Regulatory efforts to reduce dark trading in Canada and Australia: How have they worked? *

Sean Foley [a] and Tālis J. Putniņš [b]
[a] *University of Sydney*
[b] *University of Technology Sydney* and *Stockholm School of Economics in Riga*

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Abstract

Growth in dark trading has caused considerable concern among regulators and exchanges worldwide. These concerns recently prompted Canadian and Australian regulators to implement novel restrictions that require dark trades to provide meaningful price improvement relative to the best quotes at transparent exchanges. We examine the effects of these new rules. We find that in both Canada and Australia, the new rules substantially decreased the amount of dark trading; by one third of its previous level. As a consequence of tick sizes constraining the spread in most stocks, almost all dark trading post regulation occurs at the NBBO midpoint. The minimum price improvement requirements reduced broker internalization of client orders by making this practice less profitable. While these effects are largely consistent with the objectives of the regulation, we do not find evidence that the regulation achieved its higher-level objectives of improving market quality. We find no significant changes in the propensity to post lit liquidity. Furthermore, we find wider spreads in both countries post regulation in multivariate tests that exploit a control market. Our analysis reveals that the reason the regulation resulted in wider spreads is that it effectively replaced two-sided dark limit order markets with one-sided midpoint dark crossing systems in the large number of stocks that are constrained by the tick size. An implication of our findings is that minimum price improvement regulation is more likely to benefit liquidity if it is accompanied by reductions in tick sizes.

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* Email: sean.foley@sydney.edu.au and talis.putnins@uts.edu.au. The authors thank the Securities Industry Research Centre of Asia-Pacific (SIRCA), as well as ITG MatchNow, Chi-X Canada and the TMX Group for the provision of data, and CFA Institute for research funding. The authors would also like to thank Torstein Braaten, Paul Redman, Jonathan Sylvestre, Kent Bailey and Alina Bazavan for their thoughtful comments and market knowledge.

1. Introduction

Dark trading refers to trades that are executed without pre-trade transparency. While dark trading has long been a feature of equity markets in the form of upstairs block trades, only in recent years with the introduction of continuous dark pools for smaller sized non-transparent orders has it attracted the attention of regulators and policy makers worldwide. Dark pools have been very successful in attracting order flow, and are estimated to account for approximately 15% of US consolidated volume, 10% in Europe, 14% in Australia, and 10% in Canada.[1] Their success is likely related to the advantages attributed to dark pools by their proponents, such as the ability to avoid large orders being front run, reduced information leakage, and lower market impact costs.

The rapid increase of dark market share has caused considerable concern, especially among market regulators. For example, the US Securities Exchange Commission (SEC) proposed rules in 2009 for the "Regulation of non-public trading interest" and in 2010 issued a Concept Release on Equity Market Structure calling for comments on the issue of dark liquidity. The Financial Industry Regulatory Authority (FINRA) in 2013 proposed a new set of disclosure requirements for dark pool operators, and in 2014 the SEC Chairman in a recent speech said "transparency has long been a hallmark of the US securities markets, and I am concerned by the lack of it in these dark venues".[2] The Committee of European Securities Regulators (CESR) has undertaken a review of dark trading with recommendations to limit the activities of broker crossing systems, and the European Commission in 2013 proposed EU-wide rules that cap the volume traded in dark pools.

While several regulatory bodies have made proposals and conducted public consultations regarding dark trading, their hesitance in introducing new regulations reflects the scarcity of evidence on the costs and benefits of dark pools, and how the costs/benefits are distributed between different market participants. Furthermore, there is

[1] The US estimate is from Rosenblatt Securities for April 2013. The Europe estimate is for July 2013 using Thomson Reuters data as reported by the Wall Street Journal (http://online.wsj.com/article/BT-CO-20130812-701291.html). The Australian estimate is from the Australian Securities and Investments Commission Report 331 for the September quarter 2012 and includes some internalization. The Canadian estimate combines statistics from the Investment Industry Regulatory Organization of Canada and proprietary data obtained for this study and corresponds to the period Aug-Dec 2012.

[2] See Wall Street Journal, 6 June 2014 (http://online.wsj.com/articles/sec-chairman-unveils-sweeping-proposals-to-improve-markets-1401986097).

considerable uncertainty among regulators about the likely outcome of various potential regulatory interventions, what the unintended consequences of regulation of dark trading may be and how to minimize them, and how to strike the right balance between the costs of regulation and potential benefits. This study aims to address these issues by providing empirical evidence on the effects of the recent regulation of dark trading in Canada and Australia.

To date, only two countries have imposed significant new restrictions on dark trading in response to the recent growth in dark trading: Canada in October 2012 and Australia in May 2013. In both countries the restrictions require that dark trades below block size provide one full tick of price improvement (or half a tick if the spread is constrained at one tick). We use the term 'dark trades' to refer to all below block size trades that are executed without pre-trade transparency, including trades in dark pools, trades executed against hidden orders, and off-market broker internalization of client orders. In Canada below block size trades are generally trades of 5,000 shares or less. In Australia, the minimum price improvement rules coincided with a revision of the block size thresholds from $1 million for all stocks to a tiered system with thresholds of $1 million, $0.5 million or $0.2 million depending on the liquidity of the stock. These rules reduced the amount of dark trading in Canada by over one third, literally overnight, and in Australia caused a significant shift from below block size dark trades to block trades. We analyze the impact of the dark trading minimum price improvement rules introduced in both Canada and Australia and assess the extent to which they achieved their objectives. We use highly detailed proprietary trade-level data from dark trading venues.

We find that in both Canada and Australia, the new rules substantially decreased the amount of dark trading. In Australia, the reduction in dark trading was accompanied by an increase in block trading, largely because of a contemporaneous reduction in the block trade size thresholds that allow trades to avoid the minimum price improvement requirements. Not all dark trading venues/mechanisms were impacted equally. In general, venues/mechanisms where dark trades provided relatively more price improvement before the regulation did not suffer significant reductions in market share, and in many cases *gained* volume from venues/mechanisms where dark trades offered little or no price improvement.

Almost all dark trades, in both countries, were driven to execute at the NBBO midpoint after the regulation. The absence of dark trades between the NBBO and its midpoint is largely because the spread for the majority of liquid stocks in both countries is only one or two ticks wide. A consequence of forcing all dark trades to the midpoint is the inability for a two-sided dark market to exist, in which dark liquidity concurrently exists on both the buy and sell sides. We also find a decline in broker internalization of client orders in the dark following the introduction of minimum price improvement rules.

Somewhat less consistent with the regulatory objectives, we find no evidence of an increased propensity for market participants to post lit liquidity, as measured by lit limit order submissions to traded volume and lit depth to traded volume. Furthermore, we find no evidence that average trade sizes in the dark increased; they remained approximately unchanged in Canada and significantly decreased in Australia.

The ultimate effect of the regulation on higher-level market quality characteristics such as liquidity and informational efficiency was less predictable ex-ante due to the large number of competing effects. Our findings suggest that the impact of the regulation on liquidity in particular is not in line with the regulatory objectives. More specifically, we find that quoted and effective spreads, as well as price impacts, are wider after the regulation in both countries, indicating a deterioration in liquidity. Our analysis controls for trends in market characteristics that may be unrelated to dark trading, such as total dollar volume and volatility. We also control for trends in liquidity in a closely related market that was not subject to minimum price improvement requirements, thereby removing trends in liquidity that are not associated with the regulation. Our measures of spreads that involve trades (e.g., effective spreads) include all lit and dark trades, and therefore reflect average transaction costs for all trades. The increase in spreads is larger in Australia than Canada (e.g., quoted spreads increase by 19% from their pre-regulation levels in Australia, and 5% in Canada). The effect on informational efficiency is relatively small in magnitude and due to differences across the informational efficiency metrics we do not draw strong conclusions about how the regulation impacted informational efficiency.

Did the regulations achieve their objectives? The regulations did achieve some of the more basic and immediate objectives, such as reducing the amount of dark trading,

ensuring that dark trades provide meaningful price improvement, and reducing the amount of internalization in the dark. However, they do not appear to have been successful in the higher-level objective of encouraging the posting of lit liquidity and thereby improving liquidity. Our analysis reveals that, consistent with theory, the main reason why the minimum price improvement regulation resulted in wider spreads and larger price impacts is that it effectively terminated two-sided dark limit order markets in the large number of stocks where the spread is constrained by the tick size. In such stocks, dark trades are forced to execute at the midquote, which transforms the structure of the dark market into a crossing system in which liquidity can only exist on one side of the market at any point in time. While this may seem harmless and consistent with benefiting the market by preventing dark orders from 'jumping the queue' in lit markets, it causes a fundamental change in the nature of dark trading.

This study is broadly related to the recent literature on the effects of dark trading. The theoretical literature predicts that dark trading could have a positive or a negative impact on market quality depending on the microstructure of how dark trading takes place. A general conclusion from such studies is that dark trading that is organized as a dark limit order book in which dark liquidity can be posted on both the buy and sell side of the market is more likely to have a positive effect on market liquidity compared to dark trading at the midquote. For example, Boulatov and George (2013) find that dark limit order markets encourage informed traders to supply liquidity because they can profit from doing so without revealing much of their private information. Transparency makes them reluctant to supply liquidity because other traders gain an informational advantage by observing the limit order schedules before deciding how to trade. Boulatov and George (2013) show that dark limit order markets not only increase liquidity provision by informed traders but also the aggressiveness with which they trade, which improves informational efficiency.[3] In contrast, Zhu (2014) shows that informed traders are less likely than uninformed traders to send orders to a dark midpoint market because their tendency to cluster on the same side of the market gives them a lower execution

[3] Fragmentation across lit and two-sided dark trading venues can benefit liquidity by (i) increasing the number of liquidity providers (e.g., Bias et al., 2000), (ii) encouraging liquidity provision through 'queue jumping' (bypassing time priority; e.g., Foucault and Menkveld, 2008), and (iii) allowing liquidity providers to compete on a finer pricing grid (e.g., Biais et al., 2010; Buti et al., 2013).

probability than uninformed orders. The increased concentration of informed traders in the lit market increases adverse selection risks and harms liquidity. Hendershott and Mendelson (2000) show that when traders route orders to the lit market after failing to execute them in a midpoint crossing system (using the lit market as a 'market of last resort') they make lit order flow more prone to imbalances, increasing inventory and adverse selection risks, and harming liquidity.

What this implies for minimum price improvement regulation is that for the many stocks that have spreads that are constrained by the minimum tick size, minimum price improvement requirements will cause a substitution from dark limit order trading to dark midpoint trading. According to theory, this change in the structure of dark trading may have a negative impact on market liquidity. Our empirical results support this notion.

The empirical literature on the impact of dark trading finds mixed results. To some extent the mixed results can be attributed to the difficulty in overcoming the endogeneity problem in studying dark trading as well as difficulties in obtaining detailed data on dark trading. Kwan et al. (2014) examine how the tick size influences dark trading and find that market participants use US dark pools to obtain a finer pricing grid when stock prices are constrained by the tick size. Ready (2014) analyzes the determinants of volume in two block crossing systems (Liquidnet and POSIT) and finds that dark trading activity is higher for stocks with lower levels of adverse selection risks. Degryse et al. (2014) analyze 52 Dutch stocks and conclude that fragmentation of volume across visible order books improves consolidated liquidity, while dark trading has a detrimental effect. Buti et al. (2011) use data from 11 out of 32 US dark pools and conclude that dark pool activity improves spreads, depth and short-term volatility. Nimalendran and Ray (2014) examine data from one of the 32 US dark pools and find informational linkages between lit and dark venues due to traders using algorithms to split orders across venues. Comerton-Forde and Putniņš (2013) find that in Australia low levels of dark trading may improve price discovery, but when below block sized dark volume exceeds 10% of total trading, informational efficiency deteriorates.

Most closely related to our study is the small number of papers examining the effects of regulatory changes impacting dark trading and internalization. Larrymore and

Murphy (2009) study the impact of the Toronto Stock Exchange's Price Improvement Rule in 1998, which disallowed internalization without price improvement. They find that when the price improvement requirement is introduced, there is an increase in the average level of price improvement, reductions in both quoted and effective spreads, lower return volatility, and greater market depth. They suggest the decrease in internalization led market makers to compete more aggressively for order flow, and narrowed spreads due to decreases in adverse selection risks. The recent regulatory changes analysed in this paper differ from the change studied by Larrymore and Murphy (2009) in that they do not target internalization, but rather dark trading more broadly. In Canada, systematic off-market internalization does not exist during our sample due to the earlier price improvement requirements for internalization of order flow and therefore the regulation impacts an entirely different segment of trading activity. In Australia, the recent price improvement requirements for dark trading impact both internalization and other users of dark trading facilities.

This paper proceeds as follows. Section 2 details the institutional setting and recent regulation of dark trading in Canada and Australia. Sections 3 and 4 describe the data and methods. Section 5 presents the results and Section 6 concludes. Appendices, tables and figures are at the end of the document.

2. Institutional setting

2.1 Trading venues and order types

2.1.1 Canada

Canada has experienced rapid fragmentation of its trading landscape over the last decade. In addition to the main listing exchange, the Toronto Stock Exchange (TSX), at the end of our sample there are six Alternative Trading Systems, on which trading occurs with pre-trade transparency ('lit' venues): Alpha, Chi-X, CX2, Pure Trading, TMX-Select, and Omega. TSX is still the dominant market, executing approximately 63% of Canadian dollar volume during the sample period, followed by Chi-X (13%) and Alpha (12%). Additionally, there are four continuous auction venues in which orders can be submitted without pre-trade transparency: ITG's MatchNow, Alpha Intraspread, Chi-X

and TSX.[4] MatchNow and Alpha Intraspread fall into the category of markets often referred to as 'dark pools' because only dark orders can be submitted to these venues and therefore dark orders execute exclusively against other dark orders. They account for approximately 5.4% and 1.9% of Canadian dollar volume, respectively, during our sample period. In contrast, Chi-X and TSX allow dark orders in addition to lit orders and the two types of orders interact and can execute against one another. Following the introduction of the minimum price improvement rules in 2012, Alpha Intraspread (which had been a stand-alone continuous dark pool) was merged with the Alpha lit exchange. Subsequently, Intraspread orders were able to interact with both lit and dark liquidity, similar to the situation in both the TSX and Chi-X. Table 1 provides a summary of the market shares, order types and other characteristics of each of the Canadian trading venues.

< Table 1 here >

Prior to 15 October 2012, all dark orders were required to provide some price improvement, resulting in dark executions within the national best bid and offer (NBBO) spread. The required amount of price improvement, however, was not specified by legislation. MatchNow and Intraspread both offered two types of price improvement: midpoint (i.e., 50% improvement over the NBBO) and 20% (on MatchNow) or 10% (on Instraspread) improvement over the NBBO. Price improvement of 10%, for example, means that if a stock has a national best bid of $10.00 and a national best offer of $10.01, a passive dark buy order could be placed at a price of $10.001 (an improvement of 10% of the NBBO spread) and a passive dark sell order could be placed at a price of $10.009 (also an improvement of 10% of the NBBO spread).

Both MatchNow and Intraspread supported price priority, meaning a passive midpoint order would execute before a passive 20% or 10% price improvement order. When an active order is submitted to a dark pool, the matching engine first checks if there are any passive orders available to execute against. If there are, the order is

[4] MatchNow was launched in July 2007. Intraspread was launched in May 2011. Chi-X introduced dark mid-point orders in February 2008. TSX introduced dark orders between April and May 2011.

executed and immediately reported to the Canadian marketplace.[5] If the active order cannot be matched it is either cancelled (akin to a fill or kill order) or it is forwarded to a lit venue based on the user's routing table preferences. TSX and Chi-X only offered floating midpoint orders, which could execute against both incoming active lit orders as well as other dark orders. A more detailed explanation of the introduction of dark orders on the TSX is provided by Foley et al. (2012).

In addition to the continuous dark pools, systems to negotiate block trades without pre-trade transparency have existed for decades. Two that currently operate in Canada are Liquidnet and Instinet. These venues provide 'trade blotter' services that facilitate the execution of 'upstairs' trades. Typically, clients enter their desire to trade large blocks into the system. The system then identifies whether any potential counterparties exist, and if so, allows the counterparties to negotiate the trade anonymously. While these systems also have limited or no pre-trade transparency, they differ from dark pools that have captured significant market share in recent years in that they are generally only used by large institutional traders, are non-continuous, and only offer services for block trades. Although block trading facilities have existed for many years, the combined market share of Liquidnet and Instinet in Canadian equities during the third quarter of 2012 was only 0.2%.[6] Brokers are also able to internalize orders off-market. The order exposure rule requires however, that internalized trades are provided one full tick of price improvement, in conjunction with the fair access regulations that prohibit venues from providing exclusive access to certain types of clients.[7] This has hampered the development of automated 'internalizers' such as those that exist in the US, Australia and elsewhere.

The order execution priority rules in Canada differ significantly from those in other countries, primarily in the existence of broker preferencing, which allows passive orders resting in the limit order book to break time priority if an incoming active order is from the same broker. Many of the dark trading venues have employed unique priority

[5] The reporting is facilitated by TMX Datalinx and is required according to Universal Market Integrity Rules. While this forms a consolidated feed of quotes and trades, it does not provide the NBBO for Canada; rather, participants must reconstruct it from the order flow. For more information see www.tmxdatalinx.com.
[6] This statistic is taken from the IIROC "Marketplace Statistics Report" available at www.iiroc.ca.
[7] See the Universal Market Integrity Rules (UMIR) section 6.3.

systems in order to differentiate themselves from other venues. Of these, the most complex are found on Alpha Intraspread. Intraspread provides priority based on the amount of price improvement first, with orders offering 50% of the spread receiving priority over those that offer 10% of the spread. Given equal price improvement, broker preferencing provides priority for orders from the same broker. Assuming equality on these two rules, priority will be given to passive orders that are able to fulfill the entire active order. If all four of these priorities are equivalent, time priority will be given to the oldest order.

2.1.2 Australia

The Australian equity market is dominated by the Australian Securities Exchange (ASX), which provides services in listing, trading, clearing and settlement. The monopoly enjoyed by ASX in the provision of trading services ended on 31 October, 2011 when Chi-X Australia was granted a market license by the Australian government to trade ASX-listed equities. The ASX maintains a monopoly on settlement and clearing functions. The ASX is one of the top ten equity markets in the world by market capitalization. There are approximately 2,200 companies listed on the ASX with a market capitalization of around $1.5 trillion. There are around 90 brokers in Australia. The top 12 brokers account for approximately 80 percent of equity turnover. Most of the top brokers are large global players in the securities industry.

The ASX and Chi-X Australia operate transparent central limit order books (CLOB) in which orders are matched based on price then time priority. Both markets trade continuously between approximately 10am and 4pm.[8] Unlike the US, there are no 'trade-through' rules in Australia that require orders to be routed to the market with the best available quote; instead, brokers have a statutory 'best execution' obligation to their clients.

The Market Integrity Rules require that trades be executed on the ASX or Chi-X Australia, with pre-trade transparency, unless they fall into one of the exceptions that

[8] The ASX opens trading with a series of call auctions between 10:00am and 10:09am. The market is closed with a call auction that takes place between 16:10 and 16:12 at a random time within a 60 second window. Continuous trading on Chi-X occurs from 10:00am to 4:12pm with no opening or closing auctions (order entry is only possible from 10:00am).

allow trades to be executed away from these lit CLOBs. The exceptions include: (i) block trades that exceed a size threshold, and (ii) dark trades that comply with certain requirements.

There are two types of block trades that have exceptions to the pre-trade transparency requirements: (i) *block special crossings* which are single trades with a minimum value ($1 million before 26 May 2013 and either $1 million, $0.5 million or $0.2 million depending on the liquidity category of the stock after 26 May 2013) and *portfolio special crossings* which comprise a portfolio of at least ten stocks with a minimum value for each stock of at least $200,000 and a combined portfolio value of at least $5 million. Block trades meeting these requirements can be negotiated away from the lit CLOBs at any price and immediately reported to either the ASX or Chi-X Australia. We treat block trades in Australia as a separate category in our analysis.

Below block size trades (which we refer to simply as dark trades) can be executed without pre-trade transparency in a number of ways/venues. These include *priority crossings*, *Centre Point priority crossings*, and *NBBO crossings*: trades for which a broker has both sides of a trade and wants to avoid the CLOB time priority rules. These exceptions are used by brokers to execute trades in the large number of broker dark pools (often referred to as dark 'crossing systems' in Australia), and systematic internalizers. The first broker dark pool in Australia was launched in 2005. Since then the number of broker dark pools has grown rapidly to a count of 21 in May 2013.[9] The pre-trade transparency exceptions are also used to report manually matched dark trades or manually internalized trades to the lit markets. In the data, we are able to precisely identify all trades that fall into this category; however, within this category, we cannot distinguish between trades that were executed in the broker dark pools versus dark trades that were manually matched, or trades that involve broker internalization versus client-to-client trades.

In addition to the 20 or so broker dark pools, both ASX and Chi-X Australia provide mechanisms for executing below block size dark trades. Since its commencement in June 2010, ASX operates a dark pool named *Centre Point. Centre*

[9] The list of broker crossing systems registered with ASIC is available at http://www.asic.gov.au/asic/ASIC.NSF/byHeadline/List-of-crossing-systems-registered-with-ASIC

Point is separate from the lit CLOB (lit orders do not interact with orders in *Centre Point*) and executes orders at the midpoint of the best bid and ask quotes in the CLOB. In contrast, Chi-X Australia does not have a separate dark venue, but instead allows fully dark order types that can interact with lit orders on its market. For more details on the institutional mechanisms by which dark trades are executed in Australia see Comerton-Forde and Putnins (2013) and ASIC Report 331.

Table 2 provides a breakdown of the dollar volume executed in each of the Australian lit and dark venues during our sample period. Trading in the ASX lit CLOB (and block trades reported to the ASX) account for 70.3% of total dollar volume. Chi-X has a 9.4% market share during our sample period, which includes lit trades and dark trades arising from hidden orders. The broker dark pools, systematic internalization and manual dark trades collectively account for approximately 15% of total traded dollar volume. Finally, the ASX *Centre Point* dark pool executes around 5% of total dollar volume.

