Staff Report on Algorithmic Trading in U.S. Capital Markets

As Required by Section 502 of the
Economic Growth, Regulatory Relief, and Consumer Protection Act of 2018

This is a report 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.

August 5, 2020

Table of Contents

I. Introduction

A. Congressional Mandate

The Economic Growth, Regulatory Relief, and Consumer Protection Act of 2018 requires the staff of the U.S. Securities and Exchange Commission (the "SEC" or "Commission") to submit to Congress a report on the risks and benefits of algorithmic trading in the U.S. capital markets.[1] Specifically, § 502 provides:

(a) In General. Not later than 18 months after the date of enactment of this Act, the staff of the Securities and Exchange Commission shall submit to the Committee on Banking, Housing, and Urban Affairs of the Senate and the Committee on Financial Services of the House of Representatives a report on the risks and benefits of algorithmic trading in capital markets in the United States.

(b) Matters Required To Be Included. The matters covered by the report required by subsection (a) shall include the following:

  (1) An assessment of the effect of algorithmic trading in equity and debt markets in the United States on the provision of liquidity in stressed and normal market conditions.

  (2) An assessment of the benefits and risks to equity and debt markets in the United States by algorithmic trading.

  (3) An analysis of whether the activity of algorithmic trading and entities that engage in algorithmic trading are subject to appropriate Federal supervision and regulation.

  (4) A recommendation of whether

    (A) based on the analysis described in paragraphs (1), (2), and (3), any changes should be made to regulations; and

    (B) the Securities and Exchange Commission needs additional legal authorities or resources to effect the changes described in subparagraph (A).

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[1] Economic Growth, Regulatory Relief, and Consumer Protection Act, Pub. L. No. 115-174, § 502, 132 Stat. 1296, 1361-62 (2018).

B. Overview

As required by § 502 of the Economic Growth, Regulatory Relief, and Consumer Protection Act of 2018, this staff report describes the benefits and risks of algorithmic trading in the U.S. equity and debt markets.

Broadly speaking, and as more fully discussed below, algorithmic trading in the equities—and to a lesser extent—in the debt market, has improved many measures of market quality and liquidity provision during normal market conditions, though studies have also shown that some types of algorithmic trading may exacerbate periods of unusual market stress or volatility. Advances in technology and communications have enabled many market participants to more efficiently provide liquidity, more efficiently access market liquidity, implement new trading services, and more effectively manage risk across a range of markets.

Furthermore, commenters have observed that the increasing complexity of multiple interconnected markets may have increased the risk that operational or systems failures at trading firms, platforms, or infrastructure may have broad, potentially unexpected, detrimental effects on the markets and investors. A number of observers have noted that even as some uses of algorithms may contribute to market complexity, algorithms generally help market participants navigate market complexity. A common theme echoed by nearly all market professionals, academic researchers, and other students of the securities markets is that that algorithmic trading, in one form or another, is an integral and permanent part of our modern capital markets.

Several variations of algorithmic trading strategies have developed and expanded over the last several decades. These developments have been driven, in pertinent part, by the growth in available market data generated by and consumed by market professionals, major advances in computational power and the speed of data transmission, and the exponential increase in the speed of securities trading. Enhancements in algorithmic trading strategies have also been driven by investor demands for execution quality, the search for alpha and trading profits, and the application of sophisticated quantitative analytics. The Commission and other regulators have responded with a range of tools intended to mitigate risks to investors and to help ensure fair, efficient, and orderly markets. Commission staff will continue to monitor technological change and its influence on investment, trading, and the capital markets, and will continue to assess the need for additional regulation, resources, or legal authority.[2]

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[2] The significant and rapid economic impact precipitated by the COVID-19 pandemic was reflected in extraordinary trading in the U.S. secondary markets for equity and debt during the spring of 2020. While this report briefly discusses recent market events, including certain significant impacts on trading as market participants reacted to the effects of COVID-19, the report is focused on the broader questions raised in § 502. In April 2020,

C. Algorithmic Trading and Markets

The use of algorithms in trading is pervasive in today's markets. Any analysis of the role that algorithmic trading plays in the US equity and debt markets requires an understanding of equity and debt market structure,[3] the role played by different participants in those markets, and the extent to which algorithmic trading is used by market professionals.[4]

In describing the uses of algorithms in trading, it is useful to first define an *algorithm*. At its most general level, an algorithm is a finite, deterministic, and effective problem-solving

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the Commission announced the formation of an internal, cross-divisional COVID-19 Market Monitoring Group to assist with Commission and staff actions and analysis related to the effects of COVID-19 on markets, issuers, and investors, and with responding to requests for information, analysis and assistance from fellow regulators and other public sector partners. *See* "SEC Forms Cross-Divisional COVID-19 Market Monitoring Group," Press Release 2020-95 (Apr. 24, 2020); *see also* "COVID-19 Market Monitoring Group — Update and Current Efforts," Statement of Chairman Jay Clayton and S.P. Kothari (May 13, 2020), *available at:* https://www.sec.gov/news/public-statement/statement-clayton-kothari-covid-19-2020-05-13 (describing some of the initial work of the COVID-19 Market Monitoring Group); COVID-19 Market Monitoring Group, "Credit Ratings, Procyclicality and Related Financial Stability Issues: Select Observations" (Jul. 15, 2020), *available at:* https://www.sec.gov/news/public-statement/covid-19-monitoring-group-2020-07-15.

[3] The section of this staff report on equity market structure echoes aspects of the Commission's 2010 Concept Release on Equity Market Structure. *See Concept Release on Equity Market Structure*, Exch. Act. Rel. No. 61358, 75 Fed. Reg. 3594 (Jan. 21, 2010) ("Concept Release"). That Concept Release described the transition of modern equity trading markets away from a largely centralized, manual structure to the dispersed, automated structure that exists today. The Concept Release provided many useful institutional details; this report updates some of these details, and describes important developments that have occurred since 2010. When discussing debt markets, this report focuses on corporate and municipal bonds. While the markets for U.S. Treasury securities are described briefly, they are not a focus of this report.

[4] The main body of this staff report presumes familiarity with core concepts in securities market structure, such as the distinction between acting as a broker and trading as principal, key differences between types of trading venues such as national securities exchanges and alternative trading systems, the difference between providing and demanding liquidity, and legal obligations such as best execution. Background on these concepts may be found in the appendix to this report, which provides a more general orientation to market participants, roles, and obligations.

method suitable for implementation as a computer program.[5] In modern equity and debt markets, many problems are solved and decisions made in this computational, algorithmic manner. Today, algorithms address many of the problems and decisions that have long been central to the business of trading. What instrument(s) should be invested in or traded? What price should be bid or offered? What order size is optimal? What should be the response to a request for a quotation? What risk will be taken on by facilitating a trade? How does that risk change with the size of the trade? Is the risk of a trade appropriate to a firm's available capital? What is the relationship between the price of different but related securities or financial products? To what market should an order be sent? Is it more effective to provide liquidity or demand liquidity? Should an order be displayed or non-displayed? To which broker should an order be sent? When should an order be submitted to a trading center? In general, algorithms utilize a rich array of market information to very quickly assess the state of the market, to determine when, where, and how to trade, and then to implement the resulting trading decision(s) in the marketplace.[6]

As described in more detail below, algorithms are broadly used in contemporary securities markets, and the range of uses differs across asset classes and across the roles and investment objectives of market participants. In light of the wide diversity of algorithms in modern trading, it is not a goal of this report to define a single type of trading or activity as uniquely algorithmic. Rather, this staff report attempts to describe many dimensions of the contemporary secondary markets for equity and debt securities that operate algorithmically. The types of trading described in more detail below each fundamentally depend upon computerized algorithms, and the data and technological infrastructure through which they operate, to address the types of problems and tasks described above.

The staff's approach differs from the more narrow approaches taken in much of the literature on algorithmic trading, which generally seek to examine a specific type of algorithmic activity. For example, one study defines algorithmic trading as "a tool for professional traders that may observe market parameters or other information in real-time and automatically generates/carries out trading decisions without human intervention."[7] Other approaches, for example, characterize algorithmic trading as the use of programmed

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[5] *See*, *e.g.*, Robert Sedgewick & Kevin Wayne, *Algorithms*, 4 (4th Ed. 2011) ("The term algorithm is used in computer science to describe a finite, deterministic, and effective problem-solving method suitable for implementation as a computer program").

[6] These are just a few of the questions and decisions that algorithms address in today's markets and the scope as well as the granularity of issues that algorithms address is virtually unbounded.

[7] Peter Gomber, Björn Arndt, Marco Lutat, Tim Uhle, *High Frequency Trading*, 14 (Goethe Univ. Frankfurt Am. Main, Working Paper, 2011) (available at https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1858626).

trading instructions to execute small portions of larger orders over time.[8] While activity meeting these definitions is encompassed in the approach taken here, this staff report's coverage is broader, reaching areas where algorithms are used and may be important, but in some cases may not be used as exclusively or extensively as in the activities described in these examples.[9]

II. Overview of Equity Market Structure

Today's equity market structure is highly fragmented, consisting of fifteen national securities exchanges, over thirty alternative trading systems, multiple single-dealer platforms within broker-dealers, and other forms of order matching. The equity markets are also highly complex, with dozens of different order types, a multitude of market connectivity options, and a rich array of market information products providing data in speeds often measured in microseconds. This data is the key input into the wide variety of algorithmic trading strategies that rapidly submit orders across venues, creating and moving the prices of securities, which, in turn, generate more data that drives the next set of algorithmic trading decisions.

In Section 11A of the Exchange Act,[10] Congress directed the Commission to facilitate the establishment of a national market system. The Commission is required to do so in accordance with the findings and objectives Congress outlined in the Exchange Act:

- The securities markets are an important national asset which must be preserved and strengthened;
- New data processing and communications techniques create the opportunity for more efficient and effective market operations;
- It is in the public interest and appropriate for the protection of investors and the maintenance of fair and orderly markets to assure–
  - Economically efficient execution of securities transactions;
  - Fair competition among brokers and dealers, among exchange markets, and between exchange markets and markets other than exchange markets;

[8] *See* Katie Kolchin, *Electronic Trading Market Structure Primer*, SIFMA Insights, pp. 15-16 (Oct. 10, 2019), *available at:* https://www.sifma.org/resources/research/electronic-trading-market-structure-primer/.

[9] For a more detailed discussion of some of the methodological issues involved with trying to precisely define algorithmic trading and its subsets, *see* Staff of Division of Trading and Markets, U.S. Securities & Exchange Commission, *Equity Market Structure Literature Review Part II: High Frequency Trading*, 4-11 (Mar. 18, 2014) ("HFT Literature Review").

[10] 15 U.S.C. 78k-1.

- The availability to brokers, dealers, and investors of information with respect to quotations for and transactions in securities;
- The practicability of brokers executing investors' orders in the best market; and
- An opportunity, consistent with economically efficient execution and the ability to execute orders in the best market, for investors' orders to be executed without the participation of a dealer; and

- The linking of all markets for qualified securities through communication and data processing facilities will foster efficiency, enhance competition, increase the information available to brokers, dealers, and investors, facilitate the offsetting of investors' orders, and contribute to best execution of such orders.

These findings and objectives give a paramount place to the interests of investors, and conclude that the interests of investors are best served by a market structure that is designed to promote and maintain both (1) an opportunity for interaction of all buying and selling interest and (2) fair competition among all types of market centers.[11] As the Commission has noted, these objectives can be difficult to reconcile.[12] For example, maximizing order interaction in individual securities may be in tension with market center competition for order flow, and market center competition for order flow may lead to fragmentation in the order flow for individual securities.[13] As the Commission has stated, its "task has been to facilitate an appropriately balanced market structure that promotes competition among markets, while minimizing the potentially adverse effects of fragmentation on efficiency, price transparency, best execution of investor orders, and order interaction."[14]

The secondary market for U.S.-listed equity securities that has developed within this structure is now primarily automated.[15] The process of trading has changed dramatically

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[11] *Notice of Filing of Proposed Rule Change by the New York Stock Exchange, Inc. to Rescind Exchange Rule 390; Commission Request for Comment on Issues Relating to Market Fragmentation*, Exch. Act Rel. No. 42450, 65 Fed. Reg. 10577, 10580 (Feb. 28, 2000) ("Fragmentation Release").

[12] *See id.* ("although the objectives of vigorous competition on price and fair market center competition may not always be entirely congruous, they both serve to further the interests of investors and therefore must be reconciled in the structure of the national market system"); *see also* Concept Release at 3597.

[13] *See*, *e.g.*, Concept Release at 3597.

[14] *Id.*

[15] *See*, *e.g., id.* at 3594.

primarily as a result of developments in technologies for generating, routing, and executing orders, as well as by the requirements imposed by law and regulation.[16] Today, equity trading volume generally is dispersed among many automated trading centers that compete for order flow in the same stocks, principally by offering execution services designed to fill the needs of the wide variety of market participants.[17] Maintaining fair, efficient, and orderly markets requires an understanding of the dependence of modern markets on algorithms used, among other things, for order routing, handling, and execution.

The following overview summarizes elements of the market structure most salient to algorithmic trading, including the various types of equity trading centers and the market data that facilitates communication among trading centers and participants.

A. Trading Centers

A reasonable place to start in describing current equity market structure is an overview of the major types of trading centers and their share of volume in NMS stocks.[18] Broadly speaking, the market can be divided into registered national securities exchanges and off-exchange trading venues, which include alternative trading systems (ATSs) and several types of broker-dealer internalization platforms.[19] Nearly all of these trading centers depend on automated systems and algorithms to perform their important role in the market structure for U.S. equities.

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[16] *Id.*

[17] *Id.*

[18] *See*, *e.g.*, *id.* at 3597-3600. "NMS stock" means any security or class of securities, other than an option, for which transaction reports are collected, processed, and made available pursuant to an effective transaction reporting plan. *See* 17 CFR 242.600(b)(48) (defining "NMS stock" as "any NMS security other than an option"), 17 CFR 242.600(b)(47) (defining "NMS security" as "any security or class of securities for which transaction reports are collected, processed, and made available pursuant to an effective transaction reporting plan, or an effective national market system plan for reporting transactions in listed options"). In general, NMS stocks are those listed on a national securities exchange. *See* Concept Release at 3597 n.20.

[19] A broker-dealer internalizes an order when it executes the order out of its own inventory of securities, rather than routing it to an exchange or other platform, or matches buyers and sellers together outside of an ATS or exchange. *See*, *e.g.*, U.S. Securities & Exchange Commission Investor Publications, *Trade Execution: What Every Investor Should Know* (Jan. 16, 2013), available at https://www.sec.gov/reportspubs/investor-publications/investorpubstradexechtm.html; Concept Release at 3599-3600.

Table 1 summarizes, for all NMS stocks in 2019, the percentage of trades, share volume, and dollar volume executed on each registered exchange or reported to each trade reporting facility.[20] As summarized in Table 2, approximately 78% of all trades were executed on registered exchanges, and 22% off-exchange; 63% of all shares traded were executed on-exchange, and 37% off-exchange; and 65% of dollar-volume was executed on-exchange, and 35% off-exchange.

Table 1: Percentage of All Trades, Shares, and Dollar Volume in 2019 at National Securities Exchanges or Reported to Trade Reporting Facilities (TRFs)

Venue/TRF	Trades	Shares	$ Vol.
Cboe BYX	6.2%	3.8%	3.0%
Cboe BZX	8.7%	5.5%	6.4%
Cboe EDGA	4.3%	2.2%	2.1%
Cboe EDGX	6.4%	4.8%	4.7%
IEX	3.8%	2.7%	2.9%
Nasdaq	24.1%	17.2%	19.7%
Nasdaq BX	3.1%	1.8%	1.8%
Nasdaq PSX	0.9%	0.7%	0.9%
NYSE	8.5%	13.5%	12.4%
NYSE American	0.4%	0.3%	0.2%
NYSE Arca	9.4%	8.4%	9.3%
NYSE Chicago	<0.01%	0.4%	0.8%
NYSE National	2.1%	1.4%	0.8%
TRF Nasdaq Carteret	18.6%	29.7%	29.3%
TRF Nasdaq Chicago	0.1%	0.1%	0.1%
TRF NYSE	3.5%	7.5%	5.6%

Source: NYSE TAQ

[20] Trades executed otherwise than on a national securities exchange must be reported in a timely manner to a trade-reporting facility. *See*, *e.g.*, FINRA Rules 6300A - 6380B, 7200A - 7280B. Currently there are three Trade Reporting Facilities.

Table 2: Percentage of All NMS Stock Trades, Shares, and Dollar Volume in 2018 at All Registered Exchanges or Reported to TRFs

Venue	Trades	Shares	$ Vol.
Exchanges	78%	63%	65%
Off-Exchange	22%	37%	35%

Source: NYSE TAQ

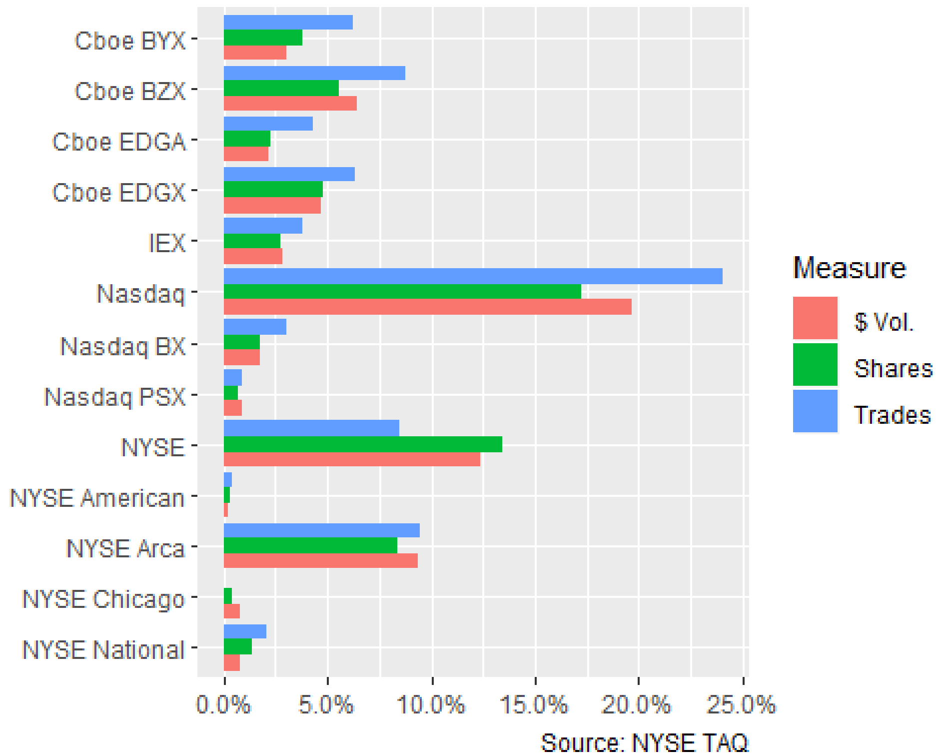
Currently, only national securities exchanges display quotations in the consolidated quotation data widely distributed to the public.[21] Trades executed off-exchange (*i.e.*, about 35% of equity dollar volume, as shown in Table 2) take place on ATSs and dealer platforms where quotes are not publicly displayed. Because they do not publicly display quotes, these venues are commonly referred to as "dark pools" of liquidity.

