

Equity Market Structure Literature Review

Part I: Market Fragmentation

by

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U.S. Securities and Exchange Commission

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¹ This review was prepared by the Staff of the U.S. Securities and Exchange Commission. The Commission has expressed no view regarding the analysis, findings, or conclusions contained herein.

The following is the first part of a planned series to review recent economic literature on equity market structure. This SEC staff review summarizes those economic papers that analyze recent financial market data (2007 and later) and reach findings that in the staff's view are most relevant to important market structure issues facing the SEC.²

Part I discusses papers that address the issue of market fragmentation – both visible and dark. The staff anticipates posting additional parts in the future that address such topics as high frequency trading and market structure performance in general, including volatility and investor transaction costs. In addition, the staff may post supplements to existing reviews as significant new papers are introduced.

The staff's hope is that the literature review will help promote a dynamic exchange on market structure with and among the public, including investors, academics, securities industry participants, and others.

² This literature review does not include purely theoretical papers and also does not focus on the theoretical explanations of results often set forth in data papers. These theoretical papers and explanations are of great interest, and some are seminal papers that set up the economic foundation of many of the empirical papers. The primary objective of this literature review, however, is to set forth empirical results as a step in the staff's continued consideration of equity market structure issues.

Part One: Market Fragmentation

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I. SEC Market Structure Review

In 2010, the SEC published a Concept Release on Equity Market Structure.³ The Concept Release noted that the SEC was conducting “a comprehensive review of equity market structure” to help it more fully understand and assess the effects of sweeping changes in equity markets, particularly since Regulation NMS was implemented in 2007.⁴ The SEC emphasized that it was assessing whether market structure rules had kept pace with changes in trading technologies and practices.

The Concept Release requested comment on three broad categories of issues: (1) the quality of performance of the current U.S. equity market structure, including investor transaction costs, price discovery, and capital formation; (2) high frequency trading; and (3) undisplayed liquidity. The Concept Release noted that the topics discussed in the release should not be construed in any way as limiting the scope of comments that would be considered. It encouraged commenters to submit views on any aspects of the equity market structure that they believed were important.⁵

Commenters submitted thoughtful letters expressing their views about the current market structure, though they often offered contrasting conclusions on a variety of issues. To probe further into these issues, the SEC staff also has undertaken their own analyses that are designed to generate a sound empirical basis for conclusions on whether problems exist that require regulatory action and, if so, on potential initiatives to address the problems. These inquiries include directly analyzing relevant U.S. market data, both public and non-public, and also monitoring data analyses prepared by others.

II. SEC Staff Review of Economic Literature on Equity Market Structure

Since the Concept Release was published in 2010, academic economists and others have prepared over 100 papers that analyze market data and reach findings that bear on issues raised in the Concept Release and by commenters. The economic literature is a valuable resource for evaluating market structure, and the SEC staff closely monitors the literature to inform its thinking. As noted in footnote 2 above, this staff literature review does not attempt to cover all relevant papers, but rather focuses on papers that analyze recent financial market data (2007 and later) and reach empirical findings. It does not discuss papers that examine data from time periods prior to the implementation of Regulation NMS in 2007 or purely theoretical papers that do not include data-driven tests of the theoretical model.

Given that the high-level conclusions in paper abstracts can vary widely, even among those that attempt to answer similar questions (for example, “dark pool trading improves [detracts from] a particular dimension of market quality”), the literature review focuses

³ Securities Exchange Act Release No. 34-61358, 75 FR 3594 (Jan. 21, 2010) (“Concept Release”).

⁴ 75 FR at 3596.

⁵ 75 FR at 3602.

on aspects of the papers that may help reconcile conclusions that might otherwise appear inconsistent. These aspects include:

- (1) the nature of a paper's data set, such as the particular financial products, time periods, frequency of observations, and any information content that is not generally available in public data sources;
- (2) the metrics chosen to measure market quality, such as quoted, effective, and realized spreads, quoted depth, short-term volatility, variance ratios of volatility of various durations, and autocorrelation in returns; and
- (3) econometric techniques used to identify causation, such as exploiting natural experiments.

The third aspect relating to causation is particularly important to evaluate, given that the equity markets are complex ecosystems in which many different factors can affect outcomes. These factors include changes in trading technology (for both investors and short-term traders), regulatory changes, fluctuations in the economy, the rise of new financial products (such as ETPs), new types of traders and strategies, and new types of trading venues and services. Often, these factors are dynamically linked and interlinked, which makes assessing causation an even more difficult task.

As discussed further below, for example, a particularly difficult issue arises when evaluating how activity on dark trading venues affects various market quality metrics, such as quoted spreads. On the one hand, the width of spreads in a stock may influence an order router's choice of venue. On the other hand, the order router's choice of venue may affect the width of spreads. The authors of the papers reviewed here employ a variety of econometric techniques to address this type of endogeneity.⁶

Another area of focus in the literature review relates to extraordinary price volatility. Many papers measure market quality over time periods that predominantly reflect normal trading conditions. But an essential aspect of a high-quality market structure is its ability to withstand relatively brief periods of serious stress – typically related to significant order imbalances that cause rapid and severe price changes. No market structure, of course, can eliminate extraordinary price moves entirely, but a robust market structure should handle shocks in a manner as fair and orderly as possible. Indeed, the performance of a market structure in these relatively infrequent periods may play an even greater role in affecting investor confidence than its performance in normal trading conditions, since investors may especially value the ability to trade during periods of market stress. On the other hand, a market structure that places too much focus on safeguards of stability may impose unwarranted costs. The literature review highlights papers that focus on these important market stability issues.

⁶ For a formal introduction to endogenous variables see Woodridge, Jeffrey M. "Econometric Analysis of Panel Data", MIT Press, 2002, pp. 50-51.

Finally, the literature review discusses findings that relate to market quality for smaller company stocks. The Concept Release emphasized that a vital function of the equity markets is to support the capital raising function and that a market structure might perform quite differently for stocks of companies with varying levels of capitalization.⁷ It specifically requested comment on whether the current market structure supported the capital raising function for smaller companies. The literature review follows up on this concern by highlighting papers that analyze data specifically with respect to smaller companies, particularly when the findings differ from those for larger company stocks.

III. Market Fragmentation – Overview of Regulatory Concerns

In the Concept Release, the SEC noted that one of the primary Exchange Act objectives for the national market system is to promote competition among trading venues, yet promoting competition can sometimes be difficult to reconcile with other Exchange Act objectives for the national market system.⁸ Competition can benefit investors through, among other things, lower fees and innovative trading services. When many trading venues compete for order flow in a stock, however, the competition can lead to fragmentation of trading among those venues. Such fragmentation potentially can detract from other important Exchange Act objectives, including the efficient execution of transactions, best execution of investor orders, price transparency, and an opportunity for investor orders to interact with each other.⁹

The Concept Release emphasized that the SEC’s “task has been to facilitate an appropriately balanced market structure that promotes competition among markets, while minimizing the potentially adverse effects of fragmentation. . . . Given the complexity of this task, there clearly is room for reasonable disagreement as to whether the market structure at any particular time is, in fact, achieving an appropriate balance of these multiple objectives. Accordingly, the Commission believes that it is important to monitor these issues and, periodically, give the public, including the full range of investors and other market participants, an opportunity to submit their views on the matter.”¹⁰

In this regard, the Concept Release noted that increased competition for order flow in NYSE-listed stocks led to major changes in the level of fragmentation.¹¹ Prior to the implementation of Regulation NMS in 2007, the market for NYSE-listed stocks was highly centralized, with the NYSE executing 79% of volume in its listings.¹² The remaining 21% was executed primarily off-exchange by broker-dealer internalizers. Trading in NYSE-listed stocks also was subject to intermarket rules protecting displayed quotations against trade-throughs and locking/crossing quotations, but these rules

⁷ 75 FR at 3604.

