via a liability desk.

Second, we search for trader IDs that accumulate large inventory positions across all Canadian marketplaces. We determine each trader's maximum cumulative position for the classification period in non-cross-listed stocks, assigning a zero inventory at the beginning of the period. We focus on non-cross-listed stocks to reduce the possibility that a seemingly large inventory position of an entity is offset by an equally large position elsewhere. Since a trader may buy in one jurisdiction and sell in another, for instance, to exploit an arbitrage opportunity, it is imaginable that a Canada-only position is off-set by a U.S.-based position. We acknowledge that this classification is imperfect, for instance, because a trader ID may trade on behalf of multiple retail clients who jointly accumulate a large position or because a DMA client may use different trader IDs for buying and selling securities. To mitigate these imperfections, we set a high bar for the required cumulative position. We classify the trader ID as an institution if its maximum cumulative position during the classification period exceeds $10,000,000 in absolute value.

OA.3.4. Unclassified

Traders are unclassified if they do not fall within the prior three categories.

OA.3.5. Intermediation in the dark

HFT and other traders are further classified based on the extent to which they intermediate by posting liquidity on both sides of the market in dark pool Ad and D. Figure OA.3 illustrates the differences in the level of intermediation in the two dark pools Ad and D. To

obtain the figure, we first sort traders that post liquidity on both sides of the market in the dark by their intermediation score, from lowest to highest. For each trader and each dark pool (Ad and D), we compute the total passive dollar volume, summing over all sample dates prior to the introduction of the MPIR and over all stocks in our sample. We then cumulate the passive volume within each dark pool over all traders, starting with the trader who has the lowest intermediation score. The figure plots the marginal intermediation score of traders against their cumulative passive volume (expressed as a fraction of the dark pool's total passive volume). The figure illustrates, for instance, that over 87% of passive liquidity in market Ad was provided by trader IDs with intermediation scores of 0.3 or less (i.e., trader IDs that post an almost similar number of orders on both sides of the market), whereas less than 22% of passive liquidity in market D was provided by such trader IDs.

In the main body of the paper, we use a threshold value of 0.3. The results are robust to selecting a slightly higher threshold (0.4 or 0.5). A lower threshold, such as 0.2 fails to capture some traders that we believe to be DPMMs and leads to inconsistencies in the classification across the two dark pools. For market Ad, there are 27 IDs with imbalance scores below 1; and there are no IDs with scores between 0.3 and 0.5. For market D, the number of IDs with an imbalance score below 1 is smaller than 10. If we use 0.4 or 0.5 for the threshold value, then we add IDs that account for about 1.8% of liquidity in marketplace D, and there are no changes for market Ad. Doing so does not change the results of our analysis in Table 4 qualitatively (the numerical estimates change slightly), and the cross-trader volume shares reported in Table 1 change slightly. Overall, the sorting of IDs by threshold is very clear in the data (see Figure OA.3), and the results are not sensitive to small variations in the classification threshold, and we choose the lowest single-digit number threshold that leads to consistent classifications for both dark pools.

OA.4. Detailed summary statistics by trader type and robustness tests

Table OA.2 provides summary statistics of the trading characteristics for each trader type. Table OA.3 provides regression results on the change in liquidity for a sub-set of tick-constrained securities.

OA.5. Cost and benefit measures for each trader type

We define a range of cost and benefit measures for each trader type. This section presents summary statistics for additional measure definitions and regression specification for robustness.

Table OA.4 provides mean measures before and after the MPIR for alternative specifications of effective spreads, price improvement and exchange maker-taker fees for retail traders. Table OA.5 reports regression results for alternative effective spread definitions and Table OA.6 reports regression results for alternative exchange fee definitions. Table OA.7 presents summary statistics for our trading cost and benefit variables for high frequency and other dark pool market makers. Table OA.8 estimates the effect of the introduction of the MPIR on the measures of trading fees for high-frequency and other dark pool market-makers.