1. National Securities Exchanges

In 2019, national securities exchanges together executed approximately 78% of trades, 63% of share volume, and 65% of dollar volume in NMS stocks. In 2019, no single exchange accounted for more than 24% of all NMS stock trades, 17% of all NMS stock share volume and 20% of NMS stock dollar volume. Figure 1 compares the percentages of trades, share volume, and dollar volume across all registered exchanges in 2019.

[21] These consolidated market data plans are discussed more fully below. *See infra* Section III.B.

Figure 1: % of Trades, Shares, and Dollar Volume in 2019



While there are now fifteen registered national securities exchanges for equities, and thirteen equities exchanges operating,[22] twelve are owned by three corporate entities, commonly known as "exchange families."[23] Figure 2 shows the percentage of trades, share volume, and dollar volume executed at each exchange family during all of 2019.[24]

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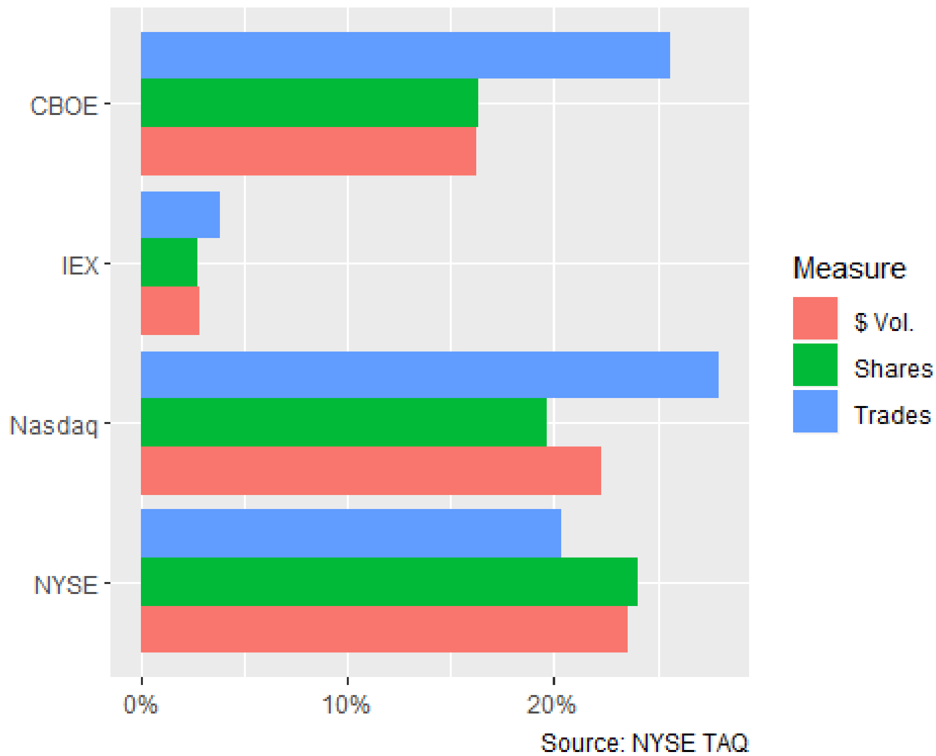
[22] As of the date of publication of this staff report, Long-Term Stock Exchange, Inc. and MEMX LLC have not begun trading operations.

[23] The exchange families are (1) CBOE Global Markets, Inc., which owns CBOE BYX Exchange, Inc., CBOE BZX Exchange, Inc., CBOE EDGA Exchange, Inc., and CBOE EDGX Exchange, Inc.; (2) Nasdaq, Inc., which owns Nasdaq BX, Inc., Nasdaq PHLX LLC, and The Nasdaq Stock Market LLC; and (3) Intercontinental Exchange, Inc., which owns New York Stock Exchange LLC, NYSE Arca, Inc., NYSE American LLC, NYSE Chicago, Inc., and NYSE National, Inc.

[24] Long-Term Stock Exchange is not reflected in the 2019 data because it was not yet executing trades as a national securities exchange.

Figure 2: % of Trades, Shares, and Dollar Volume in 2019, by Exchange Family



Trading and communication at national securities exchanges are now almost entirely automated. Order entry, message acknowledgement, matching algorithms, trade confirmations, and market data systems all operate at microsecond or nanosecond timescales.

To reduce time delay, or "latency," between exchange systems and market participants, and to otherwise facilitate order entry and trade execution, exchanges offer data and connectivity services to market participants, including for example, allowing participants to place their servers close to exchange matching engines and data feeds to minimize data transmission time. Exchanges also offer market participants a variety of services for (1) receiving and processing data, and (2) moving data between data centers around the country (such as fiber-optic cables, millimeter waves, and microwaves). Put simply, computers running sophisticated algorithms consume and analyze this data to help market participants respond to market developments.

In addition to offering various data services, national securities exchanges generally offer an extensive range of order types that facilitate automated trading. These order types provide market participants with a multitude of options for interacting with other market participants, including, for example, (1) providing liquidity by posting orders to a central limit order book, (2) removing liquidity by matching with an order already resting on the book, (3) displaying quotes to the market, (4) providing non-displayed liquidity, (5) accessing liquidity within the quoted spread, (6) accessing non-displayed liquidity, or (7) repricing orders based on changing market conditions or to meet certain regulatory obligations. Market participants often use algorithms to pursue more than one of these or other order options simultaneously. Because most exchange matching algorithms use a system based upon price-time priority, many order types are oriented towards helping participants achieve or retain priority in an order book queue.[25] Two exchanges also offer order types that automatically reprice orders based on predicted changes in prices derived from activity at other markets.[26] One registered exchange offers a "speedbump," or intentionally-implemented delays in executions, intended to mitigate the advantages that some market participants may have in receiving and processing market data and rapidly taking liquidity.[27]

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[25] Generally, under a system of price-time priority, better priced orders are at the top of the order queue, with ties at the same price resolved in favor of the order first to arrive in time. Ties in arrival time (rare given the granularity of current timestamps) are sometimes resolved in favor of the order with the largest size. The New York Stock Exchange has a "parity" model, in which each floor broker, a stock's designated market maker, and the central limit order book receive parity in the execution of orders, with allocations for smaller orders determined through a "parity wheel." Nasdaq PSX operates on a "price-setter pro rata" model, under which resting orders that set the PSX BBO are guaranteed a certain proportion of an execution against incoming marketable orders, with other resting orders at the same price filled on a size pro-rata basis out of the remaining shares. Cboe EDGX uses price-retail-time priority, in which displayed limit orders from or on behalf of individual retail investors are given priority over other orders at the same price.

[26] *See* IEX Rule 11.190(g); NYSE American Rule 7.31E(h)(3)(D).

[27] *See* IEX Rule 11.510(a). NYSE American recently eliminated its delay mechanism. *See NYSE American LLC; Notice of Filing and Immediate Effectiveness of Proposed Rule Change To Amend Exchange Rules 1.1E and 7.29E To Eliminate the Delay Mechanism and Amend Exchange Rule 7.31E and Related Exchange Rules To Re-Introduce Previously-Approved Order Types and Modifiers*, Exch. Act Rel. No. 87550, 84 Fed. Reg. 64359 (Nov. 21, 2019). Recently, several exchanges have proposed "asymmetrical" speedbumps that would intentionally delay incoming marketable orders, but allowing resting orders to be cancelled or modified without delay. One was withdrawn, and one was disapproved. *See* Exch. Act Rel. No. 84337, 83 Fed. Reg. 50720 (Oct. 9, 2018) (setting aside approval order under delegated authority after filing was withdrawn); "Order Disapproving Proposed Rule Change to Introduce a Liquidity Provider Protection Delay Mechanism on EDGA," Exch. Act Rel. No. 88261, 85 Fed. Reg. 11426 (Feb. 27, 2020).

In addition to providing continuous trading through their limit order books throughout the day, national securities exchanges may perform opening and closing auctions in their listed securities.[28] These auctions have increased in importance in recent years. This increase is correlated with, and to at least some meaningful extent has been driven by, the increase in popularity of investment products that incorporate exchange closing prices in their operations, including index mutual funds.[29] The listing exchanges vary in the percentage of their volume executed in auctions. Table 3 shows, for example, the average daily percentage of share volume in auctions for the listing exchanges in 2019.

Table 3: Average Daily Percentage of Share Volume in Auctions Per Listing Exchange in 2019

VENUE	Auc. %
Cboe BZX	0.4%
Nasdaq	12.3%
NYSE	33.8%
NYSE American	14.6%
NYSE Arca	8.5%

Source: NYSE TAQ

Most exchanges have adopted fee schedules that differentiate between the providers of liquidity and the takers of liquidity.[30] Most exchanges use a "maker-taker" model, paying rebates to providers of liquidity, charging a fee to takers of liquidity, with the exchanges keeping any difference between (1) the amount paid to the exchange by takers of liquidity and (2) the amount paid by the exchange to providers of liquidity, as revenue on each

[28] As needed, the listing exchanges also perform intraday re-opening auctions. *See*, *e.g.*, *Plan to Address Extraordinary Market Volatility*, Section VII(B). Some exchanges may also perform auctions in securities that they do not list, *see*, *e.g.*, NYSE Arca Rule 7.35-E(a)(1), and some may match orders at the listing market closing auction price, *see Order Setting Aside Action by Delegated Authority and Approving a Proposed Rule Change, as Modified by Amendments No. 1 and 2, to Introduce Cboe Market Close, a Closing Match Process for Non-BZX Listed Securities under New Exchange Rule 11.28*, Exch. Act Rel. No. 88008 (Jan. 21, 2020).

[29] *See*, *e.g.*, Robin Wigglesworth, "The 30 minutes that have an outsized role in US stock trading," *Financial Times* (Apr. 24, 2018); Corrie Driebusch, Alexander Osipovich and Gregory Zuckerman, "What's the Biggest Trade on the New York Stock Exchange? The Last One," *The Wall Street Journal* (Mar. 14, 2018).

[30] Rule 610(c) of Regulation NMS caps the access fee for executions against the best displayed prices of a national securities exchange at $0.0003 per share for stocks price at or above $1.00. *See* 17 CFR § 610(c)(1).

trade. A smaller number of exchanges employ a taker-maker model, paying rebates to the consumers of liquidity, charging the providers, and again keeping the difference as revenue. An even smaller number of exchanges charge a flat fee for all orders. Because of the substantial amount of money rebated back to trading participants, some order types may be oriented towards helping participants capture these rebates.[31]

2. Alternative Trading Systems

In 2019, thirty-three ATSs executed trades in NMS stocks.[32] That year, these ATSs executed approximately 10.2% of share volume in NMS stocks. The top two ATSs each executed approximately 1-2% of share volume in NMS stocks, with most ATSs executing under 1% of share volume.

Table 4: 2019 Top Ten ATSs by Share Volume: Percentage of ATS Volume, Off-Exchange Volume, and NMS Stock Volume

ATS	% ATS	% Off-Exch.	% NMS
UBS ATS	19.3%	5.3%	2.0%
CROSSFINDER	9.8%	2.7%	1.0%
JPM-X	7.1%	1.9%	0.7%
MS POOL (ATS-4)	7.1%	1.9%	0.7%
SIGMA X2	6.7%	1.8%	0.7%
LEVEL ATS	6.6%	1.8%	0.7%
THE BARCLAYS ATS	6.0%	1.6%	0.6%
BIDS ATS	5.1%	1.4%	0.5%
SUPERX ATS	3.9%	1.1%	0.4%
MS TRAJECTORY CROSS (ATS-1)	3.1%	0.8%	0.3%

Source: FINRA OTC/ATS Transparency

[31] Such order types may include, for example, non-routable post-only orders that seek only to provide liquidity (on venues providing rebates for the provision of liquidity) and will not, upon order entry, execute against a resting order on the other side of the market (either by be re-priced automatically or cancelled) or be routed to a different trading center.

[32] As reflected in the FINRA OTC/ATS Transparency data. FINRA OTC/ATS Transparency Data is provided via http://www.finra.org/industry/OTC-Transparency and is copyrighted by FINRA.

Currently, no NMS stock ATS publishes quotation data in the consolidated data feed. [33] In other words, at the moment, all NMS stock ATSs are operating as "dark pools." ATSs could publish their quotation data to operate as electronic communications networks, or "ECNs."[34] One ATS, IntelligentCross, currently publishes its own data feed of quotations and executions on the ATS.[35]

ATSs offer many different types of services and cater to different trading objectives. Some offer block order[36] crossing networks, others match smaller customer orders with other customers and/or with broker-dealer or bank inventory, and some allow for order matching to be segmented by specific categories of market participants. In many cases, the same market makers that provide liquidity on exchanges also provide liquidity on ATSs. Frequently ATS functionality is intended to mitigate the effect of trading on subsequent prices for an instrument.[37] Some offer unique order types not available on exchanges, such as conditional orders, intended to facilitate the search for larger blocks of liquidity. Many ATSs are operated by multi-service broker-dealers, while some are operated by independent firms or consortiums. A number of ATSs have developed trading models that are alternatives to the more prevalent price-time priority matching engines: for example,

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[33] As noted above, *supra* n. 20, however, trades in these off-exchange venues are publicly reported.

[34] *See* 17 CFR § 600(b)(24); *see also* Concept Release at 3599 ("The key characteristic of an ECN is that it provides its best-priced orders for inclusion in the consolidated quotation data, whether voluntarily or as required by Rule 301(b)(3) of Regulation ATS"). In the past, some ECNs with displayed quotations have, at times, represented a significant amount of market share, and some eventually evolved into registered national securities exchanges (including all four CBOE equities exchanges, IEX, NYSE Arca, Island, Instinet, and BRUT).

[35] *See*, *e.g.*, IntelligentCross Form ATS-N, Item 15 (*filing of* Jan. 16, 2020) (*available at:* https://www.sec.gov/divisions/marketreg/form-ats-n-filings.htm).

[36] Generally speaking, a block order is a particularly large order for a given market, and its precise meaning changes in different contexts. For example, Regulation NMS defines an order of block size as an order of at least 10,000 shares or for a quantity of stock having a market value of at least $200,000. 17 CFR § 242.600(b)(10).

[37] The importance of managing the informational and price impact of order entry and trading activity is described in more detail in the Appendix. *See infra* n. 320 and accompanying text.

one ATS uses machine learning to execute orders at a time intended to minimize subsequent impacts on prices,[38] and others allow for periodic auctions.[39]

3. Broker-Dealer Internalizers

A third major category of venue for equity trading is broker-dealer internalization. Like national securities exchanges and ATSs, internalizers are heavily dependent on sophisticated algorithms to conduct their core functions. As described in more detail below, there are several types of internalization, including wholesale market makers, single-dealer platforms, and central risk book trading and block positioning. Internalized trades of broker-dealers reflect liquidity that is not included in public quotation data.[40] In 2019, approximately 27% of NMS stock share volume was executed by broker-dealer internalizers.[41]

While hundreds of broker-dealers internalize trades, much of this volume is handled by a relatively small number of large firms. Table 5 illustrates this concentration.[42] In 2019,

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[38] *See* Form ATS-N filings and information for IntelligentCross ATS, available at https://www.sec.gov/divisions/marketreg/form-ats-n-filings.htm.

[39] *See* Form ATS-N filings and information for CODA ATS, available at https://www.sec.gov/divisions/marketreg/form-ats-n-filings.htm.

[40] *See*, *e.g.*, Concept Release at 3599.

[41] This figure was calculated by subtracting the percentage of share volume in NMS stocks executed on ATSs from the total percentage of share volume in NMS stocks executed off-exchange, as reflected in NYSE TAQ data and FINRA OTC/ATS Transparency data. *Cf. also* Concept Release at 3599, noting that in September 2009 approximately 17.5% of NMS stock share volume was executed by broker-dealer internalization.

[42] This list should be read as a rough illustration of the distribution of share volume in the non-ATS off-exchange market. This list is derived from the OTC Transparency data FINRA makes available to the public on its website. FINRA's public data reflects firms with the obligation to report each off-exchange trade to a TRF (generally the executing broker-dealer), so only shows the firm involved on one side of each trade. Moreover, trading by broker-dealers that are not registered with FINRA (but that are registered with another SRO) is not reflected in this data, regardless of the volume of such off-exchange trading, because non-FINRA-members never have obligations to act as the reporting party under FINRA's trade reporting rules. *See* FINRA Rule 6110(b). Currently, a list of OATS Reporting Non-FINRA Member firms is available at https://www.finra.org/industry/oats/oats-reporting-non-finra-member-firm-list. Finally, FINRA's data for the period covered here groups all firms executing a number of trades below certain thresholds into a single *de minimis* category (though more recent FINRA data no longer includes a *de minimis*

each of the two largest internalizers executed more share volume off-exchange than was executed in any individual ATS, and more share volume than was executed on each of eight national securities exchanges.[43] Internalizers can be significant sources of liquidity in today's markets.

Table 5: 2019 Top Ten Internalizing Broker-Dealers by Share Volume: Percentage of Internalized Volume, Off-Exchange Volume, and NMS Stock Volume

Firm	% Intern.	% Off-Exch.	% NMS
CITADEL SECURITIES LLC	24.3%	16.7%	6.2%
VIRTU AMERICAS LLC	13.2%	9.0%	3.4%
G1 EXECUTION SERVICES, LLC	6.9%	4.8%	1.8%
TWO SIGMA SECURITIES, LLC	1.5%	1.0%	0.4%
WOLVERINE SECURITIES, LLC	0.7%	0.5%	0.2%
JANE STREET CAPITAL LLC	0.5%	0.4%	0.1%
UBS SECURITIES LLC	0.4%	0.3%	0.1%
VIRTU FINANCIAL BD LLC	0.3%	0.2%	0.1%
GOLDMAN SACHS & CO. LLC	0.3%	0.2%	0.1%
ACS EXECUTION SERVICES, LLC	0.1%	0.0%	0.0%

Source: FINRA OTC/ATS Transparency

B. Market Data

Modern equity markets are connected in part by the data flowing between market centers. An enormous volume of data is available to market participants. In recent years, there has been an exponential growth in the amount of market data that is available, the speed with which it is disseminated, and the computer power used to analyze and react to price movements. As discussed below, for different types of investors and market professionals, the speed with which information can be acquired, analyzed, and acted upon is valued to

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category). *See* FINRA Rule 6110(b); *Order Approving Proposed Rule Change To Expand OTC Equity Trading Volume Data Published on FINRA's Website*, Exch. Act Rel. No. 86706, 84 Fed. Reg. 44341 (Aug. 23, 2019) (change to FINRA rules that would, among other things, eliminate the *de minimis* exception to public disclosures as of December 2, 2019); FINRA Regulatory Notice 19-29 (Sept. 13, 2019). In other words, it is likely that the attributions of volume in this data source understate the volume of some market participants, and omit entirely other market participants.

[43] Both of these broker-dealers offer a range of internalization services, including for both retail and institutional investors, and, as reflected in retail broker order routing public disclosures, are particularly significant internalizers of retail investor trades.

varying degrees. Most equity market participants use, in some respect, quotation data[44] and last-sale transaction data.[45] Market centers and securities information processors (SIPs), described below, also communicate important regulatory and administrative messages, such as when trading in a particular security is unexpectedly halted or paused. Some data feeds carry additional information about market dynamics, such as messages providing updates on order imbalances at regular intervals leading up to the daily closing auction.[46]

This wide range of market data provided to market participants by exchanges is distributed through two broad categories of data feeds: (1) consolidated data feeds, and (2) proprietary data feeds.