⁸ 75 FR at 3597.

⁹ See Section 11A(a)(1)(C) (setting forth objectives for the national market system); Concept Release, 75 FR at 3597.

¹⁰ 75 FR at 3597.

¹¹ 75 FR at 3594-3596.

¹² 75 FR at 3595.

protected both automated quotations of electronic venues and the much slower manual quotations of exchanges with trading floors.

The market structure for Nasdaq-listed stocks was quite different. The Concept Release noted, for example, that trading in Nasdaq-listed stocks had long been divided among many different automated trading venues, including electronic communications networks (“ECNs”) and off-exchange market makers.¹³ By the end of 2005, Nasdaq had acquired (and was still operating) two ECNs, in addition to its own electronic trading system. Together, these three venues accounted for approximately 52% of volume in Nasdaq-listed stocks, while another 29% was reported to Nasdaq as “internalization and other,” and the remaining 19% was executed by several other exchanges.¹⁴ Moreover, trading in Nasdaq-listed stocks was not subject to any intermarket trade-through or locking/crossing rules.

Regulation NMS, among other things, adopted new intermarket trade-through and locking/crossing rules. These rules apply uniformly to all U.S.-listed stocks and protect only automated quotations. In regard to NYSE-listed stocks, the SEC stated that one of its objectives was to promote fair competition by eliminating any competitive advantage the prior rules gave slower manual markets.¹⁵ In regard to Nasdaq-listed stocks, it noted that, for many active stocks, approximately 1 of every 11 shares traded was a significant trade-through and that the introduction of intermarket trading rules by Regulation NMS was designed to promote fair and orderly trading.¹⁶

Given these significant differences in the two market structures, the implementation of Regulation NMS affected them quite differently. The NYSE’s market share in its listings declined from 79% in 2005 to 25% in 2009, while the total volume in NYSE-listed stocks during this period increased by 181% with the introduction of more automated trading on the NYSE and elsewhere.¹⁷ In contrast, the market structure for Nasdaq listed stocks continued to be highly automated and competitive. Nasdaq’s combined market share in its listings declined from 52% in 2005 to 33% in 2009, while total trading volume in Nasdaq-listed stocks increased by only 30%.¹⁸ Across all U.S.-listed stocks in September 2009, lit venues (those that display quotations in the consolidated quote streams) collectively executed approximately 75% of volume across all U.S.-listed stocks, and dark venues collectively executed the remaining 25%.¹⁹

¹³ 75 FR at 3594 & n. 5.

¹⁴ See historical market share statistics available from NASDAQ OMX, <http://www.nasdaqomxtrader.com/trader.aspx?id=marketshare>.

¹⁵ Securities Exchange Act Release No. 34-51808, 70 FR 37496, 37501 (June 29, 2005) (“Regulation NMS Adopting Release”).

¹⁶ Regulation NMS Adopting Release, 70 FR at 37502.

¹⁷ Concept Release, 75 FR at 3595-3596. In May 2013, the NYSE’s share of trading volume in its listings was 20.8%.

¹⁸ See historical market share statistics available from NASDAQ OMX, <http://www.nasdaqomxtrader.com/trader.aspx?id=marketshare>. In May 2013, Nasdaq’s share of trading volume in its listings was 23.9%.

¹⁹ 75 FR at 3598. In May 2013, dark venues collectively executed approximately 35% of trading volume in U.S.-listed equities. BATS Global Markets,

This post-Regulation NMS market structure was the context for the Concept Release’s concerns about fragmentation and whether the market structure had achieved an appropriate balance between competition and other Exchange Act objectives. It particularly requested comment on dark trading venues, including their effects on execution quality for individual and institutional investors and on public price discovery.²⁰ For example, it noted that an increasing percentage of the orders of long-term investors appeared to be executed in dark venues, leaving the lit venues dominated primarily by proprietary traders employing short-term strategies. As a result, the overall percentage of volume executed in dark venues might mask potentially important changes in the nature of the flow at lit and dark venues. The Concept Release asked about the effect of this trend on market quality.²¹

Commenters responding to the Concept Release were divided in their views on dark venue trading. In general, many believed that dark venues have contributed to market innovations, competition, and reduced execution costs, but others were concerned about the effect of dark venue trading on transparency and the quality of price discovery. As discussed below, researchers have sought to address these questions empirically, as well as others that relate to both visible and dark fragmentation.

IV. Executive Summary of Fragmentation Papers

An informative group of papers study the effects of fragmentation in the U.S. and other countries. As noted above, competition among trading venues and fragmentation are closely related concepts. We use the term “fragmentation” in a neutral sense as dispersal of volume among different venues, as it is typically used in the papers, without any negative connotation.

We have reviewed research about other countries because their markets appear to have experienced trading, technological, and regulatory changes that are, in many ways, analogous to the U.S. markets. In this respect, empirical studies of other markets can help provide a broader perspective on the performance of the U.S. markets. Given, however, that papers examine different time periods and market structures, caution is warranted in interpreting the results in these papers with respect to the current U.S. equity markets. Furthermore, while papers employ a variety of metrics of market quality, some important dimensions of market quality, such as the transaction costs of institutional investors when executing their typically large orders, are more difficult to measure.

In general, the papers highlight the importance of distinguishing between visible fragmentation (dispersal of volume among lit trading venues) and dark fragmentation (dispersal of volume between lit and dark trading venues), as well as the magnitude of

http://batstrading.com/market_summary/fullversion (after excluding approximately 1% of off-exchange volume executed by ECNs).

²⁰ 75 FR at 3612-3614.

²¹ 75 FR at 3613.

each type of fragmentation. It is important to note that the papers we discuss below generally do not address the dispersal of volume across dark venues. In the U.S. market, for example, information identifying the particular venue that executed off-exchange trades is not publicly available. Also, with one exception, the papers do not address the effects of dark orders on lit venues.

A. Visible Fragmentation

A series of papers examine the entry of new lit venues as competitors to previously dominant exchanges following the implementation of the Markets in Financial Instruments Directive (“MiFID”) in Europe in 2007. Gresse (2012), Spankowsky, Wagener, and Burghof (2012), Degryse, de Jong, and van Kervel (2011), Fioravanti and Gentile (2011), Riordan, Storkenmaier, and Wagener (2012), and Chlistalla and Lutat (2010) find that the enhanced competition led to an increased level of visible fragmentation as the new entrants captured significant order flow. The papers generally find that the visible fragmentation resulted in market quality improvements in the form of reduced transaction costs, though Fioravanti and Gentile (2011) find that increased visible fragmentation reduces price efficiency.

Two caveats are worth noting for the findings of these papers regarding visible fragmentation. First, there may be a point at which too much visible fragmentation leads to deteriorating market quality, and this turning point may vary depending on the market capitalization of a stock. In this regard, all of the papers examining MiFID dealt with relatively low levels of visible fragmentation following the introduction of competition in a market that previously was dominated by a single exchange.