< Table 2 here >

There are a number of important differences between the dark pools operated in Australia and those operated in the US. First, unlike the US markets where these types of venues need to be registered as an Alternative Trading System (ATS), dark pools in Australia are not licensed as markets, but instead operate under the rules of an exchange. Second, the level of interconnectedness between dark pools is much lower. Orders sent to one dark pool are not typically routed to other pools. There are however, a small number of agency-only brokers operating dark liquidity aggregator businesses. Orders typically sweep through a single dark pool before being sent to the lit exchange or they rest in the dark pool order book.[10] It is also common for parts of an order to be simultaneously posted to the lit exchange and a dark pool. Third, with the exception of block trades, dark pools in Australia may only match orders at or within the spread at prices that are multiples of the minimum tick size on the exchange or the midpoint of the

[10] *ASIC Report 331* reports that a number of dark pools have subsequently become more market-like and have built connections to other pools.

spread. Finally, the *ASIC Market Integrity Rules* require that all dark pool trades be immediately reported to an exchange and disseminated to the market. In the US, dark pool trades must also be reported to the consolidated tape (dark pools usually report their trades to a trade reporting facility (TRF) such as those operated by NYSE and Nasdaq, which in turn report the trades to the consolidated tape), but a delay of up to 30 seconds is permitted (see Nimalendran and Ray, 2014).

Exchange trading fees are charged as a proportion of dollar trading value. Anticipating the entry of Chi-X Australia, ASX reduced its trading fees on 1 July 2010. CLOB trades are currently charged at 0.15 bps (they were 0.28 bps prior to 1 July 2010), *Block* and *Portfolio crossing* fees are 0.10 bps (they were 0.15 bps prior to 1 July) and *priority crossing* fees are 0.05 bps (down from 0.075 bps). *Centre Point priority crossings* are charged at 0.15 bps while *Centre Point* trades are charged at 0.5 bps. With the exception of *Centre Point* trades, these fees are capped at $75 per trade.[11] Chi-X Australia's fee structure from market launch is 0.06 bps for passive order executions and 0.12 bps for active order executions.

2.2 Regulation

2.2.1 Canada

The Investment Industry Regulatory Organization of Canada (IIROC) sets and enforces the Universal Market Integrity Rules (UMIR), which govern trading on debt and equity marketplaces in Canada. On 13 April 2012 IIROC notice 12-0130 announced changes to the UMIR, which became effective on 15 October 2012. These changes imposed a minimum threshold for price improvement by dark orders of one full tick relative to the prevailing NBBO, except when the spread is already constrained to one tick, in which case dark orders are allowed at the midpoint of the NBBO (half a tick price improvement). This new requirement provides an exemption for dark orders larger than either 50 standard trading units (STU), which is usually 5,000 shares, or $100,000.[12] Such large dark orders are able to execute at the NBBO, without providing *any* price improvement, as long as they give priority to lit orders at the same price on the same

[11] Details available at: http://www.asxgroup.com.au/media/PDFs/20100603_asx_fees_rebates.pdf

[12] A standard trading unit is 100 shares for stocks priced above $1.00, 1,000 shares for stocks priced between $0.10 and $1.00, and 10,000 shares for stocks priced below $0.10.

trading venue. Prior to the change in regulation, dark orders were required to provide a "better price" than the prevailing NBBO but with no minimum increment of price improvement to constitute a "better price".[13]

< Table 3 here >

To comply with the new regulations all venues providing dark orders were required to adjust the types of dark orders provided. Table 3 documents these changes for each venue. For the continuous dark pools Intraspread and MatchNow, orders offering 10% or 20% price improvement were removed on 15 October 2012. Intraspread retained dark midpoint orders and added the potential for large orders to execute at the NBBO. MatchNow removed their 20% order type but chose not to introduce orders at the NBBO, offering only midpoint orders after the rule change. Chi-X and TSX did not need to remove any dark order types to comply with the new rules because they did not provide dark orders at increments finer than the midquote. Both exchanges enabled large orders to execute at the NBBO, although as shown later such orders are rare.

2.2.2 Australia

The Australian Securities and Investments Commission (ASIC) is Australia's corporate, markets and financial services regulator. On 1 August 2010 responsibility for equity market supervision was transferred from ASX to ASIC. ASIC sets and enforces the Market Integrity Rules (MIR), which govern trading on equity markets in Australia.

On 21 November 2012, ASIC media release 12-290 announced changes to the MIR, which became effective on 26 May 2013. The changes to the MIR followed from an extensive review of Australian equity market structure, a focused review by a Dark Liquidity Taskforce, and a market participant consultation process.[14] Two main changes impacted on how dark trading takes place: (i) changes to the thresholds for block trades;

[13] The UMIR defined "better price" simply as a lower price than the best ask price in the case of a purchase and higher price than the best bid price in the case of a sale.

[14] See the following ASIC reports and consultation papers: Section H of Consultation Paper *Australian equity market structure: Proposals* (CP 145), Section E of Report 215 *Australian equity market structure* (REP 215), Section G of Consultation Paper 168 *Australian equity market structure: Further proposals* (CP 168), Section B of Consultation Paper *Dark liquidity and high-frequency trading: Proposals* (CP 202) and Section B of Report 331 *Dark liquidity and high-frequency trading* (REP 331).

and (ii) a new requirement for trades below block size executed without pre-trade transparency to provide meaningful price improvement.

Similar to the Canadian regulation, the amendment to "meaningful price improvement" in Australia required dark trades to provide one full tick of price improvement relative to the NBBO, or execute at the midpoint of the NBBO when the spread is one tick. Prior to the rules that came into effect on 26 May 2013, dark trades were allowed to execute at or within the best quotes, and consequently the majority of dark trades were executed at the best quotes with zero price improvement. The ASX *Centre Point* dark pool did not have to substantially alter the orders that it offers to comply with the new rules because all Centre Point trades are executed at the midquote. Similarly, hidden orders on Chi-X were only allowed at the midquote. However, the 20 or so broker dark pools, which often executed trades at the NBBO were forced to change their order entry and matching rules to comply with the new requirements.

ASIC anticipated that the meaningful price improvement rule would lower the proportion of below block size dark trading and encourage more trading to occur on the lit exchanges. They also intended the rule to protect lit orders from being traded ahead of by dark trades at the same price and therefore encourage posting lit liquidity (see ASIC Report 394). It was anticipated this would result in higher proportions of volume executing on lit markets, limit unexplained volatility and contribute to informative price formation (ASIC Regulatory Impact Statement, August 2013).

At the same time as the minimum price improvement rules, the amendments to the MIR lowered the size thresholds for block trades for most stocks. Previously, the threshold for a block trade was $1 million for all stocks. From 26 May 2013 the threshold was lowered to $0.2 million for the least liquid stocks ("Tier 3 products"), $0.5 million for medium liquidity stocks ("Tier 2 products"), and remained unchanged at $1 million for the most liquid stocks ("Tier 1 products"). ASIC publishes, on a quarterly basis, lists of the stocks categorized as high, medium and low liquidity (Tiers 1, 2 and 3). In March 2013 there were 19 listed entities classed as Tier 1, a further 21 classed as Tier 2, and the remaining overwhelming majority of listed entities were classed Tier 3, being subject to the lowest block threshold size. Trades that meet the block size thresholds are

not required to provide price improvement, whereas trades smaller than these thresholds must provide meaningful price improvement from 26 May 2013.

ASIC anticipated that the tiered block size thresholds would mitigate, to a significant extent, the impact of the meaningful price improvement rule by allowing more trades to be classified as block trades and be negotiated away from the lit market without price improvement. The intent was to strike a balance between dark liquidity's traditional function of minimizing information leakage and price impact of block orders, and protecting efficient price formation, fair time priority and liquidity of the wider market (ASIC Regulatory Impact Statement, August 2013).

3. Data and samples

We analyze the constituents of the TSX Composite Index and the ASX 200 Index, which comprise approximately 250 and 200 of the most actively traded Canadian and Australian securities, respectively.[15] Our sample spans a period of 9 months before and 9 months after the introduction of the minimum price improvement rules in each country (15 January 2012 – 15 July 2013 in Canada and 26 August 2012 – 26 February 2014 in Australia).

We restrict our sample to stocks that are included in the TSX Composite Index at both the start and end of our sample period to avoid effects arising from index inclusion/deletion. This results in 198 Canadian stocks. We obtain data on index constituents for both Canada and Australia from the *Thomson Reuters Tick History* (TRTH).

We combine tick-by-tick data on lit and dark trades from a number of sources. For Canada, we obtain proprietary data on all dark trades executed on *MatchNow* and *Chi-X* directly from the trading venues,[16] whilst details of dark trades on *Alpha* and *Intraspread* come from the TRTH database. We also obtain proprietary data from TSX,

[15] We obtain lists of the constituents of the TSX Composite Index and the ASX 200 Index on the date the minimum price improvement regulations came into effect in the corresponding country (the center of our sample windows). To reduce survivorship and sample selection biases we do not update the sample of stocks as the index constituents change.

[16] This proprietary data consists only of information that was publically reported to the consolidated tape.

which allows us to identify dark trades based on their execution prices.[17] Our data on dark trades includes the stock ticker, date, time, price and volume. We are unable to obtain data on trades negotiated on *Liquidnet*/*Instinet*; however, such trades account for a negligible fraction of total trading (and are block trades rather than below block size dark trades). IIROC Marketplace Statistics indicate that in the third quarter of 2012 *Liquidnet* and *Instinet* combined accounted for only 0.2% of total Canadian dollar volume. Thus, we effectively have data on all dark trades in Canada.

For Australia, we are able to precisely identify each dark trade that occurs during our sample, using flags attached to trades. We do this using data from the *AusEquities* database maintained by the *Securities Industry Research Centre of Asia Pacific* (SIRCA). Our data on dark trades includes a timestamp with millisecond precision, stock, price and volume. For the Australian dark trading facility *Centre Point* we also obtain all orders (including order entry, amendment and cancellation messages). During our sample period, all trades (both lit and dark) are required to be reported to an exchange immediately. As a result, we have a consolidated source for all trade types, which minimizes issues which arise in other markets due to inconsistencies in time-stamps across different trading venues.

We also obtain data on all lit trades and the best quotes for all Canadian and Australian lit marketplaces (Alpha, Omega, TSX, TMX Select, Pure and Chi-X in Canada, and ASX and Chi-X in Australia) from the TRTH database. Lit trades contain information on the stock ticker, date, time, price and volume, and the quotes comprise the best bid and best ask quote at every point in time for every venue. Timestamps on trades and quotes are recorded to the millisecond. We consolidate the best bid and ask quotes across all lit Canadian venues and all lit Australian venues at every point in time to obtain the NBBO.

To isolate the effects of the minimum price improvement regulation from other effects and trends, we also examine stocks in two control markets that are similar to the Canadian and Australian markets (i.e., are expected to exhibit similar trends) but that did

[17] This data consists only of information that was publically reported to the consolidated tape. The data are copyright TSX Inc., all rights reserved. Not to be reproduced or redistributed. TSX Inc. disclaims all representations and warranties with respect to this information, and shall not be liable to any person for any use of this information.

not experience minimum price improvement regulation. More specifically, we benchmark changes in trading characteristics in Canada against those in the US and changes in trading characteristics in Australia against those in New Zealand. Given that the New Zealand equities market is similar in structure but smaller than the Australian market, we use constituents of the NZX50 (the largest 50 stocks in New Zealand) that are not cross-listed in Australia[18] to form a benchmark that is comparable to the top 200 Australian stocks. Given the US market is larger and more diverse than the Canadian market, we select a US stock that is most similar to each of the Canadian stocks in our sample. We then match each of the 198 Canadian stocks to a US stock by minimizing the differences in traded volume and price.[19] Any matched US stock which is dual listed in Canada is removed from our sample, resulting in 191 matched US stocks. For the samples of US and New Zealand stocks, we obtain trade, quote and depth data from the *Thomson Reuters Tick History* database.

A single market order will often execute against multiple resting limit orders, resulting in a number of simultaneous trades. For the purpose of identifying instances of broker internalization in Canada we reconstruct the original market order and treat the simultaneous trades as a single trade.

For the purpose of calculating market quality metrics we use the regular market hours of 9:30am – 4:00pm for Canada, and 10:00am – 4:00pm for Australia, less the first and last 15 minutes to exclude the impacts of the opening and closing auctions and market on close facility. However, we include the first and last 15 minutes as well as the opening and closing auctions in the summations of daily volume.

4. Method

Our analysis primarily involves estimating a broad set of metrics describing trading activity and characteristics of the market and then analyzing how the set of

[18] Constituents are required to be part of the index for the duration of our sample period. This eliminates 9 securities. A further 20 securities are cross-listed in Australia, reducing our sample of NZ securities to 21.

[19] Matched stocks are chosen as those that minimize the sum of squared relative differences in price and trading volume, X_j, measured as the average daily values during the two months prior to the price improvement rules: $MatchingScore = \sum_{j=1}^{2} \left(\frac{X_j^{CA} - X_j^{US}}{(X_j^{CA} + X_j^{US})/2} \right)^2$. The superscript *CA* indexes Canadian stocks, and the superscript *US* indexes US stocks.

metrics have evolved through time and changed in response to the minimum price improvement regulation. In addition to simple pre/post comparisons, we isolate the effects of the minimum price improvement regulation from other effects and trends in the markets by controlling for time trends and market characteristics in other control markets.

4.1 Metrics measuring trading activity and market characteristics

For each stock-day, using intra-day data, we compute a set of metrics that measure (i) trading activity; (ii) order submission and execution strategies; and (iii) liquidity. The details of how the metrics are computed are provided in Appendix A. Here we just give a brief overview of the metrics in each category.

We examine patterns in trading activity using the market shares (measured in both dollar volume and number of trades) of lit, dark, and block trades. We further decompose dark trading by venue/execution mechanism. We also examine the proportions of dark trades executed at the NBBO, at the midpoint of the NBBO, and at prices between the NBBO and its midpoint ("fractional" price improvement, referring to fractions of the half-spread).

To characterize order submission strategies we examine average trade sizes of dark, lit, and block trades. As a gauge of the degree of automation and algorithmic trading in dark venues we compute order message-to-trade and order message-to-volume ratios for the dark pool for which we have access to data on order messages (ASX *Centre Point*). We also examine whether the propensity to post lit liquidity is impacted by the rule change using ratios of limit order submissions to traded volume and lit posted depth to volume. Without client-level identifiers it is impossible to precisely identify internalization (trades in which the broker acts as counterparty to a client order) on or off market. However, we construct a proxy for internalization as the ratio of trades that have the same broker on both sides (buyer and seller) to total traded dollar volume. We compute the internalization proxies for both lit trades and dark trades. The final aspect of order submission strategies that we measure is the frequency of small (1-3 share) dark trades, which are typically used to 'ping' a dark venue in search of dark liquidity. Due to board lot requirements in Canada we compute this measure only for Australia.

Our measures of liquidity are fairly standard. We compute quoted, realized and effective spreads as well as simple five-minute price impacts. We also examine depth posted at the best quotes, consolidating liquidity posted on all lit venues.

In the Internet Appendix we report results for a number of additional metrics, including high-frequency measures of informational efficiency. These include absolute autocorrelations of midquote prices, the variance ratio of Lo and MacKinlay (1988), high-frequency midquote volatility, and a high-frequency adaptation of the Hou and Moskowitz (2005) metric that measures the delay in impounding market-wide information.

4.2 The impact of minimum price improvement regulation on market characteristics

We estimate the following regressions to quantify the effect of the minimum price improvement regulation.

$$Y_{it} = \alpha_i + \beta_1 D_t^{PostPeriod} + \varepsilon_{it} \quad (1)$$

$$Y_{it} = \alpha_i + \beta_1 D_t^{PostPeriod} + \sum_{j=1}^{3} \gamma_j \, Control_{j,it} + \varepsilon_{it} \quad (2)$$

$$Y_{it} = \alpha_i + \beta_1 D_t^{PostPeriod} + \sum_{j=1}^{3} \gamma_j \, Control_{j,it} + \beta_3 Y_t^{OtherMarket} + \varepsilon_{it} \quad (3)$$

We estimate the above regression equations (1-3) separately for Canada and Australia. Y_{it} is one of the metrics measuring market characteristics, α_i is a set of stock fixed effects, $D_t^{PostPeriod}$ takes the value 1 after the minimum price improvement rule comes into effect and 0 before, and $Y_t^{OtherMarket}$ is the daily cross-sectional average of the corresponding market characteristic in the other (control) market (US for Canadian stocks, and New Zealand for Australian stocks). $Control_{j,it}$ is a set of control variables: $\$Volume_{it}$ (the natural logarithm of traded dollar volume); $Volatility_{it}$ (the stock-day's high-low price range divided by the time-weighted midquote); and $Constrained_{it}$ (the percentage of the trading day for which the stock's NBBO is constrained at the minimum tick size), which we omit when the dependent variable is a spread measure. In robustness tests we also include $Price_{it}$ (the time-weighted midquote) as a control variable and find very similar results. We use standard errors double clustered by stock and by date.

Regression (1) is the simplest possible pre/post comparison and therefore we report estimates from that regression in the descriptive statistics tables. It differs from a simple pooled t-test of the pre/post difference in means for the metric in that we use

double clustered standard errors to account for dependence in the structure of the errors across stocks and through time. Regressions (2) to (3) control for confounding effects that can influence pre/post levels of the market/trading characteristics for reasons other than the minimum price improvement regulation. Regression (2) controls for broad trends in market characteristics that are unlikely to be influenced by the regulation. Regression (3) adds a control for trends in the specific market/trading characteristic (the dependent variable) in a closely related market (USA for the analysis of Canada, and New Zealand for the analysis of Australia) that is not affected by the regulation. In effect this regression design (3) is very similar to a difference-in-differences model, because the coefficient of interest, β_1, effectively measures the pre/post difference in the difference between the market receiving the regulation and the control market.[20] The regression design in (3) has a few advantages over a difference-in-differences model, such as not inflating the number of observations by adding a collection of stocks from a 'non-treated' market, and not imposing a one-for-one correspondence between changes in the control market and expected changes in the 'treated' market. We are only able to estimate regression (3) for some metrics (e.g., liquidity and informational efficiency) because we have no data on dark trading in the control countries of US and New Zealand. Although we estimate the regressions for all metrics, we only report the regression results for the liquidity variables, which are most likely to be impacted by exogenous confounding effects (regressions for other variables are in the Internet Appendix).

4.3 The mechanisms by which the regulation impacts liquidity

The minimum price improvement regulation affects many trading characteristics, including the total amount of dark trading, the size of dark trades, the amount of internalization in the dark and lit markets, the proportion of dark trades that execute at the midpoint versus other prices at or within the NBBO, and so on. It is likely that the changes to different trading characteristics have different effects on liquidity; some may improve liquidity, while others may harm it. Therefore, we analyze the different effects on liquidity of each of the trading characteristics impacted by the regulation. This

[20] To see this, subtracting $\beta_3 Y_t^{OtherMarket}$ from both sides we obtain,
$\left(Y_{it} - \beta_3 Y_t^{OtherMarket}\right) = \alpha_i + \beta_1 D_t^{PostPeriod} + \sum_{j=1}^{4} \gamma_j \, Control_{j,it} + \varepsilon_{it}$.

provides insights about the mechanisms by which the regulation impacts liquidity and is suggestive of ways to improve the effectiveness of the regulations.

Our analysis of the mechanisms exploits cross-sectional heterogeneity in how stocks were impacted by the regulations. Different stocks experienced different changes in the various trading characteristics mentioned above, and consequently the impact of the regulation on liquidity also varies across stocks. We use a two-stage procedure. In the first stage, for each stock i, we compute the pre/post differences (post period mean minus pre period mean) in means for each of the k spread measures, $Y_{k,it}$, each of the l trading characteristics, $X_{l,it}$, and each of the j control variables, $Control_{j,it}$. The spread measures are $QuotedSpread$, $EffectiveSpread$, and $RealizedSpread$. The trading characteristics are $DarkVolumeShare$, $BlockVolumeShare$, $MidquoteVolumeShare$, $DarkTradeSize$, $BlockTradeSize$, $LitInternalizationProxy$, and $DarkInternalizationProxy$. Call the differences $\Delta Y_{k,i}$, $\Delta X_{l,i}$, and $\Delta Control_{j,i}$.

In the second stage we estimate cross-sectional regressions of the changes in liquidity on changes in trading characteristics:

$$\Delta Y_{k,i} = \alpha_k + \sum_{l=1}^{7} \varphi_{kl}\, \Delta X_{l,i} + \sum_{j=1}^{3} \rho_{kj,i}\, \Delta Control_{j,i} + \varepsilon_{k,i} \qquad (4)$$

The estimated coefficients, φ_{kl}, provide evidence on the mechanisms by which the regulation affects liquidity. In the specification above, we throw away some of the information contained in day-to-day variation, but overcome issues of inflated significance from dependent observations.

5. Results

5.1 Trading activity

The minimum price improvement requirements caused a significant decline in dark volume, and a change in the prices at which dark trades execute. Figure 1 shows the percentage of trading that occurs in the dark through time. The plots show a sharp decline in dark trading in both Canada and Australia immediately after the minimum price improvement rules take effect. The decline is present in both measures of the dark trading shares: percentage of total dollar volume and percentage of the number of trades.

< Figure 1 here >

Table 4 reports means, standard deviations and quartile points for the trading activity metrics before and after the minimum price improvement rules, allowing the patterns in the figures to be quantified. Dark trading in Canada declines from a mean (median) of 10% (8%) of total dollar volume before the regulation to 8% (5%) after. In Australia the corresponding decline is from a mean (median) of 18% (13%) to 11% (8%). The declines in dark trading in both countries of around one third are highly statistically significant using double-clustered standard errors.