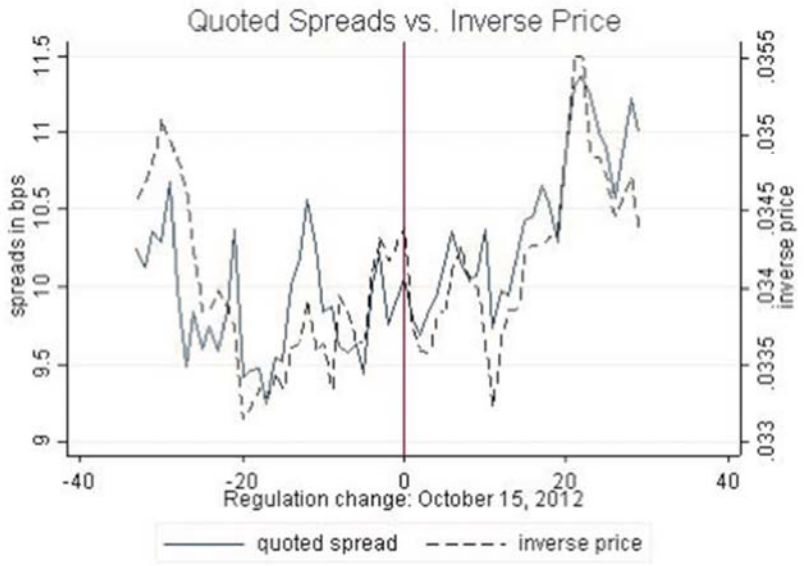

Figure OA.1: Quoted spreads and prices. The figure plots the time series of the average daily time-weighted quoted spread in basis points for our 92 sample securities and the inverse of the average time-weighted quoted midpoint price. Date 0 indicates October 15, 2012, the day when the MPIR became effective.

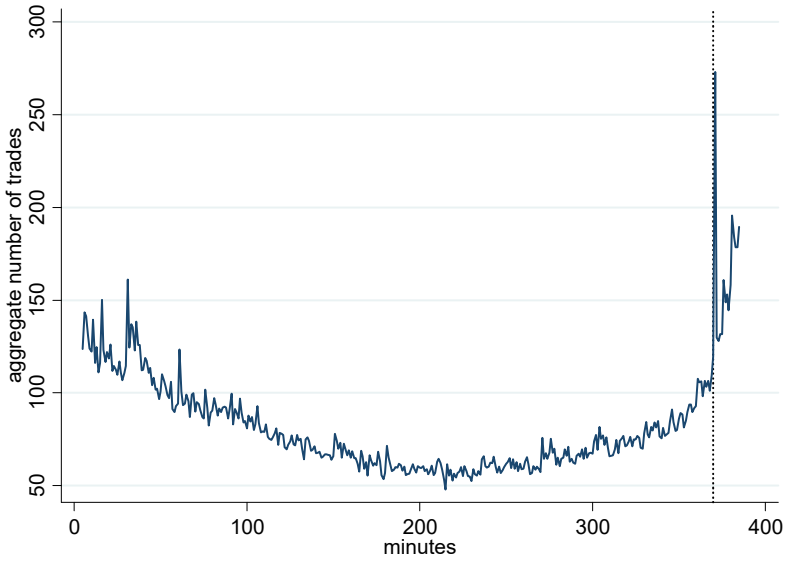

Figure OA.2: Intra-day transactions. The figure plots the aggregate by-minute number of transactions for the securities in our classification sample (92+151 securities) for the July 3 to August 24, 2012 classification period. The plot is for the time between 9:35 a.m. and 3:55 p.m. The dotted line indicates the 370th minute of the trading day, which occurs at 3:40 p.m.