The consolidated data feeds are operated by the self-regulatory organizations (SROs) via National Market System (NMS) plans pursuant to Commission regulation and oversight.[47] The consolidated data feeds include top of book quotations, last sale information, and

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[44] Quotation data can include information about both the best available prices at a given market (often called the "top of book") and quotes resting in the order book at prices higher (for sell orders) or lower (for buy orders) (often called "depth of book" data). For some market participants information about the cancellation or modification of individual quotations is also important.

[45] As noted above, the Exchange Act includes a Congressional finding that it is in the public interest and appropriate for the protection of investors and maintenance of fair and orderly markets to assure the availability to brokers, dealers, and investors of information with respect to quotations for and transactions in securities. *See* 15 U.S.C. 78k-1(a)(1)(C)(iii).

[46] Ahead of each auction, each listing exchange gathers market and limit orders to execute in the closing auction. The number of buy and number of sell orders may not align. In order to attract liquidity and potentially improve the quality of the closing auction, listing exchanges disseminate messages providing the side and size of an order imbalance as the auction approaches.

[47] This section describes the currently prevailing structure for the provision of consolidated equity data feeds. In February 2020, the Commission proposed rules that would update and expand the content of NMS market data and that would introduce a decentralized consolidation model under which competing consolidators, rather than the existing exclusive securities information processors, would collect, consolidate, and disseminate certain NMS information. *See Market Data Infrastructure*, Exch. Act Rel. No. 88216, 85 Fed. Reg. 16726 (Mar. 24, 2020) ("Market Data Infrastructure Proposal").

important regulatory messages from exchanges.[48] Currently, there are three equity market data plans: the CQ plan (for quotations in securities not listed on Nasdaq), the CTA plan (for transaction reports in securities not listed on Nasdaq), and the UTP Plan (for both quotation and transaction reports in Nasdaq-listed equities).[49] These plans together are often referred to as the "SIPs."[50]

Proprietary data feeds offer additional and different market information from the SIPs. For example, some proprietary data feeds provide all displayed order messages at an exchange, including individual odd-lot orders, as well as order modifications and cancellations; others may not provide message-by-message data, but summarize the total displayed shares available at each level in the order book; others provide only the top-of-book across an exchange family's related markets; and some offer detailed auction imbalance information. For various reasons, including because they do not need to go through a consolidation process at a separate geographic location, proprietary data feeds often reach market participants sooner than the SIPs.[51]

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[48] Best-priced quotation and last sale data is often referred to as "core data." *See*, *e.g.*, *Order Setting Aside Action by Delegated Authority and Approving Proposed Rule Change Relating to NYSE Arca Data*, Exch. Act. Rel. No. 59039, 73 Fed. Reg. 74770, 74779 (Dec. 9, 2008) ("Core data is the best-priced quotations and comprehensive last sale reports of all markets that the Commission, pursuant to Rule 603(b), requires a central processor to consolidate and distribute to the public pursuant to joint-SRO plans"); *Order Directing the Exchanges and the Financial Industry Regulatory Authority to Submit a New National Market System Plan Regarding Consolidated Equity Market Data*, Exch. Act Rel. No. 88827, 85 Fed. Reg. 28702, 28703 (May 13, 2020) ("SIP Governance Order") (noting that "core data" consists of "(1) The price, size, and exchange of the last sale; (2) each exchange's current highest bid and lowest offer, and the shares available at those prices; and (3) the national best bid and offer (''NBBO'') (i.e., the highest bid and lowest offer currently available on any exchange)").

[49] In May 2020, the Commission issued an order requiring the national securities exchanges and FINRA to consolidate the three current equity market data plans into a new single equity market data plan and to implement specific governance provisions within that plan. *See* SIP Governance Order. Certain SROs have petitioned for review of this order in the D.C. Circuit.

[50] "SIP" is an acronym for "securities information processor," which is defined in Exchange Act Section 3(a)(22)(A), 15 U.S.C. 78c(a)(22)(A); *see also* Exchange Act Section 11A(b), 15 U.S.C. 78k-1(b).

[51] However, data distributed over the consolidated feeds cannot be transmitted by proprietary feed to a vendor or user any sooner than it is transmitted to a consolidated data processor. *See* 17 CFR 603(a); *Regulation NMS*, Exch. Act Rel. No. 51808, 70 Fed. Reg. 37495, 37567 (June 25, 2005) ("Reg NMS Adopting Release") ("adopted rule 603(a)

Equity market data is physically disseminated and moved between data centers in a range of ways, including by fiber-optic cable and wirelessly via microwave towers. Moreover, the data can be physically accessed in a variety of ways, including through servers co-located in an exchange's data center, ports and wires with various capacities and bandwidths, as well as through hardware that can process data directly, rather than relying on the often slower process of using software to process the data following receipt. The methods used to physically access and process data affect the speed and efficiency with which market participants are able to transact in the markets.[52]

The availability of different levels of market data and different access speeds to both markets and market data can advantage some market participants over others. For example, by accessing more granular data from proprietary market data feeds at higher speed, some users may be able to react to market events more strategically and more quickly than participants relying only on SIP data.[53] Similarly, brokers and other market participants using advanced connectivity tools, such as microwave data transmissions and high-bandwidth connections, can process data and enter orders more rapidly than other market participants, particularly during periods of high volume when message traffic, and therefore network latency, may be at its highest.

These market data considerations—including differing levels of both content and speed of access—extend beyond the cash equity markets. Many market participants make trading decisions and control risk using information from trading venues for other types of instruments. Accordingly, market data from those trading venues can be very important to

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prohibits an SRO or broker-dealer from transmitting data to a vendor or user any sooner than it transmits the data to a Network processor"). For additional discussion of differences between the current consolidated data feeds and proprietary feeds, *see*, *e.g.*, Market Data Infrastructure Proposal at 20-25.

[52] For example, "co-location is a service that enables exchange customers to place their servers in close proximity to an exchange's matching engine in order to help minimize network and other types of latencies between the matching engine of the exchange and the servers of market participants." *Notice of Proposed Order Directing the Exchanges and the Financial Industry Regulatory Authority to Submit a New National Market System Plan Regarding Consolidated Equity Market Data*, Exch. Act Rel. No. 87906, 85 Fed. Reg. 2164, 2169 n.55 (Jan. 14, 2020) ("SIP Governance Proposed Order"). Similarly, "[d]ata connections that use fiber optic cable transmit data more slowly than data connections that use wireless microwave transmissions, though microwave connections are susceptible to interruption by weather conditions and are therefore less reliable than fiber connections." *Id.*

[53] *See*, *e.g.*, SIP Governance Proposed Order at 2169-70 (discussing potential implications for competitiveness between the consolidated data feeds and exchange proprietary feeds).

the algorithmic trading strategies of equity market participants. Common examples of this cross-market data use include access to options market data and futures market data.[54]

III. Overview of Debt Market Structure

Cash debt markets have historically operated as over-the-counter principal markets, in which participants trade for their own accounts. Historically, the market operated largely by "voice," with trades negotiated and effected bilaterally between counterparties. In the last several decades, a range of dealers and platforms have implemented several models of electronic trading. Some of these models have automated aspects of the bilateral communication and trading process, while others have provided alternative trading models such as central limit order books. The development of automated tools and platforms has differed across the Treasury, corporate, and municipal bond markets, reflecting significant underlying differences in the terms of these instruments and the structure of the markets in which they trade.

A. Types of Debt Securities or Instruments

Unlike equity securities, debt securities are not standardized, even by issuer. A given issuer might have tens, hundreds, or more than a thousand different types or "series" of debt securities outstanding, each with a different notional value, maturity date, and interest rate. When a particular issuer has multiple series of bonds outstanding, secondary market liquidity is generally concentrated in the more recently-issued bonds (and, among the more recently-issued bonds, in the series with the greater amount outstanding).

1. U.S. Treasury Securities

The market for U.S. Treasury securities is the deepest and most liquid government securities market in the world.[55] The U.S. Treasury issues bills, nominal fixed-rate coupon securities, nominal floating rate securities, and inflation-indexed securities (TIPS). Most secondary trading in Treasuries occurs across the most-recently issued (or, "on-the-run") nominal coupon securities.[56]

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[54] For example, in the futures market, the E-Mini S&P 500 Futures contract traded on the CME is often regarded as a central focal point for price formation in the equities market. *See*, *e.g.*, Joel Hasbrouck, "Intraday Price Formation in U.S. Equity Index Markets," 58 *Journal of Finance* 58: 2375-2399 (Dec. 2003).

[55] *See*, *e.g.*, *Joint Staff Report: The U.S. Treasury Market on October 15, 2014*, at 1 (July 13, 2015) ("Treasury Market Report").

[56] *Id.* at 11.

Treasury securities are traded on multiple venues.[57] Interdealer trading of on-the-run Treasury securities occurs mainly on centralized electronic trading platforms using a central limit order book. These venues are the primary points of price discovery for the on-the-run securities. This market has evolved considerably over the past decade. Where participation on interdealer platforms was once limited to primary dealers, principal trading firms now account for more than half of the trading activity in the electronic interdealer markets.[58] Dealer-to-customer trading, in both on-the-run and off-the-run securities, is usually bilateral, either through voice or through an electronic platform, using for example, a request-for-quote (RFQ) process or streaming quotes.[59] Some dealers and electronic market makers now provide their customers with a direct stream of continuous prices and sizes at which they are willing to trade in a range of issues.[60] With price discovery increasingly occurring in electronic order books, trading in off-the-run securities occurs primarily through voice channels.[61]

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[57] *Id.*

[58] *See*, *e.g.*, *id.* at 36. More specifically, the Report notes that 56% of the volume in the on-the-run 10-year note is handled by principal trading firms, with about 35% handled by bank-dealers, and the remaining 9% being split among non-bank dealers, hedge funds, and asset managers. More recent data show that, as of 2019, "PTFs account for around 60 percent of electronic IDB volumes." *See Remarks of Deputy Secretary Justin Muzinich at the 2019 U.S. Treasury Market Structure Conference*, Sept. 23, 2019 (*available at:* https://home.treasury.gov/news/press-releases/sm782).

[59] *Id.* at 11.

[60] *See*, *e.g.*, Kevin McPartland, *U.S. Treasury Trading No Longer a Divided Market*, Greenwich Associates (Dec. 12, 2018); Kevin McPartland*, How Bilateral Streams for U.S. Treasuries Really Work, And What They Mean for the Market*, Greenwich Associates (June 18, 2019), *available at:* https://www.greenwich.com/blog/how-bilateral-streams-us-treasuries-really-work.

[61] Treasury Market Report at 35. Recently, non-central limit order book electronic platforms, such as OpenDoor Trading, have begun providing electronic venues for trading in off-the-run Treasuries and TIPS. *See*, *e.g.*, John McCrank, *OpenDoor opens up trading in illiquid U.S. Treasuries,* Reuters (June 14, 2017), *available at:* https://www.reuters.com/article/us-usa-treasuries-opendoor-idUSKBN1952DN.

2. Corporate Bonds

Corporate bond trading predominantly occurs over voice. Much of this voice activity is concentrated in the largest dealers—for example, one recent study estimates that 56% of buy-side volume in U.S. investment-grade corporate bonds is with the five largest dealers.[62]

In the past decade, a number of venues have developed to trade corporate bonds electronically. A recent estimate is that 26% of corporate bond volume was traded electronically in the third quarter of 2018.[63] As described more fully below, much of this activity can be described as the automation of bilateral voice trading or RFQ trading. All-to-all trading, in which any participant can provide quotes to and trade with any other participant, is increasingly a meaningful proportion of the electronic corporate bond market; for example, approximately 8% of volume in investment grade corporate bond may be executed on all-to-all platforms.[64] Roughly 70% of corporate bond trades are for fewer than one hundred bonds, and 90% of these small trades are effected electronically; however, these small trades represent approximately 3-4% of the total value of corporate bonds traded on any given day.[65] The electronic trading venues are regulated in a range of ways, with some as ATSs, some as broker-dealers, and others outside of either of those two regulatory structures.[66] One national securities exchange, NYSE, provides the capability to trade corporate bonds.

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[62] Kevin McPartland, *Corporate Bond Trading in 2019: Competition is Good, Complexity is Not*, Greenwich Associates, p. 5 (Jan. 8, 2019).

[63] *Id.* at 2, 4.

[64] *Id.* at 8

[65] Kevin McPartland, "The Challenge of Trading Corporate Bonds Electronically," 1, Greenwich Associates (May 13, 2019) *available at:* https://www.greenwich.com/blog/challenge-trading-corporate-bonds-electronically.

[66] *See*, *e.g.* FIMSAC Electronic Trading Subcommittee Recommendation on Oversight of Electronic Trading Platforms for Corporate and Municipal Bonds (July 16, 2018). For a more detailed discussion of quoting and trading on a recent sample of corporate bond activity on ATSs, *see* Staff of the Division of Economic and Risk Analysis of the U.S. Securities and Trading Commission, *Access to Capital and Market Liquidity*, pp. 178-90 (Aug. 8, 2017) ("DERA Bond Study"), a*vailable at:* https://www.sec.gov/files/access-to-capital-and-market-liquidity-study-2017.pdf

Average daily volume traded in corporate bonds has grown from a recent low of $14.3 billion in 2008 to $31.2 billion in 2018.[67] Over the same period, the amount of corporate debt issued annually grew from approximately $717 billion in 2008 (from 946 new issues) to more than $1.3 trillion in 2018 (from 1,270 new issues) with a high of more than $1.65 trillion in 2017 (in 1,671 new issues).[68] As discussed above, most corporate bond trading is concentrated in new issues, so the increase in ADV may be related to the increase in corporate bond issuance.[69]

Generally, corporate bonds are held by investors, with trades facilitated by broker-dealers and other intermediaries. Demand for intermediation is driven by various factors, including the general difficulty of finding natural counterparties for specific bonds due to the idiosyncratic nature of different series of bonds.[70] This intermediation requires capital, which, at least at the dealer level, has been relatively more limited since the credit crisis ten years ago.[71] Technology has helped mitigate the drop in dealer liquidity, and other types of liquidity providers have entered the corporate debt markets. The trading of corporate bond ETFs, in particular, has introduced new liquidity suppliers, including those who may not be able to meet the capital requirements imposed on large dealers, including principal trading firms and quantitative hedge funds.[72]

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[67] Capital Markets Fact Book 2019, 20, SIFMA, *available at:* https://www.sifma.org/resources/research/fact-book/.

[68] *Id.* at 7-8.

[69] *See* McPartland, *Corporate Bond Trading in 2019* at 3.

[70] McPartland, *The Challenge of Trading Corporate Bonds Electronically*, at p. 2.

[71] *See*, *e.g.*, Tobias Adrian, Nina Boyarchenko, & Or Shachar, "Dealer Balance Sheets and Bond Liquidity Provision," Federal Reserve Bank of New York Staff Report No. 803 (Mar. 2017). For a more detailed discussion of research on recent trends in corporate bond market liquidity and potential relationships to regulatory changes, *see* DERA Bond Study at 109-119.

[72] McPartland, *Corporate Bond Trading in 2019* at 5. For a more detailed discussion of studies on the evolution of electronic trading in corporate bond markets, *see* DERA Bond Study at 119-123.

3. Municipal Bonds

Municipal bond investors predominantly hold municipal securities for the long-term,[73] and a significant percentage of municipal bonds are held by retail investors.[74] Trading in municipal bonds is concentrated in the period after issuance, and becomes infrequent afterwards.[75] Of the approximately one million outstanding series of municipal securities, on average slightly more than one percent trade on any given day.[76]

Municipal bonds are predominantly traded over-the-counter by voice, either between dealers and customers or between dealers.[77] The market is fragmented, given, among other things, the number of unique municipal securities, the number of issuers, and low trading volume for most bonds.[78] Largely because of their tax treatment, shorting of municipal bonds is difficult and rare.[79] In recent years, several platforms have developed that facilitate the electronic trading of municipal bonds. Several of these are ATSs. One

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[73] Simon Z. Wu, John Bagley & Marcelo Vieira, Staff of the Municipal Securities Rulemaking Board, *Analysis of Municipal Securities Pre-Trade Data from Alternative Trading Systems*, at 4 (Oct. 2018), *available at:* http://www.msrb.org/~/media/Files/Resources/Analysis-of-Municipal-Securities-Pre-Trade-Data.ashx?la=en ("MSRB ATS Study").

[74] *See*, *e.g.*, Municipal Securities Rulemaking Board, "Muni Facts," (Mar. 2019), *available at:* http://www.msrb.org/msrb1/pdfs/MSRB-Muni-Facts.pdf (noting that nearly two-thirds of municipal securities are held by individual investors either directly or through mutual funds).

[75] *Id.*

[76] *Id.*; 2018 Fact Book, 34, Municipal Securities Rulemaking Board, *available at:* http://www.msrb.org/Market-Transparency/Market-Data-Publications/MSRB-Fact-Book.aspx (average of 15,588 unique securities traded per day in 2018).

[77] MSRB ATS Study at 4.

[78] *Id.*

[79] The interest on most municipal securities is exempt from federal income tax and, in some cases, state and local taxes. The Internal Revenue Service does not allow both the borrower and lender of a municipal security to claim a tax exemption, so in effect the lender of a municipal security would be trading tax-exempt interest for taxable interest. *See* Exch. Act Rel. No. 34-33743 (Mar. 9, 1994), 59 FR 12767, 12769 n.24 (Mar. 17, 1994) *citing* Internal Revenue Code, Sec. 6045(d); *see also* FINRA Notice 15-27 (July 2015).

recent study estimates that 12-15% of municipal bond trading is electronic.[80] While some municipal bond ETFs exist, they are still a relatively small, but growing, proportion of fixed income ETFs.[81]

Among fixed income securities, municipal bonds have a uniquely high percentage of direct retail investors. For example, one recent study estimates that retail investors directly hold 42% of municipal bonds by value, compared to 13% of Treasuries and 8% of corporate bonds.[82] Retail investors may purchase municipal bonds through broker-dealers or investment advisers, who in turn source liquidity from banks or nonbank dealers and other liquidity providers.[83] The high volume of retail participation results in a large number of small trades, which may make aspects of the municipal bond market suited to electronic trading.[84]

B. Data and Communications

In debt markets, market data collection and distribution is uneven and fragmented. Pre-trade transparency information on quotes or pricing generally can only be purchased from individual platforms or arranged through bilateral relationships. Post-trade transparency, in the form of transaction reports, generally is available for corporate and municipal bonds.

1. Transaction Reports in Corporate Bonds: TRACE

Transactions in corporate bonds must be reported to the Trade Reporting and Compliance Engine (TRACE) operated by FINRA.[85] TRACE data is disseminated by FINRA immediately

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80 Kevin McPartland, *The Modernization of Municipal Bond Trading*, 2, Greenwich Associates (May 6, 2019).

81 *See id.* at 5, estimating that municipal bonds make up approximately 6% of fixed income ETF assets under management; *see also* Simon Z. Wu and Meghan Burns, Staff of the Municipal Securities Rulemaking Board, *Municipal Bond ETFs: Impact on the Municipal Bond Market*, at 5-6 (Apr. 2018), *available at:* http://www.msrb.org/~/media/Files/Resources/MSRB-Municipal-Bond-ETFs-Report.ashx.