< Table 4 here >

Turning to block trades, Figure 2 plots the percentage of dollar volume and trades executed as off-market negotiated blocks. In Canada, approximately 14% of dollar volume is executed as block trades (the share of trades is less than 1% because of the large size of block trades) and this share does not change significantly around the minimum price improvement regulation. In contrast, in Australia where the block trade size thresholds were reduced at the same time as the minimum price improvement rules were introduced, we see a significant increase in block trading. As a percentage of dollar volume, block trades in Australia represent around 10% before the regulation and 14% after. As a share of the number of trades, the increase in block trading is considerably larger due to the reduction in average block trade sizes. It is likely that the revision in block thresholds encouraged some migration from below-block size dark trading to block trading, due to the ability to avoid the minimum price improvement rules. Migration from the dark trade category to the block trade category explains some of the decrease in the dark trading share and the increase in the share of volume executed as block trades.

< Figure 2 here >

The results from regressions (reported in the Internet Appendix for brevity) confirm that the decline in dark trading activity in Canada and Australia, and the increase in block trading in Australia are robust to controlling for changes in a number of other

market characteristics. The market characteristics controlled for in the regressions include total dollar volume of trading, a measure of how frequently the bid-ask spread is constrained by the tick size (constrained spreads tend to encourage off-market trading), and volatility. The changes are also robust to controlling for the price level.

Although the minimum price improvement regulation decreased the amount of dark trading in both countries, not all dark trading venues/mechanisms were impacted equally. Figure 3 shows the breakdown of market share of dark volume and trades by venue/mechanism in each of the two countries. In Canada, because fractional price improvement dark trades (trades at prices between the NBBO and the midpoint) were not offered on Chi-X Canada or TSX, it is not surprising that the minimum price improvement regulation did not impact adversely on these venues. In fact, Chi-X Canada and TSX increased their shares of dark trading volume after the regulation, and the small increases are statistically significant in pooled t-tests. Alpha Intraspread, which offered the lowest level of price improvement (10%) and also had the fewest midpoint trades, exhibits the most marked (and sustained) reduction in dark trading volume. Its dark volume falls from 35% of Canadian dark dollar volume prior to the minimum price improvement regulations to 8% of dark dollar volume after. Mainly due to the decline in dark trading volume on Alpha Intraspread, MatchNow's share of dark Canadian dollar volume increases from 46% to around 66%, although its share of total (lit and dark) dollar volume remains largely unchanged around the new rules.

The dark trading market shares in Australia show a similar pattern in that dark trading venues that provided little or no price improvement before the regulation lost market share to those venues that predominantly or exclusively executed trades at the midpoint. Dark trading in broker dark pools and manually matched dark trades, (the category "Other dark" in Figure 3) which typically took place at the NBBO without price improvement, saw the largest reduction in trading volume. Dark trading in this category declined from around 71% of dark traded dollar volume to 37%. A large proportion of trading in this category is made up of the internalization of client order flow by brokers and matching of client orders by a broker away from the lit market. One reason why brokers may prefer to execute trades in their dark pools (whether matching client orders or internalizing orders) is that they can reduce their exchange fees without necessarily

passing on the saving to the client. A further reason why internalization may be attractive is that the broker can act as a market maker and earn a spread from acting as counterparty to buy and sell orders. The minimum price improvement rules reduce the profitability of broker internalization by limiting the spread they are able to extract from client orders. It also limits their ability to match client orders away from the lit market by constraining the set of prices at which client-to-client trades can be matched. These are the main reasons why the largest reduction in dark trading in Australia as a result of the new rules is in the category that includes dark trades executed in broker dark pools. We investigate the level of internalization later.

In contrast to the impact on broker dark pools and manually matched dark trades, the dark pool *Centre Point*, which has always executed trades at the midpoint of the NBBO, experienced an absolute and relative *increase* in volume. Its share of dark dollar volume increased from around 26% to 51%. Dark midpoint trades on Chi-X Australia also increased from around 3% to 11% of dark dollar volume, consistent with the overall increase in Chi-X Australia's lit market share.

< Figure 3 here >

Figure 4 shows the prices at which dark trades execute before and after the minimum price improvement regulation. It separates dark trades into three categories depending on the execution price relative to the prevailing NBBO and its midpoint: (i) dark trades at the midpoint, (ii) dark trades at prices between the NBBO and midpoint (termed "fractional" price improvement trades as they provide price improvement equal to a fraction of the half-spread) and (iii) dark trades at the NBBO ("touch"). The figure shows a sharp decline in dark trades providing fractional price improvement in Canada (from two thirds of Canadian dark dollar volume to zero) and a corresponding increase in dark trades at the midpoint of the Canadian NBBO. This dramatic change is because the new rules require that dark trades provide a full tick of price improvement (or execute at the midquote when the spread is constrained to one tick).

In Australia, there is also an increase in the fraction of dark trades executed at the NBBO midpoint. While fractional price improvement is technically possible in Australia,

most stocks have a spread of less than two ticks, constraining trades to midpoint executions. After the regulation, about 84% of dark trades in Australia execute at the midpoint. However, unlike Canada, dark trades prior to the minimum price improvement rules were not required to provide any price improvement and could execute at the NBBO. For this reason, it is the share of dark trades at the touch that declines in Australia (from 49% to 4%).

< Figure 4 here >

In summary, the minimum price improvement requirements caused a significant decline in dark volume in both Canada and Australia. In Australia, the contemporaneous reduction in block trade size thresholds also caused an increase in the proportion of trades executed as blocks. The revision in block size thresholds encouraged migration from below-block size dark trading to block trading, explaining some of the decrease in the dark trading share and increase in the share of volume executed as block trades. Not all dark venues were impacted equally. In Canada, Alpha Intraspread, which offered the lowest level of price improvement and had the fewest midpoint orders prior to the price improvement regulation exhibited the most marked (and sustained) reduction in trading volume. Similarly, in Australia, dark trading in broker dark pools and manually matched dark trades, which typically took place at the NBBO without price improvement, saw the largest reduction in trading volume, and the midpoint dark pool *Centre Point* experienced a relative *increase* in volume. Finally, in both countries, the minimum price improvement rules caused a significant change in the prices at which dark trades execute – a large reduction in dark trades at the NBBO or at prices between the NBBO and the midpoint and a large increase in the fraction of dark trades executed at the midpoint.

5.2 Order submission and execution strategies

To understand how the minimum price improvement rules influence trader behavior we examine a number of measures of order submission and execution strategies, starting with trade sizes. Figure 5 and the descriptive statistics in Tables 5 and 6 show that in Canada dark trades (with an average size of around $7,100) tend to be larger than

lit trades (with an average size of around $4,100) and there have not been large changes in these trade sizes around the price improvement regulation. The average size of block trades in Canada is around $1.5 million before the regulation and $1.7 million after.

< Figure 5 here >

< Table 5 here >

< Table 6 here >

In Australia, dark trades also tend to be larger than lit trades before the minimum price improvement regulation, with mean trade sizes of $5,600 for dark trades and $2,900 for lit trades. In contrast to Canada, the size of dark trades in Australia declines substantially from a mean of $5,600 to $2,300. One of the reasons for this change is the shift in dark trading away from broker crossing systems and manual dark trades (where trades tend to be larger) to ASX *Centre Point* and Chi-X hidden midpoint trades. Internalization may be one of the factors contributing to the larger dark trade sizes in broker dark pools and manual dark trades because a client order can be internalized in a single trade, whereas an order sent to the lit market or to *Centre Point* / Chi-X midpoint will often execute in parts against several counterparties, resulting in a number of smaller trades.

Block trades in Australia also decrease in size around the regulation, from a mean (median) of around $3.3 million ($2.1 million) to $1.5 million ($0.8 million). The reduction in block trade size thresholds, and resulting shift from dark trading to block trading to avoid the price improvement requirements, is likely to have contributed to the changes in dark and block average trade sizes. Trades that before the rule changes would have been executed as large dark trades, after the regulation can be executed as block trades. This removes the largest dark trades and adds relatively small block trades, thereby decreasing average dark and block trade sizes. The changes discussed above are statistically significant in regressions (reported in the Internet Appendix) controlling for other market characteristics.

One of the regulatory concerns regarding dark trading was the trend of rapidly decreasing dark trade sizes. For example, in Australia, in a four year period prior to the regulation of dark trading (from January 2008 to October 2011) the average size of a dark trade decreased more than tenfold (from $150,000 to $10,000) (Comerton-Forde and Putnins, 2013). This trend was in part due to increased use of technology to automate dark trading, leading to the emergence of dark pools. Execution of large block trades away from the lit markets was not seen as a significant concern by regulators because in most cases such trades could not be efficiently transacted on a lit market, and if they were transacted on a lit market they could be disruptive to liquidity and price discovery. The concern was that executing small trades away from the lit markets in dark pools when they could be efficiently executed on lit markets detracts from lit market liquidity and price discovery. The impact of the minimum price improvement regulation on average trade sizes indicates that the regulation did not reverse the trend of decreasing dark trade sizes. In Australia, however, largely because the regulation was accompanied by a reduction in block trade size thresholds, we observe a contemporaneous shift away from dark executions to block trade executions.

Another regulatory concern with respect to dark trading that occurs with little or no price improvement is that it discourages posting lit liquidity because a lit limit order can be bypassed by trading in the dark. Effectively, dark pools without price improvement provide a way of bypassing time-priority, thereby allowing 'queue jumping'. To investigate whether the possibility of using dark trading with little or no price improvement to jump the queue discourages lit liquidity provision we examine lit limit order submissions and lit posted depth at the best quotes, both scaled by the dollar volume of lit trades.

Figure 6 shows no obvious trends in these two measures of lit liquidity provision around the minimum price improvement regulation, other than a possible slight reduction in lit liquidity provision Canada. The pre/post t-tests reported in the descriptive statistics Tables 5 and 6 also show that the changes are not statistically significant. Similarly, multivariate regressions reported in the Internet Appendix, which control for general changes in the market and trends in the control markets, show coefficients consistent with a decline in lit liquidity provision in Canada, but the change is not statistically significant.

Thus, the evidence does not support the hypothesis proposed by regulators and others that dark trading with non-meaningful (or zero) price improvement discourages lit liquidity provision.

< Figure 6 here >

We investigate changes in the degree of algorithmic trading using order message to trade ratios, commonly used as proxies for algorithmic trading. There is little reason to think that the minimum price improvement regulation would impact on the extent of algorithmic trading in lit markets, and therefore, here, we only report measures of algorithmic trading in the dark. The Internet Appendix reports algorithmic trading proxies for the lit markets and confirms that there are no clear trends in the amount of algorithmic trading in lit markets around the regulation of dark trading.

Figure 7 plots the order message (order additions, cancellations and amendments) to trade ratios for the dark pool ASX Centre Point (the only dark trading venue for which we are able to obtain data on order messages). Algorithmic trading on Centre Point tends to increase through time and in particular increase around the minimum price improvement rules. The increase around the minimum price improvement rules is highly statistically significant in both univariate and multivariate tests. The trend mirrors Centre Point's share of dark and total dollar volume. A possible explanation is that as Centre Point's volume and liquidity increases, a larger number of execution algorithms that post orders to multiple venues and dynamically manage those orders based on market conditions commence sending orders to Centre Point.

< Figure 7 here >

Because dark pools and hidden orders, by construction, have no pre-trade transparency, one method that traders use to get an indication of whether dark liquidity exists in a dark pool or as a hidden order is to submit a small 'pinging' order and see whether it executes against the possible dark liquidity. Pinging orders may be disruptive to markets because in many cases they do not reflect a true trading intention but rather a means of acquiring information about the state of the market. They also cause a

difference in information across traders about the state of the market and the existence of liquidity.

While pinging orders are possible in Australia where there are no minimums on order sizes, requirements to trade in round board lots in Canada mean that dark pinging orders are not possible in Canada (for the stocks in our sample a board lot is 100 shares). Figure 7 plots the number of dark pinging trades (1-3 share dark trades) through time in Australia, as well as the ratio of dark pinging trades to the total number of dark trades. There is a small decline in both the total number and proportion of dark pinging orders after the introduction of minimum price improvement rules. The regressions reported in the Internet Appendix indicate that these changes are statistically significant after controlling for other trends in market characteristics.

Broker internalization of client orders in the dark has raised concerns among regulators, market participants and market operators. Brokers can benefit from internalization by reducing exchange fees and earning the spread. Their ability to profit from acting as a market maker for their client orders is enhanced by being able to selectively internalize relatively uninformed order flow and by being better able to manage inventory positions and offset imbalances through choosing which trades to internalize and which to send to a marketplace. Concerns center around the fact that in most cases internalized orders would otherwise be sent to a lit market where they would contribute to publically available liquidity and price discovery, as well as the notion that selective internalization can increase adverse selection and order imbalances in lit markets, harming their liquidity.

Without client-level identifiers or indicators for when a broker is acting in an agency versus proprietary capacity, it is impossible to precisely identify internalized trades, on or off market. We construct a proxy for internalization as the ratio of trades that have the same broker on both sides (buyer and seller) to total traded dollar volume. We compute the internalization proxies for both lit trades and dark trades. These proxies will, by construction, overestimate the true amount of internalization as many of the trades that have the same broker on both sides will be client-to-client trades that have the same broker. However, the proxies will also capture internalized trades and therefore if there are any pronounced trends in internalization they should be reflected in the proxies.

Figure 8 shows trends in lit ('on market') internalization for Canada and Australia. The levels tend to be much higher in Canada, which is largely attributable to two factors. First, broker preferencing on the main lit Canadian markets encourages trades with the same broker on both sides by giving such trades priority. Second, Canada has not witnessed the development of systematic off-market 'internalizers' due to the "fair access" requirement (that pre-dates the recent price improvement requirements for dark trades) that markets not preclude access from any class of participant. The level of lit market internalization in Canada does not display obvious changes around the recent price improvement regulation. In contrast, the lit market internalization proxies in Australia increase sharply around the minimum price improvement rules, starting to increase in the week before the rules come into effect and continuing their increase in the subsequent nine months. Many or most of the lit trades in Australia that have the same broker on both sides are likely to be client-to-client trades rather than internalized trades because the lack of broker preferencing substantially limits the ability to use the lit Australian markets for internalization.[21] The increase in the lit internalization proxy in Australia is likely to be, at least in part, due to trades that would have been matched off market in broker dark pools (whether internalized trades or client-to-client trades) being sent to the lit market.[22] This comes as a result of internalization no longer being as profitable and matching of client orders no longer allowing as much flexibility with respect to the possible trade price.

< Figure 8 here >

Figure 9 shows trends in dark internalization. In contrast to lit internalization, the level of the dark internalization proxies tend to be much higher in Australia than in Canada, despite some Canadian dark pools also using broker preferencing. This is likely due to substantial amounts of internalization in Australian broker dark pools (some of

[21] With broker preferencing, in some states of the limit order book, a broker could internalize a market buy order (for example) on market by submitting a limit sell order to the lit market at the best quotes together with the market buy so that the two orders execute against one another.

[22] For example, before the price improvement rules, a broker that had a client order resting in the lit limit order book at the time they receive an order from a different client to trade in the opposite direction could remove the limit order from the lit market and match both client orders off market.

which are purely internalization engines), as well as the relative lack of interconnectedness between many of the Australian broker dark pools. As a result of the relative lack of interconnectedness, many Australian broker dark pools are more likely to match client orders from the same broker than from two different brokers. The levels of dark internalization in both Canada and Australia decline fairly substantially after the minimum price improvement rules come into effect. In Canada, the decline is from 13% to 6% of dark dollar volume, and in Australia the decline is from around 63% to around 22%. The changes in the lit internalization proxy in Australia and the dark internalization proxies in Australia and Canada are highly statistically significant in simple pre/post t-tests (Tables 5 and 6) as well as regressions that control for other trends in the markets (Internet Appendix).

< Figure 9 here >

In summary, the minimum price improvement regulation altered several aspects of order submission and execution strategies in lit and dark venues. In Australia, where the price improvement regulation was accompanied by a reduction in the block trade size thresholds, the average size of dark trades decreased substantially as did the size of block trades. This is in part due to large dark trades being executed as block trades after the reduction in size thresholds, allowing them to avoid the minimum price improvement requirements. The level of algorithmic trading (as measured by order message-to-trade ratios) increased in the Australian dark pool Centre Point, mirroring its increase in market share and likelihood that it receives orders from multi-venue execution algorithms. Internalization in the dark decreased in both Canada and Australia, and Australia experienced a corresponding increase in lit trades that have the same broker on both sides of the trade. A few characteristics that did not change significantly around the regulation include Canadian dark (and lit) trade sizes, the propensity for market participants to post lit liquidity as measured by the ratios of lit limit orders and lit depth to lit traded volume, and Canadian lit market internalization.

5.3 Liquidity

So far we have focused on how the minimum price improvement rules impacted relatively concrete and specific characteristics such as where trades execute, at what prices trades execute, trade sizes and order submission strategies. We now turn to higher-level characteristics, various measures of liquidity, to examine the net effects of how the changes in trader behavior and order executions impact on market quality. Liquidity is influenced by a much larger range of other factors that are unrelated to dark trading. Therefore, in the subsequent analysis we pay more attention to regressions that control for confounding factors, including trends in a control market.

Figure 10 plots a range of liquidity measures for Canada and Australia, including quoted, effective and realized spreads as well as five-minute price impacts. With the exception of quoted spreads, which use the consolidated quotes from lit markets, the liquidity metrics are calculated using all lit and dark trades and therefore measure liquidity across all venues. In Canada there is considerable variation in spreads through time, making it difficult to easily discern any changes that are due to the minimum price improvement regulation. In Australia, however, there appears to be a relatively distinct increase in quoted and effective spreads as well as price impact. The simple pre/post differences for quoted and effective spreads as well as price impact in Australia (Table 7) are statistically significant.

< Figure 10 here >

< Table 7 here >

The regressions provide a more rigorous analysis of the impact of the regulation on liquidity. They control for trends in market characteristics that may be unrelated to dark trading, such as total dollar volume and volatility. They also control for trends in spreads in a closely related market that was not subject to minimum price improvement requirements, thereby removing trends that are specific to spreads but are not associated with the regulation.

Table 8 indicates a small and marginally statistically significant increase in quoted and effective spreads in Canada after the minimum price improvement regulation. For example, Model 2 (with the most extensive set of control variables) estimates quoted and effective spreads are 0.42 bps and 0.45 bps wider after the regulation comes into effect. To put this into perspective, median quoted and effective spreads in Canada are around 9 and 6 bps (Table 7). Thus, the negative impact on liquidity in Canada is not extremely large, but is notable, increasing quoted and effective spreads by 5% to 8% of their pre-regulation medians. The effect on realized spreads and price impacts (Table 10) in Canada is generally not statistically different from zero in the regressions, although the point estimates are consistent with an increase.

< Table 8 here >

< Table 10 here >

For Australia, Tables 9 and 11 indicate fairly large and statistically significant increases in quoted spreads, effective spreads, and price impacts after the price improvement rules come into effect. For example, the estimated impact on quoted and effective spreads in Model 2, controlling for trends in spreads that are unrelated to the regulation, is 5.6 bps and 4.9 bps, respectively. These increases are economically meaningful. Compared to the pre-regulation medians of 30 bps and 25 bps, the estimated increases are in the order of 19% to 20%. The estimated change in price impacts in Model 2 (Table 11), controlling for confounding effects, is 3.9 bps. Compared to the pre-regulation median of 20 bps, the estimated increase is in the order of 20%, again suggesting the change is economically meaningful

< Table 9 here >

< Table 11 here >

The different spread and price impact measures serve as proxies for different underlying reasons for illiquidity. Price impact gives us a rough indication of adverse selection risks. Realised spreads give a rough measure of inventory holding costs and fixed order processing costs as well as any economic rents extracted by liquidity providers. Finally, quoted and effective spreads tell us about the net effects of the adverse selection, inventory holding cost and fixed cost components. The fact that we see large increases in price impact in Australia, yet relatively little changes in realized spreads suggests the increases in quoted and effectively spreads are likely driven by increases in adverse selection risks. In Canada, the net effect of changes in the various components of the spread is significant, but we are unable to attribute the effect to adverse selection or other spread components.

Figure 11 plots one other measure of liquidity: posted depth at the NBBO, consolidated across all lit markets. There are no obvious trends or changes in depth around the minimum price improvement regulation, although it appears that the mean of lit depth is higher in Canada after the regulation.

< Figure 11 here >

The regressions reported in Table 10 indicates that indeed lit depth in Canada is higher after the regulation. The increase in depth is likely to be a somewhat mechanical result of trading activity returning to the lit markets. As trading activity in a market increases, one would expect its depth to increase together with its volume. Higher lit depth, however, does not imply greater liquidity if it comes at the expense of liquidity elsewhere, such as dark liquidity. The effective and realized spread and price impact measures do not suffer from this limitation because we can calculate them using both lit and dark trades. Results from the previous subsection show that lit depth scaled by lit volume in fact declines in Canada around the minimum price improvement regulation (although not significantly), suggesting that although there may have been a shift from posting liquidity in the dark to posting liquidity in lit markets, there has not been an increase in the total available depth per unit volume. For Australia, the regressions (Table 11) indicate no significant change in lit depth.

In summary, the results from the liquidity metrics do not support the hypothesis that the regulation benefited liquidity. In fact, we find evidence of the opposite. In both Canada and Australia, our regressions indicate that after controlling for trends in market characteristics, the minimum price improvement regulation is associated with an increase in spreads. The significant increases in spreads in Australia are larger in magnitude than in Canada, and are also accompanied by significant increases in price impact.

5.4 Informational efficiency

The Internet Appendix reports results for a number of high-frequency informational efficiency metrics that have been used in previous literature. These include the absolute autocorrelations of midquote prices, Lo and MacKinlay's (1988) variance ratio, high-frequency midquote volatility, and a high-frequency adaptation of the Hou and Moskowitz (2005) metric that measures the delay in impounding market-wide information.

We do not report the results here as the analysis is somewhat inconclusive. The magnitudes of the effects are relatively small and there is lack of consensus across the different metrics. In part, the lack of conclusive evidence for this characteristic of market quality may stem from the difficulty in accurately measuring informational efficiency, in contrast to more tangible characteristics such as market shares, trade sizes, and liquidity.