Degryse, de Jong, and van Kervel (2011) find that visible fragmentation may cease to be beneficial when it exceeds a certain level. The authors measure fragmentation using the Herfindahl-Hirschman Index, and they calculate visible fragmentation as one minus the sum of the squared market shares of lit venues. They find that the benefits of visible fragmentation in the form of narrower spreads and increased depth²² are consistently higher for large company stocks than small company stocks. For small company stocks, they find that displayed depth is negatively affected when their measure of fragmentation exceeds 0.36.²³

²² A cautionary note is warranted with respect to the effect of increased visible fragmentation on displayed depth. van Kervel (2012) assesses the extent to which liquidity providers for FTSE 100 stocks after MiFID may place duplicate limit orders across multiple trading venues to increase their execution probabilities, but, in the event of one order being executed, quickly cancelling the others. He finds that trades on the most active venues are quickly followed by cancellations of limit orders on competing venues and concludes that consolidated displayed liquidity may be overstated in a fragmented market.

²³ Using the paper’s measure of visible fragmentation, a single exchange market would have a fragmentation level of 0 and the maximum level of fragmentation would be just less than 1. In April 2013, the U.S. equity markets had a visible fragmentation level of approximately 0.94 across all U.S.-listed stocks.

Similarly, Gresse (2012) finds that the marginal benefits of visible fragmentation become relatively low when an equilibrium level of fragmentation is reached, and that increased visible fragmentation may harm the market depth of smaller company stocks.

The second caveat regarding visible fragmentation relates to its effect during periods of high volatility. All of the papers examining MiFID measure market quality across extended time periods and do not focus on isolated periods of high volatility. Madhavan (2012), in contrast, addresses the effect of “quote fragmentation” in U.S. equities during the Flash Crash of May 6, 2010. He measures quote fragmentation as the extent to which multiple trading venues quote at the best prices. He finds that higher levels of quote fragmentation are associated with larger price moves in equity products during the afternoon of the Flash Crash.

Finally, Jiang, McNish, and Upson (2012) and O’Hara and Ye (2011) address off-exchange fragmentation in U.S. equities during a time period when off-exchange volume includes a substantial amount of volume from both lit venues and dark venues. Both papers find that increased levels of off-exchange fragmentation are associated with improved market quality. Their results are difficult to interpret, however, because their measure of fragmentation encompassed a large amount of both lit and dark venue volume. Each paper measures fragmentation as the extent of off-exchange trading in U.S. equities during the first six months of 2008, when two lit venues appear to have executed approximately 50% of off-exchange volume.²⁴ The papers consequently do not allow finer distinctions regarding the respective effects of visible and dark fragmentation on market quality.

B. Dark Fragmentation

The majority of papers – ASIC (2013); Hatheway, Kwan, and Zheng (2013); CFA Institute (2012); Comerton-Forde and Putnins (2012); Degryse, de Jong, and van Kervel (2011); Weaver (2011) – that focus specifically on dark fragmentation conclude that it can detract from market quality, both in the form of higher transaction costs and less efficient price discovery. The papers vary, however, with respect to the level of dark trading that may lead to harmful results. They also vary in how authors address endogeneity and other causation issues, which, as discussed in Section II above, are particularly relevant when assessing the effect of dark trading venues on market quality.

²⁴ Off-exchange trading during this time period included a large volume of trading by two lit venues – BATS and Direct Edge – while they were still operating as ECNs and before they registered as national securities exchanges (at which point their volume was reported as exchange volume). According to their websites, BATS and Direct Edge collectively appear to have executed approximately 14% of total volume during this time period. See BATS Global Markets, http://www.batstrading.com/bzx/market_data/daily_volume/2008Q1/; Direct Edge, <https://www.directedge.com/About.aspx>.

For example, Comerton-Forde and Putnins (2012) examine the 500 largest Australian stocks. Using an instrumental variables approach to address endogeneity concerns,²⁵ they conclude that informational efficiency deteriorates when dark trading of less than block size exceeds 10% of total volume. They find no evidence that block-sized dark trading harms aggregate price discovery. ASIC (2013), in turn, examines the 300 most active Australian stocks and reaches a similar conclusion regarding the 10% threshold for when non-block dark trading leads to harmful effects on quoted spreads and quoted depth.

Degryse, de Jong, and van Kervel (2011) examine Dutch mid- and large-cap stocks during a time period when dark trading in those stocks represented approximately 37% of total volume. After controlling for the level of visible fragmentation and other factors, they find that an increase in dark trading of one standard deviation in a stock reduces liquidity by 9%.

Several papers focus on dark venue trading in U.S. stocks. Weaver (2011) examines trading in more than 4,000 U.S. stocks and finds that increased dark trading is associated in a linear fashion with wider spreads and higher volatility.

The CFA Institute (2012) examines dark venue trading in 450 U.S. stocks stratified across market capitalization. They also separately analyze the effect of broker-dealer internalization and dark pools. They find that some levels of dark venue trading are beneficial for quoted spreads, but estimate levels of activity at which internalization and dark pool trading become harmful. Estimates of these critical levels vary by market capitalization, ranging from 12.6% and 19.3%, respectively, for internalization and dark pool trading in large cap stocks, to 44.4% and 63.9%, respectively, for internalization and dark pool trading in small cap stocks. When analyzing the aggregate volume of dark venue trading, they estimate that 46.7% is the turning point beyond which dark trading becomes harmful.

Hatheway, Kwan, and Zheng (2013) examine a sample of 116 U.S. stocks also stratified across market capitalization. They find that non-block dark trading volume is associated with higher market-wide transaction costs, but only when controlling for the level of informed trading on a particular day. Specifically, when they apply one of the models used in O'Hara and Ye (2011) to their data sample (which does not include significant amounts of lit trading volume, as did the O'Hara and Ye (2011) sample discussed above), they find that dark trading volume is associated with narrower effective spreads. But, when controlling for the level of informed trading on a particular day, they find that non-block dark trading volume is associated with wider effective spreads and lower price

²⁵ Their instrumental variables approach is designed to address endogeneity between informational efficiency and the level of dark trading by using an instrumental variable in regression analysis that is correlated with the level of dark trading, but uncorrelated with the error term in the regression. Many papers use an instrumental variables approach, although they vary in the particular instrumental variable that is used. These instrumental variables are noted in the summaries of the individual papers in Section V below.

efficiency. Similar to Comerton-Forde and Putnins (2012), they find that trading large-sized orders on dark venues is not harmful to market quality.

Two other papers focus on dark fragmentation, but reach more ambiguous results than the majority. Gresse (2012) examines off-exchange dark trading in U.K. and French stocks and concludes that dark off-exchange volume could be harmful for quoted spreads, but could positively impact displayed depth at the inside prices. Buti, Rindi, and Werner (2011) examine a subset of off-exchange dark trading in U.S. stocks using a data sample provided by operators of certain dark pools. The dark pool trading sample accounted for approximately 4.5% of total volume in listed U.S. stocks. They find that increased dark pool activity in their sample improves market quality measures such as spreads, depth, and short-term volatility, but that it is associated with less efficient pricing (in the form of short-term overreactions) for Nasdaq-listed stocks and small and medium stocks.