82 McPartland, *The Modernization of Municipal Bond Trading*, at 3.

83 *Id.* at 5.

84 *Id.* at 7.

85 *See* FINRA Rule 6730.

upon receipt.[86] Each FINRA member that is party to a transaction in a TRACE-eligible security must report the trade as soon as practicable, but generally no later than within fifteen minutes of the execution of the trade.[87] Detailed data is available through subscription data feeds, and the FINRA website makes available for free aggregate statistics and details about individual trades, bonds, and issuers. The transaction data disseminated by FINRA includes, among other things, the issuer, CUSIP number for the bond, the entity type of the reporting and contra parties,[88] execution time, quantity, price, side (buy or sell), size,[89] and whether the trade was executed on an ATS.

FINRA has proposed publishing aggregate trade count and volume statistics for each corporate bond ATS, by CUSIP.[90] The stated purpose of this proposal is to provide the market with more readily available information about potential sources of liquidity. FINRA currently makes similar data available for equity ATSs.

2. Transaction Reports in Municipal Bonds: EMMA

Transactions in municipal bonds must be reported to the Municipal Securities Rulemaking Board's (MSRB) Real-time Transaction Reporting System (RTRS).[91] The MSRB disseminates the data upon receipt through subscription data feeds, and the MSRB's

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[86] Following a recommendation by the Commission's Fixed Income Market Structure Advisory Committee, FINRA has proposed a pilot program to study potential changes to corporate block trade dissemination. *See* FINRA Notice 19-12 (Apr. 12, 2019). Under the proposed pilot, the cap for disclosing the exact size of a trade would be raised to $10 million for investment-grade corporate bonds and to $5 million for non-investment grade, and delay by 48 hours dissemination of reports for trades above those caps.

[87] *See* FINRA Rule 6730(a).

[88] These entity types can be broker-dealer, customer, non-member affiliate, and alternative trading system. Six months after a trade, the FINRA-member parties to each trade are identified.

[89] For trades in investment grade bonds up to $5 million, the exact size of the trade is disseminated, but for trades above $5 million, the trade size is listed as "5MM+"; the analogous cap for non-investment-grade corporate bonds is $1 million. After six months, the exact size of capped reports is revealed. These rules mean that, for example, for several months, a $6 million dollar trade and a $100 million trade in an investment grade bond would both be reported as "5MM+".

[90] *See* FINRA Notice 19-22 (July 9, 2019).

[91] Reports can be sent either directly to the MSRB or through the NSCC. *See* MSRB Rule G-14 RTRS Procedures(a)(i). Most trades must be reported within fifteen minutes. *See* MSRB Rule G-14 RTS Procedures(a).

Electronic Municipal Market Access (EMMA) website makes available the trade data together with free aggregate statistics about individual trades, bonds, and issuers. The transaction data disseminated includes, among other things, the issuer, CUSIP number of the bond, trade date and time, price, size, trade type (*i.e.*, inter-dealer or dealer-customer), and whether the trade was executed on an ATS.

IV. Benefits and Risks of Algorithmic Trading in Equities

As described above, the current markets for secondary trading in NMS stocks are predominantly electronic. While some pockets of activity can be described as manual, most of the lifecycle of trading is automated. Algorithms now facilitate the provision of and search for liquidity by a broad range of participants in the equities market across a diverse set of trading venues. This pervasive automation has also created new operational risks for firms and the market infrastructure more generally. Broadly speaking, studies have shown that algorithmic trading in equities has improved many measures of market quality and liquidity provision during normal market conditions, though other studies have also shown that some types of algorithmic trading may exacerbate periods of unusual market stress or volatility.

A. Investors

For many investors, both retail and institutional, algorithms play a significant role in the investment and trading process. While investor orders are generally routed and executed through broker algorithms of various types, the ability to use routing and execution algorithms directly is also becoming more accessible to investors, as are the data feeds and processing tools that are essential to the use of algorithms. Some investors, both retail and institutional, also use algorithms to actively make investment and trading decisions through the rapid analysis of potentially voluminous amounts of market data. In other cases, investors track an outside reference, such as an index, and investment and trading decisions may be informed by algorithmically-determined decisions about composition implicit in a benchmark index or other standard or set of rules.[92]

[92] This may be the case for some index mutual funds and ETFs, and investors holding ETNs may have a similar investment experience.

1. Retail Investors

As has been the case for many years,[93] retail brokers largely route marketable retail investor orders (*i.e.*, orders that can be executed immediately) to internalizing broker-dealers known as "wholesale" market makers for execution.[94] Wholesale market-makers can frequently provide retail orders with some degree of price improvement, meaning they can execute the orders inside the spread of the national best bid and national best offer.[95] Wholesale market-makers may also be able to provide retail orders with size improvement (*i.e.*, more shares at a single price point than may be available at the national best bid or national best offer quoted on national securities exchanges). Some retail brokers receive payment for order flow in exchange for routing orders to these market-makers.[96] Wholesale market makers are willing to provide price improvement to retail investors and purchase order flow from brokers because access to the orders provides wholesalers, who

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[93] *See*, *e.g.*, Concept Release at 3600 ("OTC market makers, for example, appear to handle a very large percentage of marketable (immediately executable) order flow of individual investors that is routed by retail brokerage firms").

[94] *See*, *e.g.*, CFA Institute, *Dark Pools, Internalization, and Equity Market Quality*, at 16 (2012) ("Internalization is also thought to account for almost 100% of retail marketable order flow").

[95] In recent years, several firms, coordinated by the Financial Information Forum, have voluntarily disclosed retail execution quality statistics that include information on the average percentage of retail orders given price improvement and the average price improvement on each order. *See*, *e.g.* https://fif.com/tools/retail-execution-quality-statistics. These summary statistics are distinct from the disclosures required by SEC Rule 605. A staff review of these voluntary statistics from several retail brokers and wholesale market-makers for Q1 of 2019 indicates that some wholesale market-makers provide price improvement to more than approximately 85% of retail orders from a range of order sizes. In some cases, such as for smaller orders in more frequently-traded stocks, on average more than 95% of retail orders received price improvement. The monthly disclosures required by SEC Rule 605 also include information about each market center's price improvement, but do not specifically break out statistics for retail orders. Because wholesale market-makers do not engage in quoting activity as part of their internalization activities, they can execute trades at prices more granular than the one-penny increment required for quotes in most equity securities.

[96] For a more thorough description of payment for order flow practices, their historical development and regulation, and some potential concerns about the practice, *see* Staff of the Division of Trading and Markets, U.S. Securities & Exchange Commission, *Memorandum to Equity Market Structure Advisory Committee on Certain Issues Affecting Customers in the Current Equity Market Structure*, 5-11 (Jan. 26, 2016).

generally have more information and processing power than retail traders and brokers, with a relatively low risk of adverse selection[97] and a potential opportunity to profit from the informational content in aggregate retail order flow. For example, because wholesale market-makers are allowed to choose whether to execute any given order based on their own preferences and views of market conditions, they may, for example, trade against incoming retail orders or route relatively risky or unfavorable orders to exchanges or other market centers.[98]

This discussion demonstrates the significant extent to which fast, effective processing of market data is central to the business of wholesale market-making in the cash equity markets: the market maker algorithm's data-driven assessment of the market is not only central to its obligations with respect to best execution and compliance with the order protection rule, but allows it to make order-handling decisions, and provides the standards for evaluating price improvement. Wholesale market-makers also, over the long term, acquire voluminous amounts of market data, including information about retail order flows, which can be used in future modeling for order-handling, trading, and risk decisions.

Some specialized retail brokers allow individual retail customers to use more sophisticated broker algorithms that operate in a manner that is generally otherwise available only to institutional investors as described below, or allow retail customers to use their own algorithms. These specialized retail brokers typically operate on a smaller scale than the retail brokers described above, and may not rely as heavily on wholesaler market-makers as more traditional retail brokers.

2. Institutional Investors

The broad category of "institutional investors" encompasses a diverse range of market participants.[99] This category includes, among others, registered investment companies, pension funds, insurance companies, endowments, and private investment funds such as hedge funds, all of which employ a wide variety of trading strategies. While their needs and approaches to trading vary, they generally share a common focus on achieving high execution quality, which requires them to effectively manage the explicit and implicit costs of trading. The diversity of approaches to trading among institutions is reflected in the

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[97] *Id.* at 6; *see also* Concept Release at 3612 ("Liquidity providers generally consider the orders of individual investors very attractive to trade with because such investors are presumed on average to not be as informed about short-term price movements as are professional traders").

[98] A broker serving retail customers may also operate an affiliated alternative trading system to which the retail orders may be routed.

[99] *See infra* Section X.A for additional detail on the composition of this category of investors.

range of ways that they may use algorithms to (1) decide what to trade, (2) manage trade execution and (3) assess trading performance.

A number of institutional entities, such as mutual funds, track indices, and others may invest in products, such as ETFs, that do so, and, as a result, they generally trade in response to market movements and other factors with the objective of keeping their underlying investments in line with a benchmark index.[100] Similarly, some institutions may have targeted or fixed-weight proportions of equities within their investment portfolios, and so trade into or out of positions when market changes cause a portfolio to deviate too far from this target. For these institutions and investments, the decision algorithms built into their products or strategies affect which instruments to trade and when.

Index-oriented trading is not the only form of algorithmic trading that is driven by market movements. For example, some systematic institutional equity trading is algorithmically connected to other asset classes or indicators. This type of linkage is present in, for example, index option delta and gamma[101] hedging strategies. These strategies generally drive increased selling in equities markets when measures of volatility (such as the VIX) increase. Systematic volatility targeting and risk-parity strategies may similarly adjust their portfolio holdings depending on movements in some measure of volatility.[102] Volatility-oriented strategies may have a momentum effect on stock prices: because volatility often rises with declining prices, strategies that drive increased selling of equities

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[100] Such trading is pronounced and apparent on days when commonly-used benchmark indices are rebalanced.

[101] In options trading, "delta" measures the amount the cost of an option is expected to change given a change in the cost of the underlying asset. Delta is a proportion between 0 and 1, or 0 and -1, depending on whether the option is a long or short put or call. For example, the cost of an option with a delta of .50 would be expected to move $0.50 for every $1 price change in the underlying stock. "Gamma" is an estimate of how much an option's *delta* is expected to change given a change in the cost of the underlying asset. Gamma is a proportion between 0 and 1 for long options, or, for short options, 0 and -1. To extend the previous example, if an option has a delta of .50 and a gamma of .15, with a one dollar increase in the cost of the underlying stock, the cost of the option will increase by $0.50, and the option's delta will increase from .50 to .65. For a more thorough summary introduction, *see*, *e.g.*, the "Advanced Concepts" section at https://www.optionseducation.org/.

[102] Generally speaking, volatility targeting strategies increase or decrease leverage in a portfolio as volatility moves above or below a target level. In risk-parity strategies, a portfolio is determined by the proportion of risk contributed to the portfolio by each asset, rather than by the proportion of capital allocated to each asset.

as volatility rises may, at least in the near term, further contribute to or exacerbate price declines.[103]

Institutional investors use a variety of approaches when executing trades. Some firms have their own trader or traders who implement investment decisions made by portfolio managers. At long-only mutual funds, for example, institutional traders typically utilize algorithms provided to them by brokers, although some create their own algorithms that determine when, where and how to execute an order, and then use brokers to execute orders in the marketplace. Other institutional firms may not have a dedicated trading staff but may employ professionals who create, analyze and execute algorithmic trading models. At firms where trading is highly automated, trading staff may perform a more monitor-like function, ensuring that systems are operating properly, and that trading is occurring as intended and within risk limits. Some institutional investors may design and operate their own trading algorithms, while others may purchase firm-specific algorithmic trading services from third parties. The technical expertise, infrastructure, and resources required to design and manage algorithmic trading systems directly may be outside the abilities of many institutional investors, or they may prefer to outsource trade execution (as well as other aspects of their investment strategy) to other market participants. Notably, some technology providers are beginning to offer predictive analytics products that operate on real-time market data and incorporate machine learning. These types of products potentially could provide a more generally available tool that is analogous to and competitive with the low-latency data access, processing, and execution tools used by some of the fastest market participants.[104]

Institutions that do not create their own algorithms generally use algorithms provided to them by institutional brokers. Over the past decade, the "manual handling of institutional orders is increasingly rare, and has been replaced by sophisticated institutional order execution algorithms and smart order routing systems."[105] Institutional firms may send a single large "parent" order to a broker that will generally divide it into many smaller "child" orders to be executed in the market. Institutions may also send several larger orders to multiple brokers for similar treatment. In some cases, institutional investors may also send orders directly to specific broker algorithms or suites of algorithms.[106] An institutional firm may have a core group of brokers used in most securities or market conditions, but

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[103] *See*, *e.g.*, Campbell R. Harvey *et al.*, *The Impact of Volatility Targeting*, J. Portfolio Mgmt, 14, 30-31 (Vol. 45, Fall 2018).

[104] *See*, *e.g.*, the "Signum" product offered by Exegy (https://www.exegy-signum.com).

[105] *Disclosure of Order Handling Information*, Exch. Act Rel. No. 78309, 81 Fed. Reg. 49432, 49436 (July 27, 2016) ("Order Handling Proposing Release").

[106] Institutional broker algorithms are more fully described below.

generally will be able to call on a larger pool of specialized brokers. However, use of broker algorithms appears to be highly concentrated; for example, one recent study estimates that approximately two-thirds of institutional order flow is sent through the three largest broker algorithm suites.[107]

Institutional firms are focused on costs of trading, with such costs being characterized as "explicit" and "implicit."[108] Because institutions generally trade in substantial size, both explicit transaction costs—*e.g.*, commissions paid to brokers—and implicit costs—*e.g.*, information leakage and resulting adverse market impact—can be significant. However, the broker routing and execution process can often be opaque to institutional investors.[109] For example, an institutional investor may not know the number or identity of venues to which its orders have been routed, whether and how extensively a broker employs actionable indications of interest, or whether there are compensation arrangements between brokers and market centers that may affect broker routing decisions. Institutional investors generally conduct, either on their own or through a third-party provider, transaction cost analysis in order to assess the quality of executions received from different brokers, different algorithms, or in different market centers. The availability of data is central to this cost assessment process, as is the capacity to effectively analyze it and incorporate the results into future execution decisions. As described in more detail below, the Commission recently took steps to improve the scope and consistency of data available to investors about broker order handling.[110]

Increasingly, institutional firms route to brokers and assess their performance using a tool called an "algo wheel."[111] An algo wheel, which can be operated by an investor or provided by a third-party, connects investors into multiple broker algorithm offerings, and chooses brokers and individual algorithms based on specified constraints or preferences. An algo wheel allows a firm to closely track the performance of broker algorithms under different market conditions, and can enable a firm to switch between different brokers without input from a human trader. One recent study estimates that about a quarter of institutional "buy-

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[107] Richard Johnson, *Trends in Global Equity Electronic Execution*, 7, Greenwich Associates (Apr. 23, 2019).

[108] *See*, *e.g.*, 81 Fed. Reg. at 49436 ("Institutional customers have long focused on the execution quality of their large orders, and the potential impacts from information leakage and conflicts of interest faced by their broker-dealers").

[109] *Id.*

[110] *See Disclosure of Order Handling Information*, 83 Fed. Reg. 58338 (Nov. 19, 2018) ("Order Handling Adopting Release"). *See also* Order Handling Proposing Release for additional background on institutional order routing practices.

[111] *See*, *e.g.*, Johnson, *Trends in Global Equity Execution*, at 5-7.

side" investors use algo-wheels,[112] while another recent study estimates about 14% of such investors use algo wheels.[113] Much of the performance measurement built into algo wheels is associated with transaction cost analysis, but algo wheels can also inform the evaluation of best execution, since they can facilitate assessments of which brokers route most effectively under different circumstances.[114]

B. Brokers

Brokers are tasked by their customers with finding liquidity in a complex, fragmented market, achieving best execution, and minimizing information leakage and other implicit costs. To try to meet these goals, brokers use, and offer to their customers, a wide range of execution algorithms.

While brokers tend to offer a large suite of algorithms, many of the core types of algorithms are more or less similar across brokers. For example, many brokers offer algorithms that provide their customers with a volume-weighted average price (VWAP), a time-weighted average price (TWAP), a minimum implementation shortfall (*i.e.*, minimizing the total costs of trading relative to the market price at the time a trading decision is made), or trading at a specified percentage of market volume (PVOL or POV). Broker algorithms may seek to take liquidity resting at trading venues, to provide liquidity at venues, or some combination of the two.[115] Broker algorithms take into consideration the diversity of venues available, including exchanges, ATSs, single dealer platforms, and central risk books. Moreover, algorithms account for the increasingly wide and complex range of order types available at venues such as exchanges and ATSs, which may have different effects on how orders are handled.

Brokers generally allow some degree of customization for their algorithms to suit customer needs. However, at some firms this process can be highly manual, and so may be available

[112] *Id.* at 6.

[113] Campbell Peters, "Technology and the Buy-Side Liquidity Chase", TabbFORUM (July 19, 2019).

[114] *Id.* at 7; *see also* Larry Tabb, *Algo Wheels: Best Execution, Workflow Solution, or Both?*, TabbFORUM (Oct. 15, 2019).

[115] *See*, *e.g*, Order Handling Proposing Release at 49436.

only to large customers.[116] Improvements in software used in the customization process may make precise customization more widely available.[117]

In searching for liquidity, many brokers turn initially to off-exchange venues. In some cases, this may include in-house sources of liquidity, such as alternative trading systems, single-dealer platforms, or central risk books operated by the broker or an affiliate.[118] Some studies have raised questions, however, about whether execution quality may suffer when brokers prefer their own or an affiliated ATS.[119]

An increasingly common tool used across multiple dark pools, particularly for large block size orders, is the so-called "conditional order." Conditional orders allow investors to algorithmically search for liquidity in multiple venues simultaneously, but require the user of a conditional order to affirmatively execute the order or begin negotiations for a trade when a response is received.[120] This additional step can allow a search for liquidity to minimize risks of being executed in a size or on other terms that are different than anticipated or desired, but also may create risks of information leakage.[121]

C. Principal Trading

Equities markets have long included firms trading their own principal acting as market intermediaries, transferring risk between other market participants and attempting to profit directly from this intermediation. On exchanges, historically such participants included, for example, specialists, registered market makers, and floor traders;[122] off

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[116] Larry Tabb, *Fragmentation vs. Liquidity: Can Technology Resolve the Debate?*, TabbFORUM (Aug. 4, 2019), *available at:* https://tabbforum.com/opinions/fragmentation-vs-liquidity-can-technology-resolve-the-debate/.

[117] *Id.*

[118] Single dealer platforms and central risk books are described more fully below.

[119] Amber Anand, Mehrdad Samadi, Jonathan Sokobin, & Kumar Ventkataraman, FINRA Office of the Chief Economist, *Institutional Order Handling and Broker-Affiliated Trading Venues* (Feb. 22, 2019), *available at:* https://www.finra.org/sites/default/files/OCE_WP_jan2019.pdf.

[120] Campbell Peters, *Conditional Orders: The Great Liquidity Aggregator*, TabbFORUM (May 30, 2019).

[121] Tabb, "Fragmentation vs. Liquidity: Can Technology Resolve the Debate?"