5.5 The mechanisms by which the regulation impacts liquidity

The previous subsections show that the minimum price improvement regulations achieved some of the more basic and immediate objectives, such as reducing the amount of dark trading, ensuring that dark trades provide meaningful price improvement, and reducing the amount of internalization in the dark. However, they have not been successful in their higher-level objectives of encouraging the posting of lit liquidity and thereby improving overall liquidity. A natural question this raises is where did the regulations go wrong with respect to promoting overall market quality and can the regulation of dark trading be better designed to achieve such market quality objectives?

The theoretical literature on the effects of transparency in markets provides a hypothesis about where the regulation went wrong and how it could be improved. An

important effect of the regulation was to push almost all dark trading to the NBBO midpoint. While this may seem harmless and consistent with benefiting the market by preventing dark orders from 'jumping the queue' in lit markets, it causes a fundamental change in the nature of dark trading. When forced to the midpoint, dark trading changes from a two-sided market (in which dark liquidity can exist on both the buy and sell sides) to a one-sided market, in which dark liquidity can only ever exist on the buy or the sell side at any point in time. Theory suggests a number of reasons why two-sided dark trading may benefit markets, yet one-sided dark trading can be harmful.[23] Thus, our hypothesis is that the substitution of two-sided dark markets with one-sided midpoint dark markets went against the intended effect of the regulation and harmed liquidity. Under this hypothesis we would expect to see spreads increase in the proportion of dark trading at the midquote. We would also expect to see the regulation have a larger detrimental impact on the liquidity of stocks that are more often constrained by the tick size (have spreads that are often only one tick wide) than stocks that are less often constrained, because in the former case the regulation is more likely to force dark trades to the NBBO midpoint.

We test this hypothesis by exploiting the cross-sectional heterogeneity in how stocks were impacted by the regulations. Different stocks experienced different changes in various trading characteristics (trade sizes, the amount of dark trading, the proportion of dark trades executed at the midquote), and consequently the impact of the regulation on liquidity also varies across stocks. For each stock, we compute the pre/post differences in means for each of the spread measures, several trading characteristics, and each of the control variables. We then estimate cross-sectional regressions of the changes in spreads on changes in trading characteristics and control variables.

Tables 12 and 13 report the results from the cross-sectional regressions in Canada and Australia, respectively. In specification (1) we regress the change in the dependent variable on the change in each of the independent variables separately, whereas in

[23] For example, Boulatov and George (2013), Rindi (2008) and Buti and Rindi (2013) find that two-sided dark markets encourage competition in liquidity supply, especially between informed traders. Two-sided dark trading may also benefit liquidity through competition induced by the possibility of 'queue jumping' (Foucault and Menkveld, 2008) and by allowing liquidity providers to compete on a finer pricing grid (e.g., Biais et al., 2010; Buti et al., 2013). In contrast, Zhu (2014) and Hendershott and Mendelson (2000) show that one-sided dark trading can harm liquidity by increasing adverse selection risks and order imbalances in the lit market.

specification (2) we include all the independent variables and control variables simultaneously. The results support our hypothesis. In Canada, stocks that had an increase in the share of dark volume executed at the midpoint around the regulation also had an increase in their quoted spreads, their effective spreads and price impacts. None of the other trading characteristics have a significant and consistent effect on spreads in both the univariate and multivariate regressions. In Australia, the results are very similar and even stronger in statistical significance and coefficient magnitude. Namely, an increasing share of trades executed at the midquote is expected to increase quoted and effective spreads and price impacts. Unlike Canada, the amount of dark trading also has a significant positive relation with quoted, effective and realized spreads. In other words, in Australia, changes to both the level of dark trading and the prices at which dark trades execute had an impact on liquidity, with the reduction in the level of dark trading having a beneficial effect, and the increase in midpoint dark trading having a detrimental effect.

< Table 12 here >

< Table 13 here >

To interpret the magnitude of these results, consider the median share of dark trades executed at the midpoint before and after the regulation (to be comparable with our earlier characterization of changes in median spreads). In Canada, the median share of dark trades executed at the midpoint increases from 24% to close to 100%. This increase of 76% is expected to increase quoted spreads by 2.22 bps (0.03×74). The magnitude of this increase is larger than the net effect of the regulation on quoted spreads (a median effect of 0.42 bps), suggesting that other channels through which the regulation affected spreads are likely to have had a net benefit to liquidity. This detrimental effect of pushing dark trades to the midpoint is so large that it alone can explain why the regulation led to wider spreads in Canada.

In Australia, the median share of dark trades executed at the midpoint increases from 46% to close 89%. This increase of 43% is expected to increase quoted spreads by 15 bps (0.35×43). Similar to Canada, the magnitude of this increase is larger than the net

effect of the regulation on quoted spreads (a median effect of 5.6 bps), suggesting that other channels through which the regulation affected spreads (such as reducing the level of dark trading) are likely to have had a net benefit to liquidity. Again, the detrimental effect of pushing dark trades to the midpoint is so large that it alone can explain why the regulation led to wider spreads in Australia.

The results are consistent with the models of Zhu (2014) and Hendershott and Mendelson (2000). Both of these models show that dark trading at the midpoint can harm liquidity by increasing adverse selection risks and order imbalances in the lit market. Consistent with the predicted increase in adverse selection risks, our results indicate that an increasing share of midpoint dark trading tends to increase price impacts. The higher adverse selection risks also cause wider effective and quoted spreads.

Our estimates suggest that, hypothetically, had the regulation been designed in a manner that did not affect the proportion of dark trades forced to execute at the midquote, the regulation would have improved liquidity. One way to reduce the amount of dark trading that is forced to occur at the midpoint, and at the same time require meaningful price improvement for dark trades, is to ensure the tick size is sufficiently small so that the lit spread is not constrained to one tick.

An additional test of our hypothesis about midpoint dark trading, and one that tests the validity of suggestion for revised tick sizes, is whether stocks that are constrained by the tick size had a relatively larger deterioration in liquidity around the regulation. We partition stocks in each country into two groups based on the proportion of time their spread is constrained by the tick size ($Constrained_{it}$) during the period before the minimum price improvement regulation. The group of stocks that are above (below) the median level of $Constrained_{it}$ during the pre-regulation period form the high (low) constraint group. For each group of stocks in each country we repeat our regression analysis that estimates the effects of the regulation on each of the liquidity metrics.

Table 14 reports the results of the regressions that partition stocks on the basis of how often they are constrained by the tick size. The results support our hypothesis. In both countries, the detrimental effect of the regulation on effective spreads, quoted spreads, and price impacts is larger in stocks that are more often constrained by their tick

size. In Canada, it is only the highly constrained group of stocks that appear to have significant deterioration in liquidity as a result of the regulation.

Together, the results in this subsection support the hypothesis that dark trading at the midpoint is harmful to liquidity and is the main reason why the minimum price improvement regulation led to wider spreads and larger price impacts. The results suggest that existing minimum price improvement regulation (such as the rules implemented in Canada and Australia) could be improved by implementing changes to tick sizes so as to allow dark trades to provide price improvement yet maintain a two-sided dark limit order market rather than be forced to the midpoint. An implication for jurisdictions considering minimum price improvement rules is to concurrently conduct a review of tick sizes and their optimality. The US Securities and Exchange Commission has proposed a pilot study of the effects of changing the tick size.[24] However, the main change due to be tested is an *increase* in the tick size from $0.01 to $0.05. Our results suggest that if minimum price improvement is to be mandated for dark trades, the SEC should also test a regime of *decreased* tick sizes.

6. Conclusions

We analyze the recent introduction of minimum price improvement requirements for dark trades in Canada and Australia. To date, these are the only two countries to have imposed significant regulation on dark trading in response to regulatory concern that growth in dark trading may have adverse effects on public markets. We examine how the regulations impacted trading and order submissions using a series of specific metrics. We also examine the ultimate impact on market quality, as measured by a series of liquidity and informational efficiency measures.

Our evidence indicates that the regulation impacted most characteristics of trading and order submissions in a relatively predictable way. In both countries the regulation caused a substantial reduction in the amount of dark trading. In Australia, the reduction in dark trading was accompanied by an increase in block trading, largely because of a contemporaneous reduction in the size thresholds that allows trades to qualify as blocks and thereby avoid the minimum price improvement requirements. Not all dark trading

[24] See http://www.sec.gov/divisions/marketreg/tick-size-pilot-plan-final.pdf

venues and mechanisms were impacted equally. In general, venues/mechanisms in which dark trades tended to execute with relatively more price improvement before the regulation did not suffer significant reductions in market share, and in many cases *gained* volume from venues/mechanisms in which dark trades offered little or no price improvement. Almost all dark trades, in both countries, were driven to execute at the NBBO midpoint after the regulation. The absence of dark trades at prices between the NBBO and its midpoint is largely because the spread for the majority of stocks in both countries is only one or two ticks wide. A consequence of forcing all dark trades to the midpoint is that two-sided dark markets in which dark liquidity concurrently exists on both the buy and sell sides cannot exist. We also find a decline in broker internalization of client orders in the dark following the introduction of minimum price improvement rules.

Somewhat less consistent with the regulatory objectives, we find no evidence of an increased propensity for market participants to post lit liquidity, as measured by lit limit order submissions to traded volume and lit depth to traded volume. Furthermore, we find no evidence that average trade sizes in the dark increased; they remained approximately unchanged in Canada and significantly decreased in Australia.

In contrast, the effect of the regulation on higher-level market quality characteristics such as liquidity and informational efficiency was less predictable ex-ante due to the large number of competing effects. Our findings suggest the impact of the regulation on liquidity in particular is not in line with regulatory objectives. More specifically, we find that quoted and effective spreads as well as price impacts in both countries are increased after the regulation, indicating a deterioration in liquidity. Our analysis controls for trends in market characteristics that may be unrelated to dark trading, such as total dollar volume and volatility. We also control for trends in liquidity in a closely related market that was not subject to minimum price improvement requirements, thereby removing trends in liquidity that are not associated with the regulation. Our measures of spreads that involve trades (e.g., effective spreads) include all lit and dark trades, and therefore reflect average transaction costs for all trades. The increase in spreads is larger in Australia than Canada (e.g., in Australia quoted spreads increase by 19% from their pre-regulation levels, and 5% in Canada). The effect on

informational efficiency is relatively small in magnitude and due to differences across the informational efficiency metrics we do not draw strong conclusions about how the regulation impacted informational efficiency.

Did the regulations achieve their objectives? The regulations did achieve some of the more basic and immediate objectives, such as reducing the amount of dark trading, ensuring that dark trades provide meaningful price improvement, and reducing the amount of internalization in the dark. However, they do not appear to have been successful in the higher-level objective of encouraging the posting of lit liquidity and thereby improving overall liquidity.

A natural question raised by our analysis is where did the regulations go wrong with respect to promoting liquidity, and can regulation of dark trading be better designed to achieve improvements in market quality? Our analysis reveals that, consistent with theory, the main reason why the minimum price improvement regulation resulted in wider spreads and larger price impacts is that it effectively prohibited two-sided dark limit order markets in the large number of stocks where the spread is constrained by the tick size. In such stocks, dark trades are forced to execute at the midquote, which transforms the structure of the dark market into a crossing system in which liquidity can only exist on one side of the market at any point in time. While this may seem harmless and consistent with benefiting the market by preventing dark orders from 'jumping the queue' in lit markets, it causes a fundamental change in the nature of dark trading. Theory predicts that two-sided dark limit order markets can improve liquidity, yet dark crossing systems are harmful and our empirical results support this notion.

An implication of our findings is that existing minimum price improvement regulations (such as the rules implemented in Canada and Australia) could be improved by implementing changes to tick sizes so as to allow dark trades to provide price improvement, yet also maintain a two-sided dark limit order market, rather than be forced to the midpoint. An implication for jurisdictions considering minimum price improvement rules is to concurrently conduct a review of tick sizes and consider reductions in tick sizes if spreads are often constrained to one tick. The US Securities and Exchange Commission has proposed a pilot study of the effects of changing the tick size. However, the main change due to be tested is an *increase* in the tick size from

$0.01 to $0.05. Our results suggest that if minimum price improvement is to be mandated for dark trades, the SEC should also test a regime of *decreased* tick sizes.

References

Anderson, R.M., K.S. Eom, S.B. Hahn, and J.-H. Park, 2013, Autocorrelation and partial price adjustment, *Journal of Empirical Finance* 24, 78-93.

Amihud, Y., 2002, Illiquidity and stock returns: Cross-section and time-series effects, *Journal of Financial Markets* 5, 31–56.

Biais, B., C. Bisiere, and C. Spatt, 2010, Imperfect competition in financial markets: An empirical study of Island and Nasdaq, *Management Science* 56, 2237-2250.

Biais, B., D. Martimort, and J. Rochet, 2000, Competing mechanisms in a common value environment, *Econometrica* 68, 799-837.

Boulatov, A., and T.J. George, 2013, Hidden and displayed liquidity in securities markets with informed liquidity providers, *Review of Financial Studies* 26, 2095-2137.

Bound, J., D.A. Jaeger, and R.M. Baker, 1995, Problems with instrumental variables estimation when the correlation between the instruments and the endogenous explanatory variable is weak, *Journal of the American Statistical Association* 90, 443-450.

Buti, S., and B. Rindi, 2013, Undisclosed orders and optimal submission strategies in a limit order market, *Journal of Financial Economics* (forthcoming).

Buti, S., B. Rindi, and I.M. Werner, 2011, Diving into dark pools, *Unpublished manuscript*.

Buti, S., B. Rindi, Y. Wen, and I.M. Werner, 2013, Tick size regulation and sub-penny trading, *Unpublished manuscript*.

Chordia, T., R. Roll, and A. Subrahmanyam, 2008, Liquidity and market efficiency, *Journal of Financial Economics* 87, 249-268.

Comerton-Forde, C., and T.J. Putniņš, 2013, Dark trading and price discovery, *Unpublished manuscript*.

Degryse, H., F. de Jong, and V. van Kervel, 2014, The impact of dark trading and visible fragmentation on market quality, *Review of Finance* (forthcoming).

Easley, D., N.M. Kiefer, and M. O'Hara, 1996, Cream-skimming or profit-sharing? The curious role of purchased order flow, *Journal of Finance* 51, 811-833.

Foley, S., K. Malinova, and A. Park, 2012, Dark trading on public exchanges, *Unpublished manuscript*.

Foucault, T., and A.J. Menkveld, 2008, Competition for order flow and smart order routing systems, *Journal of Finance* 63, 19–58.

Hendershott, T., and C.M. Jones, 2005, Island goes dark: Transparency, fragmentation, and regulation, *Review of Financial Studies* 18, 743–793.

Hendershott, T., and H. Mendelson, 2000, Crossing networks and dealer markets: Competition and performance, *Journal of Finance* 55, 2071- 2115.

Hou, K., and T.J. Moskowitz, 2005, Market frictions, price delay, and the cross-section of expected returns, *Review of Financial Studies* 18, 981–1020.

Huang, R.D., and H.R. Stoll, 1996, Dealer versus auction markets: A paired comparison of execution costs on NASDAQ and the NYSE, *Journal of Financial Economics* 41, 313–357.

Karolyi, G.A., K.-H. Lee, and M.A. van Dijk, 2012, Understanding commonality in liquidity around the world, *Journal of Financial Economics* 105, 82-112.

Kwan, A., R. Masoulis, and T. McInish, 2014, Trading rules, competition for order flow and market fragmentation, *Journal of Financial Economics* (forthcoming).

Kyle, A.S., 1985, Continuous auctions and insider trading, *Econometrica* 53, 1315-1335.

Kyle, A.S., 1989, Informed speculation with imperfect competition, *Review of Economic Studies* 56, 317-356.

Larrymore, N.L., and A.J. Murphy, 2009, Internalization and market quality: An empirical investigation, *Journal of Financial Research* 32, 337–363.

Lee, C.M.C., and M.J. Ready, 1991, Inferring trade direction from intraday data, *Journal of Finance* 46, 733–746.

Lo, A., and C. MacKinlay, 1988, Stock market prices do not follow random walks: Evidence from a simple specification test, *Review of Financial Studies* 1, 41–66.

Nimalendran, M., and S. Ray, 2014, Informational linkages between dark and lit trading venues, *Journal of Financial Markets* 17, 230-261.

Ready, M., 2014, Determinants of volume in dark pool crossing networks, *Unpublished Manuscript.*

Rindi, B., 2008, Informed traders as liquidity providers: Anonymity, liquidity and price formation, *Review of Finance* 12, 497-532.

Ye, M., 2011, A glimpse into the dark: Price formation, transaction cost and market share of the crossing network, *Unpublished manuscript*.

Zhu, H., 2014, Do dark pools harm price discovery?, *Review of Financial Studies* (forthcoming).

TABLES AND FIGURES FOLLOW

Table 1
Summary of all trading venues in Canada

This table provides an overview of all of the lit and dark trading venues in Canada. The types of orders allowed include lit-only, dark-only or both lit and dark. The execution priority rules for each trading venue are reported in the table. They include: price priority (highest price receives priority, including most price improvement for dark orders), visibility (meaning lit orders receive priority over dark orders), broker (passive orders that are from the same broker as incoming active orders receive priority), size (passive orders are prioritized by their ability to entirely fill incoming active orders) and time (older orders are given priority over newer orders). The approximate market share of total traded dollar volume (including dark and lit trades on all listed venues) is reported for the period 15 January 2012 – 15 July 2013. The market share of Liquidnet / Instinet is obtained from IIROC statistics, whereas the other market shares are calculated from our data.

Venue	Lit / Dark	Market share	Priority rules
TSX	Both	62.5%	Price, visibility, broker, time
Chi-X	Both	13.0%	Price, visibility, time
Alpha (Lit)	Both (post 15 Oct 2012)	12.0%	Price, visibility, broker, time
MatchNow	Dark	5.4%	Price, size (proportional)
Alpha Intraspread	Dark	1.9%	Price, broker, size, time
Pure	Lit	2.4%	Price, broker, time
TMX Select	Lit	1.7%	Price, time
Omega	Lit	0.7%	Price, broker, time
CX2	Lit	0.2%	Price, broker, time
Liquidnet / Instinet	Dark (block)	0.2%	Negotiated trades

Table 2
Summary of all trading venues in Australia

This table provides an overview of all of the lit and dark trading venues in Australia. The types of orders allowed include lit-only, dark-only or both lit and dark. The "Other Dark" venues include trades executed in broker dark pools as well as manually matched dark trades. The execution priority rules for each trading venue are reported in the table. They include: price priority (highest price receives priority, including most price improvement for dark orders) and time priority (older orders are given priority over newer orders). The approximate market share of total traded dollar volume (including dark and lit trades on all listed venues) is reported for the period 26 August 2012 to 26 February 2014. The market shares are calculated from our data.

Venue	Lit / Dark	Market share	Priority rules
ASX	Lit	74.8%	Price, time
Chi-X	Both	8.6%	Price, time
Other Dark	Dark	11.0%	Varied
ASX Centre Point	Dark	5.6%	Price, time

Table 3
Effect of price improvement regulation by venue

This table shows the price improvement (as a percentage of the prevailing national best bid and offer (NBBO) spread) provided by dark order types on each of the Canadian venues that accept dark orders, before and after the introduction of minimum price improvement requirements on 15 October 2012. Before the change in regulation dark venues offered only midpoint (50% price improvement) and fractional price improvement (10% or 20% of the NBBO spread). After the regulation change, large dark orders (those greater than 50 Standard Trading Units or greater than $100,000) are able to trade at the NBBO (0% price improvement) or at the midquote in all venues apart from MatchNow, while small dark orders can only trade at the midquote.

Venue	Order Size	Before 15 Oct 2012	After 15 Oct 2012
Intraspread	Large	10% + 50%	0% + 50%
	Small	10% + 50%	50%
MatchNow	Large	20% + 50%	50%
	Small	20% + 50%	50%
Chi-X	Large	50%	0% + 50%
	Small	50%	50%
TSX	Large	50%	0% + 50%
	Small	50%	50%

Table 4
Descriptive statistics on trading activity in Canada and Australia

This table reports descriptive statistics on trading activity variables in Canada during the nine months preceding the minimum price improvement rules (15 January 2012– 14 October 2012) and nine months after (15 October 2012 – 15 July 2013), and in Australia during the nine months preceding the minimum price improvement rules (26 August 2012 – 25 May 2013) and nine months after (26 May 2013 – 26 February 2014). $DarkVolumeShare_{it}$ and $DarkTradeShare_{it}$ report, respectively, the percentage of total value and the percentage of total trades executed in all dark venues. $BlockVolumeShare_{it}$ and $BlockTradeShare_{it}$ report the same percentages for off-market block trading. $MNowDarkShare_{it}$, $XCDarkShare_{it}$, $ALPDarkShare_{it}$ and $TSXDarkShare_{it}$ report the percentage of dark value traded on MatchNow, Chi-X Canada, Alpha Intraspread and TSX, respectively. $ASXCPShare_{it}$, $CHIXDarkShare_{it}$ and $OtherDarkShare_{it}$ report the percentage of dark value traded on ASX Centre Point, Chi-X Mid and other broker dealer dark pools, respectively. $MidquoteVolumeShare_{it}$, $FractionalVolumeShare_{it}$ and $TouchVolumeShare_{it}$ report the proportion of dark value trade with; price improvement of half the spread; price improvement of a fraction of the spread; or no price improvement, respectively. Q1 and Q3 are the 1st and 3rd quartiles and *Stdev* is the standard deviation. The last two columns report the difference in means pre/post regulation, and the significance of the difference using a two-tailed t-test. Standard errors are clustered both by stock and date.