V. Key Empirical Aspects of Individual Papers

This section summarizes the key empirical aspects of individual papers that address fragmentation in lit markets and across lit and dark trading venues. As noted above in Section II, the summaries highlight those papers that analyze data to address issues raised in the Concept Release, particularly the effect of fragmentation on market quality measures such as transaction costs and price discovery. The summaries also include papers that address other aspects of dark venue trading, such as their particular uses and effects. The summaries are ordered first by the market under examination and then alphabetically by author.

A. U.S. Markets

1. Boni, Leslie, David C. Brown and J. Chris Leach, 2013, Dark pool exclusivity matters, working paper.

Boni, Brown, and Leach (2013) examine whether the exclusiveness of a dark pool affects its execution quality. To this end, the authors contrast execution data from Liquidnet Classic – a dark pool designed to match buy-side institutional investors with other buy-side investors – with execution data originating in less-exclusive venues. The analysis encompasses 1,694 U.S. stocks during the first quarter of 2011 and focuses on large executions of at least 50,000 shares.

The authors find that a dark pool specifically designed to foster buy-side exclusivity exhibits statistical regularities consistent with a smaller execution footprint and higher overall execution quality for large trades. Specifically, large trades at the more exclusive dark pool exhibited patterns consistent with lower serial correlation in returns, less pre-trade volume and volatility increase, earlier executions within the trading day, and more large trade clustering across days.

2. Buti, Sabrina, Barbara Rindi and Ingrid M. Werner, 2011, Diving into dark pools, working paper.

Buti, Rindi, and Werner (2011) study dark pool trading activity for a large cross-section of U.S. stocks based on a unique self-reported sample of dark pool share volume during 2009. Their data sample was voluntarily provided by the operators of 11 out of roughly 32 dark pools active in the U.S. equity markets during the sample period. The data encompassed 4,482 stocks and 4.5% of consolidated share volume in U.S. listed stocks.

The authors note that market quality measures and dark pool activity are jointly determined. To address endogeneity, they instrument for dark pool activity in a particular stock using dark pool trading in other stocks with the same exchange listing, market capitalization, and sector. They use the same logic to create instrumental variables for each of their market quality measures: time-weighted percent and cent quoted spread, share-weighted percent and cent effective spread, time-weighted bid-depth, share volume, standard deviation of mid-quote returns, and intraday range divided by the intraday high.

The authors find that more dark pool activity is associated with better market quality in the form of narrower spreads and more depth. They also find that more dark pool volume is generally associated with lower share volume in larger capitalization stocks, but is associated with higher share volume in small cap stocks.

The authors observe a more complex relationship between more dark pool activity and price efficiency. More dark pool activity is associated with lower short-term volatility, suggesting an improvement in price efficiency. By contrast, the absolute autocorrelation of returns and the absolute variance ratio suggest that more dark pool activity is associated with less efficient prices for Nasdaq-listed stocks and for small and medium sized stocks. Closer examination shows that this result derives from an increase in short-term overreaction of prices.

3. CFA Institute, 2012, Dark pools, internalization, and equity market quality.

CFA Institute (2012) examines the relationship between dark trading and market quality. They use a sample of 450 stocks stratified across listing market and market capitalization. For each stock, data were obtained for a selection of dates over the period from the first quarter of 2009 through the second quarter of 2011. Off-exchange trades reported to the NASDAQ trade reporting facility (“TRF”), which reports approximately 95% of all off-exchange trading in the sample, were further subcategorized by NASDAQ according to the type of trading venue – internalization or dark pools. Trades from Direct Edge, prior to its registration as an exchange, are removed from the off-exchange sample. Matched order flow on the remaining ECNs is estimated to account for less than 1% of consolidated volume.

The authors use regression analysis to examine the relationship between dark trading and market quality. Their independent variables are internalization and dark pool volume percentages and their control variables are daily volatility, market capitalization, and

price. Their dependent variables are bid-offer spreads and depth at the best prices. The results suggest that increases in dark trading are initially associated with improvements in market quality. Bid-offer spreads narrow and best price depth increases as internalization and dark pool trading increase.

The authors also observe a threshold effect – market quality initially improves as dark trading increases but declines beyond a certain threshold. They estimate “turning points” at which the level of internalization and dark pool trading become harmful. These estimated turning points vary depending on the capitalization of a stock. The authors find that the turning point from increasing market quality to decreasing market quality with respect to internalization is as follows: large-cap stocks – 12.6%, medium-cap stocks – 18.9%, and small-cap stocks – 44.4%; and the turning point from increasing market quality to decreasing market quality with respect to dark pool trading is as follows: large-cap stocks – 19.39%, medium-cap stocks – 22.5%, and small-cap stocks – 63.9%. When analyzing the aggregate volume of dark venue trading (combined internalization and dark pool trading), the authors estimate that 46.7% is the turning point beyond which dark trading becomes harmful.

To address endogeneity concerns and validate the robustness of their results, the authors ran a second set of regressions using the generalized method of moments (“GMM”) approach incorporating the second lags of the dependent and independent variables as instruments. The GMM regressions exhibit the same relationships as their basic regressions, though with reduced statistical significance.

4. Chakravarty, Sugato, Pankaj Jain, James Upson, and Robert Wood, 2012, Clean sweep: informed trading through intermarket sweep orders, *Journal of Financial and Quantitative Analysis (JFQA)* 47, 415-435.

Chakravarty, Jain, Upson and Wood (2012) examine the use of intermarket sweep orders (“ISOs”) in the Regulation NMS market structure with multiple exchanges that display quotes protected against trade-throughs on other venues. An ISO is a limit order designated for automatic execution on a specific trading venue even when another exchange is publishing a better quotation, as long as the trader submits concurrent orders to the other exchange. Their sample consists of 508.7 million trades between Aug 2007 and May 2008 in 72 NYSE-listed stocks and 48 Nasdaq-listed stocks.

After controlling for reporting lag between trades and quotes, they find that 46% of the trades and 41% of the volume in the sample period were driven by ISO trades. ISO trades are significantly smaller than non-ISO trades on average, regardless of the market capitalization of the subsample. They further find that ISOs become more prevalent when markets become more volatile. They conclude that if liquidity is readily available in the market, a trader will most likely use a non-ISO for fear of becoming subject to inferior trade execution prices via ISO.

5. Hatheway, Frank, Amy Kwan and Hui Zheng, 2013, An empirical analysis of market segmentation on U.S. equities markets, working paper.

Hatheway, Kwan, and Zheng (2013) analyze the impact of dark trading venues on market quality. They use a sample of 116 U.S.-listed stocks, stratified by market capitalization, for the period from January 2011 through March 2011 (a period when both BATS and Direct Edge were operating as registered exchanges and their volume was no longer reported as off-exchange). The authors measure dark trading as the dollar volume (which reflects both trade price and share volume) of trades executed off-exchange. They also measure the extent of price improvement for these dark trades. They find that 50.5% of dark trades are executed with no price improvement and another 19.0% are executed with price improvement of less than ½ cent.

The authors assess the impact of dark trading on transaction costs as measured by effective spreads. They first use Heckman's two-step procedure to account for the self-selection bias produced by investors who choose whether to trade on lit or dark venues.²⁶ They use standard control variables of price, trade size, market capitalization, and trade values. In addition, they control for the level of informed trading on a particular day by measuring adverse selection costs – specifically, the average movement of the quoted prices in the 30 second and 5 minute periods following all transactions for each trading day. The authors assert that controlling for the level of informed trading is necessary because, in the presence of a high level of informed trading: (1) the ratio of dark trading to lit trading will decrease, and (2) higher adverse selection risk on a particular day will increase effective spreads because liquidity providers will demand more to cover for the increased risk of trading.