[122] *See*, *e.g.*, *Stock Exchange Practices*, Senate Report No. 1455, 73rd Congress 2d Session (June 16, 1934).

exchanges, OTC market making and block positioning were often performed by large investment banks and the broker-dealer affiliates of large banks.[123] In modern electronic equity markets, much of this activity is handled by a range of technologically and quantitatively sophisticated firms trading as principal, who rely on algorithms in many aspects of their business in order to trade competitively.

1. High Frequency Trading

For more than ten years, most activity in the U.S. equity markets has been conducted by professional traders using short-term strategies that place a high number of orders, and generate a large number of trades, on a daily basis.[124] This activity has commonly been called high frequency trading, or "HFT," though there is no statutory or regulatory definition of this term.[125] The 2010 Concept Release noted five characteristics typical of principal trading firms engaged in HFT:

1. The use of extraordinarily high-speed and sophisticated computer programs for generating, routing, and executing orders;
2. Use of co-location services and individual data feeds offered by exchanges and others to minimize network and other types of latencies;
3. Very short time-frames for establishing and liquidating positions;
4. The submission of numerous orders that are cancelled shortly after submission; and
5. Ending the trading day in as close to a flat position as possible (that is, not carrying significant, unhedged positions overnight).[126]

Not all of these characteristics must be present for a firm to properly be described as engaging in HFT.[127] Broadly speaking, it is essential for firms engaged in these strategies to have the information technology infrastructure and computational sophistication to quickly and accurately process massive volumes of data from a wide range of sources, implement trading and risk decisions based on that data, and quickly enter orders based on those decisions before identified trading opportunities pass. To engage in high frequency trading, nearly all aspects of trading must be implemented algorithmically.

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[123] *See*, *e.g.* Larry Tabb, *The Future of Liquidity: Risk Transformation*, TabbFORUM (July 22, 2019).

[124] *See*, *e.g.*, Concept Release at 3606.

[125] Traders using these strategies may also be organized in a variety of ways, including as market-making desks within multi-service broker-dealers or as hedge funds. *Id.*

[126] *Id.*

[127] *See* HFT Literature Review at 4.

High frequency trading is not a singular, monolithic type of activity.[128] It includes a range of strategies, which, as described more fully below, may have different effects on market quality, particularly under different types of market conditions. The distinction between strategies that primarily provide liquidity and those that primarily demand liquidity may be particularly important when analyzing potential effects on market quality.[129] The 2010 Equity Market Structure Concept Release described four broad types of short-term high frequency trading strategies: passive market-making, arbitrage, structural, and directional.[130]

a. Passive Market-Making

Passive market-making involves submitting non-marketable orders on both sides (buy or "bid," and sell or "offer") of the marketplace. Profits are earned primarily by earning the spread between bids and offers, supplemented by liquidity rebates offered by many exchanges for offering resting liquidity.[131] Passive market makers may trade aggressively, sometimes rapidly demanding liquidity, in order to quickly liquidate positions accumulated through providing liquidity. Passive orders are generally not executed immediately and rest on an order book, and so must be updated as conditions change. Passive market-makers are vulnerable to "adverse selection," or prices moving quickly in one direction against their bids or offers, which can make it difficult to profitably trade out of a position.[132] As part of managing this risk, these strategies can produce enormous volumes of modification and cancellation messages.

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[128] *See*, *e.g.* HFT Literature Review at 9.

[129] *See*, *e.g.* Donald MacKenzie, *'Making', 'taking' and the material political economy of algorithmic trading*, Economy and Society, 47:4, 501-23 (2018) at 502 (describing the distinction between liquidity providing and liquidity demanding algorithms as "the single most important divide *within* HFT" (emphasis in original)); *id.* at 511 (noting that while HFT strategies at times necessarily blend passive and aggressive activity, it is more common to predominantly specialize in one or the other); HFT Literature Review at 9-10.

[130] *See* Concept Release at 3607-10. The summary here largely follows the more detailed discussion in the Concept Release.

[131] In order to trade as a market maker, the market participant must be able to consistently move their orders to the order book in each venue in which it trades. This effort requires fast, high-quality market data, as well as technology capable of quickly processing it. Many exchanges also offer order types that may assist resting orders in achieving or maintaining queue priority as conditions change.

[132] Some exchanges, such as IEX and NYSE American, offer order types that will automatically reprice certain resting orders based on algorithmically-generated predictions of when market-wide prices may be moving against the order. For a more

b. Arbitrage

Arbitrage strategies generally seek to capture pricing discrepancies between related products or markets, such as between an ETF and its underlying basket of stocks, or between futures contracts on the S&P 500 index and ETFs on that index.[133] Arbitrage strategies are likely to demand liquidity and involve substantial hedging of positions across products and markets. These strategies do not depend on directional price moves in a single product, but on the divergence and convergence of prices between products.[134]

c. Structural

Structural strategies attempt to exploit structural vulnerabilities in the market or in certain market participants. For example, traders with the lowest-latency market data and processing tools may be able to profit by trading with market participants who receive and process data more slowly and, as a result, have not yet updated their prices to reflect the most recent events.[135]

d. Directional

Directional strategies generally involve establishing a short-term long or short position in anticipation of a price move up or down. These strategies generally require demanding liquidity to build such a position.[136] Some directional strategies may focus on predicting price movements faster than other market participants, which requires sophisticated analytics and rapid processing abilities. For example, order anticipation strategies may attempt to predict or infer the existence of a large buyer or seller in the market, in order to

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general discussion of adverse selection and its role in market-making and quote-setting, *see* Merritt B. Fox, Lawrence R. Glosten, & Gabriel V. Rauterberg, *The New Stock Market: Law, Economics, and Policy*, ch. 3 (2019) ("The New Stock Market").

[133] Some ETF market-makers also act as Authorized Participants in ETFs, though the roles are distinct. Managing the ETF create-redeem process requires technological sophistication additional to that required for market-making.

[134] *See* HFT Literature Review at 8.

[135] *See*, *e.g.*, MacKenzie *supra* note 129 at 512-13 (noting that the response times for this type of strategy, as reported in interviews with high frequency traders, has declined from about 5 microseconds in 2011 to 300 nanoseconds in 2018).

[136] *See*, *e.g.*, *id.* at 512.

buy or sell ahead of the large order.[137] Trading on such predictions may often contribute to the process of price discovery in a stock.[138]

2. Single Dealer Platforms

On single dealer platforms, an individual dealer stands ready to trade with other market participants, generally offering some mode of indicative pricing.[139] Some single dealer platforms may execute block trades, and others may focus on smaller trades. Some single dealer platforms account for meaningful percentages of consolidated volume. For example, recent estimates indicate that some single dealer platforms may account for as much as 1% of consolidated average daily share volume.[140]

Like other participants in equities markets, single dealer platforms must rapidly process large volumes of market data in order to make trading and risk decisions, as well as effectively handle the routing and communications necessary to managing a large number of electronic orders.

3. Central Risk Books

Central risk books have become important sources of block liquidity for many market participants.[141] Central risk books, generally offered as a type of principal trading by large,

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[137] As the Concept Release notes, such order anticipation is an old strategy to which investors have long been vulnerable. *See* Concept Release at 3609. This vulnerability makes information leakage a central concern for institutional investors.

[138] The Equity Market Structure Concept Release also noted that another type of directional strategy, momentum ignition, "may raise concerns." *Id.* Momentum ignition strategies involve initiating a series of orders and trades in order to attempt to ignite a rapid price move up or down. As the Commission noted in the Concept Release, any market participant that manipulates the market has engaged in prohibited conduct. *See id.*

[139] In a recent request for comment on a proposed disclosure rule, FINRA proposed a definition of "single dealer platform": "an electronic trading platform owned and operated by a member on which the member trades solely for its own account when executing orders routed to the [single dealer platform] and represents either the buy or sell side of each trade on a proprietary basis." *See* FINRA Regulatory Notice 18-28.

[140] *See* Rosenblatt Securities, *Let There Be Light: Rosenblatt's Monthly US Dark Liquidity Tracker* (Dec. 18, 2019).

[141] *See*, *e.g.*, Campbell Peters, *Technology and the Buy-side Liquidity Chase*, TabbFORUM (July 19, 2019); Valerie Bogard, Justin Schack, & Anish Puaar, *Central Risk Books: What the Buy Side Needs to Know*, Rosenblatt Securities Trading Talk (Oct. 11, 2018) ("Rosenblatt CRBs").

global firms, aggregate firm-wide risk across desks, regions, and asset classes, seeking to maximize firms' capital while staying within overall risk limits.[142] This process can reduce hedging costs and optimize resources across a firm. This data aggregation and analysis requires significant quantitative and technological sophistication, including the ability to reconcile the cross-market risk profiles of different instruments with potentially very different types of market and product data.[143] This process can allow central risk books to provide liquidity for large orders, often with favorable pricing, and generally depends upon having sufficient capital to take on positions and hedge risk.[144]

Central risk book liquidity can be accessed through a variety of channels, including through broker trading desks and algorithms, and may be reflected in ATSs.[145] Some firms generate streaming indications of interest, including actionable indications of interest, available through information services such as Bloomberg. One survey notes that the liquidity offered by central risk books is "most likely smaller blocks of blue-chip stocks, rather than large blocks of small- or mid-cap stocks."[146]

D. Operational Risks to Firms and the Market

The electronic, automated, and interconnected nature of modern equity markets has created operational risks for both individual firms and the markets as a whole. As illustrated by the types of events described below, operational failures can have detrimental effects throughout the market system. As multiple regulators have now emphasized, it is essential for a range of market participants to have in place policies, procedures, and practices to ensure the robust operation and resilience of technological systems.[147]

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142 Rosenblatt CRBs at 1. Firms other than large, global banks may also offer central risk books or employ central risk management structures. *See*, *e.g.*, Larry Tabb, *The Central Risk Book: Rethink Risk, Rethink Trading* (Dec. 5, 2017).

143 Rosenblatt CRBs at 2; Tabb, *The Central Risk Book*.

144 Rosenblatt CRBs at 2.

145 *Id.* at 3-4.

146 Peters, *Technology and the Buy-Side Liquidity Chase*, *supra* note 141.

147 *See*, *e.g.*, *Risk Management Controls for Brokers or Dealers With Market Access*, Exch. Act Rel. No. 63241, 75 Fed. Reg. 69791 (Nov. 15, 2010) ("Market Access Rule Adopting Release"); *Regulation Systems Compliance and Integrity*, Exch. Act Rel. No. 73639, 79 Fed. Reg. 72252 (Dec. 5, 2014) ("SCI Adopting Release"); FINRA Regulatory Notice 15-09 (Mar. 2015).

Errors from improper technology development, testing, and implementation at individual firms can have severe effects on those firms. For example, in 2012, a broker-dealer experienced a significant error in its equity order routing system following a systems update, erroneously sending millions of orders into the market over a forty-five minute period, and ultimately costing the firm more than $460 million in losses.[148] Similarly, improper controls at individual firms can negatively impact markets. For example, between 2011 and 2013, a firm improperly allowed essentially anonymous non-U.S. traders to enter billions of orders into U.S. markets, and did so without implementing risk management controls reasonably designed to ensure compliance with applicable regulatory requirements, which also resulted in the firm violating other regulatory requirements.[149] Another firm, as a result of a coding change and series of changes to routing logic, and a failure to impose adequate post-trade surveillance, between 2010 and 2014 erroneously allowed millions of orders with a notional value of approximately $116 billion to be sent in violation of Rule 611 of Regulation NMS.[150]

It also is important for algorithmic trading platforms and other core infrastructure systems to maintain proper controls and data integrity.[151] During the last decade, for example, inadequate policies and procedures and systems errors at exchanges resulted in violations of the securities laws as well as trading disruptions;[152] systems failures have interrupted initial public offerings;[153] capacity failures at one of the equity consolidated data feeds caused one SIP provider to fail, leading to a trading halt in all securities listed on one

[148] *See Knight Capital Americas LLC*, Exch. Act Rel. No. 70694 (Oct. 16, 2013) (settled matter).

[149] *Wedbush Securities Inc., Jeffrey Bell, and Christina Fillhart*, Exch. Act Rel. No. 73652 (Nov. 20, 2014) (settled matter).

[150] *Latour Trading LLC*, Exch. Act Rel. No. 76029 (Sept. 30, 2015) (settled matter).

[151] For more comprehensive discussions of systems events throughout the securities markets, *see Regulation Systems Compliance and Integrity*, Exch. Act Rel. No. 69077, 78 Fed. Reg. 18084 (Mar. 25, 2013) ("SCI Proposing Release") at 18089-90; SCI Adopting Release at 72254-56.

[152] *EDGX Exchange, Inc., EDGA Exchange, Inc., and Direct Edge ECN LLC*, Exch. Act Rel. No. 65556 (Oct. 13, 2011) (settled matter); *New York Stock Exchange LLC, NYSE Arca, Inc., NYSE MKT LLC f/k/a NYSE Amex LLC, and Archipelago Securities, L.L.C.*, Exch. Act Rel. No. 72065 (May 1, 2014) (settled matter).

[153] SCI Proposing Release at 18089; *The Nasdaq Stock Market, LLC and Nasdaq Execution Services, LLC*, Exch. Act Rel. No. 69655 (May 29, 2013) (settled matter).

exchange;[154] and opening auctions have been delayed as a result of high volumes and unusual volatility.[155] A previous Commission staff report concluded that the interaction between automated execution programs and algorithmic trading strategies can quickly erode liquidity and result in disorderly markets, and that concerns about data integrity, especially those that involve the publication of trades and quotes to the consolidated tape (SIP), can contribute to pauses or halts in many automated trading systems and in turn lead to a reduction in general market liquidity.[156]

E. Studies of Effects on Market Quality and Provision of Liquidity

As illustrated by much of the preceding discussion, algorithms are used in a diverse range of trading activities and, across the various activities and market participants in the cash equity market, are virtually ubiquitous. This ubiquity and diversity has, understandably, meant that studies on "algorithmic trading" are not always focused on the same activity. For example, much of the literature on algorithmic trading focuses on high frequency trading, either through proxy measurements of HFT activity, or using datasets that specifically identify high frequency trading firms or accounts. The methodology used in any given case for identifying the relevant firms or accounts can shape the results found, as can decisions about whether to focus on metrics relevant to primarily passive liquidity-providing activity, aggressive liquidity-taking activity, or all trading without a distinction between liquidity providing and taking.[157] It is unsurprising that academic studies generally are narrowly focused, as the amount of data, computing power and sophistication necessary to engage in broader study are daunting and costly, and relevant data may not be widely available or easily accessible. As a result, Commission staff notes that using a single or just a few studies as a basis for broad market conclusions entails risk and that it is likely that greater insight will be provided by viewing academic literature as a whole, recognizing

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[154] SCI Adopting Release at 72255

[155] Staff of the Office of Analytics and Research, Division and Trading and Markets, *Equity Market Volatility on August 24, 2015* (Dec. 2015) (*available at:* https://www.sec.gov/marketstructure/research/equity_market_volatility.pdf) ("Aug. 24, 2015 Report").

[156] *Findings Regarding the Market Events of May 6, 2010: Report of the Staffs of the CFTC and SEC to the Joint Advisory Committee on Emerging Regulatory Issues* (Sept. 30, 2010), *available at:* https://www.sec.gov/news/studies/2010/marketevents-report.pdf ("Flash Crash Report"), at p. 8; SCI Proposing Release at 18089.

[157] For a more fulsome discussion of these methodological issues, *see* HFT Literature Review at 4-11.

the general and individual limitations of the work, as opposed to viewing studies in isolation.

The following summary attempts to distill a range of studies from the academic literature, many of which have focused on high frequency trading. Generally, studies on this type of algorithmic trading indicate that some dimensions and activities can have positive effects on market quality and efficiency, while others may impose costs on other market participants or pose risks during periods of unusual market stress. More detailed discussions of individual academic studies are available in a later section of this staff report, as well as in literature reviews previously published by Commission staff.[158]

Studies have generally concluded that high frequency trading may have improved standard measures of market quality during normal market periods.[159] For example, passive market-making activity is generally viewed as reducing spreads, through competition to both narrow spreads and achieve queue priority,[160] and through the improved risk management that is possible with automated systems.[161] In addition, liquidity-demanding strategies may help to improve price efficiency. Some studies have concluded that HFT activity can reduce intraday volatility,[162] though results are mixed on this point.[163]

Some studies have concluded that high frequency trading activity may also contribute to increased costs for other market participants.[164] For example, the ability of HFT algorithms

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[158] *See* HFT Literature Review.

[159] For example, "primarily passive HFT strategies appear to have beneficial effects on market quality, such as by reducing spreads and reducing intraday volatility on average" (*See* HFT Literature Review at 9) and "aggressive HFT strategies can improve certain dimensions of price discovery, at least across very short time-frames" (HFT Literature Review at 10).

[160] J. Hasbrouck, *High frequency quoting: Short-term volatility in bids and offers,* 53 J. *Fin.and Quantitative Analysis* 613 (2018); J. Brogaard & C. Garriott*, High-Frequency Trading Competition*, 54 J. Fin. and Quantitative Analysis 1469 (2019).

[161] T. Hendershott, C.M. Jones & A.J. Menkveld, *Does Algorithmic Trading Improve Liquidity?*, 66 J. Finance 1 (2011).

[162] J. Hasbrouck & G. Saar, *Low-Latency Trading,* 16 J. Financ. Mark. 646 (2013).

[163] HFT Literature Review at 10.

[164] *Id.* at 10-11; A. Shkilko & K. Sokolov, *Every Cloud Has a Silver Lining: Fast Trading, Microwave Connectivity and Trading Costs* (Working Paper 2016), available at: https://ssrn.com/abstract=2848562 (arguing that bad weather affecting microwave communications improves outcomes for other market participants).

to achieve queue priority can make it difficult for even marginally slower firms to successfully provide liquidity.[165] Some strategies may also involve trading against stale orders that have not been updated to incorporate information available to participants with the fast data processing technology.[166] Studies have also found evidence that HFT firms engage in order anticipation and momentum ignition strategies.[167] HFT firms can exploit information asymmetries derived from the speed with which they can access and process trading information as compared to other market participants.

Several studies have concluded that improvements in speed are valuable primarily on a relative basis, and that they do not necessarily provide more fundamental value.[168] Some have argued that the technological "arms race" may therefore be socially wasteful.[169]

Various studies conclude that during periods of unusually high volatility or market stress the use of algorithms may exacerbate price movements. There is evidence that during periods of market stress, market participants self-impose trading halts or otherwise slow their activity in order to minimize their market risk.[170] The withdrawal of liquidity caused by such a pause may cause prices to move further and more rapidly than they otherwise would due to a sudden absence of countervailing trading pressure. There is also evidence that some algorithmic trading firms aggressively trade into rapid price movements,

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[165] C. Yao & M. Ye, *Why Trading Speed Matters: A Tale of Queue Rationing under Price Controls*, 31 Rev. Fin. Stud. 2157 (2018).

[166] E. Budish, P. Cramton &J. Shim, *The High-Frequency Trading Arms Race: Frequent batch Auctions as a Market Design Response*, 130 Q. J. of Econ. 1547 (2015); J. Brogaard, T. Hendershott & R. Riordan, *High Frequency Trading and the 2008 Short-Sale Ban*, 124 J. Fin. Econ. 22 (2016); M. Aquilina, E. Budish, and P. O'Neill, *Quantifying the High-Frequency Trading "Arms Race": A Simple New Methodology and Estimates*, UK Financial Conduct Authority Occasional Working Paper No. 50 (2020) (*available at:* https://www.fca.org.uk/publications/occasional-papers/occasional-paper-no-50-quantifying-high-frequency-trading-arms-race-new-methodology).