	Pre-Regulation					Post-Regulation						
	Q1	Mean	Median	Q3	Stdev	Q1	Mean	Median	Q3	Stdev	Difference	t-stat
Panel A. Canada												
$DarkVolumeShare_{it}$	4.33	9.66	7.71	12.48	8.17	2.50	7.89	5.35	10.31	8.38	-1.77	-6.01
$DarkTradeShare_{it}$	3.99	7.64	6.43	9.73	5.68	2.61	6.59	5.08	8.87	5.81	-1.05	-5.08
$BlockVolumeShare_{it}$	0.00	13.96	6.14	21.45	21.38	0.00	14.04	5.91	20.32	26.41	0.08	0.16
$BlockTradeShare_{it}$	0.00	0.09	0.03	0.11	0.18	0.00	0.08	0.03	0.11	0.15	-0.01	-3.64
$MNowDarkShare_{it}$	25.05	45.94	43.90	65.72	26.31	50.10	66.11	70.02	86.29	24.85	20.16	21.54
$CXCDarkShare_{it}$	0.90	10.95	5.48	14.77	15.06	2.02	13.77	9.09	19.66	15.85	2.83	5.87
$ALPDarkShare_{it}$	8.69	34.73	30.56	56.34	28.14	0.00	7.77	1.29	7.81	15.56	-26.96	-22.49
$TSXDarkShare_{it}$	0.23	8.38	3.35	10.78	13.10	0.90	12.35	6.97	17.68	15.64	3.97	9.80
$MidQuoteVolumeshare_{it}$	8.86	32.72	24.23	50.44	28.87	100.00	96.61	100.00	100.00	11.18	63.89	40.34
$FractionalVolumeshare_{it}$	49.55	67.27	75.77	91.14	28.89	0.00	0.00	0.00	0.00	0.00	-67.27	-46.8
$TouchVolumeShare_{it}$	0.00	0.01	0.00	0.00	0.64	0.00	3.39	0.00	0.00	11.18	3.38	16.93
Panel B. Australia												
$DarkVolumeShare_{it}$	6.46	17.60	13.27	24.27	15.48	4.27	10.94	8.47	14.66	9.97	-6.66	-19.60
$DarkTradeShare_{it}$	10.82	21.24	18.98	29.51	14.11	9.56	18.66	16.55	25.88	12.42	-2.58	-7.12
$BlockVolumeShare_{it}$	6.80	10.15	9.28	12.24	5.03	10.00	14.24	13.24	17.36	5.91	4.09	12.29
$BlockTradeShare_{it}$	0.00	0.01	0.00	0.00	0.10	0.00	0.04	0.00	0.05	0.14	0.03	11.10
$ASXCPShare_{it}$	7.48	25.95	21.53	39.24	22.24	34.71	51.35	51.69	68.58	24.84	25.40	32.82
$CHIXDarkShare_{it}$	0.00	3.13	1.03	3.63	6.02	2.83	11.45	7.70	15.55	13.00	8.32	24.60
$OtherDarkShare_{it}$	55.89	70.92	75.12	90.66	23.59	17.49	37.20	33.92	53.89	25.26	-33.72	-39.22
$MidQuoteVolumeshare_{it}$	24.72	44.50	45.76	63.90	25.72	75.25	83.51	88.93	97.57	17.81	39.01	43.98
$FractionalVolumeshare_{it}$	0.09	6.84	2.24	8.35	11.41	0.74	12.82	7.62	19.08	15.62	5.98	14.81
$TouchVolumeShare_{it}$	26.92	48.67	44.79	69.24	27.41	0.05	3.66	1.25	4.05	8.00	-45.01	-53.87

Table 5

Descriptive statistics on order submission strategies for Canada

This table reports descriptive statistics on order submission strategies in Canada during the nine months preceding the minimum price improvement rules (15 January 2012– 14 October 2012) and nine months after (15 October 2012 – 15 July 2013). $DarkTradeSize_{it}$, $BlockTradeSize_{it}$ and $LitTradeSize_{it}$ report the average dollar volume of trades occurring in the dark, block and lit markets, respectively. $LitLimitOrdersToVolume_{it}$ reports the ratio of the dollar volume of lit limit order submissions to the dollar volume of lit trades (lit market orders). $DepthToVolume_{it}$ is the ratio of the time-weighted average dollar-volume of lit limit orders at the NBBO to the dollar volume of lit trades. $LitInternalizationProxy_{it}$ is calculated as the ratio of the dollar volume of lit trades that have the same broker on both sides to the total dollar volume of lit trades. $DarkInternalizationProxy_{it}$ is calculated as the ratio of the dollar volume of dark trades that have the same broker on both sides to the total dollar volume of dark trades. Q1 and Q3 are the 1st and 3rd quartiles and *Stdev* is the standard deviation. The last two columns report the difference in means pre/post regulation, and the significance of the difference using a two-tailed t-test. Standard errors are clustered both by stock and date.

	Pre-Regulation					Post-Regulation						
	Q1	Mean	Median	Q3	Stdev	Q1	Mean	Median	Q3	Stdev	Difference	t-stat
$DarkTradeSize_{it}$ ($'000)	3.11	7.06	5.39	8.51	10.26	2.47	7.10	4.96	8.50	15.21	0.04	0.25
$BlockTradeSize_{it}$ ($'000,000)	0.44	1.48	0.81	1.52	3.45	0.41	1.74	0.82	1.62	4.84	0.26	3.13
$LitTradeSize_{it}$ ($'000)	1.98	4.10	3.33	5.29	3.90	1.81	4.29	3.53	5.69	4.63	0.19	2.73
$LitLimitOrdersToVolume_{it}$	412.45	881.66	599.27	928.31	3235.40	354.45	755.97	507.67	812.61	8446.15	-125.69	-1.50
$DepthToVolume_{it}$	0.00	0.02	0.01	0.02	0.09	0.00	0.02	0.01	0.02	0.23	0.00	-0.07
$LitInternalizationProxy_{it}$	5.28	18.34	11.97	25.81	17.69	5.63	18.58	12.39	25.83	17.68	0.24	0.70
$DarkInternalizationProxy_{it}$	4.77	13.43	10.71	18.37	12.47	0.00	5.71	2.35	6.76	9.82	-7.72	-20.07

Table 6

Descriptive statistics on order submission strategies for Australia

This table reports descriptive statistics on trading activity variables in Australia during the nine months preceding the minimum price improvement rules (26 August 2012 – 25 May 2013) and nine months after (26 May 2013– 26 February 2014). $DarkTradeSize_{it}$, $BlockTradeSize_{it}$ and $LitTradeSize_{it}$ report the average dollar volume of trades occurring in the dark, block and lit markets, respectively. $CentrePointMessagesToTrades_{it}$ is the ratio of the number of ASX Centre Point order messages (order additions, cancellations and amendments) to the number of Centre Point trades. $CentrePointMessagesToVolume_{it}$ is the ratio of the number of ASX Centre Point order messages (order additions, cancellations and amendments) to the dollar volume of Centre Point trades. $LitLimitOrdersToVolume_{it}$ reports the ratio of the dollar volume of lit limit order submissions to the dollar volume of lit trades (lit market orders). $DepthToVolume_{it}$ is the ratio of the time-weighted average dollar-volume of lit limit orders at the NBBO to the dollar volume of lit trades. $PingingFrequency_{it}$ is the number of 1-3 share dark trades per stock-day. $PingingFraction_{it}$ is the ratio of the number of 1-3 share dark trades to the total number of dark trades. $LitInternalizationProxy_{it}$ is calculated as the ratio of the dollar volume of lit trades that have the same broker on both sides to the total dollar volume of lit trades. $DarkInternalizationProxy_{\mathrm{it}}$ is calculated as the ratio of the dollar volume of dark trades that have the same broker on both sides to the total dollar volume of dark trades. Q1 and Q3 are the 1st and 3rd quartiles and *Stdev* is the standard deviation. The last two columns report the difference in means pre/post regulation, and the significance of the difference using a two-tailed t-test. Standard errors are clustered both by stock and date.

	Pre-Regulation					Post-Regulation						
	Q1	Mean	Median	Q3	Stdev	Q1	Mean	Median	Q3	Stdev	Difference	t-stat
$DarkTradeSize_{it}$ ($'000)	0.81	5.63	1.79	4.01	36.05	0.55	2.34	1.16	2.45	13.47	-3.29	-6.66
$BlockTradeSize_{it}$ ($'000,000)	1.26	3.33	2.07	3.76	6.14	0.39	1.52	0.76	1.60	2.71	-1.81	-9.61
$LitTradeSize_{it}$ ($'000)	1.30	2.88	2.14	3.61	2.63	1.16	2.55	1.91	3.20	2.23	-0.33	-7.36
$CentrePointMessagesToTrades_{it}$	3.39	17.07	6.94	14.84	59.42	14.52	99.67	31.38	84.80	222.12	82.60	17.76
$CentrePointMessagesToVolume_{it}$	0.53	0.81	0.74	1.03	0.40	2.27	3.08	2.71	3.45	1.69	2.270	6.39
$LitLimitOrdersToVolume_{it}$	182.78	389.29	226.06	286.00	4319.08	201.55	487.51	253.29	322.85	15267.54	98.22	1.48
$DepthToVolume_{it}$	1.59	107.27	4.29	10.61	17131.74	1.42	114.69	4.03	10.50	10018.05	7.42	0.12
$PingingFrequency_{it}$	0.00	22.25	4.00	18.00	69.78	0.00	16.24	4.00	15.00	34.04	-6.01	-4.16
$PingingFraction_{it}$	0.00	6.56	2.34	7.51	11.28	0.00	5.60	1.92	6.22	10.02	-0.96	-3.20
$LitInternalizationProxy_{it}$	2.84	4.92	4.35	6.14	3.96	3.65	6.31	5.46	7.73	5.23	1.39	15.65
$DarkInternalizationProxy_{it}$	41.74	63.17	66.51	88.34	28.16	2.58	22.05	12.51	33.65	24.81	-41.12	-41.48

Table 7
Descriptive statistics on liquidity variables for Canada and Australia

This table reports descriptive statistics on liquidity variables in Canada during the nine months preceding the minimum price improvement rules (15 January 2012– 14 October 2012) and nine months after (15 October 2012 – 15 July 2013), and in Australia during the nine months preceding the minimum price improvement rules (26 August 2012 – 25 May 2013) and nine months after (26 May 2013– 26 February 2014). $QuotedSpread_{it}$ is time-weighted based on the lit national best bid and offer (NBBO). $RealizedSpread_{it}$ and $EffectiveSpread_{it}$ are volume-weighted averages for the trades in each stock-day. Realized spreads are calculated using the NBBO midquote five minutes after the trade. Quoted, effective and realized spreads are measured relative to the midquote, in basis points. $LitDepth_{it}$ measures the time-weighted dollar volume available at the national NBBO across all lit markets. Q1 and Q3 are the 1st and 3rd quartiles and *Stdev* is the standard deviation. The last two columns report the difference in means pre/post regulation, and the significance of the difference using a two-tailed t-test. Standard errors are clustered both by stock and date.

	Pre-Regulation					Post-Regulation						
	Q1	Mean	Median	Q3	Stdev	Q1	Mean	Median	Q3	Stdev	Difference	t-stat
Panel A. Canada												
$QuotedSpread_{it}$	5.06	11.65	8.84	14.66	9.68	5.04	11.94	8.88	14.93	10.01	0.29	0.95
$EffectiveSpread_{it}$	3.44	8.35	6.06	10.15	8.43	3.45	8.53	6.08	10.58	7.82	0.18	0.60
$RealizedSpread_{it}$	0.60	4.80	3.25	7.60	12.01	0.88	4.99	3.49	7.80	11.40	0.19	0.86
$Price\ Impact_{it}$	-0.18	3.55	2.15	6.03	11.54	-0.13	3.53	2.01	5.93	11.42	-0.02	-0.12
$LitDepth_{it}$	32.52	92.18	51.76	101.55	129.08	32.23	103.26	52.68	106.52	169.58	11.08	3.56
Panel B. Australia												
$QuotedSpread_{it}$	14.73	44.25	30.09	47.96	48.58	14.95	52.66	31.95	52.65	64.80	8.41	4.67
$EffectiveSpread_{it}$	12.78	40.45	25.38	42.58	49.92	12.45	48.17	26.16	48.11	66.26	7.72	4.13
$RealizedSpread_{it}$	-2.97	7.97	1.77	10.08	37.41	-3.81	9.21	0.74	9.13	51.28	1.24	1.13
$Price\ Impact_{it}$	10.71	32.48	20.13	36.17	44.47	11.27	38.96	21.71	41.53	59.51	6.48	5.35
$LitDepth_{it}$	42.11	283.85	102.76	258.37	932.49	38.36	267.62	96.45	262.85	762.24	-16.23	-1.02

Table 8

The impact of minimum price improvement regulation on transaction costs in Canada

The dependent variables are estimates of transaction costs for each stock-day. Two specifications are provided for each variable. Specification (1) shows the impact of the regulation using a dummy variable, while also including control variables. Specification (2) adds the date-mean of a set of matched US stocks to control for exogenous variation in the market. $QuotedSpread_{it}$ are time-weighted based on the lit national best bid and offer (NBBO).$RealizedSpread_{it}$ and $EffectiveSpread_{it}$are volume-weighted averages for the trades in each stock-day. Realized spreads are calculated using the NBBO midquote five minutes after the trade. Quoted, effective and realized spreads are measured relative to the midquote, in basis points. The key independent variable, $D_t^{PostPeriod}$, is a dummy variable that takes 1 in the period post-regulation and 0 otherwise. $\$Volume_{it}$ is the natural logarithm of traded dollar volume. $Volatility_{it}$ is the stock-day's high-low price range divided by the time-weighted midquote. $US\ Mean_t$ is the mean value for the given variable per date for a matched sample of US firms. Standard errors are clustered both by stock and date, and t-statistics are reported in parentheses. ***, ** and * indicate statistical significance at 1%, 5% and 10% levels, respectively.

	$QuotedSpread_{it}$		$EffectiveSpread_{it}$		$RealizedSpread_{it}$	
	(1)	(2)	(1)	(2)	(1)	(2)
$Intercept$	70.58	66.61	51.07	50.57	33.40	31.96
	(15.70)***	(15.12)***	(11.99)***	(11.12)***	(11.69)***	(10.74)***
$D_t^{PostPeriod}$	0.63	0.42	0.44	0.45	0.30	0.21
	(2.97)***	(1.75)*	(1.97)**	(1.94)*	(1.57)	(1.13)
$\$Volume_{it}$	-3.98	-3.94	-2.90	-2.88	-1.85	-1.81
	(-14.52)***	(-14.31)***	(-11.13)***	(-10.77)***	(-10.96)***	(-10.43)***
$Volatility_{it}$	0.02	0.02	0.02	0.02	0.00	0.00
	(11.23)***	(11.01)***	(10.23)***	(10.14)***	(6.79)***	(6.74)***
$US\ Mean_t$		0.27		0.01		0.24
		(3.62)***		(0.14)		(3.52)***

Table 9

The impact of minimum price improvement regulation on transaction costs in Australia

The dependent variables are estimates of transaction costs for each stock-day. Two specifications are provided for each variable. Specification (1) shows the impact of the regulation using a dummy variable, while also including control variables. Specification (2) adds the date-mean of a set of matched NZ stocks to control for exogenous variation in the market. $QuotedSpread_{it}$ are time-weighted based on the lit national best bid and offer (NBBO). $RealizedSpread_{it}$ and $EffectiveSpread_{it}$ are volume-weighted averages for the trades in each stock-day. Realized spreads are calculated using the NBBO midquote five minutes after the trade. Quoted, effective and realized spreads are measured relative to the midquote, in basis points. The key independent variable, $D_t^{PostPeriod}$, is a dummy variable that takes 1 in the period post-regulation and 0 otherwise. $\$Volume_{it}$ is the natural logarithm of traded dollar volume. $Volatility_{it}$ is the stock-day's high-low price range divided by the time-weighted midquote. $NZ\ Mean_t$ is the mean value for the given variable per date for a matched sample of NZ firms. Standard errors are clustered both by stock and date, and t-statistics are reported in parentheses. ***, ** and * indicate statistical significance at 1%, 5% and 10% levels, respectively.

	$QuotedSpread_{it}$		$EffectiveSpread_{it}$		$RealizedSpread_{it}$	
	(1)	(2)	(1)	(2)	(1)	(2)
$Intercept$	262.52	265.25	254.28	255.95	131.68	131.49
	(12.20)***	(12.20)***	(11.68)***	(11.88)***	(8.39)***	(8.46)***
$D_t^{PostPeriod}$	5.31	5.62	4.57	4.88	1.24	1.22
	(4.37)***	(4.56)***	(3.50)***	(3.81)***	(1.22)	(1.26)
$\$Volume_{it}$	-15.90	-15.89	-15.66	-15.66	-7.68	-7.69
	(-11.45)***	(-11.45)***	(-11.03)***	(-11.01)***	(-7.89)***	(-7.91)***
$Volatility_{it}$	0.09	0.09	0.09	0.09	-0.02	-0.02
	(10.45)***	(10.44)***	(10.43)***	(10.46)***	(-6.76)***	(-6.61)***
$NZ\ Mean_t$		-0.05		-0.03		0.01
		(-1.87)*		(-1.30)		(0.31)

Table 10
The impact of minimum price improvement regulation on liquidity in Canada

The dependent variables are estimates of liquidity for each stock-day. Two specifications are provided for each variable. Specification (1) shows the impact of the regulation using a dummy variable, while also including control variables. Specification (2) adds the date-mean of a set of matched US stocks to control for exogenous variation in the market. $PriceImpact_{it}$ is volume-weighted for the trades in each stock-day, is calculated using the NBBO midquote five minutes after the trade and is measured relative to the midquote, in basis points. $LitDepth_{it}$ measures the time-weighted dollar volume available at the national NBBO across all lit markets. The key independent variable, $D_t^{PostPeriod}$, is a dummy variable that takes 1 in the period post-regulation and 0 otherwise. $\$Volume_{it}$ is the natural logarithm of traded dollar volume. $Constrained_{it}$ is the percentage of the trading day for which the stock's NBBO spread is constrained at one tick. $Volatility_{it}$ is the stock-day's high-low price range divided by the time-weighted midquote. $US\ Mean_t$ is the mean value for the given variable per date for a matched sample of US firms. Standard errors are clustered both by stock and date, and t-statistics are reported in parentheses. ***, ** and * indicate statistical significance at 1%, 5% and 10% levels, respectively.

	$PriceImpact_{it}$		$LitDepth_{it}$	
	(1)	(2)	(1)	(2)
$Intercept$	18.62	18.35	-0.57	-0.60
	(9.64)***	(8.92)***	(-7.38)***	(-7.56)***
$D_t^{PostPeriod}$	0.10	0.13	0.01	0.01
	(0.77)	(0.96)	(2.97)***	(2.71)***
$\$Volume_{it}$	-1.18	-1.20	0.04	0.04
	(-8.98)***	(-8.84)***	(8.19)***	(8.16)***
$Constrained_{it}$	2.17	2.25	0.12	0.12
	(4.18)***	(4.29)***	(5.78)***	(5.84)***
$Volatility_{it}$	0.01	0.01	-0.00	-0.00
	(9.04)***	(8.82)***	(-4.46)***	(-4.34)***
$US\ Mean_t$		0.11		0.00
		(1.58)		(2.99)***

Table 11

The impact of minimum price improvement regulation on liquidity in Australia

The dependent variables are estimates of liquidity for each stock-day. Two specifications are provided for each variable. Specification (1) shows the impact of the regulation using a dummy variable, while also including control variables. Specification (2) adds the date-mean of a set of matched NZ stocks to control for exogenous variation in the market. $PriceImpact_{it}$ is volume-weighted for the trades in each stock-day, is calculated using the NBBO midquote five minutes after the trade and is measured relative to the midquote, in basis points. $LitDepth_{it}$ measures the time-weighted dollar volume available at the national NBBO across both lit markets. The key independent variable, $D_t^{PostPeriod}$, is a dummy variable that takes 1 in the period post-regulation and 0 otherwise. $\$Volume_{it}$ is the natural logarithm of traded dollar volume. $Constrained_{it}$ is the percentage of the trading day for which the stock's NBBO spread is constrained at one tick. $Volatility_{it}$ is the stock-day's high-low price range divided by the time-weighted midquote. $NZ\ Mean_t$ is the mean value for the given variable per date for a matched sample of NZ firms. Standard errors are clustered both by stock and date, and t-statistics are reported in parentheses. ***, ** and * indicate statistical significance at 1%, 5% and 10% levels, respectively.

	$PriceImpact_{it}$		$LitDepth_{it}$	
	(1)	(2)	(1)	(2)
$Intercept$	107.73	108.07	-1.75	-1.79
	(10.91)***	(10.96)***	(-2.57)**	(-2.66)***
$D_t^{PostPeriod}$	3.83	3.87	0.01	0.01
	(5.04)***	(5.10)***	(0.91)	(1.28)
$\$Volume_{it}$	-8.36	-8.35	0.10	0.10
	(-13.99)***	(-13.94)***	(2.37)**	(2.38)**
$Constrained_{it}$	24.98	24.96	0.71	0.71
	(4.81)***	(4.84)***	(4.32)***	(4.32)***
$Volatility_{it}$	0.11	0.11	-0.00	-0.00
	(15.09)***	(15.10)***	(-2.33)**	(-2.32)**
$NZ\ Mean_t$		-0.03		0.00
		(-1.73)*		(2.23)**

Table 12
Determinants of liquidity and transaction cost measures in Canada

The dependent variables are estimates of liquidity and transaction cost measures for each stock-day. Two specifications are provided for each dependent variable and are the result of two stages. In the first stage the dependent variable is regressed on the impact of the regulation by stock using a dummy variable, while also controlling for traded volume, volatility and the level of constraint. Specification (1) regresses the change in the dependent variable on the change in the independent variables separately. In Specification (2) the change in the dependent variable is regressed on the change in each of the seven trading variables. $QuotedSpread_{it}$ is time-weighted based on the lit national best bid and offer (NBBO). $RealizedSpread_{it}$ and $EffectiveSpread_{it}$ are volume-weighted averages for the trades in each stock-day, calculated using the NBBO midquote five minutes after the trade. Quoted, effective and realized spreads are measured relative to the midquote, in basis points. $PriceImpact_{it}$ is volume-weighted for the trades in each stock-day and is calculated using the NBBO midquote five minutes after the trade and is reported in basis points. $LitDepth_{it}$ measures the time-weighted dollar volume available at the national NBBO across all lit markets. $\$Volume_{it}$ is the natural logarithm of traded dollar volume. $LitInternalizationProxy_{it}$ is calculated as the ratio of the dollar volume of lit trades that have the same broker on both sides to the total dollar volume of lit trades. $DarkInternalizationProxy_{it}$ is calculated as the ratio of the dollar volume of dark trades that have the same broker on both sides to the total dollar volume of dark trades. $BlockTradeSize$ and $DarkTradeSize$ report the average dollar volume of trades occurring in the block and dark markets, respectively. $BlockVolumeShare_{it}$ and $DarkVolumeShare_{it}$ report, respectively, the percentage of total value executed in block and dark venues. $MidquoteVolumeShare_{it}$ reports the percentage of dark dollar volume executed at a midpoint price. $Volatility_{it}$ is the stock-day's high-low price range divided by the time-weighted midquote. Standard errors are clustered both by stock and date, and t-statistics are reported in parentheses. ***, ** and * indicate statistical significance at 1%, 5% and 10% levels, respectively.