The authors find that non-block dark trading volume is associated with higher transaction costs. Specifically, their results suggest that a 10% rise in absolute market share by dark venues leads to a 4.5% increase in effective spreads. In contrast, the authors find that dark trading in large sizes (defined as the top 1% of trades by trade value in a stock) is associated with narrower effective spreads.

The authors obtain this result, however, only when controlling for the level of informed trading on a particular day. Specifically, when they apply one of the models used in O'Hara and Ye (2011) to their data sample (which does not include significant amounts of lit trading volume, as did the O'Hara and Ye (2011) sample discussed below), they find that dark trading volume is associated with narrower effective spreads.

To address the potential endogeneity of dark trading and effective spreads, the authors utilize an instrumental variable for dark trading – the ratio of the average transaction size on dark venues to the average trade size across all markets. They find that the results of their instrumental variable approach are consistent with their main results and that their

²⁶ Woolridge (2002) pp. 563-564 provides a brief introduction to the problem of selection bias and Heckman's two-step procedure to correct for selection bias.

conclusion that dark fragmentation worsens transaction costs is robust to adjustments for endogeneity.

The authors also examine the effect of dark trading on price efficiency, as measured by variance ratios of volatility over four frequencies – 60/600 seconds, 60/1800 seconds, 300/900 seconds, and 300/1800 seconds. Using a similar methodology as they used for effective spreads, they find that all of the variance ratios are negatively affected by the level of dark trading. They also find that that short-term volatility significantly exceeded the corresponding long-term volatility during their sample period, and conclude that the price inefficiency resulting from dark trading mainly comes in the form of excess short-term volatility. They do not find, however, that dark trading in large size detracts from price efficiency.

6. Jiang, Christine, Thomas McNish and James Upson, 2012, Market fragmentation and information quality: the role of TRF trades, working paper.

Jiang, McNish, and Upson (2012) analyze and compare the information quality of order flows on exchange and off-exchange trading venues. Their sample consists of trading in 200 NYSE-listed stocks, stratified by market capitalization, during the period from January through June 2008. Approximately 25% of their sample volume was executed off-exchange. As noted in Section IV.A above, approximately 50% of off-exchange trading in U.S.-listed stocks during the sample period of January through June 2008 was executed by two lit venues – BATS and Direct Edge – when they had not yet registered as exchanges and were operating as ECNs. Accordingly, the authors' sample does not allow finer distinctions regarding the respective effects of visible and dark fragmentation.

The authors find that use of off-exchange venues is higher with increased market speed and trading intensity, but decreases with higher intraday volatility. They also find that off-exchange trading is significantly less informed than on-exchange trading. They find that transaction costs in the form of effective spreads, realized spreads, and adverse selection were lower off-exchange. In contrast, they find that information quality (measured as the ratio of exchange information share to exchange volume) was better on-exchange. They conclude that segmentation of uninformed liquidity traders in off-exchange venues leaves a higher proportion of informed traders on exchanges, which results in improved information quality on the exchanges.

7. Madhavan, Ananth, 2012, Exchange-traded funds, market structure, and the Flash Crash, working paper.

Madhavan (2012) examines quote and volume fragmentation in U.S. equities and their relationship to the Flash Crash of May 6, 2010. His sample was 6,173 exchange-traded equity instruments. He focuses on the time period of 20 trading days prior to the Flash Crash and the day of the Flash Crash.

To measure the effect of the Flash Crash on a particular security, the author calculates the maximum drawdown on a stock, defined as one less the ratio of the low price to the high price of a stock as observed between 1:30 to 4:00 pm on the day of the Flash Crash. To measure trade fragmentation, he calculates the HHI using the volume shares of venues. To measure quote fragmentation, he calculates HHI using the frequency with which a venue displays the national best bid or offer. He calculates trade and quote fragmentation during the period from 1:30 to 4:00 on each of the 20 trading days prior to the Flash Crash and on the day of the Flash Crash

After controlling for dollar volume, 5-minute volatility, the inverse of the opening price on Flash Crash day, past intermarket sweep order (“ISO”) activity, and whether a security is an exchange-traded product (“ETP”), the author finds that the level of both trade fragmentation and quote fragmentation during the preceding 20 days is associated with larger drawdowns during the Flash Crash. When using fragmentation levels on the day before the Flash Crash, he finds that volume fragmentation is statistically insignificant, while quote fragmentation is significantly associated with drawdowns, leading him to assert that volume and quote fragmentation are different economic phenomena. He concludes that quote fragmentation is an important risk factor in explaining the propagation of a liquidity shock, consistent with the thinning out of order books in those stocks with the most aggressive quotation activity by higher frequency traders.

8. Nimalendran, Mahendrarajah and Sugata Ray, 2012, Informational linkages between dark and lit trading venues, working paper.

Nimalendran and Ray (2012) examine the informational linkages between a dark pool and lit exchanges. They use a proprietary data set containing transaction data for 100 U.S.-listed stocks stratified by market capitalization that was voluntarily provided by an off-exchange crossing network (“CN”). The time period was from June through December 2009. The average market share of the CN for the 100 stocks was about 0.52% of total volume.

The CN executed three principal types of trades: (1) trades involving the CN’s brokerage desk that were manually worked for large passive traders (13% of volume and 36% of transactions), (2) trades with average size of around 60,000 shares involving two large “natural” traders that were manually negotiated (59% of volume and 1% of transactions), and (3) trades between CN members or between a member and external liquidity supplied from another dark venue (28% of volume and 63% of transactions). The authors characterize the third category as algorithmic trades. Except for manually executed block trades, the counterparties to more than 90% of the trades were external market participants discovered through various means of communications across multiple dark venues.

The authors find that algorithmic trades for less liquid stocks lead to higher spreads and price impact on the lit exchanges, as well as correlated trading on the lit exchanges. In addition, signed trades for these stocks predict future returns over the next 15 to 120

minutes. In contrast, trades for liquid stocks, trades by the CN brokerage desk, and members trading large blocks in negotiated crosses transmit less information to the lit venues. They conclude that their results suggest that dark venues allow informed agents to trade strategically on both dark and lit venues and facilitate the price discovery process.

9. O'Hara, Maureen and Mao Ye, 2011, Is market fragmentation harming market quality?, *Journal of Financial Economics* 100, 459-474.

O'Hara and Ye (2011) examine the effects of off-exchange trading on market quality. Their sample is trading in 262 common stocks listed on the NYSE and Nasdaq during the time period from January through June 2008. Their measure of market fragmentation is the level of off-exchange volume reported in those stocks. During the sample period, the level of off-exchange trading in all U.S.-listed securities was approximately 27%. As noted above in Section IV.A, approximately 50% of off-exchange trading in U.S.-listed securities during the sample period was executed by two lit venues – BATS and Direct Edge – when they had not yet registered as exchanges and were operating as ECNs. Accordingly, the authors' sample does not allow finer distinctions regarding the respective effects of visible and dark fragmentation

The authors employ three different analyses to assess the effect of off-exchange trading: (1) Heckman's two-step procedure to investigate whether selection bias across markets affects the relation between off-exchange trading and market quality; (2) a matched pairs investigation to control for other firm-specific factors that could affect market quality; and (3) a regression analysis to control for a larger set of factors potentially affecting the relationship of off-exchange trading and market quality.