[167] HFT Literature Review at 10.

[168] M. Gai, C. Yao & J. Ye, *The Externalities of High Frequency Trading* (Working Paper 2013), available at: https://ssrn.com/abstract=2066839; Budish et al., *supra* note 167; M. Baron et al., *Risk and Return in High-Frequency Trading*, 54 J. Fin. And Quantitative Analysis 993(2019).

[169] Budish et al., *supra* note 166.

[170] Flash Crash Report at 6; HFT Literature Review at 34.

exacerbating price movements by quickly exhausting available resting liquidity.[171] Some researchers have argued, however, that quantitative investors may ultimately act as shock absorbers, since quantitative models will be able to signal when prices are so low that profit potential is worth the risk of trading during periods of extreme stress.[172]

F. Effects of the COVID-19 Pandemic

Beginning in late February 2020, world markets came under severe stress as a result of the global COVID-19 pandemic. Volatility, trading volumes, and message traffic increased significantly above their recent averages, and remained at elevated levels for several weeks. For example, the VIX, a widely-used measure of market volatility, peaked at an intraday value of 83.56 on March 16th, which is about five times higher than its average value for 2019.[173]

At the same time, many market participants and SROs were forced to alter their operational, supervisory, and compliance protocols to accommodate their trading and support personnel working from home or back-up facilities. Despite these challenges, U.S. equity markets functioned without significant technical, or logistical, disruption.

Research on market activity and the actions of market participants, as well as the role of algorithmic trading during the initial stages of the pandemic, is ongoing and developing. It is beyond the scope of this report to provide a comprehensive overview of COVID-19's impact on U.S. capital markets. However, the following initial observations may be relevant to this report.

1. NYSE Floor Closure

The New York Stock Exchange (NYSE) operates a hybrid market model unique to U.S. equity markets. It combines electronic trading with human presence and participation in the matching process on a physical trading floor. Designated Market Makers (DMMs, formerly known as "specialists") have obligations to provide fair and orderly markets in their designated securities. In addition to DMMs, a number of Floor Brokers maintain

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[171] *See*, *e.g.*, Flash Crash Report at 48.

[172] Kevin McPartland, *Benefits and Future of Quantitative Investing*, Greenwich Associates, pp. 7-8 (May 17, 2018).

[173] *See also*, *e.g.*, SIFMA, *COVID-19 Related Market Turmoil Recap: Part I - Equities, ETFs, Listed Options & Capital Formation*, p. 6 (Jun. 2020) (noting a record closing VIX value of 82.69 on Mar. 16, 2020).

physical presence on the floor of NYSE.[174] While most intraday trading on NYSE happens electronically, DMMs and Floor Brokers typically play a significant role during the opening and closing auctions. Specifically, they fulfill three main functions in the NYSE hybrid market model:

- Provide access to "D Orders," a unique order type only available through floor personnel.[175] While D Orders are available throughout the trading session, most executions occur in the closing auction.

- Provide access to NYSE's "Parity and Priority" structure, which allows orders entered via DMMs and Floor Brokers to have the same priority on the NYSE book as electronic orders which arrived earlier.[176] As noted above, this structure differentiates NYSE's model from the price-time priority available on most of the other exchanges.

- Serve as a source of information for off-floor traders, especially around auctions and significant market events.

On March 23, 2020, in response to the spread of COVID-19 in the New York metropolitan area and in the interests of its employees' safety, NYSE moved to fully-electronic trading and temporarily closed its main physical trading floor.[177] According to NYSE's filing with the Commission of March 20, 2020:

> Because the Trading Floor facilities will be closed, Floor brokers will not be able to enter orders on the Trading Floor. As a result, there will not be any Floor Broker Participants in allocations and there will not be any order types unique to Floor brokers, such as D Orders. In addition, because DMMs will not be on the Trading Floor, DMMs will not engage in any manual actions, such as

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[174] *See*, *e.g.*, 2020 NYSE Trading Floor Broker Directory, *available at:* https://www.nyse.com/publicdocs/nyse/NYSE_Trading_Floor_Broker_Directory.pdf.

[175] *See*, *e.g.*, NYSE, "The Floor Broker's Modern Trading Tool," *available at:* https://www.nyse.com/article/trading/d-order.

[176] *See*, *e.g.*, NYSE, "Parity & Priority Fact Sheet," *available at:* https://www.nyse.com/publicdocs/nyse/markets/nyse/Parity_and_Priority_Fact_Sheet.pdf.

[177] *See Notice of Filing and Immediate Effectiveness of Proposed Rule Change To Amend Rules 7.35A, 7.35B, and 7.35C for a Temporary Period*, Exch. Act Rel. No. 88,444 (Mar. 20, 2020), 85 Fed. Reg. 17141 (Mar. 26, 2020). During this period, several options exchanges also closed their trading floors. These closures are not discussed here because options trading is not the focus of this report.

> facilitating an Auction manually or publishing pre-opening indications before a Core Open or Trading Halt Auction.[178]

On May 26, 2020, NYSE commenced "Phase I" of the reopening process, allowing a number of Floor Brokers to return to the floor of the exchange.[179] It was followed on June 17th by "Phase II," in which certain DMMs were allowed to be physically present on the floor and resume their main functions in a limited number of stocks.[180]

The move by NYSE to fully electronic trading did not result in any significant market interruption or system-related issues. However, there are differing anecdotal views and limited research on how the floor closure affected certain metrics of market quality, such as liquidity and price formation during the opening and closing auctions, as well as effective spreads and displayed liquidity during the trading day. For example, Brogaard, Ringgenberg, and Roesch (2020) compared changes in intraday market quality metrics on NYSE with a control group comprising NASDAQ stocks.[181] They show a relatively larger increase in effective spreads in NYSE stocks as compared to the control group following the floor closure, as well as more significant degradation in other metrics, such as volatility and "pricing errors." The authors subsequently conclude that the NYSE hybrid model benefits overall intraday trading quality, with most of the benefit concentrated around opening and closing, when volatility is at its highest.

2. Volatility Controls

A later section of this report describes various measures the Commission and other regulators have implemented to modulate extreme price swings in individual securities

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[178] *Id.* at 17142 (internal citations omitted).

[179] *See, e.g.*, *Notice of Filing and Immediate Effectiveness of Proposed Rule Change To Extend the Temporary Period for Specified Commentaries to Rules 7.35, 7.35A, 7.35B, and 7.35C*, Exch. Act Rel. No. 88,933 (May 22, 2020), 85 Fed. Reg. 32059 (May 28, 2020).

[180] *See, e.g.*, *Notice of Filing and Immediate Effectiveness of Proposed Rule Change To Add, for a Temporary Period That Begins on June 17, 2020, Commentary .06 to Rule 7.35A; Commentary .03 to Rule 7.35B; Supplementary Material .20 to Rule 76; and an Amendment to Supplementary Material .30 to Rule 36 To Support the Partial Return of Designated Market Makers to the Trading Floor*, Exch. Act Rel. No. 89,086 (Jun. 17, 2020), 85 Fed. Reg. 37712 (Jun. 23, 2020).

[181] Jonathan Brogaard, Matthew Ringgenberg, & Dominick Rösch, *Does Floor Trading Matter?* (Jun. 2020), *available at:* https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3609007.

and equity markets as a whole.[182] Their implementation and usefulness have been extensively tested during the period of market volatility caused by the COVID-19 pandemic. For example, Market Wide Circuit Breakers (MWCB) were triggered four times during March 2020. Notably, on March 9th, the MWCB was triggered for the first time since both the reference index for the MWCB (from the DJIA to S&P500) and the thresholds for different CB levels were changed in 2012. All four MWCBs were Level 1 circuit breakers, *i.e.*, triggered by a 7% drop in the index. The MWCBs appeared to have operated as intended, with generally issue-free pausing and re-opening processes, as well as orderly trading following re-opening of the market. The incidence of individual stock volatility halts also significantly increased in March. For example, on March 18, 2020, there were 1,475 limit-up limit-down volatility halts in 643 unique symbols, compared to a typical daily median count of approximately ten halts in approximately seven unique symbols.[183]

3. Liquidity and Spreads

Periods of heightened volatility normally lead to a degradation in market quality and increased implicit execution costs for investors. The period of severe market volatility caused by COVID-19 has resulted in increased effective spread measures and market impact costs across the board. Mittal, Saraiya, and Berkow (2020)[184] compare various market characteristics during the period of heightened volatility with the period of relative calm in January 2020. They find that the normalized spread costs during the crisis period increased by 7.2 times for S&P 500 stocks and 4.1 times for Russel 2000 stocks. They also find that the realized market impact (in addition to spread costs) of trading a number of shares equivalent to 2% of the daily volume for an S&P 500 stock during the crisis is comparable to that of 10% of the daily volume during the "normal" period.

4. General Observations on Initial Months of COVID-19

During the initial months of the COVID-19 pandemic, the fully electronic, complex, and interconnected U.S. equity markets operated without significant disruption. Notably, this continuity was accomplished with most brokers, buy-side traders, exchange personnel, and regulators working from home. Even on days when markets were paused due to sharp drops, re-openings resulted in orderly resumption of trading. Impact cost and spreads measures have responded, as they always do, to heightened uncertainty, as liquidity providers re-priced their risk and investors' demand for liquidity has increased. And while

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[182] *See infra* Section VI.B.

[183] Source: NYSE TAQ. To find typical daily values, the distribution of limit-up limit-down halts was calculated from January 1, 2019 through June 30, 2020.

[184] Hitesh Mittal, Nigam Saraiya, and Kathryn Berkow, *US Equity Liquidity in the COVID-19 Crisis* (Mar. 31, 2020), *available at:* https://bestexresearch.com/wp-content/uploads/2020/04/BestEx-Research-Market-Impact-Analysis-20200331.pdf

the markets came under severe stress, with unprecedented volatility and sharp daily fluctuations, they have proved to be resilient, efficient, and transparent.

V. Benefits and Risks of Algorithmic Trading in Corporate and Municipal Bonds

In the secondary markets for corporate and municipal debt securities, algorithms have begun to address a range of long-identified information issues, including the distribution and gathering of quotations, pricing, and trade matching and execution. These changes have been accompanied by the growth of liquidity provision by participants other than traditional dealers and an expansion of portfolio trading and bond exchange-traded products.

A. Liquidity Search and Trade Execution

In some portions of the debt markets, algorithms are reshaping the problems of finding and providing liquidity. The most notable developments are the automation of the request-for-quote process and streaming quotations directly between counterparties.[185] The relative openness of many RFQ platforms and streaming quotation tools has allowed technologically-sophisticated non-dealer liquidity providers to move into the corporate and municipal bond markets.

In the corporate bond market, algorithms are central to the process of automating the RFQ process.[186] An automated RFQ process may look something like the following stylized example.[187] A platform may allow parties to identify or restrict the specific types of counterparties with whom they may communicate, using factors such as whether a party underwrote a new issue, has traded recently in a particular security, or has expressed interest in trading a similar bond. A platform may also allow the party posting an RFQ to

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[185] While not widely adopted across all types of debt securities, limit order books on platforms such as Brokertec and Nasdaq Fixed Income have become a key locus of trading in the interdealer market for benchmark, on-the-run U.S. Treasury securities. Some of the risks associated with electronic central limit order book trading in the U.S. Treasury market are described in the Treasury Market Report on the events of October 15, 2014. *See* Treasury Market Report. Beyond Treasury securities, and even outside of the interdealer market in on-the-run Treasury securities, central limit order books have not seen widespread adoption in the debt markets. *See*, *e.g.*, Kevin McPartland, *Treasury Traders Shy Away from Order Books*, Greenwich Associates (Jan. 30, 2018).

[186] McPartland, *Corporate Bond Trading in 2019*, at 7.

[187] *See id.*

set parameters, including, among other things, limiting pricing responses to a specified deviation from a pricing estimate, defining the time during which pricing responses must be received, and identifying a minimum number of pricing responses needed. Then, with these parameters set, when a party posts an RFQ, it is automatically sent to a dealer or counterparty list. Counterparties then respond automatically, generally based on their own pricing logic and algorithms. The platform then automatically confirms the best price, consistent with parameters set by the party posting the RFQ. Some platforms may allow the party posting to an RFQ to review RFQ results and affirmatively confirm a trade rather than executing the trade automatically.

In the corporate bond market, $1 million is currently a rough upper bound for trades that can consistently be executed in an automated manner.[188] The use of automated trading declines above that size, with very little adoption for block trades.

In many bonds, particularly bonds issued in smaller sizes and bonds that have been outstanding, pricing is a difficult task because each instrument trades relatively infrequently, and can do so at inconsistent sizes and under different market conditions. A variety of algorithms are designed to address this issue. Many models use so-called "matrix pricing" to estimate the price of a particular bond by looking at data for similar bonds, with, for example, comparable issuers, maturities, coupons, or credit ratings. A number of platforms now use machine learning algorithms to generate a price or spread for specific instruments.[189]

For an increasing number of bonds, market participants now stream to counterparties continuous prices or quote continuous prices on a platform. Dealers, principal traders, and customers are able to stream prices. These streams are generally bilateral, allowing a user to tailor liquidity sources across the market. This data can be supplemented by data from RFQ platforms, providing seekers of liquidity with an increasingly broader view of the market.[190] Streaming or quoting continuous prices has become significantly more common in municipal bonds, where the typically small trade sizes may be amenable to electronic trading.

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[188] *Id.* at 7.

[189] *See*, *e.g.*, MarketAxess Research, *Composite+: Algorithmic Pricing in the Corporate Bond Market*, *available at* https://content.marketaxess.com/sites/default/files/2018-08/MKTX_Composite%2B_whitepaper.pdf.

[190] *See*, *e.g.*, McPartland, *How Bilateral Streams for U.S. Treasuries Really Work, And What They Mean for the Market* (discussing use of streaming quotes in U.S. Treasury market); SIFMA, *SIFMA Electronic Bond Trading Report: US Corporate & Municipal Securities*, p. 8 (Feb. 2016) (noting growing adoption of streaming price protocols from dealers in corporate and municipal securities).

B. ETF Market Making and Arbitrage

The share of global assets under management in fixed income ETFs has increased significantly over the past decade.[191] A recent estimate is that approximately 1.6% of global fixed income assets under management are in fixed-income ETFs.[192] ETFs have made it possible for investors to indirectly take positions on cash bond markets by trading intraday in the more liquid and transparent equity market. ETFs also provide investors with a generally more efficient means of accessing a diversified exposure to bonds as compared with directly assembling a bond portfolio.

The growth in ETFs has presented arbitrage opportunities to firms willing to trade between the ETF market and the underlying bonds. A market maker that is an Authorized Participant of an ETF can use the create-and-redeem process to manage the risk of taking on positions in either the equity market (for the ETF) or cash bond market (for the underlying bonds). This cross-market trading and risk-management activity depends on the effective and rapid processing of data on potentially hundreds of individual securities. Like the expansion of RFQ platforms, this arbitrage opportunity has attracted non-dealer liquidity providers to be active in the corporate and municipal cash bond markets.[193] Developments in the technological infrastructure to conduct ETF arbitrage and market-making have also facilitated the expansion of portfolio trading, where investors can request a single price for a list of bonds, as opposed to trading them individually.[194]

C. Studies of Effects on Market Quality and Provision of Liquidity

Academic research on the effects of algorithmic trading on secondary debt markets is relatively limited. Lack of available data is an important constraint. Order level data is usually only available in the most liquid and "electronified" markets, such as on-the-run Treasuries.[195] Order level data is usually not available in less liquid debt markets.

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[191] FIMSAC Subcommittee on ETFs and Bond Funds, "Report", at 6 (Apr. 10, 2019).

[192] *Id.*

[193] McPartland, *The Challenge of Trading Corporate Bonds Electronically*, at 5-6. ("the profit opportunity presented by fixed-income ETF arbitrage strategies has brought a number of principal trading firms and some quantitative hedge funds into the corporate bond market").

[194] *Id.*

[195] Most of the academic research on algorithmic trading in the fixed income markets comes from studying the on-the-run Treasuries market. Fleming (2016) estimates that trading in on-the-run securities accounts for roughly 85% of total trading volume across nominal Treasury securities. The majority of trading in on-the-run Treasuries occurs

Although transaction data is available through TRACE, there is no attribute on TRACE-disseminated reports that identifies trades executed by algorithms.

Overall, research shows that algorithmic trading is prevalent in already liquid debt markets (e.g., on-the-run Treasuries). Studies of these markets generally find an overall positive effect of algorithmic trading on liquidity and price discovery during "normal" times. They also find that "electronification" lowers trading costs, since less intermediation is required for transactions to be executed. There is, however, some evidence of algorithmic trading being associated with increased volatility, but such evidence is not prevalent, and it generally is present during special market conditions, such as periods of unusually high volatility.[196] However, there are very few studies focusing on algorithmic trading in the corporate and municipal bond markets.[197]

The Treasury Market Report on the extraordinary volatility of October 15, 2014 highlighted several areas of risk related to the use of automated trading.[198] These risks are similar to those that others have described with respect to automated trading in equities markets, including: operational risks from malfunctioning or incorrectly deployed algorithms; market liquidity risks from abrupt changes in trading strategies; market integrity risks from acts of manipulation; transmission risks from interconnected markets with closely related instruments; clearing and settlement risks from firms clearing outside a central counterparty structure; and risks to the effectiveness of risk management from the speed at which markets and risk positions can change.

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electronically on the BrokerTec platform. Fleming, Mizrach, and Nguyen (2018) analyze the microstructure of the BrokerTec electronic platform, and report that it accounts for 60% of electronic interdealer trading for each of the on-the-run 2-, 5- and 10-year notes. *See also* the discussion of potential limitations of use of academic research, *supra* Section IV.E.

[196] For a more detailed discussion of studies analyzing electronic markets for U.S. Treasury securities, *see infra* Section VII.B.

[197] *See*, *e.g.*, Bank of International Settlement, *Electronic trading in fixed income markets*, at 23 (Jan. 2016) (noting that "[e]mpirical works on the impact of AT and particularly HFT on market quality are numerous, but unfortunately relatively few studies focus specifically on bond markets due to a lack of data").

[198] *See* Treasury Market Report Appendix C.

VI. Regulatory Responses to Market Complexity, Volatility, and Instability

Algorithmic trading, including trading that relies on rapid access to and processing of large amounts of market data, is ubiquitous in our equity markets and is increasingly important in our debt markets. Algorithmic trading has brought secondary market participants important benefits such as increased liquidity, cost reductions, and improvements in other measures of market quality. But advances in technology, and related developments in the provision of and access to market data, have also contributed to the growth of complexity in markets, arguably have contributed to episodes of volatility and dislocation, and have changed (and in some cases increased) the firm-level and market risks stemming from system errors and operational failures.

Over the last decade, the Commission and self-regulatory organizations have taken various steps to address these developments, including the evolving firm-level and market risks. Many of these steps are outlined below and Commission staff will continue to monitor these developments and, as may be necessary or appropriate, provide advice and make recommendations to the Commission, including whether the Commission may or may not need additional statutory authority to address market developments and emerging risks.