	$QuotedSpread_{it}$		$EffectiveSpread_{it}$		$RealisedSpread_{it}$		$PriceImpact_{it}$		$LitDepth_{it}$	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
$Intercept$		-0.26		0.43		0.94		-0.51		2.97
		(-0.39)		(0.53)		(1.30)		(-1.10)		(0.28)
$LitInternalizationProxy_{it}$	-0.00	0.00	-0.00	-0.00	-0.00	-0.00	-0.00	0.00	-0.00	-0.00
	(-0.56)	(1.91)*	(-0.56)	(-0.28)	(-0.25)	(-0.90)	(-0.63)	(0.91)	(-7.61)***	(-4.92)***
$DarkInternalizationProxy_{it}$	-0.08	0.07	-0.07	0.03	-0.05	-0.00	-0.03	0.03	-0.81	0.25
	(-2.60)***	(2.23)**	(-2.31)**	(0.69)	(-1.91)*	(-0.04)	(-1.40)	(1.24)	(-2.17)**	(0.51)
$BlockTradeSize_{it}$	0.71	0.18	0.59	0.16	0.28	0.10	0.32	0.06	1.03	-4.16
	(2.87)***	(0.95)	(2.37)**	(0.70)	(1.43)	(0.47)	(2.13)**	(0.47)	(0.34)	(-1.35)
$DarkTradeSize_{it}$	0.08	0.18	0.00	0.06	-0.04	-0.07	0.04	0.14	-0.23	0.38
	(0.82)	(2.36)**	(0.01)	(0.68)	(-0.57)	(-0.84)	(0.75)	(2.45)**	(-0.19)	(0.30)
$BlockVolumeShare_{it}$	0.22	-0.05	0.20	-0.04	0.12	-0.05	0.08	0.01	0.24	-0.33
	(10.05)***	(-1.32)	(8.42)***	(-0.72)	(6.25)***	(-1.02)	(5.11)***	(0.34)	(0.73)	(-0.50)
$DarkVolumeShare_{it}$	-0.27	-0.10	-0.15	0.15	-0.08	0.15	-0.07	-0.00	-3.48	-3.75
	(-4.91)***	(-1.45)	(-2.72)***	(1.84)*	(-1.80)*	(2.06)**	(-2.23)**	(-0.03)	(-5.37)***	(-3.47)***
$MidQuoteVolumeshare_{it}$	0.04	0.03	0.03	0.01	0.01	-0.01	0.01	0.02	0.30	-0.03
	(4.62)***	(2.39)**	(2.98)***	(0.78)	(1.92)*	(-0.44)	(2.50)**	(2.01)**	(2.73)***	(-0.15)
$\$Volume_{it}$		-7.77		-7.24		-4.70		-2.53		28.28
		(-17.85)***		(-13.59)***		(-9.79)***		(-8.13)***		(4.06)***
$Volatility_{it}$		297.91		221.29		78.96		142.33		-1371.04
		(8.69)***		(5.27)***		(2.09)**		(5.80)***		(-2.50)**

Table 13

Determinants of liquidity and transaction cost measures in Australia

The dependent variables are estimates of liquidity and transaction cost measures for each stock-day. Two specifications are provided for each dependent variable and are the result of two stages. In the first stage the dependent variable is regressed on the impact of the regulation by stock using a dummy variable, while also controlling for traded volume, volatility and the level of constraint. Specification (1) regresses the change in the dependent variable on the change in the independent variables separately. In Specification (2) the change in the dependent variable is regressed on the change in each of the seven trading variables. $QuotedSpread_{it}$is time-weighted based on the lit national best bid and offer (NBBO). $RealizedSpread_{it}$ and $EffectiveSpread_{it}$are volume-weighted averages for the trades in each stock-day, calculated using the NBBO midquote five minutes after the trade. Quoted, effective and realized spreads are measured relative to the midquote, in basis points. $PriceImpact_{it}$ is volume-weighted for the trades in each stock-day and is calculated using the NBBO midquote five minutes after the trade and is reported in basis points. $LitDepth_{it}$ measures the time-weighted dollar volume available at the national NBBO across both lit markets. $\$Volume_{it}$is the natural logarithm of traded dollar volume. $LitInternalizationProxy_{it}$ is calculated as the ratio of the dollar volume of lit trades that have the same broker on both sides to the total dollar volume of lit trades. $DarkInternalizationProxy_{it}$ is calculated as the ratio of the dollar volume of dark trades that have the same broker on both sides to the total dollar volume of dark trades. $BlockTradeSize$ and $DarkTradeSize$ report the average dollar volume of trades occurring in the block and dark markets, respectively. $BlockVolumeShare_{it}$ and $DarkVolumeShare_{it}$ report, respectively, the percentage of total value executed in block and dark venues. $MidquoteVolumeShare_{it}$reports the percentage of dark dollar volume executed at a midpoint price. $Volatility_{it}$ is the stock-day's high-low price range divided by the time-weighted midquote. Standard errors are clustered both by stock and date, and t-statistics are reported in parentheses. ***, ** and * indicate statistical significance at 1%, 5% and 10% levels, respectively.

	$QuotedSpread_{it}$		$EffectiveSpread_{it}$		$RealisedSpread_{it}$		$PriceImpact_{it}$		$LitDepth_{it}$	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
$Intercept$		-2.40		-3.52		4.38		-7.90		-197.89
		(-0.42)		(-0.58)		(1.05)		(-2.26)**		(-2.29)**
$LitInternalizationProxy_{it}$	1.51	0.06	1.75	0.07	0.27	0.38	1.48	-0.31	3.12	-13.36
	(1.17)	(0.05)	(1.41)	(0.06)	(0.38)	(0.46)	(1.88)*	(-0.44)	(0.23)	(-0.77)
$DarkInternalizationProxy_{it}$	-0.47	0.12	-0.47	0.10	-0.10	0.15	-0.37	-0.05	-2.11	-3.90
	(-4.31)***	(0.79)	(-4.37)***	(0.63)	(-1.52)	(1.43)	(-5.63)***	(-0.60)	(-1.76)*	(-1.74)*
$BlockTradeSize_{it}$	-0.00	0.00	-0.00	0.00	-0.00	0.00	-0.00	0.00	-0.00	-0.00
	(-1.04)	(0.62)	(-0.93)	(1.59)	(-0.31)	(2.12)**	(-1.28)	(0.23)	(-0.02)	(-0.15)
$DarkTradeSize_{it}$	0.00	-0.00	0.00	-0.00	0.00	-0.00	0.00	0.00	0.00	0.00
	(0.84)	(-1.33)	(0.73)	(-1.35)	(0.47)	(-2.02)**	(0.73)	(0.05)	(0.10)	(0.94)
$BlockVolumeShare_{it}$	-0.38	0.50	-0.47	0.19	-0.13	0.06	-0.34	0.14	-0.33	17.83
	(-1.10)	(1.11)	(-1.25)	(0.41)	(-0.59)	(0.18)	(-1.45)	(0.49)	(-0.08)	(2.63)***
$DarkVolumeShare_{it}$	1.04	1.08	0.82	0.89	0.44	0.65	0.38	0.24	0.96	9.96
	(3.34)***	(3.05)***	(2.71)***	(2.36)**	(2.55)**	(2.50)**	(1.96)*	(1.11)	(0.28)	(1.86)*
$MidQuoteVolumeshare_{it}$	0.60	0.35	0.57	0.36	0.15	0.14	0.42	0.22	1.26	0.70
	(5.71)***	(2.58)**	(5.55)***	(2.53)**	(2.41)**	(1.42)	(6.64)***	(2.69)***	(1.04)	(0.34)
$\$Volume_{it}$		-26.05		-24.32		-12.60		-11.72		32.17
		(-8.99)***		(-7.94)***		(-5.99)***		(-6.64)***		(0.74)
$Volatility_{it}$		1743.23		1624.55		43.04		1581.51		2895.13
		(10.33)***		(9.11)***		(0.35)		(15.38)***		(1.14)

Table 14

The impact of minimum price improvement regulation on transaction costs and liquidity by level of constraint

The dependent variables are estimates of liquidity and transaction cost metrics for each stock-day. The data has been separated into two halves by the level of constraint in the pre-period, with *Low Constraint* being the half of stocks with the lowest average pre-period level of constraint, and *High Constraint* being those stocks with highest level of constraint in the pre-period. $QuotedSpread_{it}$ is time-weighted based on the lit national best bid and offer (NBBO). $RealizedSpread_{it}$ and $EffectiveSpread_{it}$ are volume-weighted averages for the trades in each stock-day. $RealizedSpread_{it}$ is calculated using the NBBO midquote five minutes after the trade. Quoted, effective and realized spreads are measured relative to the midquote, in basis points. $PriceImpact_{it}$ is volume-weighted for the trades in each stock-day is calculated using the NBBO midquote five minutes after the trade and is measured relative to the midquote, in basis points. $LitDepth_{it}$ measures the time-weighted dollar volume available at the national NBBO across both lit markets. The key independent variable, $D_t^{PostPeriod}$, is a dummy variable that takes 1 in the period post-regulation and 0 otherwise. $\$Volume_{it}$ is the natural logarithm of traded dollar volume. $Constrained_{it}$ is the percentage of the trading day for which the stock's NBBO spread is constrained at one tick. $Volatility_{it}$ is the stock-day's high-low price range divided by the time-weighted midquote. Standard errors are clustered both by stock and date, and t-statistics are reported in parentheses. ***, ** and * indicate statistical significance at 1%, 5% and 10% levels, respectively.

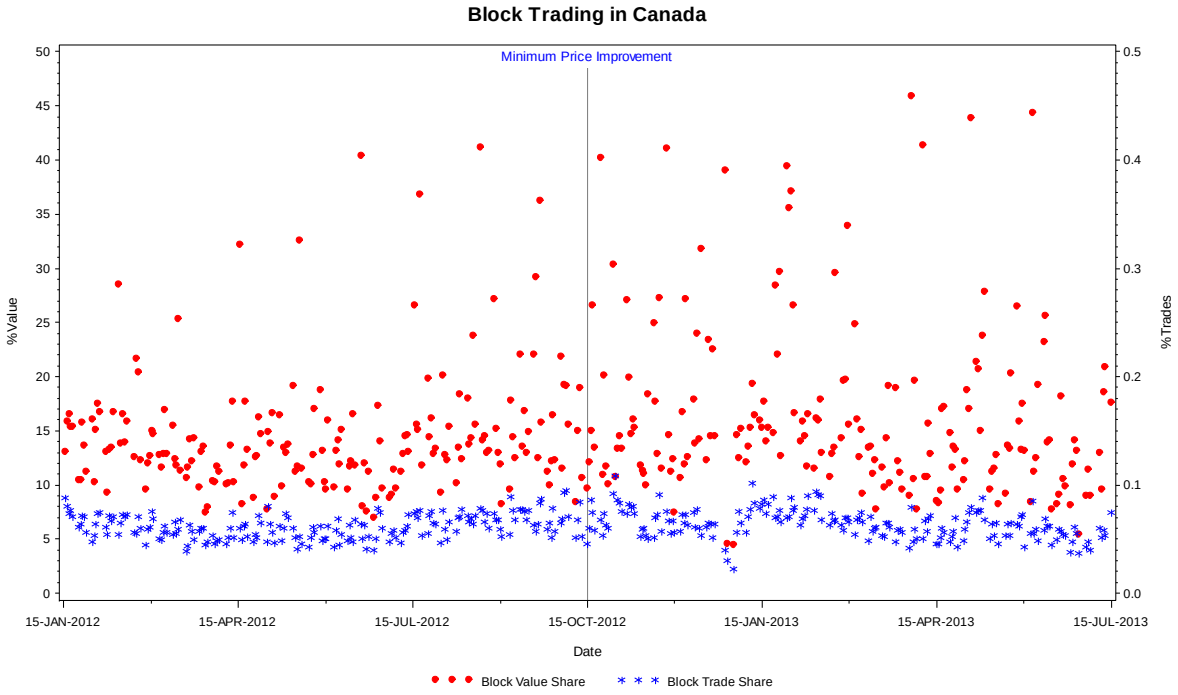
	Low Constraint					High Constraint				
	$Quoted\ Spread_{it}$	$Effective\ Spread_{it}$	$Realized\ Spread_{it}$	$Price\ Impact_{it}$	$Lit\ Depth_{it}$	$Quoted\ Spread_{it}$	$Effective\ Spread_{it}$	$Realized\ Spread_{it}$	$Price\ Impact_{it}$	$Lit\ Depth_{it}$
Panel A. Canada										
$Intercept$	74.77	54.70	37.09	17.33	-0.20	70.54	51.95	31.62	12.27	-1002.27
	(10.20)***	(6.91)***	(6.59)***	(6.67)***	(-4.90)***	(12.40)***	(12.12)***	(13.97)***	(5.53)***	(-6.40)***
$D_t^{PostPeriod}$	-0.01	-0.27	0.07	-0.34	0.00	1.30	1.16	0.57	0.34	16.16
	(-0.04)	(-0.98)	-0.27	(-2.40)**	-1.33	(4.55)***	(5.14)***	(3.27)***	(1.75)*	(3.10)***
$\$Volume_{it}$	-4.21	-3.13	-2.11	-0.97	0.02	-3.97	-2.93	-1.72	-1.30	52.33
	(-9.12)***	(-6.12)***	(-5.98)***	(-4.82)***	(5.58)***	(-11.67)***	(-11.39)***	(-13.37)***	(-8.55)***	(7.79)***
$Constrained_{it}$				-1.75	0.03				11.07	327.97
				(-1.29)	(1.65)*				(7.99)***	(4.44)***
$Volatility_{it}$	156.93	133.25	65.65	68.44	-0.45	216.91	162.35	36.65	119.10	-509.39
	(5.39)***	(3.50)***	(3.86)***	(3.02)***	(-2.62)***	(11.88)***	(11.57)***	(4.49)***	(10.73)***	(-3.06)***
Panel B. Australia										
$Intercept$	243.92	235.73	109.88	125.53	-346.98	363.19	346.7	197.29	66.14	-5488.82
	(9.59)***	(9.17)***	(6.63)***	(10.25)***	(-5.42)***	(9.45)***	(8.70)***	(5.99)***	(3.76)***	(-2.18)**
$D_t^{PostPeriod}$	4.83	4.04	-0.23	4.29	4.18	5.78	5.08	2.53	3.89	32.39
	(3.56)***	(2.81)***	(-0.22)	(3.63)***	-0.43	(2.98)***	(2.39)**	-1.52	(4.29)***	(2.34)**
$\$Volume_{it}$	-15.23	-14.91	-6.55	-8.36	23.03	-21.59	-20.91	-11.47	-9.37	223.14
	(-8.79)***	(-8.40)***	(-6.16)***	(-10.03)***	(6.15)***	(-8.84)***	(-8.21)***	(-5.69)***	(-11.62)***	(2.02)**
$Constrained_{it}$				0.50	131.63				86.50	2718.38
				-0.09	(3.99)***				(6.42)***	(2.71)***
$Volatility_{it}$	727.86	769.94	-187.40	957.51	-525.50	911.75	926.62	-259.15	1201.88	-3034.09
	(7.01)***	(6.89)***	(-3.47)***	(11.12)***	(-2.10)**	(8.25)***	(8.14)***	(-7.70)***	(11.59)***	(-2.44)**

Figure 1
Percentage of trading without pre-trade transparency

This figure shows daily dark trading in Canada and Australia as a percent of total consolidated dollar volume and trades for constituents of the TSX Composite Index, from 15 January 2012 to 15 July 2013, and for constituents of the ASX200 Index, from 26 August 2012 to 26 February 2014. In Canada the dark trading percent aggregates the dollar volume (or trade count) of dark trades executed on any dark venue and dividing it by the total dollar volume (or trade count) of trading on all of the main venues (TSX, Chi-X, Alpha, MatchNow, Intraspread, TMX Select, Chi-X2, Pure Trading, and Omega). The aggregation of trading volume uses proprietary data from MatchNow, Chi-X and TSX. The aggregation of dark trading volume does not include dark block trades executed on Liquidnet/Instinet.The same process is repeated for Australia, with dark venues including ASX Centre Point, Chi-X Mid and other dark executions. The vertical bar indicates the introduction of minimum price improvement requirements on 15 October 2012 in Canada and 26 May 2013 in Australia.

Figure 2
Block executions

This figure shows total daily block trading in Canada and Australia as a fraction of total consolidated dollar volume and trades for constituents of the TSX Composite Index, from 15 January 2012 to 15 July 2013, and for constituents of the ASX200 Index, from 26 August 2012 to 26 February 2014. $BlockValueShare_{it}$ is constructed by aggregating the dollar value of block trades and dividing it by the total dollar volume of trading on all of the main venues. $BlockTradeShare_{it}$ represents the percentage of all trades executed in block venues. The vertical bar indicates the introduction of minimum price improvement requirements on 15 October 2012 in Canada and 26 May 2013 in Australia.



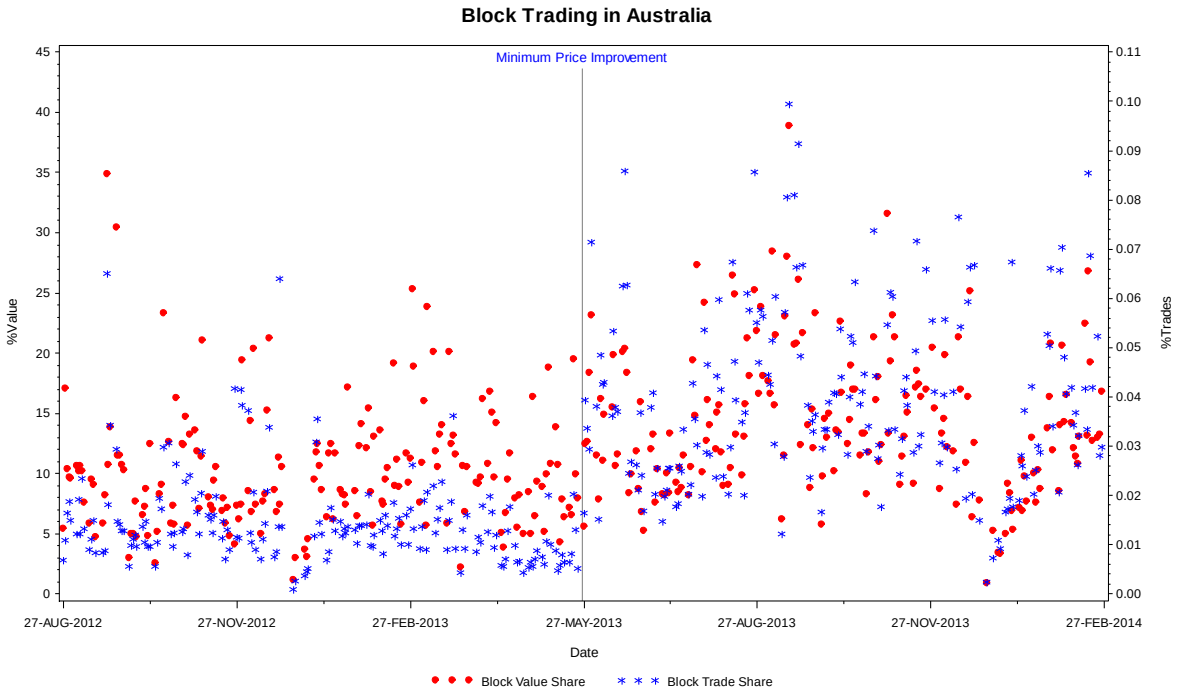
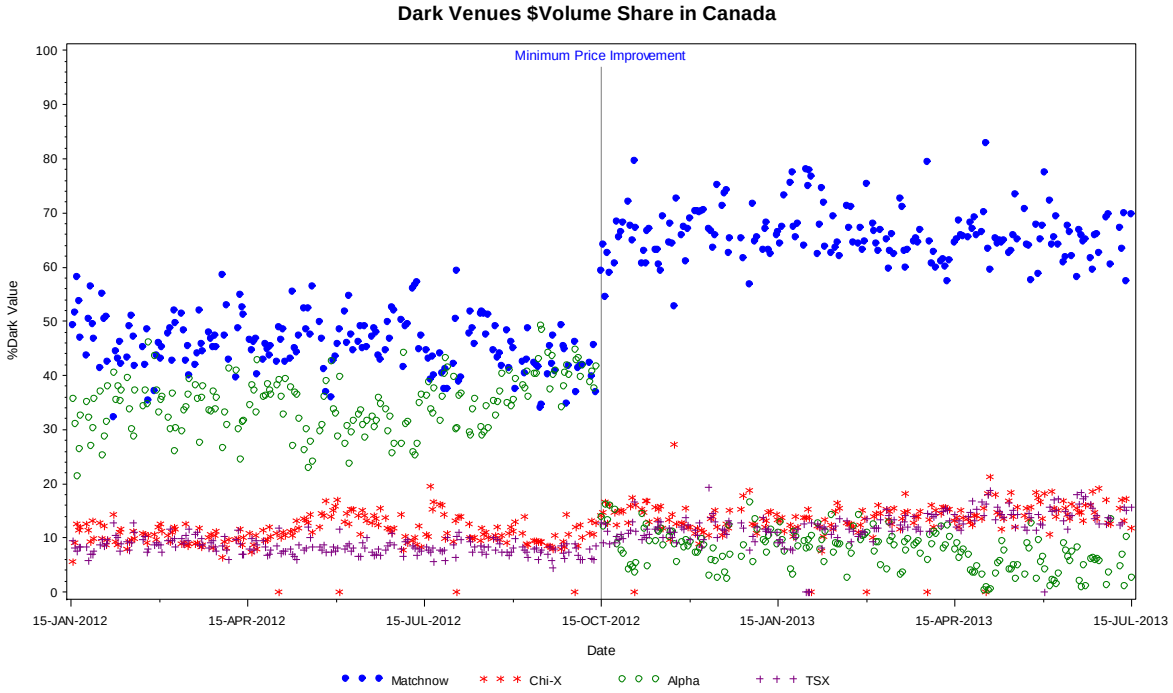


Figure 3
Dollar volume traded in the dark by venue

This figure shows the location of dark trading in Canada and Australia by venue as a fraction of total dark dollar volume for constituents of the TSX Composite Index, from 15 January 2012 to 15 July 2013, and for constituents of the ASX200 Index, from 26 August 2012 to 26 February 2014. The dark trading fraction is constructed by aggregating the dollar value of dark trades executed on each of the dark venues and dividing it by the total dollar volume of trading on all dark venues. Once constructed at the stock-day level, these measures are then equally weighted across each stock in our sample. The vertical bar indicates the introduction of minimum price improvement requirements on 15 October 2012 in Canada and 26 May 2013 in Australia.