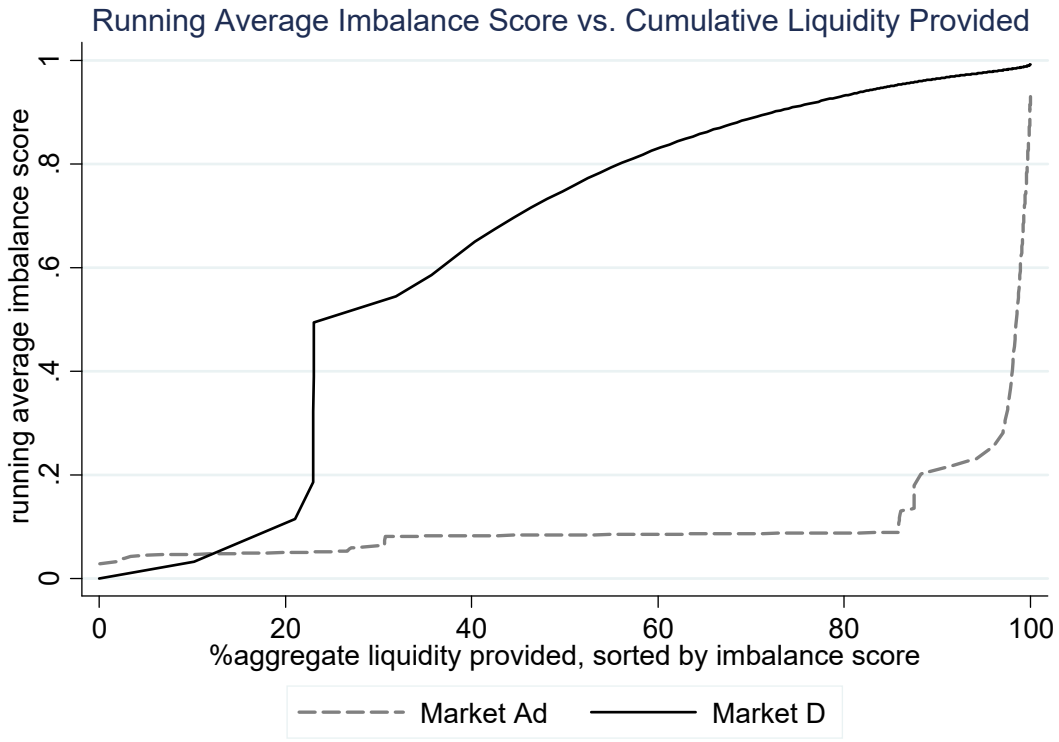

Figure OA.3: Difference in characteristics of liquidity providers in dark pools Ad and D. The figure plots cumulative percentage liquidity provided against the running average of the imbalance score of the traders that supply the liquidity, where we compute the cumulative volume after sorting traders by their imbalance score. The imbalance score is twice the absolute value of the fraction of buy order volume of all order volume less ½. The plot illustrates that the main liquidity providers in market A submit orders in a much more balanced fashion The plot is based on aggregate dollar-volume before the introduction of the dark liquidity rules, from August 27 to October 15, 2012. The vertical line at 0 marks the event date, October 15, 2012.

Table OA.1: Trading fees by marketplace

This table reports the trading fees by marketplace, depending on the price of the security for lit and dark trades. There are several breakpoints ($0.10, $1, $5); our sample contains nine securities that trade below $5, but all trade above $1. In the table, negative numbers signify a rebate. For market B, fees depend on the total dollar volume that a broker trades on a particular venue; those brokers with the highest volume receive the most favorable conditions (for the marginal unit traded). All numbers are in cents per 100 shares.

	lit		dark	
Market	taker/ aggressive	maker/ passive	taker/ aggressive	maker/ passive
Panel A: price>=$5				
Ad			4	0
Al	28	-25		
B	33-35	-32 to -31	10	0
C	29	-25	29	-20
D			10	10
Panel B: price<$5				
Ad			4	0
Al	25	-21		
B	33-35	-32 to -31	10	0
C	29	-25	29	-20
D			5	5

Table OA.2: Summary statistics for trader types usage of trading venues

This table summarizes where different types of traders trade. The column dominator indicates the denominator used to compute the fraction of trades. For each group of traders we examine all combinations of dark and lit and aggressive and passive trades. We differentiate by aggressive trades and by dark vs. passive trades. For aggressive (marketable) orders, an order contributes to dark volume when it trades against a passive dark order and to lit volume when it executes against a displayed order. All figures are for the means of the aggregate dollar volume across all securities for that type per day.