A. Improving Market Transparency

To promote a better understanding of the operation of our algorithm-driven and increasingly complex equity markets as well as our evolving debt markets, recently the Commission, SROs, and Commission staff have sought to expand transparency into several aspects of modern markets with an eye toward various regulatory objectives, including facilitating further analysis of market efficiency and integrity and fostering competition.[199]

1. Large Trader Reporting

In 2011, the Commission adopted rules to assist the Commission in identifying and obtaining trading information on market participants that conduct a substantial amount of

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[199] A number of these initiatives require the Commission or Commission staff to collect, store, or access sensitive market and participant data and information. *See, e.g.*, Chairman Jay Clayton, "Statement on Cybersecurity" (Sept. 20, 2017) (*available at:* https://www.sec.gov/news/public-statement/statement-clayton-2017-09-20). The Commission and Commission staff review these various data sets with the perspective that data should only be collected and accessed to the extent that it is necessary to further the agency's mission and that it can reasonably be protected. *Id.*

trading activity in U.S. securities markets.[200] This rule improves the Commission's ability to identify large market participants, and collect and analyze information on their trading activity.[201] Firms began reporting required information in 2012.

2. Consolidated Audit Trail

In July 2012, the Commission approved Rule 613 of Regulation NMS, which requires the self-regulatory organizations to submit and implement a national market system plan to create a consolidated audit trail (CAT) that would allow regulators to efficiently and accurately track virtually all activity in U.S. equity and options markets.[202] The Commission approved a National Market System Plan for implementing the CAT in November 2016.[203] In September 2019, the Commission proposed amendments to the NMS Plan designed to improve transparency and financial accountability of the development of the CAT.[204] In March 2020, the Commission granted conditional exemptive relief to, among other things, reduce the amount personally identifiable information in the CAT database.[205] Additional details on Plan implementation and proposed timelines are available on the Plan website.[206]

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[200] *See* 17 CFR § 240.13h-1, 249.327; *Large Trader Reporting*, Exch. Act Rel. No. 64976, 76 Fed. Reg. 46959 (Aug. 3, 2011).

[201] 76 Fed. Reg. at 46961, 46963 (the system of large trader reporting "represents an important enhancement to the Commission's capabilities to uniformly identify large traders and quickly obtain information on their trading activity in a manner that can be implemented expeditiously by leveraging an existing reporting system").

[202] *See* 17 CFR § 242.613; *Consolidated Audit Trail*, Exch. Act Rel. No. 67457, 77 Fed. Reg. 45721 (Aug. 1, 2012).

[203] *See Order Approving the National Market System Plan Governing the Consolidated Audit Trail*, Exch. Act. Rel. No. 79318, 81 Fed. Reg. 84696 (Nov. 23, 2016).

[204] *See Proposed Amendments to the National Market System Plan Governing the Consolidated Audit Trail*, Exch. Act Rel. No. 86901, 84 Fed. Reg. 48458 (Sep. 13, 2019).

[205] *See Order Granting Conditional Exemptive Relief, Pursuant to Section 36 and Rule 608(e) of the Securities Exchange Act of 1934, from Section 6.4(d)(ii)(C) and Appendix D Sections 4.1.6, 6.2, 8.1.1, 8.2, 9.1, 9.2, 9.4, 10.1, and 10.3 of the National Market System Plan Governing the Consolidated Audit Trail*, Exch. Act Rel. No. 88393 (Mar. 17, 2020).

[206] *See* Consolidated Audit Trail, LLC, https://www.catnmsplan.com/.

3. FINRA ATS and OTC Transparency

As discussed above, FINRA makes publicly available statistics on off-exchange equity executions, both in alternative trading systems and at non-ATS OTC venues.[207] FINRA began collecting statistics on volume and number of transactions from ATSs in 2014, and then made the statistics publicly available on an aggregated basis.[208] In 2015, FINRA expanded the scope of publicly disseminated data to include non-ATS equity volume executed over-the-counter.[209] FINRA also expanded its public disclosures to include information about equity block-size transactions on ATSs[210] and in non-ATS over-the-counter transactions.[211] FINRA has also proposed including in its public disclosures data on ATS transactions in corporate and agency debt securities.[212] While FINRA at one point charged for professional or vendor access to the data discussed above, this data is now widely and freely available for public use.[213]

4. MSRB ATS Trade Indicator

In 2016, the MSRB began requiring a specific indicator on trade reports for trades executed on ATSs.[214] This indicator is included both on trades where an ATS takes a principal position between buyer and seller, and where an ATS connects a buyer and seller but does not take a principal or agency position between the parties. The ATS indicator is included on transaction data disseminated publicly.

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[207] *See*, *e.g.*, FINRA Rule 6110(b); *see also* File No. SR-FINRA-2013-042, 79 Fed. Reg. 4213 (Jan. 17, 2014) (approving FINRA's collection and public dissemination of ATS statistics); File No. SR-FINRA-2015-020, 80 Fed. Reg. 61246 (Oct. 9, 2015) (approving expansion to OTC data generally).

[208] *See*, *e.g.* FINRA Regulatory Notice 14-07 (Feb. 2014).

[209] *See*, *e.g.*, FINRA Regulatory Notice 15-48 (Nov. 2015).

[210] *See* FINRA Regulatory Notice 16-14 (Apr. 2016).

[211] *See* FINRA Regulatory Notice 18-28 (Sept. 11, 2018).

[212] *See* FINRA Regulatory Notice 19-22 (July 9, 2019).

[213] *See* File No. SR-FINRA-2015-023, 80 Fed. Reg. 39811 (July 10, 2015).

[214] *See* MSRB Regulatory Notice 2015-07 (May 26, 2015); MSRB Rule G-14 RTRS Procedures(b).

5. TRACE for U.S. Treasury Securities

Beginning in July 2017, FINRA began requiring member firms to report to TRACE transactions executed in U.S. Treasury securities.[215] This requirement was, in part, a response to the unusual market volatility of October 15, 2014, which highlighted, among other things, the need for official-sector access to data regarding the cash market for Treasury securities.[216] Treasury securities are traded by broker-dealers that are FINRA members, as well as by market participants who are not registered broker-dealers, such as commercial banks and principal trading firms.[217] To expand the scope of its data collection in Treasury securities, in 2019 FINRA began requiring certain large ATSs to report to TRACE the identities of non-FINRA member counterparties.[218] Currently, the data submitted to TRACE is available only to regulators, including the Department of the Treasury. However, in 2020 FINRA will begin publishing weekly aggregated transaction information and statistics on U.S. Treasury Securities.[219]

6. Rule ATS-N

In August 2018, the Commission expanded the disclosure requirements for NMS Stock ATSs and required ATSs to implement safeguards to protect subscribers' confidential trading information.[220] On new Form ATS-N, ATSs must disclose key information about their manner of operations and the ATS-related activities of their broker-dealer operators and affiliates. These disclosures are intended to allow market participants to better

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[215] *See* FINRA Regulatory Notice 16-39 (Oct. 2016); SR-FINRA-2016-027, 81 Fed. Reg. 73167 (Oct. 24, 2016) (SEC approval of FINRA rules requiring reporting). The reporting requirement was effective July 10, 2017.

[216] *See* FINRA Notice 16-39 at 2.

[217] *Id.*

[218] *See* FINRA Regulatory Notice 18-34 (Oct. 4, 2018); File No. SR-FINRA-2018-023, 83 Fed. Reg. 40601 (Aug. 15, 2018). The requirement was effective April 1, 2019. The requirement will not include trades between two non-FINRA member firms.

[219] *See*, *e.g.*, *Financial Industry Regulatory Authority, Inc.; Order Approving Proposed Rule Change To Allow FINRA To Publish or Distribute Aggregated Transaction Information and Statistics on U.S. Treasury Securities*, Exch. Act Rel. No. 87837, 84 FR 71986 (Dec. 30, 2019); *see also* U.S. Department of the Treasury, *Quarterly Refunding Statement* (Feb. 5, 2020) (noting that "the public report of weekly aggregated transactions will provide the most comprehensive account of how much, in what security types, and in what segments of the market Treasury securities are traded").

[220] *See* ATS-N Adopting Release, 83 Fed. Reg. 38768 (Aug. 7, 2018).

understand how their orders will interact and be executed inside each ATS, and to help market participants understand differences, if any, in the treatment in the ATS between subscribers, on the one hand, and the broker-dealer operator and its affiliates, on the other hand. The disclosure is also intended to facilitate analysis of potential conflicts of interest more generally as well as risks of information leakage. In addition, the disclosures are intended to make NMS Stock ATSs more comparable with one another, and to help market participants compare these venues with other market centers in the national market system.

7. Disclosure of Order Handling Information

In November 2018, the Commission amended its requirements with respect to order handling and routing disclosures.[221] These amendments enhanced the quarterly public reports that broker-dealers were already required to publish, by mandating disclosure of, among other things, payment for order flow arrangements and profit-sharing relationships. The amendments also require broker-dealers, upon request by a customer who places a "not held" order,[222] to provide a customer with a standardized set of individualized disclosures about the firm's handling of the customer's orders, including average rebates received from (or fees paid to) trading venues, and information about orders that provided or removed liquidity.[223]

8. Staff Reports on Episodes of Extreme Volatility

To facilitate market understanding of the dynamics of complex markets during periods of extreme volatility, Commission staff, in some cases working alongside the staff of other financial regulators, have published reports describing and analyzing market events. Specifically, reports were published following the Flash Crash of May 6, 2010,[224] the unusual volatility in the U.S. Treasury market on October 15, 2014,[225] and the equity market volatility of August 24, 2015.[226] These reports discuss in detail the market

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[221] *See* 17 CFR § 242.605-606; Order Handling Adopting Release.

[222] A not-held order generally gives a broker-dealer price and time discretion in the handling of that order.

[223] *See* 17 CFR § 242.606(b)(3).

[224] *See* Flash Crash Report.

[225] *See* Treasury Market Report.

[226] August 24, 2015 Report; Austin Gerig and Keegan Murphy, *The Determinants of ETF Trading Pauses on August 24th, 2015* (Feb. 2016), available at: https://www.sec.gov/marketstructure/research/determinants_eft_trading_pauses.pdf.

dynamics during these periods of unusual volatility. They also provide insight into the complexity and data-driven nature of markets as well as some of the limits of regulatory oversight and analysis as a result of data limitations. Some of these limitations have been or are expected to be addressed, including when the CAT is more fully operational.

9. Market Structure Statistics and Research

The SEC website publishes market data statistics and research on market structure issues, and makes available tools for the public to visualize changes in market structure data.[227] The statistics available on this website are derived from the Commission's Market Information Data Analytics System (MIDAS), which provides Commission staff with market data comparable to that used by some of the more sophisticated market participants, including the equity and options SIPs, equity exchange proprietary data, fixed-income data, futures market data, and cryptocurrency data.

B. Mitigating Price Volatility

As algorithmic and electronic trading have become more prevalent in today's markets, several notable events and other considerations have lent support to the concern that algorithmic markets may be increasingly prone to quick, large market moves unrelated to fundamental economic information about the underlying companies or the broader economy. To help mitigate the negative effects of algorithmic price swings that may occur too rapidly for human detection and engagement and may unduly destabilize markets, the Commission and other regulators have implemented several controls to modulate large, rapid price moves in individual equity securities and the equity markets more generally.

1. Regulation SHO (Short Selling) Circuit Breaker

In 2010, the Commission approved rules requiring trading centers to have in place policies and procedures to restrict short selling in NMS stocks when a stock has declined 10% or more relative to the previous day's closing price.[228] Once this short-sale circuit breaker has been triggered, for the remainder of the day and the following day, short sale orders may generally, subject to certain exemptions, not be executed or displayed at a price that is less than or equal to the current national best bid.[229] This rule is intended to prevent short

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[227] *See Market Structure*, https://www.sec.gov/marketstructure/. Members of the public may also email Commission staff about this website and market structure issues at marketstructure@sec.gov.

[228] *See* 17 CFR § 242.201; *Amendments to Regulation SHO*, Exch. Act Rel. No. 61595, 75 Fed. Reg. 11231 (Mar. 10, 2010).

[229] 17 CFR § 242.201(b).

selling, including potentially manipulative or abusive short selling, from driving down further the price of a security that has already experienced a significant intra-day price decline, and to facilitate the ability of long sellers to sell first upon such a decline.[230]

2. Single-Stock Circuit Breakers

One response to the volatility in equity markets on May 6, 2010 was the introduction of a single-stock circuit breaker pilot program.[231] This program was implemented through three stages of rule filings by the exchanges and FINRA, beginning in June 2010.[232] In the first stage, the Commission approved rules to pause trading during periods of extraordinary market volatility in stocks included in the S&P 500.[233] The second stage added to the pilot securities in the Russell 1000 index, as well as specified exchange traded products.[234] The third stage added all remaining NMS stocks to the pilot.[235] All rights and warrants were later exempted from the pilot.[236] The single-stock circuit breaker pilot expired at the end of July 31, 2012, and was replaced by the "limit-up, limit-down" plan, described below.

3. Limit-Up, Limit-Down Plan

To replace the expiring single-stock circuit breaker pilot, in 2012 the SEC approved on a pilot basis, and in 2013 the SROs implemented, the Plan to Address Extraordinary Market Volatility, more frequently called the "limit-up, limit-down" plan.[237] The Plan has since been amended eighteen times, and has been made permanent.[238] Under the Plan, the SIPs

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[230] 75 Fed. Reg. at 11231.

[231] 77 Fed. Reg. 33499-500 (June 6, 2012).

[232] *Id.*

[233] *See* Exch. Act Rel. Nos. 62252 (June 10, 2010), 75 Fed. Reg. 34186 (June 16, 2010); 62251 (June 10, 2010), 75 Fed. Reg. 34183 (June 16, 2010).

[234] *See* Exch. Act Rel. Nos. 62884 (Sept. 10, 2010), 75 Fed. Reg. 56618 (Sept. 16, 2010)); and Securities Exch. Act Rel. No. 62883 (Sept. 10, 2010), 75 Fed. Reg. 56608 (Sept. 16, 2010).

[235] *See* Exch. Act Rel. No. 64735 (June 23, 2011), 76 Fed. Reg. 38243 (June 29, 2011).

[236] *See*, *e.g.*, Exch. Act Rel. No. 65810 (Nov. 23, 2011) 76 Fed. Reg. 74080 (Nov. 30, 2011) (SR-NYSE-2011-57).

[237] *See* Exch. Act Rel. No. 67091, 77 Fed. Reg. 33498 (June 6, 2012).

[238] *See*, *e.g.*, Exch. Act Rel. No. 85623, 84 Fed. Reg. 16086 (Apr. 4, 2019) (approving the eighteenth amendment).

distributing consolidated data for individual stocks calculate price bands for each stock above and below a reference price. If the national best bid or national best offer of a stock equals or falls outside the upper or lower limits of one of these bands, the stock enters a "limit state." If a stock remains in a limit state for fifteen seconds, trading in the stock is paused for five minutes. Trading in the stock then reopens with an auction at the stock's primary listing exchange. The Plan is intended to pause trading when rapid price moves result from, for example, erroneous trades or gaps in liquidity, while not inappropriately restricting more fundamental price moves.[239]

Securities are divided into tiers, with each tier having a different threshold for the applicable price bands. Generally more liquid stocks have tighter price bands, and less-liquid stocks have wider price bands. The price bands are also wider for stocks in the more liquid tier in the minutes leading up to the closing auction, to avoid entering a pause during the price movement that may accompany the close of each trading day.[240]

All trading centers are required to establish, maintain, and enforce written policies and procedures designed to comply with the Plan.

4. Market-Wide Circuit Breakers

Also following the extraordinary volatility on May 6, 2010, the national securities exchanges and FINRA, in 2012, updated their rules providing for market-wide circuit breakers in the event of severe, market-wide downturns.[241] The market-wide circuit breaker is intended to pause, and, if needed, halt all trading in the event that the broad market is declining rapidly.

Generally, if the S&P 500 index declines 7% since the end of the previous day's close (Level 1), trading in all equity stocks and options is paused for fifteen minutes. If it declines to 13% from the prior day's close (Level 2), the market pauses again for fifteen minutes. If the index declines 20% from the prior day's close (Level 3), then all trading is paused until the next trading day. After 3:25pm, pauses will not occur at the 7% and 13% level, though a halt will occur for the remainder of the day if a decline reaches the 20% level.

A market-wide circuit breaker has been triggered four times. On both March 9, 2020 and March 12, 2020, several minutes after the market opened, the S&P 500 index declined 7% from the prior trading day's closing price, triggering fifteen-minute Level 1 halts in all

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[239] 77 Fed. Reg. at 33500.

[240] *See* 84 Fed. Reg. at 16092 (approving proposal to eliminate the doubling of price bands for Tier 2 stocks at the end of the trading day).

[241] *See* Exch. Act Rel. No. 67090, 77 Fed. Reg. 33531 (June 6, 2012) (approving, on a pilot basis, the SRO market-wide circuit breaker rules adjusting limits and using the S&P 500 index rather than the Dow Jones Industrial Average).

equities and options trading. On March 16, 2020, the Level 1 halt was triggered nearly immediately after the market opening, when the S&P 500 index rapidly declined more than 7% compared with the prior trading day's close. On March 18, 2020, the Level 1 was triggered early in the afternoon, several hours after the opening of regular continuous trading. In each case, trading resumed in an orderly fashion following the halts. Level 2 and Level 3 market-wide circuit breakers have not been triggered to date.

C. Facilitating Market Stability and Security

Due to the complexity and interconnection of modern markets, algorithmic trading presents significant operational and related risks to market participants, investors and our economy more broadly, and the Commission, SROs, and Commission staff have focused on matters related to risk management, operational controls, resilience, and security.

1. Market Access Rule

In response to operational risks posed by the growth and expansion of algorithmic trading, and the risks posed by sponsored and direct access specifically, in 2010, the Commission adopted a rule requiring broker-dealers with direct access, or who provide sponsored market access to others, to adopt a system of risk management controls and supervisory procedures reasonably designed to manage financial, regulatory, and other risks of that access.[242] These requirements apply to broker-dealers with access to trading directly on exchanges or ATSs, including broker-dealers providing sponsored or direct access.[243] They also apply to broker-dealer operators of ATSs that provide access to trading on their ATSs to a person other than a broker-dealer.[244]

The required financial risk management controls and supervisory procedures must be reasonably designed to prevent the entry of orders that exceed appropriate pre-set credit or capital thresholds, or that appear to be erroneous.[245] The regulatory risk management controls and supervisory procedures must also be reasonably designed to prevent the entry of orders unless there has been compliance with all regulatory requirements that (1) must be satisfied on a pre-order entry basis, (2) are designed to prevent the entry of orders that the broker or dealer or customer is restricted from trading, (3) restrict market access

[242] *See* 17 CFR § 240.15c3-5; Market Access Rule Adopting Release.

[243] 17 CFR §240.15c3-5(a)(1).

[244] *Id.*

[245] 17 CFR § 240.15c3-5(c)(1).

technology and systems to authorized persons, and (4) assure appropriate surveillance personnel receive immediate post-trade execution reports.[246]

The risk management controls and supervisory procedures required by the Market Access Rule must be reviewed for effectiveness at least annually, and the broker-dealer's chief executive officer must certify annually that the broker-dealer's controls and procedures comply with the requirements.[247] FINRA and the Commission's examination staff inspect broker-dealer compliance with the Market Access Rule.