The first stage of Heckman's two step procedure enabled the authors to reject the hypothesis of a selection bias in the data and conclude that selection bias at the market level is not the important problem that it was for earlier fragmentation studies. After controlling for market cap, average daily trading volume, average order size, and the inverse of price, the second stage of the Heckman correction indicated that an increase in off-exchange trading is associated with lower effective spreads.

In the matched pairs analysis, the authors control for firm-specific factors by matching their 262 sample stocks with other stocks on market capitalization, price, and listing exchange. For each pair, the stock with the higher level of off-exchange volume was placed in the "fragmented" sample and the one with the lower level was placed in the "consolidated" sample. They use these samples to investigate transaction costs, as measured by effective spreads, realized spreads and execution speed. For all stocks, they find lower effective spreads and execution speed in the fragmented sample, with realized spreads not statistically different. When they segment the sample by firm size, they find that off-exchange trading generally helps small firms and does not harm larger firms.

The authors also use the matched pair samples to investigate price efficiency, as measured by short-term volatility over 15-minute intervals and by a variance ratio (15/30 minutes). They reach mixed findings that vary for stocks listed on the NYSE and Nasdaq. The fragmented sample for small Nasdaq-listed stocks had less volatility and more favorable variance ratios, while there were no statistical differences in the samples for large Nasdaq stocks. For NYSE-listed stocks, the fragmented sample had more volatility for both small and large stocks, though there was weak statistical evidence that variance ratios for small fragmented stocks were more favorable than for small consolidated stocks.

Finally, the authors employ regression analysis to assess the effect of off-exchange trading on effective spreads. After controlling for number of trades, trade size, price inverse, daily returns, and market capitalization, they find that higher levels of off-exchange trading lowers effective spreads.

10. Ready, Mark J., 2013, Determinants of volume in dark pools, working paper.

Ready (2013) investigates the determinants of trading volume in the two largest dark pools that seek to attract institutional block trades – Liquidnet and POSIT. His data sample is the 500 Nasdaq-listed stocks with the highest dollar volume for the nine calendar quarters from July 2005 through September 2007. The combined market share of the two dark pools in September 2007 is approximately 1.6% of consolidated volume in the 500 stocks. The author also uses Section 13F institutional holdings data and a proprietary data set of institutional trades to evaluate the determinants of institutions' usage of the two dark pools.

The author finds that the two dark pools specializing in blocks have a lower share of institutional volume for stocks with the highest consolidated volume. He also finds that the two pools capture lower levels of institutional volume for stocks with higher levels of adverse selection, for stocks with larger percentage spreads, and for stocks with lower spreads per share. He concludes that his findings are consistent with traders routing orders in these stocks to venues other than block trading venues to satisfy soft dollar agreements.

11. Upson, James, Sugato Chakravarty, Pankaj Jain and Thomas McInish (2011), Trading aggressiveness and market breadth around earnings announcements, working paper.

Upson, Chakravarty, Jain and McInish (2011) examine trading aggressiveness and market breadth around earnings announcements. They define market breadth as the number of quoting market centers matching the best prices, by side of the market. They believe market breadth is an important dimension of liquidity when multiple markets quote the same security and there are enforceable regulatory penalties for a violation of price priority. Their sample is comprised of all NYSE-listed stocks with a minimum price of \$10 on the last day of trading in 2007 that also are included in the Daily Trade and Quote

database. Their analysis is based on data from the last quarter of 2007 and the first quarter of 2008. Specifically, they measure the liquidity of the market during periods of high volatility around earnings announcements for NYSE firms. After controlling for reporting lag between trades and quotes, they find that liquidity suppliers significantly decrease market breadth prior to earnings announcements, and that large uninformed liquidity demanders significantly increase their use of ISOs during periods of market volatility.

12. Weaver, Daniel, 2011, Internalization and market quality in a fragmented market structure, working paper.

Weaver (2011) examines the effect of off-exchange trading on market quality. His sample is trading in U.S.-listed common stocks during October 2010. He notes that, by this time, both BATS and Direct Edge were registered as exchanges and their substantial volume was not included in his sample of off-exchange trading. He believes that more than 90% of his off-exchange sample reflects volume from dark venues – either broker-dealer internalization or dark pools. His sample included 1,456 NYSE-listed stocks, 2,383 Nasdaq-listed stocks, and 301 Amex-listed stocks.

After controlling for price, trading volume, and 15-minute volatility, the author finds that increased off-exchange trading is associated in a linear fashion with wider quoted spreads, effective spreads, and realized spreads. For example, he finds that a NYSE listed stock with 40 percent of its volume reported off-exchange will on average have a dollar effective spread that is \$0.0128 wider than a similar stock with no off-exchange volume. In addition, after controlling for average daily number of trades, he finds an association between increased off-exchange trading and increased 15-minute volatility.

13. Ye, Mao, 2010, Non-execution and market share of crossing networks, working paper.

Ye (2010) examines the non-execution probability and market share of dark pools. His data is obtained from eight off-exchange crossing networks that made available execution quality reports pursuant to Rule 605 of Regulation NMS for the period from January through March 2010. He also uses Rule 605 reports for all stock exchanges during the sample period. His sample encompasses 1,141 NYSE-listed stocks and 1,627 Nasdaq-listed stocks.

The author finds that, while there are several advantages to trading in crossing networks (such as lower effective spreads and lower price impacts of trades), the risk of non-execution is a key drawback of execution quality in dark trading venues. He finds that execution probability in the crossing networks is 4.11% for NYSE-listed stocks and 2.17% for Nasdaq-listed stocks, compared to execution probability of 31.47% and 26.48%, respectively, on exchanges. Non-execution in the dark pools is positively correlated with price impact, decreases in trading volume, and increases in volatility, while the dark pools have higher market share for stocks with lower volatility and higher

volume. For stocks with higher effective spreads, he finds that traders do not achieve higher reductions in effective spreads by trading in dark pools.

B. Australian Markets

1. Australian Securities & Investments Commission ("ASIC"), 2013, Report 331: Dark liquidity and high-frequency trading.

ASIC (2013) assesses the impact of dark liquidity and high-frequency trading²⁷ on the quality and integrity of Australia's equity markets. The paper examines trading in the most active 300 securities listed on the Australian Stock Exchange ("ASX") in the third quarters of 2011 and 2012. Building on the findings of Comerton-Forde and Putnins (2012), the paper identifies securities where the median proportion of below block size dark trading is above 10 percent of total volume on more than half of the trading days in the sample.

The paper finds that, while the volume of dark trading has remained around 25-30 percent of total equity market share, the composition of dark trading has changed. Specifically, a higher proportion of below block size trading occurred in dark venues. The ASIC found that, of the top 300 securities studied, 85 percent experienced an increase in below block size dark trading in the third quarter of 2012 as compared to the third quarter of 2011. According to the ASIC, securities that increased to below block size dark trading of more than 10% tended to exhibit a widening in quoted spreads and decreases in quoted depth compared to other securities.

ASIC noted that its analysis did not control for market-wide factors that may influence spreads and depth. The analysis also did not attempt to control for endogeneity of below block size dark trading and spreads and depth.