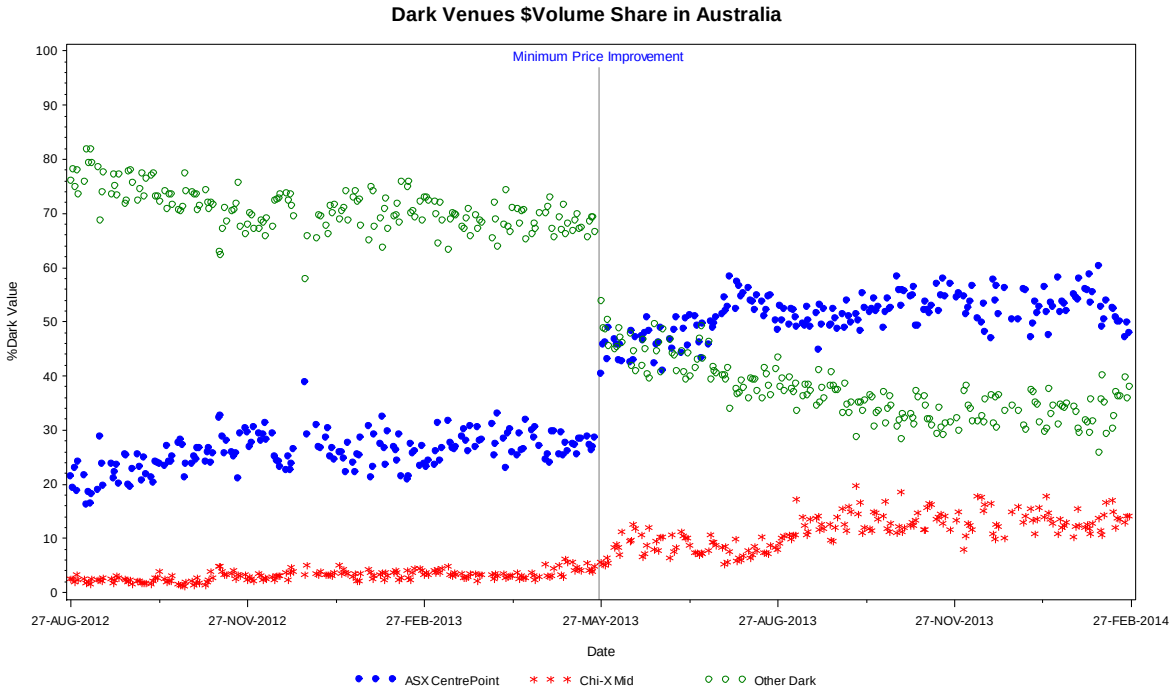
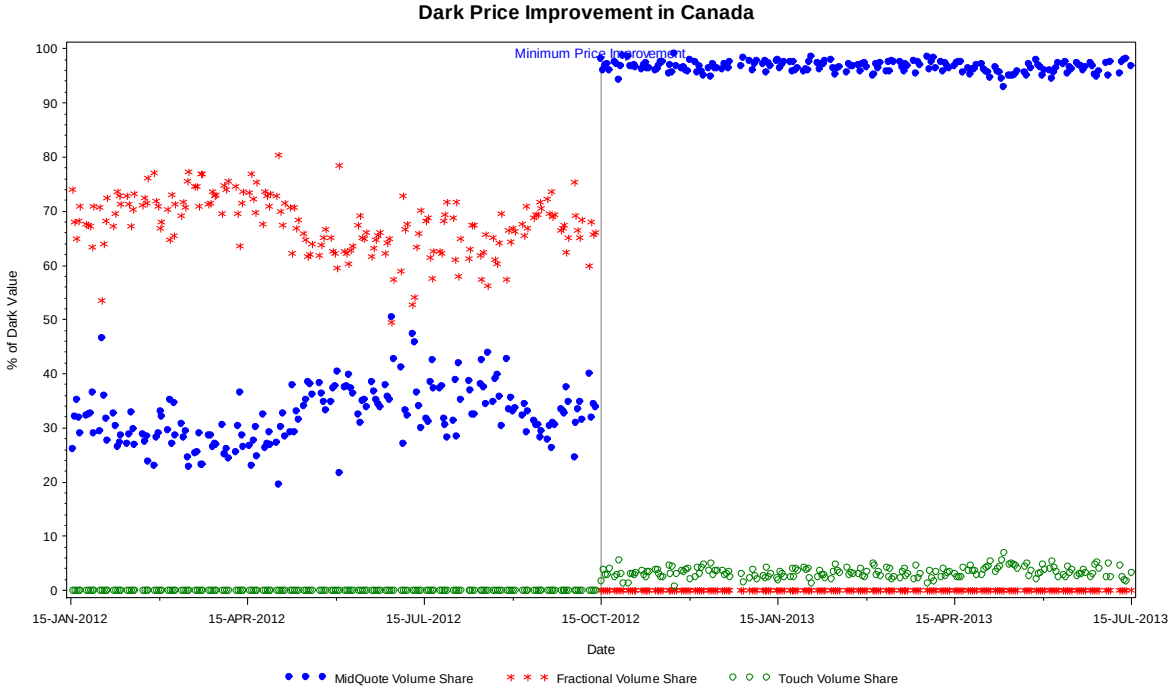


Figure 4
Price improvement of dark executions

This figure shows the level of price improvement provided to dark executions in Canada and Australia for constituents of the TSX Composite Index, from 15 January 2012 to 15 July 2013, and for constituents of the ASX200 Index, from 26 August 2012 to 26 February 2014. Midquote orders are those that execute half way between the best bid and ask. Fractional orders provide price improvement of some fraction of the spread. Touch orders are dark orders that are executed at the best bid or offer, and do not receive any price improvement. All three measures represent the dollar volume of that order type divided by all dark dollar volume. Once constructed at the stock-day level, these measures are then equally weighted across each stock in our sample. The vertical bar indicates the introduction of minimum price improvement requirements on 15 October 2012 in Canada and 26 May 2013 in Australia.



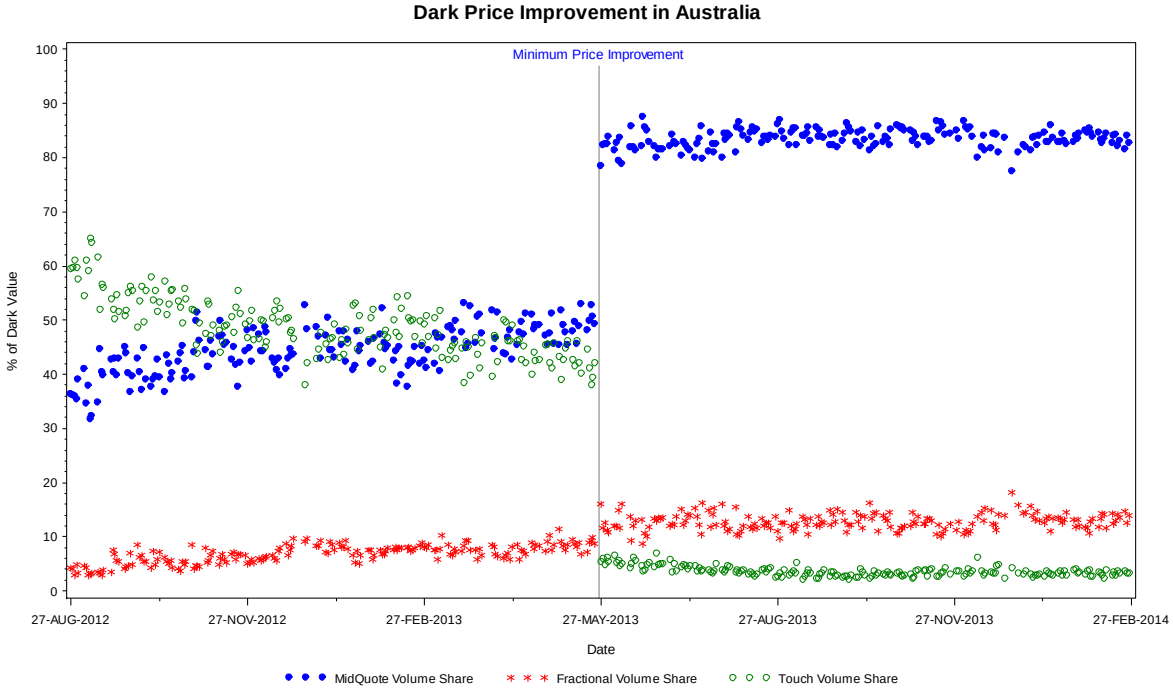
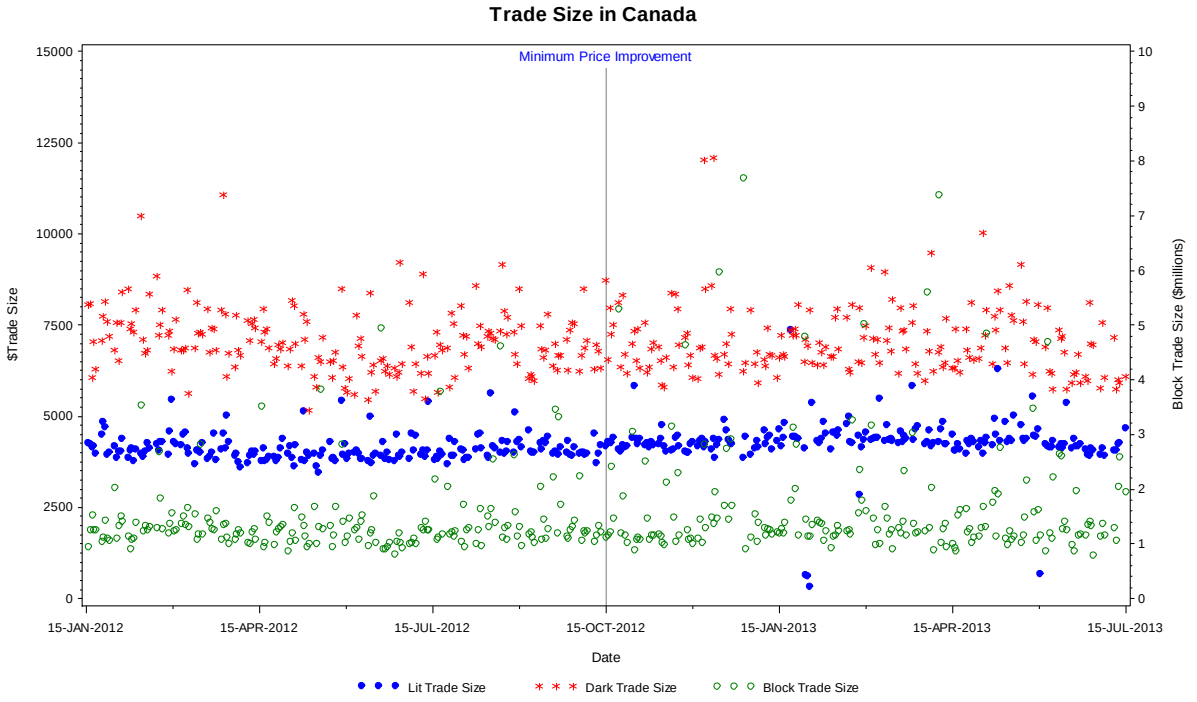


Figure 5
Dark, lit and block trade sizes

This figure shows daily trade sizes in Canada for constituents of the TSX Composite Index, from 15 January 2012 to 15 July 2013, and for constituents of the ASX200 Index, from 26 August 2012 to 26 February 2014. $DarkTradeSize_{it}$, $BlockTradeSize_{it}$ and $LitTradeSize_{it}$ report the average dollar volume of trades occurring in the dark, block and lit markets, respectively. Once constructed at the stock-day level, these measures are then equally weighted across each stock-day in our sample. The vertical bar indicates the introduction of minimum price improvement requirements on 15 October 2012 in Canada and 26 May 2013 in Australia.



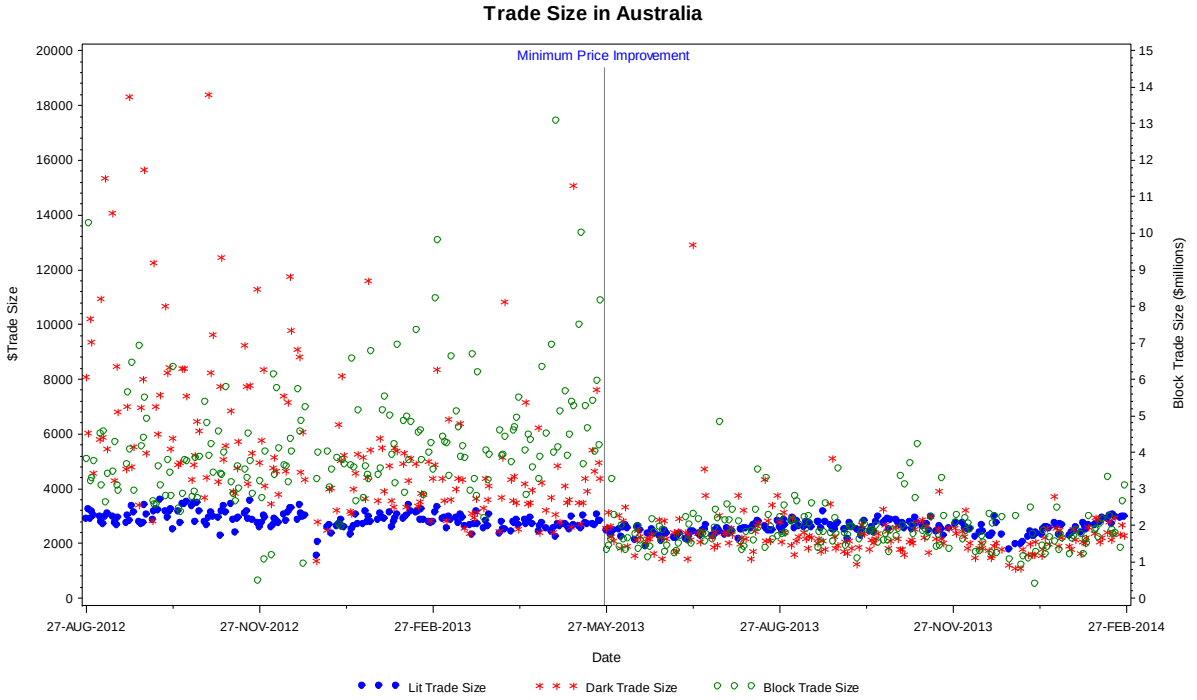
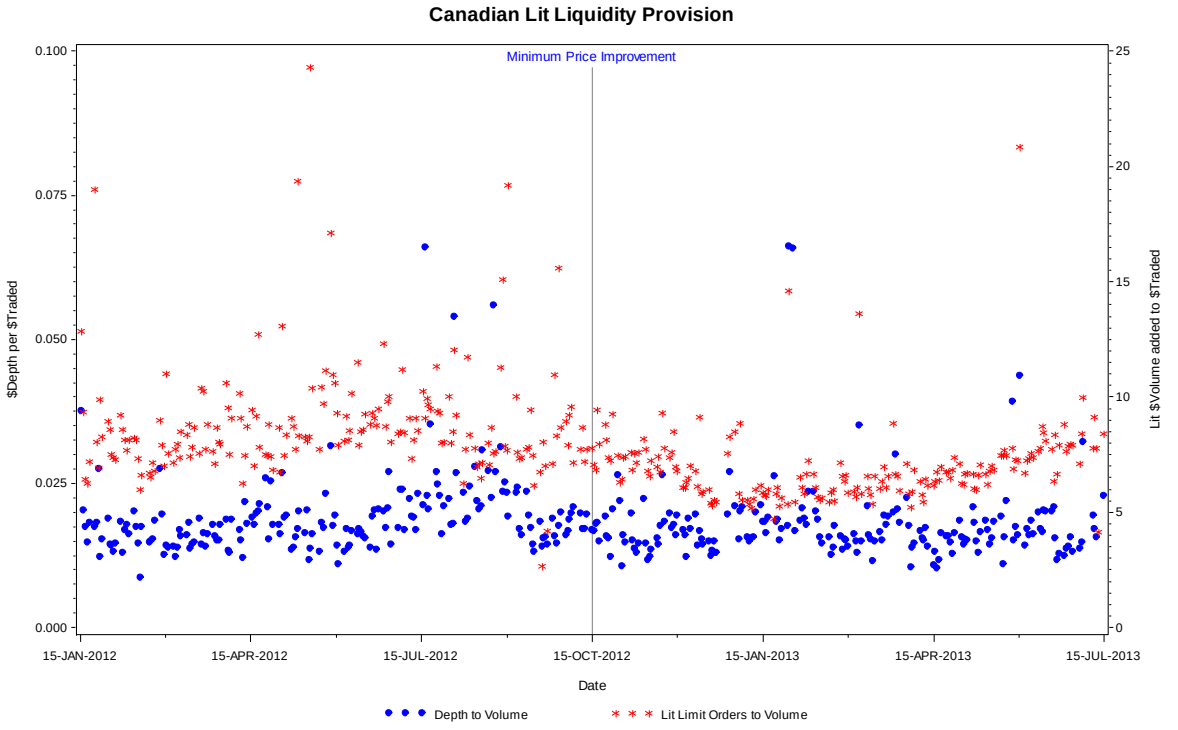


Figure 6
Lit liquidity provision

This figure shows the patterns of liquidity provision in Canada and Australia for constituents of the TSX Composite Index, from 15 January 2012 to 15 July 2013, and for constituents of the ASX200 Index, from 26 August 2012 to 26 February 2014. $LitLimitOrdersToVolume_{it}$ reports the ratio of the dollar volume of lit limit order submissions to the dollar volume of lit trades (lit market orders). $DepthToVolume_{it}$ is the ratio of the time-weighted average dollar-volume of lit limit orders at the NBBO to the dollar volume of lit trades. Once constructed at the stock-day level, these measures are then equally weighted across each stock in our sample. The vertical bar indicates the introduction of minimum price improvement requirements on 15 October 2012 in Canada and 26 May 2013 in Australia.