		Before MPIR					After MPIR				
	Denominator	Market A	Market B	Market C	Market D	other	Market A	Market B	Market C	Market D	other
Panel A: HFT											
dark & aggressive	all volume by HFT	0.0	0.0	0.3	1.1	0.0	0.0	0.0	0.5	1.6	0.0
dark & passive	all volume by HFT	1.6	0.3	0.1	0.4	0.0	0.1	0.2	0.1	0.1	0.0
lit & aggressive	all volume by HFT	7.4	25.4	7.5	n/a	1.3	7.6	23.9	7.4	n/a	1.3
lit & passive	all volume by HFT	9.8	28.1	14.3	n/a	2.5	13.4	26.1	15.2	n/a	2.5
aggressive	all aggressive volume by HFT	17.3	59.2	18.1	2.5	2.9	18.0	56.4	18.8	3.8	3.1
passive	all passive volume by HFT	20.0	49.7	25.3	0.6	4.3	23.3	45.6	26.5	0.2	4.3
dark	all dark volume by HFT	42.2	7.6	11.6	38.6	0.0	3.6	8.0	23.1	65.3	0.0
lit	all lit volume by HFT	17.9	55.6	22.6	n/a	3.9	21.5	51.3	23.3	n/a	3.9
Panel B: Retail											
dark & aggressive	all volume by retail	27.6	0.0	0.0	1.5	0.0	4.4	0.0	0.0	1.6	0.0
dark & passive	all volume by retail	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
lit & aggressive	all volume by retail	11.4	20.4	3.4	n/a	1.5	29.7	23.5	4.4	n/a	1.9
lit & passive	all volume by retail	13.6	20.6	0.0	n/a	0.0	13.0	21.4	0.0	n/a	0.0
aggressive	all aggressive volume by retail	59.4	30.9	5.1	2.2	2.4	52.0	35.8	6.8	2.5	3.0
passive	all passive volume by retail	39.7	60.2	0.0	0.1	0.0	37.8	62.1	0.0	0.1	0.0
dark	all dark volume by retail	94.9	0.0	0.0	5.1	0.0	71.1	0.0	0.0	28.9	0.0
lit	all lit volume by retail	35.2	57.8	4.8	n/a	2.2	45.5	47.7	4.7	n/a	2.1
Panel C: Insto											
dark & aggressive	all volume by buy-side	0.0	0.1	0.4	1.4	0.0	0.0	0.1	0.6	1.0	0.0
dark & passive	all volume by buy-side	0.6	1.7	0.6	3.6	0.0	0.7	1.7	0.5	5.3	0.0
lit & aggressive	all volume by buy-side	6.5	33.8	10.5	n/a	2.5	7.1	31.6	11.3	n/a	2.5
lit & passive	all volume by buy-side	3.6	31.8	1.8	n/a	1.3	3.9	30.6	1.5	n/a	1.6
aggressive	all aggressive volume by buy-side	11.8	61.4	19.8	2.5	4.5	13.1	58.4	22.0	1.9	4.6
passive	all passive volume by buy-side	9.4	74.4	5.2	8.0	3.0	10.1	70.5	4.4	11.5	3.4
dark	all dark volume by buy-side	7.1	20.8	12.0	60.2	0.0	7.5	17.9	11.1	63.5	0.0
lit	all lit volume by buy-side	11.0	71.5	13.3	n/a	4.2	12.2	69.0	14.3	n/a	4.5

Table OA.3: Regressions on the change in liquidity for tick-constrained securities