2. Comerton-Forde, Carole and Talis J. Putnins, 2012, Dark trading and price discovery, working paper.

Comerton-Forde and Putnins (2012) empirically analyze the impact of dark trading on price discovery. They examine the 500 largest equities by market capitalization listed on the ASX, which account for approximately 95% of the total market capitalization of all ASX-listed stocks. To avoid potential effects from fragmentation in lit liquidity, they limit their sample to the period from February 2008 to October 2011, when ASX was the only lit venue trading the stocks. The authors also distinguish between dark block trades and dark non-block trades. During the full sample period, dark non-block trades represented 7.8% of dollar volume and dark block trades represented 2.2% of dollar volume in their sample stocks.

²⁷ The discussion of high-frequency trading in ASIC (2013) will be addressed in a subsequent part of this literature review.

The authors use regression models to control for market capitalization, bid-ask spread, the proportion of the trading day for which the stock's spread is constrained to the minimum tick size, total dollar volume, 1 minute mid-quote volatility, and messages-to-trades ratio (intended to serve as a proxy for algorithmic trading). They use three types of informational efficiency measures for their analysis of price discovery – autocorrelation-based measures, volatility variance ratios, and measures of short-term return predictability using lagged market returns.

The authors find that low levels of dark non-block trading are not harmful to price discovery, but as dark non-block trading increases past 10% of total dollar volume it reaches a tipping point and begins to have a negative impact. Similarly, they find that low levels of dark block trades can improve informational efficiency, but when the level exceeds 15% of total dollar volume the effect turns negative.

The authors use similar regression models to assess the effect of increasing levels of dark trading on quoted spreads and the price impact of lit trades. They find that as dark block and non-block trading increases, quoted spreads widen and the permanent price impact of lit trades increases. They estimate that increasing dark trading from 0 to 10% of dollar volume could be expected to increase quoted spreads by 12% after controlling for other factors.

Though they expect that endogeneity concerns would be more severe in causally relating dark trading and liquidity than in relating dark trading and price discovery, the authors use instrumental variables to control for potential endogeneity. They instrument the level of dark trading in a stock-day with the average level of dark trading on that day for all other stocks in the relevant market capitalization quartile. The authors find that results from the two-stage instrumental variables regressions are very similar to those from the simple panel regression, suggesting that endogeneity has little, if any, effect on their results.

3. He, William Peng and Andrew Lepone, 2010, Determinants of liquidity and execution probability in exchange operated dark pool: evidence from the Australian Securities Exchange, working paper.

He and Lepone (2010) analyze trading from July through December 2010 on Centre Point, a dark venue operated by the ASX that executes orders at the midpoint of bid-ask prices. Using a proprietary data set that allowed the identification of trades and orders in Centre Point, they find that execution probability of Centre Point orders increases when dark pool trading is most active and when average Centre Point order size is greater. They find no evidence of Centre Point trading being detrimental to market quality on the ASX, as measured by quoted spreads.

C. Canadian Markets

- 1. Foley, Sean, Katya Malinova and Andreas Park, 2013, Dark trading on public exchanges, working paper.**

Foley, Malinova, and Park (2013) study the impact of fully hidden orders on the lit Toronto Stock Exchange (“TSX”) during 2011. These dark orders were first introduced on TSX in 2011 and reached 3.3% of volume during the sample period. Using a difference-in-difference event study, a control group of stocks, and a volatility index to account for market-wide fluctuations, the authors find that the introduction of dark orders increased both quoted and effective spreads, suggesting that dark trading caused an increase in trading costs. This result remained constant when the authors accounted for and ignored the trading fees levied by TSX. They did not, however, find any change in volume or volatility with the introduction of dark orders.

D. European Markets

- 1. Chlistalla, Michael and Marco Lutat, 2011, Competition in securities markets: the impact on liquidity, *Financial Markets and Portfolio Management* 25(2), 149-172.**

Chlistalla and Lutat (2011) examine the impact of a new equity market entrant, Chi-X, on the liquidity of the incumbent market, Euronext Paris, after the implementation of MiFID. They use a sample of 37 French blue-chip stocks from the CAC-40 index during 2007-2008. They study the sample stocks during the 60 days preceding the commencement of trading in those stocks on Chi-X and the 30 days following.

The authors’ market quality metrics are relative quoted spread, the value displayed at the top of the book, and an exchange liquidity measure (“XLM”) (depth of the order book to execute an order of 100,000 Euros). They use a control sample of other European stocks to ensure that the effects discovered resulted from the entry of Chi-X and not from some other change in the markets.

The authors find that the entrance of the new competitor, Chi-X, stimulated liquidity of the most actively traded stocks in the sample. The stimulus resulted in tighter quoted spreads and greater XLM, though value displayed at the top of book decreased. The positive liquidity effect, however, was not found for less liquid stocks in the sample where the Chi-X trading activity was relatively low.

- 2. Degryse, Hans, Frank de Jong and Vincent van Kervel, 2013, The impact of dark trading and visible fragmentation on market quality, working paper.**

Degryse, De Jong, and van Kervel (2013) evaluate fragmentation specifically to assess the respective effects of trading on visible venues and dark venues. Their sample is all Dutch mid- and large-cap stocks (38 stocks) from January 2006 (a time period before fragmentation set in) to the end of 2009.

For each stock, the authors construct a consolidated limit order book to get a picture of the consolidated liquidity available in the market. They measure liquidity primarily as “Depth(X),” which aggregates the Euro value of the number of shares offered within a fixed interval around the midpoint (10, 20, 30, 40, and 50 basis points). They also use other measures of liquidity, such as quoted spreads and quoted depth at the best prices. The authors measure visible fragmentation using the Herfindahl-Hirschman Index (“HHI”). They also examine trade data from dark venues, which reflected 37% of the total volume in their sample.

The authors find that the effect of visible fragmentation on consolidated liquidity is generally positive, with narrower spreads and improved Depth(X) measures. Notably, they find that quoted depth only at the best prices (which reflected narrower quoted spreads) declined. Considering the low correlation between Depth(X) and quoted depth only at the best prices, they noted that quoted depth did not appear to be a suitable liquidity measure in the period they studied. They further find that best-market liquidity (defined as liquidity available at the best visible venue only) is not reduced by visible fragmentation. The authors qualify their findings by noting that visible fragmentation reduces “local liquidity” (liquidity at traditional stock exchanges), and therefore investors without access to all markets are worse off in a fragmented market environment.

The authors also find that the benefits of visible fragmentation in the form of narrower spreads and increased depth are consistently higher for large company stocks than small company stocks. In particular, for large company stocks, the effects of visible fragmentation are monotonic, meaning additional fragmentation narrows spreads and increases depth at all levels. For small company stocks, in contrast, they find that displayed depth is negatively affected at fragmentation levels when 1 less the HHI exceeds 0.36.

In contrast to the findings regarding visible fragmentation, the authors find that the effect of dark trading on consolidated liquidity is negative, and that an increase in dark trading of one standard deviation lowers consolidated liquidity by 9%. They believe that controlling for visible fragmentation is important when testing for the effects of dark trading in their sample, because trading activity across the different venues is likely to be correlated. For example, dark pool activity is higher for larger firms in their sample, which also benefit from higher levels of visible fragmentation.

To address concerns about the endogeneity of visible fragmentation and dark trading in their conclusions, the authors use instrumental variables. For visible fragmentation, the authors use as instruments the average order size of the visible new entrants and the number of limit orders to market orders on visible new entrants. They instrument dark trading with the size of the average dark order. They conclude that the instrumental variable analyses confirm the robustness of their findings.