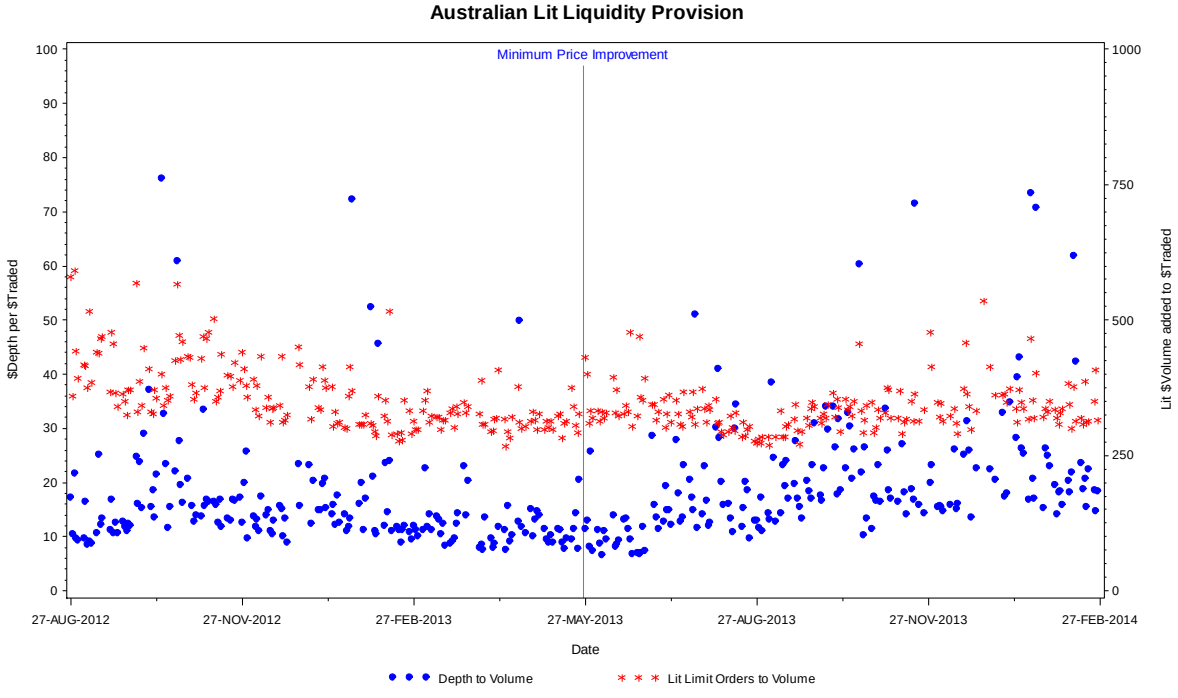
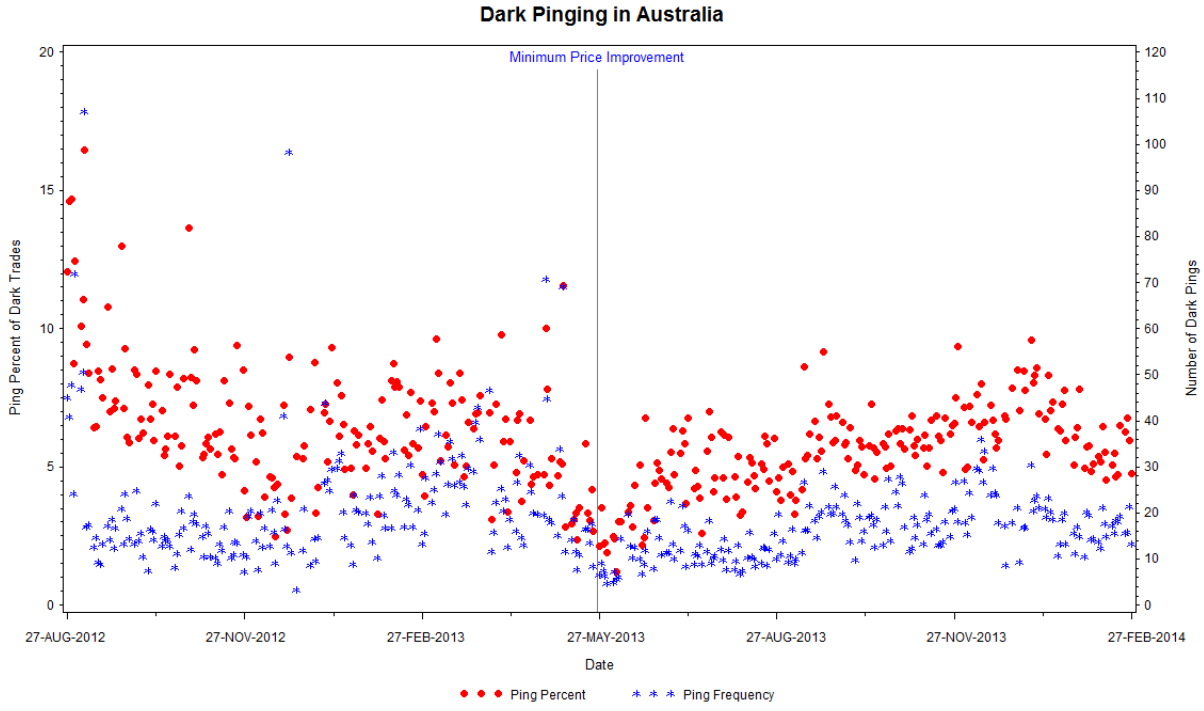


Figure 7
Australian dark trading conduct

This figure estimates the level of pinging for constituents of the ASX200 Index, from 26 August 2012 to 26 February 2014. A trade is considered to be a Ping if it is for 3 shares or less. $PingPercent_{it}$ reports the number of dark ping trades as a percent of the total number of trades executed in the dark. Once constructed at the stock-day level, this measure is then equally weighted across each stock in our sample. $PingFrequency_{it}$ measures the average number of pings per stock-day in Australia. $CentrePointMessagesToTrades$ is the ratio of the number of ASX Centre Point order messages (order additions, cancellations and amendments) to the number of Centre Point trades. $CentrePointMessagesToVolume$ is the ratio of the number of ASX Centre Point order messages (order additions, cancellations and amendments) to the dollar volume of Centre Point trades. The vertical bar indicates the introduction of the minimum price improvement requirements on 26 May 2013 in Australia.



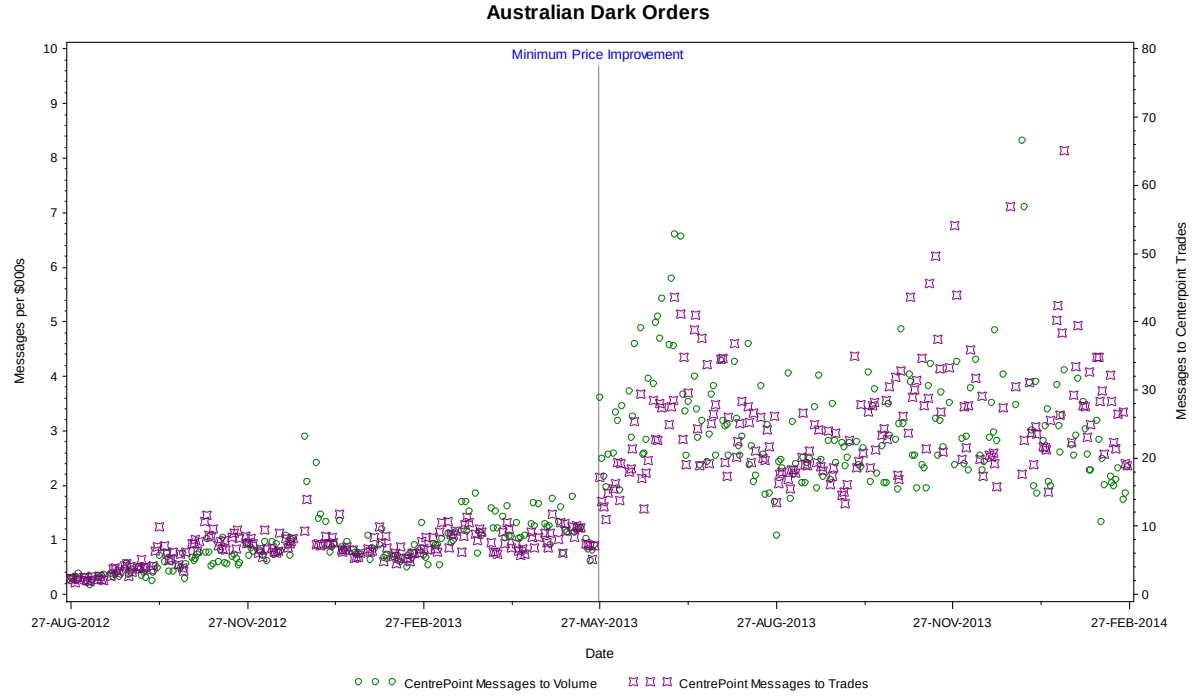


Figure 8
On-market internalization

This figure shows the level of a proxy for the amount of on-market broker internalization in Canada and Australia for constituents of the TSX Composite Index, from 15 January 2012 to 15 July 2013, and for constituents of the ASX200 Index, from 26 August 2012 to 26 February 2014. $LitInternalizationProxy_{it}$ reports the value of trades for which the buying and selling broker are identical. In Canada, this metric provides an upper bound on the amount of on-market internalization, since it is possible that a broker had time priority at the time of execution (ie every same-broker trade is not necessarily evidence of a breach of price-time priority). In Australia, this metric is constructed using only ASX data due to data constraints. Once constructed at the stock-day level, these measures are then equally weighted across each stock in our sample. The vertical bar indicates the introduction of minimum price improvement requirements on 15 October 2012 in Canada and 26 May 2013 in Australia.

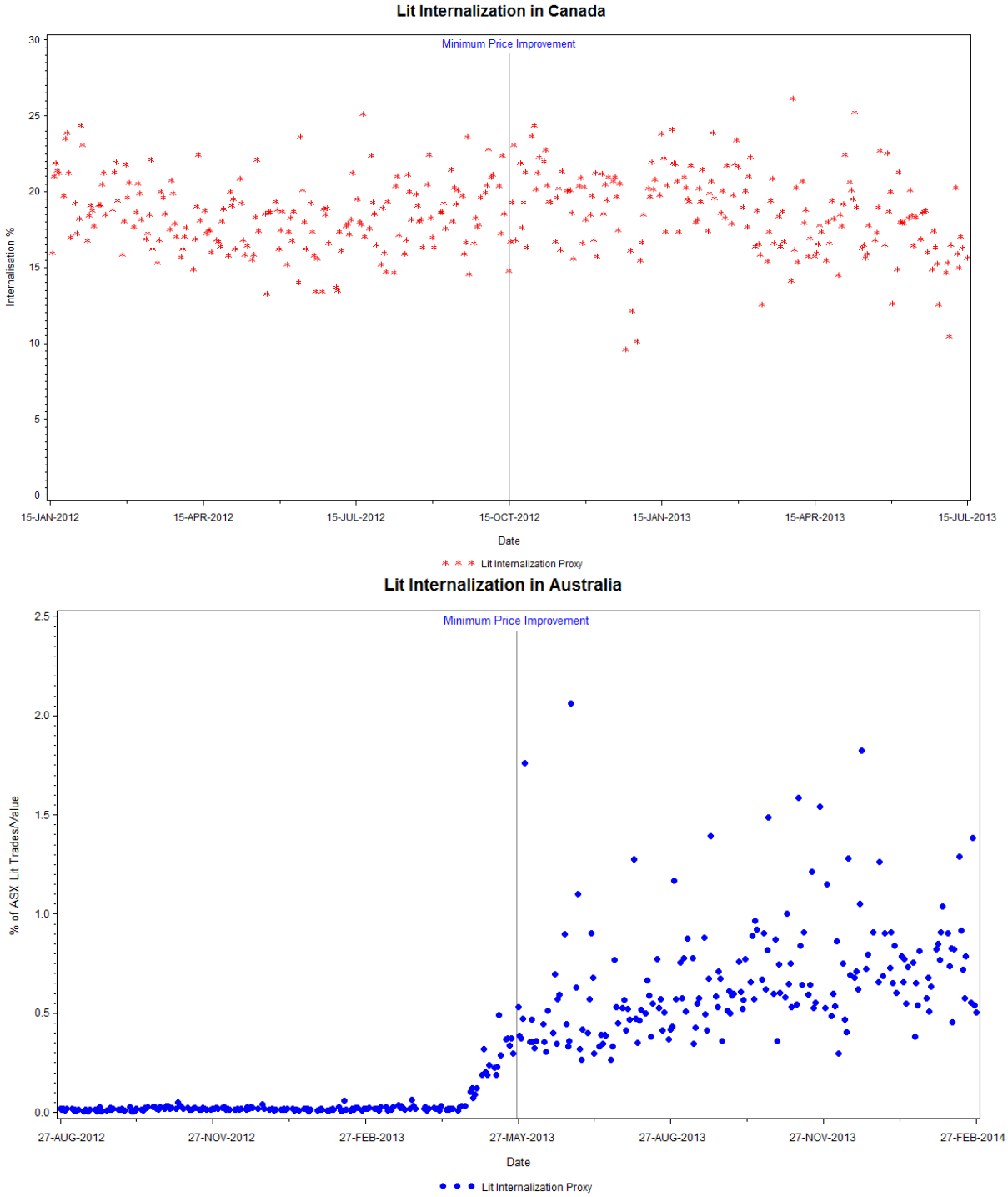
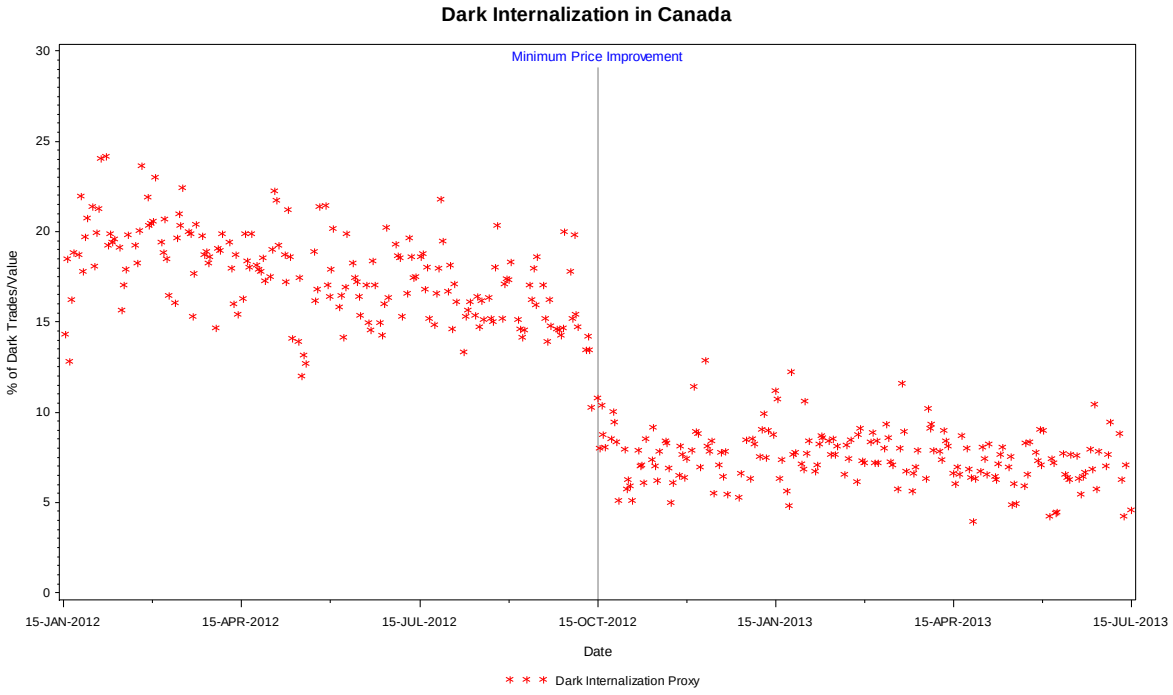


Figure 9
Dark internalization

This figure shows the level of a proxy for the amount internalization of dark trades in Canada and Australia for constituents of the TSX Composite Index, from 15 January 2012 to 15 July 2013, and for constituents of the ASX200 Index, from 26 August 2012 to 26 February 2014. $DarkInternalizationProxy_{it}$ is calculated as the ratio of the dollar volume of dark trades that have the same broker on both sides to the total dollar volume of dark trades. Once constructed at the stock-day level, these measures are then equally weighted across each stock in our sample. The vertical bar indicates the introduction of minimum price improvement requirements on 15 October 2012 in Canada and 26 May 2013 in Australia.



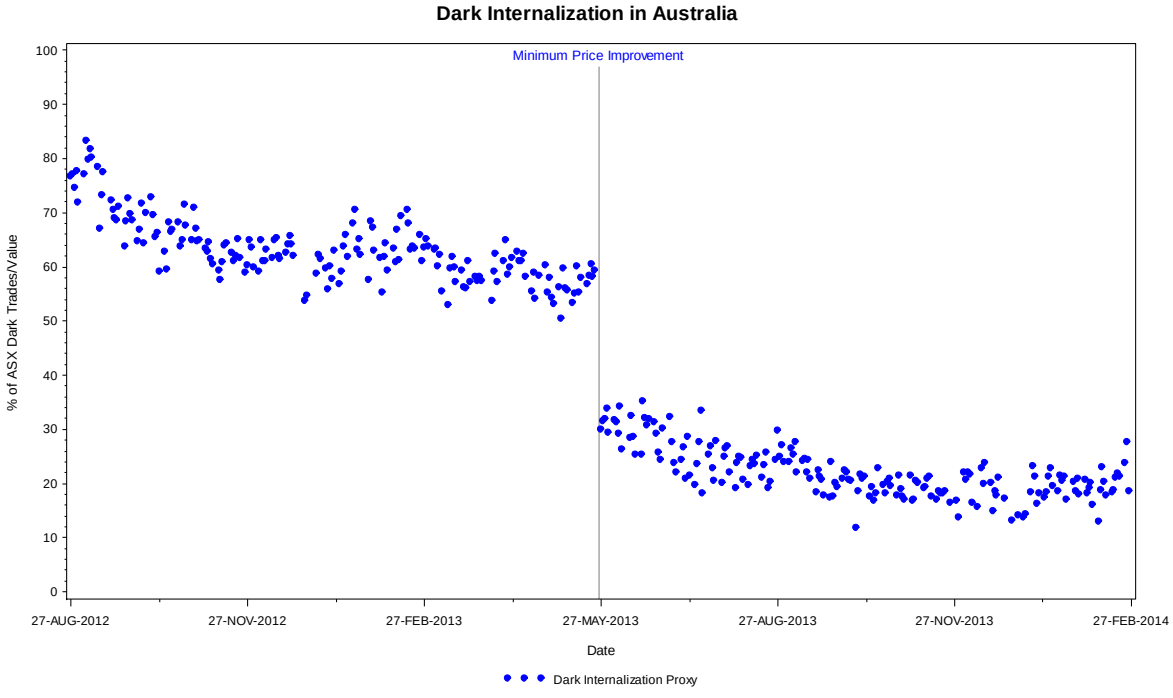


Figure 10
Transaction cost measures

This figure shows daily transaction cost measures in Canada and Australia for constituents of the TSX Composite Index, from 15 January 2012 to 15 July 2013, and for constituents of the ASX200 Index, from 26 August 2012 to 26 February 2014. $QuotedSpread_{it}$ are time-weighted based on the lit national best bid and offer (NBBO). $RealizedSpread_{it}$ and $EffectiveSpread_{it}$ are volume-weighted averages for the trades in each stock-day. $RealizedSpread_{it}$ is calculated using the NBBO midquote five minutes after the trade. Quoted, effective and realized spreads are measured relative to the midquote, in basis points. $PriceImpact_{it}$ is volume-weighted for the trades in each stock-day is calculated using the NBBO midquote five minutes after the trade and is measured relative to the midquote, in basis points. These measures are then equally weighted across each stock in our sample. The vertical bar indicates the introduction of minimum price improvement requirements on 15 October 2012 in Canada and 26 May 2013 in Australia.

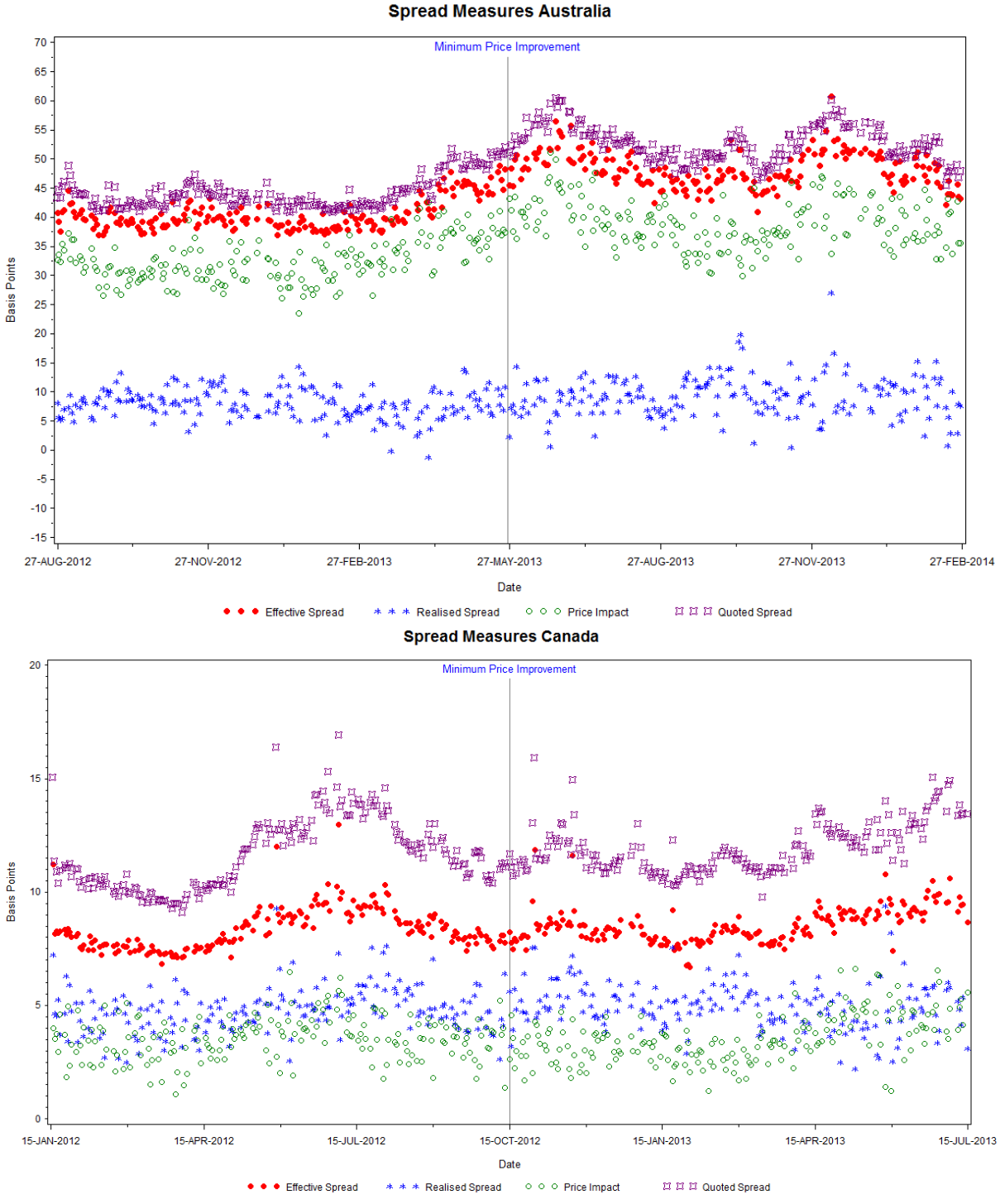


Figure 11
Quoted Depth measures

This figure shows daily measures of quoted depth in Canada and Australia for constituents of the TSX Composite Index, from 15 January 2012 to 15 July 2013, and for constituents of the ASX200 Index, from 26 August 2012 to 26 February 2014. $LitDepth$ is constructed as the time-weighted dollar value of orders available at the NBBO aggregated across all lit venues. Once constructed at the stock-day level, this measure is then equally weighted across each stock in our sample. The vertical bar indicates the introduction of minimum price improvement requirements on 15 October 2012 in Canada and 26 May 2013 in Australia.