This table presents regressions for the impact of MPIR on bid-ask spreads, depth and the % of the day time that quotes of the respective market are at the NBBO before and after the MPIR. The underlying sample is restricted to the 50 securities that, prior to MPIR have quoted spreads of 1 cent for at least 80% of the trading day. Quoted spreads are measured as time weighted average in cents and basis points of the midpoint; the percentages of time are numbers between 0 and 1; $-depth is measured as the time-weighted average of the local BBO, as the amount contributed to the NBBO, as the amount contributed when at market is at the NBBO. All specifications contain security fixed-effects. Standard errors are clustered by time and security, and t-statistics are in parentheses. * indicates significance at the 10% level, **at the 5% level, and *** at the 1% level.

	local quoted spread in cents	local quoted spread in bps	%time at NBBO with either bid or ask	%time at NBBO with both bid and ask	%day local spread tick-constrained	log($-depth)	log($-depth) posted at top of the book	log($-depth) when posting at NBBO
Market Al x MPIR	-0.05*	0.32	0.01***	0.04***	0.05***	0.24***	0.25***	0.28***
	(-1.801)	(0.849)	(2.642)	(3.757)	(3.477)	(6.963)	(6.580)	(6.677)
Market B x MPIR	-0.02	0.36	0.00	0.01	0.02**	-0.03	-0.02	-0.02
	(-1.545)	(1.150)	(1.178)	(1.561)	(2.127)	(-0.815)	(-0.701)	(-0.529)
Market C x MPIR	-0.06**	0.38	0.01**	0.03***	0.05***	0.03	0.03	0.06
	(-2.156)	(0.969)	(2.453)	(3.575)	(3.202)	(1.010)	(0.949)	(1.462)
VIX	0.02**	0.18**	-0.00*	-0.01**	-0.01*	-0.01*	-0.01	-0.01
	(2.373)	(2.509)	(-1.840)	(-2.497)	(-1.898)	(-1.770)	(-1.305)	(-1.622)
CRCI	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.01
	(0.381)	(0.247)	(0.504)	(0.976)	(0.992)	(0.762)	(0.964)	(0.978)
Observations	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600

Table OA.4: Retail trader cost and benefit summary statistics

This table presents summary statistics for alternative specification for our measures of trading costs and benefits for retail traders before and after the MPIR. Effective spreads are measured in cents and basis points with and without maker-taker fees. Maker-taker fees are computed as the difference between maker rebates received on passive limit orders and taker fees paid on marketable orders; a negative number thus indicates that the net exchange fees paid by a trader ID are negative.

		before	after
effective spread (in cents)		1.5	1.5
effective spread (in bps)		7.6	7.9
effective spread w MT fees (in cents)		1.7	1.8
effective spread w MT fees (in bps)		9.2	10.0
fees in $	all venues	-71.5	-234.6
	Al	-3.3	-166.0
	Al & Ad	-35.3	-170.4
fees in bps	all venues	-0.3	-0.8
	Al	-0.1	-0.6
	Al & Ad	-0.2	-0.6
fees per share traded	all venues	-0.04	-0.09
	Al	-0.01	-0.06
	Al & Ad	-0.02	-0.06

Table OA.5: Regression on change in effective spreads for retail traders

This table estimates the effect of the introduction of the minimum price improvement rule on the effective spreads that retail traders pay for their marketable orders. All specifications contain security fixed-effects. Standard errors are in parentheses and are clustered by time and security. * indicates significance at the 10% level, **at the 5% level, and *** at the 1% level.