3. Fioravanti, S.F. and M. Gentile, 2011, The impact of market fragmentation on European stock exchanges, working paper.

Fioravanti and Gentile (2011) examine how market fragmentation affected the quality of trading on European regulated markets after MiFID. They use a sample of 50 stocks included in the Stoxx Europe 50 Index. Their time period is the beginning of 2008, when the share of trading on multilateral trading facilities (“MTFs”) was approximately null, to February 2011, when the MTF share increased to 18% of total turnover.

The authors measure fragmentation using the inverse HHI (based on trading volume at lit venues). They measure liquidity as relative quoted spread, price impact (defined as the ratio between daily return and trading volume), and displayed depth at the best prices. They measure informational efficiency with two indicators of return autocorrelation. The first is based on an estimate of stock returns as a function of market returns and an estimate of stock returns as a function of lagged market returns. The second indicator is a variance ratio computed using 15 and 30 minute return variances. To address endogeneity, they use a difference-in-difference approach that identifies a control sample of stocks with unfragmented trading. To address potential selection bias, they employ Heckman’s two-step procedure.

The authors find that increasing visible fragmentation leads to a narrower relative quoted spreads, reduced price impact, and increased quoted depth at the best prices. With respect to price discovery, in contrast, they find that an increase in visible fragmentation leads to reduced informational efficiency – a significant increase of both the delay indicator and the variance ratio indicator.

4. Gresse, Carole, 2012, Effects of lit and dark trading venue competition on liquidity: the MiFID experience, working paper.

Gresse (2012) examines how MIFID impacted the fragmentation of European markets and how, in turn, this fragmentation, both visible and dark, impacted various aspects of market quality. Her sample is composed of three groups of stocks – the FTSE-100, CAC-40, and SBF-120 (the non-CAC-40 components of the index). Her sample periods are October 2007 prior to the implementation of MiFID, and three separate months in 2009 (January, June, and September) to correspond to different levels of fragmentation after MiFID. Dark venue volume represented 19.3%, 24.0%, and 14.5% of total volume for her sample stocks in the FTSE-100, CAC-40, and SFT120, respectively, in September 2009.²⁸

Market quality is measured as quoted spreads, effective spread, and displayed depth at the best prices, both globally and for each primary market. To address endogeneity, the author instruments for fragmentation with a number of variables including the number of

²⁸ The author notes that the accuracy of the sources for dark venue trading figures “is a matter of discussion in several respects.” Also, the figures do not include data from several dark pools, but the collective volume from these pools did not exceed a few percent of total trading volume at the time of the study.

markets quoting the stock, the percentage of markets quoting the best bid and ask prices, and market value.

The author finds that visible fragmentation generally benefits market quality in the form of narrower spreads and greater quoted depth at the best prices or, in the worst-case scenario, does not affect it. After an equilibrium level of visible fragmentation is reached, marginal gains in liquidity become relatively low in economic magnitude. One exception to these benefits is that visible fragmentation decreased depth at the best prices for smaller stocks.

With respect to dark fragmentation, the author found that it increased depth at the best prices, but widened quoted spreads. She notes, however, that the size of dark trading in her sample was very volatile, and that the various forms of dark trading should be distinguished.

5. Riordan, Ryan, Andreas Storckenmaier and Martin Wagener, 2011, Do multilateral trading facilities contribute to market quality?, working paper.

Riordan, Storckenmaier, and Wagener (2011) examine the effects of increasing visible fragmentation on market quality. Their sample is trading in FTSE 100 constituents during April and May 2010 across four lit venues – the London Stock Exchange (“LSE”) and three multilateral trading facilities (“MTFs”). Taken together, these venues account for 95% of the non-OTC trades in the stocks sampled during the observation period.

To measure the impact of increasing MTF market share, the authors compare the 2010 observation period to the same trading days in 2009. Visible fragmentation increased during this period as the LSE’s share of volume across the four venues decreased from 70.2% in 2009 to 51.8% in 2010. After controlling for market capitalization, daily volatility, and daily closing prices, the authors find that quoted spreads and effective spreads declined, indicating that liquidity improved over time despite increased fragmentation.

6. Spankowski, Ulli F.P., Martin Wagener and Hans-Peter Burghof, 2012, The role of traditional exchanges in fragmented markets, working paper.

Spankowski, Wagener, and Burghof (2012) examine the effects of market fragmentation on market quality in the European markets, including how the effect varies at different times of day. Their sample was trading during 2009 in 69 of the FTSE 100 stocks on four venues – the LSE and three MTFs. Together, these venues accounted for almost 100% of the non-OTC trading volume in FTSE 100 constituents. They measure market quality as quoted spreads, effective spreads, realized spreads, price impacts, and order book depth at the best prices and at three ticks behind the best prices.

The authors find that, over the course of 2009, LSE lost significant market share in favor of the other venues and that the change correlated with an improvement in market quality across all venues. After controlling for market capitalization, daily volatility, and daily closing prices, they find that quoted and effective spreads decreased on all platforms, while realized spreads decreased on two of the platforms and did not change significantly on two others. Price impacts also decreased across all platforms. Order book depth at the best prices and three ticks away increased significantly on the LSE, did not change on two other venues, and decreased on one.

The authors also note an apparent investor preference to trade on the exchange market during opening and closing times, but then switching to the other venues during the trading day. They believe that this pattern indicates a preference for exchange trading during periods of increased volatility and price uncertainty.

7. van Kervel, Vincent, 2012, Liquidity: what you see is what you get?, working paper.

van Kervel (2012) examines the magnitude of order cancellations in a market structure with multiple limit order book venues when a trade occurs on one of the venues. His sample is trading during November 2009 in ten FTSE 100 stocks that were randomly selected from each market cap decile. At that time, the LSE executed 66% of lit trading volume, leaving the remaining 34% to four competing lit venues.

The author finds that trades on one venue were followed by limit order cancellations on competing venues. For example, within 100 milliseconds, trades on the three most active trading venues are followed by cancellations on the same side of competing limit order books of 38 to 85% of the trade size. He also finds that trades on one side of the market were followed by additional new limit orders on the other side of the market. For example, a trade on the ask side was followed by new limit orders on the bid side of 30 to 70% of the trade size.

The author concludes that, while previous research typically shows a beneficial effect of visible fragmentation on liquidity, the benefits, while still positive, are mitigated because of duplicate limit orders. He emphasizes, however, that the magnitude of cancellations will depend on the fraction of investors that have access to smart order routing technology that enables them to access several venues simultaneously.

VI. Questions for Consideration

This is the first of a planned series to review recent economic literature on equity market structure. As noted above, the SEC staff review summarizes those economic papers that analyze recent financial data (2007 and later) and reach findings that in the staff's view are most relevant to important market structure issues facing the SEC. The staff's hope is that the literature review will help promote a dynamic exchange on market structure with and among the public, including investors, academics, and market participants.

For example, does the review accurately describe the economic literature dealing with market fragmentation and dark venue trading, both with respect to its executive summary and its summaries of individual papers? Are there papers other than those identified in the review that should be included? In addition, most of the papers described above are working papers, which have not yet been through a peer review process and are subject to change as the authors respond to feedback. How reliable are all of the results of the papers discussed above? Are some results are less reliable and why? Finally, what is the usefulness and applicability of the papers' analyses, metrics, and findings for the specific purpose of the staff's continued consideration of equity market structure issues.

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