	Effective spreads in cents		Effective spreads in bps		Effective spreads with fees in cents		Effective spreads with fees in bps	
MPIR	-0.02	-0.03	0.15	0.04	0.05	0.03	0.74**	0.65*
	(0.07)	(0.10)	(0.28)	(0.30)	(0.07)	(0.10)	(0.36)	(0.35)
VIX	0.00	0.00	0.03	0.02	0.00	0.00	0.05	0.05
	(0.01)	(0.01)	(0.04)	(0.05)	(0.01)	(0.01)	(0.05)	(0.06)
CRCI		-0.01		-0.03		0.00		-0.03
		(0.01)		(0.04)		(0.01)		(0.04)
Observations	5,771	5,771	5,771	5,771	5,771	5,771	5,771	5,771

Table OA.6: Regressions on change in maker-taker fees for retail brokers

This table estimates the effect of the introduction of the minimum price improvement rule on the maker-taker fees paid by retail brokers. Fees are measured in total dollars and basis points. All specifications contain security fixed-effects. Standard errors are in parentheses and are clustered by time and security. * indicates significance at the 10% level, **at the 5% level, and *** at the 1% level.

	total dollar fees (maker minus taker)			*fees per dollar traded in bps*		
	all markets	Al and Ad	Al	all markets	Al and Ad	Al
MPIR	-138.82***	-118.39***	-143.69***	-0.40***	-0.36***	-0.42***
	(25.09)	(24.42)	(28.44)	(0.09)	(0.08)	(0.09)
VIX	-0.57	0.09	-1.53	0.00	0.00	0.00
	(6.12)	(3.17)	(2.80)	(0.01)	(0.00)	(0.00)
CRCI	5.82	4.16	4.29*	0.02*	0.00	0.00
	(5.19)	(2.78)	(2.35)	(0.01)	(0.00)	(0.00)
Observations	5,738	5,738	5,738	5,738	5,738	5,738

Table OA.7: HF and non-HF dark pool market makers cost and benefit summary statistics

This table presents summary statistics for our trading cost and benefit variables for high-frequency (HF) and non-HF dark pool market makers. Returns to trading are defined in Section 8.2.1 (equation (7)); these are measured as the minimum of buying and selling volume multiplied with the difference of volume weighted average selling and buying prices for the respective trader group. Maker-taker fees are the sum of all make rebates received less take fees paid. Maker-taker fees are reported in total dollars, basis points and cents per share traded. Results are reported for all venues, Ad and Al together, and Al alone.

		HF DPMMs		non-HF DPMMs	
		before	after	before	after
returns to trading in $	all venues	1.2	-10.9	-59.5	44.0
	Al	6.1	13.6	8.5	49.5
	Al & Ad	-26.5	15.3	-63.3	44.1
maker taker fees in $	all venues	399.1	536.7	-0.9	32.9
	Al	117.1	211.0	3.8	35.2
	Al & Ad	117.1	210.9	3.8	35.2
maker taker fees in bps	all venues	1.1	1.4	0.1	1.0
	Al	0.3	0.5	0.1	1.1
	Al & Ad	0.3	0.5	0.1	1.1
maker taker fees per share traded	all venues	0.1	0.2	0.0	0.1
	Al	0.0	0.0	0.0	0.1
	Al & Ad	0.0	0.0	0.0	0.1

Table OA.8: Regressions on change in maker-taker fees for HF and non-HF dark pool market makers

This table estimates the effect of the introduction of the minimum price improvement rule on the measures of trading fees for HFT and non-HFT dark pool market-makers. All specifications contain security fixed-effects. Standard errors are in parentheses and are clustered by time and security. * indicates significance at the 10% level, **at the 5% level, and *** at the 1% level.

	total dollar fees (maker minus taker)					
		HF DPMM			non-HF DPMMs	
	all markets	Ad and Al	Al	all markets	Ad and Al	Al
MPIR	140.79***	108.09***	108.12***	12.00	9.72	9.72
	(35.87)	(20.89)	(20.90)	(11.50)	(10.34)	(10.34)
VIX	-3.14	-1.00	-0.99	1.19	0.13	0.13
	(9.87)	(3.08)	(3.08)	(1.96)	(1.83)	(1.83)
CRCI	-0.04	1.93	1.91	-5.02**	-5.33***	-5.33***
	(7.98)	(2.76)	(2.76)	(2.13)	(1.98)	(1.98)
Observations	5792	5792	5792	5792	5792	5792