2. Regulation SCI

To help manage and mitigate operational risks in the markets,[248] the Commission in 2014 adopted Regulation Systems Compliance and Integrity ("Regulation SCI"), which requires classes of important market participants ("SCI entities") to implement comprehensive policies and procedures to help ensure the resilience and robustness of their information technology systems, and that those systems operate in compliance with the federal securities laws and applicable (e.g., SRO) rules. Regulation SCI also requires SCI entities to report to the Commission on certain events to facilitate Commission oversight of market infrastructure.[249] Covered entities include most SROs, high-volume ATSs, NMS plan processors, and certain clearing agencies.

SCI entities must mandate participation by members or participants in scheduled testing of business continuity and disaster recovery plans, and coordinate with each other on an industry- or sector-wide basis.[250] In addition to requiring notification of certain events to the Commission, the rules also require SCI entities to provide information about events to affected members or participants, or, for major events, to all members or participants of

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[246] 17 CFR § 240.15c3-5(c)(2).

[247] 17 CFR § 240.15c3-5(e).

[248] *See*, *e.g.*, 79 Fed. Reg. at 72253 ("At the same time, these technological advances have generated an increased risk of operational problems with automated systems, including failures, disruptions, delays, and intrusions. Given the speed and interconnected nature of the U.S. securities markets, a seemingly minor systems problem at a single entity can quickly create losses and liability for market participants, and spread rapidly across the national market system, potentially creating widespread damage and harm to market participants, including investors"). Commission staff continues to analyze and assess changes in market operational and cybersecurity risks, and whether to recommend to the Commission related regulatory action.

[249] *See* 17 CFR § 242.1000-1007; SCI Adopting Release.

[250] 17 CFR § 242.1004.

the entity.[251] SCI entities must also review their systems annually, submit quarterly reports on material systems changes to the Commission, and maintain appropriate books and records.[252] The Commission's examination staff inspects SCI entities for compliance with Regulation SCI, generally on an annual basis.

3. FINRA Guidance on the Supervision of Algorithmic Trading

Recognizing the potential for algorithmic trading strategies to adversely impact market and firm stability, FINRA in 2015 provided guidance to its broker-dealer members on effective supervision and control practices for member firms and market participants that use algorithmic strategies.[253] FINRA's guidance is intended to complement Regulation SCI, and to emphasize to broker-dealers the importance of robust policies and procedures designed to protect against some of the risks addressed by Regulation SCI for SCI entities.[254]

At a general level, FINRA's guidance suggests that firms: undertake a holistic review of their trading activity and consider implementing a cross-disciplinary committee to assess and react to the evolving risks associated with algorithmic strategies; focus efforts on the development of algorithmic strategies and on how those strategies are tested and implemented; test algorithmic strategies prior to being put into production; develop their policies and procedures to include review of trading activity after an algorithmic strategy is in place or has been changed; and ensure that there is effective communication between compliance staff and the staff responsible for algorithmic strategy development.[255]

4. FINRA Registration Requirement for Developers of Algorithms

In 2016, FINRA implemented a rule requiring registration as a Securities Trader by each associated person who is primarily responsible for the design, development, or significant modification of an algorithmic trading strategy or the day-to-day supervision or direction

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[251] 17 CFR § 242.1002.

[252] 17 CFR § 242.1003.

[253] *See* FINRA Regulatory Notice 15-09 (Mar. 2015).

[254] *Id.* at 4.

[255] *Id.* at 5-7.

of these activities.[256] To register as a Securities Trader, associated persons must pass qualification exams.[257]

5. Inspections and Examinations for Controls on Algorithmic Trading

In its 2020 Examination Priorities, the staff of the Commission's Office of Compliance Inspections and Examinations (OCIE) stated that it will focus on, among other things, controls around the use of automated trading algorithms by broker-dealers.[258] Noting that "[p]oorly designed trading algorithms have the potential to adversely impact market and broker-dealer stability," staff stated that OCIE may "examine how broker-dealers supervise algorithmic trading activities, including the development, testing, implementation, maintenance, and modification of the computer programs that support their automated trading activities and controls around access to computer code."[259]

6. Participation in Financial Stability Oversight Council

The Chairman of the Commission is one of the voting members of the Financial Stability Oversight Council (FSOC).[260] FSOC has also taken notice of the important recent technological and structural changes in financial markets. For example, in its 2019 annual report, FSOC noted that:

> The evolution of financial markets has been driven by technological advances and regulatory developments. While new technologies have reduced

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[256] *See* FINRA Regulatory Notice 16-21 (June 2016); Exch. Act Rel. No. 77551, 81 Fed. Reg. 21914 (Apr. 13, 2016) (Order Approving File No. SR-FINRA-2016-007).

[257] FINRA Rule 1220(b)(4) (requiring passage of the Securities Industry Essentials exam and the Series 57 Securities Trader Representative Exam).

[258] *See* Staff of the Office of Compliance Inspections and Examinations, *2020 Examination Priorities*, p. 17 (Jan. 7, 2020) ("2020 Exam Priorities") (*available at:* https://www.sec.gov/about/offices/ocie/national-examination-program-priorities-2020.pdf).

[259] *Id.*

[260] The other voting members of the Council are the Secretary of the Treasury (who chairs the Council), the Chairman of the Board of Governors of the Federal Reserve System, the Comptroller of the Currency, the Director of the Consumer Financial Protection Bureau, the Chairperson of the Federal Deposit Insurance Corporation, the Chairperson of the Commodity Futures Trading Commission, the Director of the Federal Housing Finance Agency, the Chairman of the National Credit Union Administration, and a presidentially-appointed independent member with insurance expertise.

> transaction costs and made financial data more widely available, the increased use of technology and the entry of new types of market participants have created new types of risks. The increased use of automated trading systems and the ability to quote and execute transactions at higher speeds increase the potential for severe market disruptions from operational events at market makers or other participants. In some markets, economies of scale associated with new technologies have led to higher concentration and greater dependency for liquidity on a small number of participants. The emergence of new trading venues has fragmented trading and required the implementation of technological solutions to connect markets. The Council recommends that regulators continue to evaluate structural changes in financial markets and consider their impact on the efficiency and stability of the financial system. Regulators should also assess the complex linkages among markets, examine factors that could cause stress to propagate across markets, and consider potential ways to mitigate these risks. [261]

FSOC is also responsible for, among other things, designating key financial market utilities as "systemically important" ("SIFMUs"). These utilities perform a variety of functions in the market, including the clearance and settlement of cash, securities, and derivatives transactions; many of them are central counterparties and are responsible for clearing a large majority of trades in their respective markets.[262]

D. Additional Ongoing and Potential Commission and Staff Actions

In addition to the actions discussed above that are focused on improving transparency, mitigating volatility and enhancing the stability and security of our trading infrastructure, on an ongoing basis, Commission staff monitors and assesses market integrity, efficiency, and resiliency. In particular, Commission staff currently is monitoring and assessing changes driven by advances in technology, the virtual ubiquity of algorithmic trading in listed equities, the increasing reliance on algorithmic trading in debt securities, and the firm-specific and general dependence on electronic systems as well as the risks created by these developments. The Commission has taken various actions at the recommendation of the staff in response to these developments. In addition, as indicated in the Commission's published rulemaking agenda, the Commission and staff are contemplating further relevant measures. Ongoing and potential actions include:

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[261] Financial Stability Oversight Council, *2019 Annual Report*, pp. 5-6 (Dec. 4, 2019) (*available at:* https://home.treasury.gov/system/files/261/FSOC2019AnnualReport.pdf).

[262] For a list of the designated SIFMUs, as well as the bases for the Council's designations, *see* https://home.treasury.gov/policy-issues/financial-markets-financial-institutions-and-fiscal-service/fsoc/designations.

- In January 2020, the Commission proposed an order with respect to the governance of the consolidated equity market data plans,[263] and in May 2020, the Commission approved an order directing the SROs to submit a new National Market System Plan for consolidated equity market data.[264] Certain SROs have petitioned for review of this order in the D.C. Circuit.
- In February 2020, the Commission proposed rules related to equity market data infrastructure.[265] Commission staff will continue to consider the issues raised in, as well as public feedback on, these proposals.
- The Limit-Up, Limit-Down Plan provides that the Operating Committee of the Plan will annually provide the Commission and make publicly available a report concerning the Plan's performance during the preceding year, which will include an update on Plan operations, an analysis of any amendments implemented during the period covered by the report, and analysis of potential material emerging issues that may directly impact the operation of the Plan.[266] The Division of Trading and Markets and the Division of Economic and Risk Analysis will continue to analyze this information and make recommendations as appropriate.
- OCIE staff will examine firms with respect to their controls around automated trading algorithms.[267]
- OCIE staff will continue to evaluate whether SCI entities have established, maintained, and enforced SCI policies and procedures as required, and will continue to perform examinations to review whether SCI entities have taken appropriate action in response to past examinations.[268]
- The Division of Trading and Markets is considering recommending that the Commission propose amendments to the National Market System Plan Governing the Consolidated Audit Trail regarding data security.[269]

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[263] *See* SIP Governance Proposed Order.

[264] *See* SIP Governance Order.

[265] *See* Market Data Infrastructure Proposal.

[266] *See Plan to Address Extraordinary Market Volatility*, Appendix B.

[267] 2020 Exam Priorities, at 16-17.

[268] *Id.* at 20.

[269] *See* Unified Agenda of Regulatory and Deregulatory Actions, RIN 3235-AM62 (Fall 2019) (*available at:*

VII. Summary of Studies on Algorithmic Trading

A. Equities

This section summarizes some of the analysis and conclusions from the academic literature that focuses on the market effects of algorithmic trading and high-frequency trading, including effects on liquidity, price efficiency, and volatility. This section directly references some of the relevant academic studies.[270] In addition, it also discusses the analysis and conclusions from regulatory studies as well as the academic literature that focuses on the market effects of some of the market and regulatory initiatives discussed above.

A number of the academic studies discussed below examine the effects of algorithmic trading, which encompasses the activity of a broad set of market participants, including high-frequency traders ("HFTs").[271] Since HFTs, at least historically, have accounted for a large portion of algorithmic trading activity in the U.S. equity markets, many studies specifically focus on examining the effects of HFTs. As discussed above, high-frequency trading is classified as a subcategory of algorithmic trading and generally refers to professional traders who use extremely fast data access and processing capabilities to execute short-term strategies. HFTs generally trade frequently intra-daily and avoid carrying a position overnight.[272]

The literature on algorithmic trading by HFTs in the secondary markets for U.S. equities is extensive. Commission staff previously published literature reviews on the related topics

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https://www.reginfo.gov/public/do/eAgendaViewRule?pubId=201910&RIN=3235-AM62).

[270] The studies discussed in this section use data from both the US and foreign markets (mainly Canada and Europe) to examine the effects of algorithmic trading and high-frequency trading. While studies of foreign markets do not directly examine US markets, they can provide insight into the effects of algorithmic trading and high-frequency trading that could be applicable to US markets. Some of the studies of foreign markets discussed here use detailed data or market structure changes as identification in order to study some effects of algorithmic trading and high-frequency trading that might be difficult to examine using the available data on US markets.

[271] *See supra* Section IV.

[272] *See supra* Section IV.C.1.

of market fragmentation[273] and high-frequency trading.[274] In addition to summarizing the economic literature available at the time, these reviews discuss some of the methodological issues associated with studying algorithmic trading and HFTs, such as the difficulty of identifying relevant activity, particularly in publicly available datasets that do not explicitly flag algorithmic trading or high frequency trading.[275] Additionally, many articles survey the academic literature related to algorithmic trading and HFTs.[276]

Overall, most academic studies find that algorithmic trading and HFTs have improved market quality and helped reduce transaction costs.[277] There is ample evidence suggesting that, under normal market conditions, algorithmic trading and HFTs improve liquidity and price efficiency and reduce short term volatility. However, there is some evidence, mostly from the Flash Crash, that in certain instances algorithmic trading and HFTs may exacerbate price movements during periods of high volatility or market stress.

1. Liquidity

The academic literature has provided some important insight into questions associated with algorithmic trading and high-frequency trading. Although the results are not without exceptions or limitations, the literature has generally established that algorithmic trading and high-frequency trading improve liquidity, at least under normal market conditions. Some academic studies that examine different types of HFTs find that the results vary

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[273] *See* Staff of the Division of Trading and Markets, *Equity Market Structure Literature Review Part I: Market Fragmentation* (Oct. 7, 2013) (*available at* https://www.sec.gov/marketstructure/research/fragmentation-lit-review-100713.pdf).

[274] *See* HFT Literature Review.

[275] *See*, *e.g.* HFT Literature Review, pp. 4-11.

[276] *See* Biais and Woolley (2011), Chordia, Goyal, Lehmann and Saar (2013), Easley, L´opez de Prado and O'Hara (2013), Gomber, Arndt, Lutat and Uhle (2011), Goldstein, Kumar and Graves (2014), Jones (2013), Kirilenko and Lo (2013), Biais and Foucault (2014), O'Hara (2015), Chung and Lee (2016), Menkveld (2016), Davies and Sirri (2018), and Gomber and Zimmerman (2018).

[277] It also should be recognized that, both in discrete market segments and more generally, sophisticated and well-resourced market participants, including exchanges, dealers and proprietary trading firms, have data access and computing capabilities that significantly exceed those of most academics. Further, it also should be recognized that because the market has been subject to rapid change as a result of technological, regulatory and other developments, the efficacy of period-to-period comparisons may be limited. *See also* the discussion above with respect to potential limitations on the use of academic studies, *supra* Section IV.E.

based on the type of HFT. Most studies that examine HFT market makers find that they improve liquidity and reduce spreads. Other studies find that HFTs who "pick off" stale orders can worsen liquidity by increasing "adverse selection" costs.[278] The rest of this section discusses in more detail the different effects that studies believe algorithmic trading and high-frequency trading have or may have on liquidity, including the effects of liquidity supply by algorithmic trading and HFTs, the effects of HFTs activities that may increase adverse selection, the effects of HFTs competition, and the effects of changes in HFTs speed.

a. Algorithmic Trading and HFT Liquidity Supply

A number of academic studies find that algorithmic trading and high-frequency trading reduces bid-ask spreads. Most of these studies argue that faster speeds or an improved ability to monitor the market allow algorithmic traders and HFT liquidity suppliers to reduce their adverse selection costs, which allows them to quote tighter spreads. For example, Hendershott, Jones, and Menkveld (2011) examine the introduction of algorithmic trading on the NYSE and find that it reduces the bid-ask spread, which they attribute to algorithmic trader price quotes experiencing lower adverse-selection cost. Additionally, Brogaard, Hagströmer, Nordén, and Riordan (2015) examine an increase in the speed of HFT market makers and find it reduces their adverse selection costs, which allows them to quote tighter markets. [279]

Other academic studies find that algorithmic trading and HFTs improve liquidity by smoothing it over time. For example, Hendershott and Riordan (2013) find that algorithmic traders inter-temporally smooth liquidity by providing liquidity when bid-ask spreads are wide and taking liquidity when spreads are sufficiently narrow. Carrion (2013) finds a similar result for HFTs.[280]

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[278] In this context, "adverse selection" refers to the ability of HFTs to react faster than other participants, such as passive market makers, and trade against resting orders that have not been updated for market movements. One strategy for passive market makers to avoid or minimize "adverse selection" costs resulting from rapid market movements, would be to widen their bid-ask spread. The effectiveness of such a strategy would depend on, among other factors, whether other market makers are willing to quote a narrower spread.

[279] *See, e.g.,* Boehmer, Fong, and Wu (2018) , Carrion (2013), Hendershott and Riordan (2011), Hendershott and Riordan (2013), Korajczyk and Murphy (2019), Malinova, Park and Riordan (2018), and Riordan and Storkenmaier (2012)

[280] *See also* Hagstroomer, Norden and Zhang (2014), Hendershott and Riordan (2011), and Jarnecic and Snape (2014).

Most academic studies conclude that the tighter quotes supplied by algorithmic trading and HFTs improve effective spreads and reduce the trading costs of retail investors.[281] However, academic studies find mixed results on the impact HFTs have on institutional trading costs.[282] Brogaard et al. (2014b) finds no clear evidence that HFTs impact institutional execution costs, with institutional traders' costs remaining unchanged when HFT activity increases. Korajczyk and Murphy (2019) find evidence that HFTs only increase the costs of large institutional trades, *i.e.* above $2 million, and that they decrease the transaction costs of smaller institutional trades.[283] Tong (2015) finds that an increase in HFT activity causes an increase in the price impact of institutional orders, which increases their implementation shortfall costs.[284]

Menkveld (2016) argues that an additional benefit of HFTs is they helped the market as a whole migrate quickly to electronic trading, which, in turn, yielded lower transaction costs and more volume. He argues that there is a symbiotic relationship between new electronic venues and HFTs. New venues need HFTs to insert aggressively priced bid and ask quotes, and HFTs need the new venues to satisfy their requirements in terms of automation, speed, and low fees.

Although HFT market makers are the primary liquidity suppliers in equity markets, they usually do not have obligations to provide liquidity. One concern is that this could cause them to scale back from supplying liquidity when market conditions are uncertain or

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[281] *See, e.g.,* Conrad, Wahal, and Xiang (2015), Korajczyk and Murphy (2019), Malinova, K., A. Park, and R. Riordan (2018), Riordan and Storkenmaier (2012), and Bershova and Rakhlin (2013).

[282] As discussed above, in order to reduce their price impact, large institutional "parent" orders are divided by algorithms into many smaller "child" orders to be executed in the market. *See supra* Section IV.A.2. Beason and Wahal (2019) provide a detailed examination of the child orders produced by four widely used standardized institutional trading algorithms.

[283] They find the increased price impact caused by HFTs increases the costs of large trades, but the lower effective spread caused by HFTs lowers the costs of small trades. Van Kervel and Menkveld (2019) also find that HFTs increase the execution costs of large institutional trades. Malinova, Park and Riordan (2018) examine the average overall effects on institutional trades in the same setting as Korajczyk and Murphy (2019) and find that increased HFT activity causes them to decline.

[284] Tong (2015) also finds that an increase in HFT activity causes the effective spread of institutional orders to decline, but the increase in the price impact dominates the decrease in the effective spread and causes the implementation shortfall costs of institutional investors to increase.

otherwise unfavorable. Boehmer, Li and Saar (2018) find that the strategies of HFTs are correlated and Malceniece et al. (2019) find that HFTs cause significant increases in co-movement in the returns and liquidity of stocks. This correlation in price movements and the supply of liquidity could be the result of HFT market makers withdrawing from (and/or cause HFT market makers to withdraw from) the market at the same time. Anand and Venkataraman (2016) find evidence that market makers scale back in unison when market conditions are unfavorable, which contributes to covariation in liquidity supply, both within and across stocks.[285]

Market making quoting obligations could improve liquidity in these circumstances. Anand and Venkataraman (2016) compare HFTs without quoting obligations to designated market makers (DMMs), *i.e.* HFTs who have quoting obligations. They find that DMMs continued to participate at times when the other HFTs scale back, which reduces execution uncertainty. Clark-Joseph, Ye, and Zi (2017) also look at how DMM obligations on NYSE affect liquidity and find evidence that is consistent with the idea that DMMs cause meaningful improvements in liquidity.

b. HFT Activities and Increased Adverse Selection

This subsection discusses certain HFT activities that could increase the adverse selection costs of some traders, including: "stale quote arbitrage," "order anticipation," "quote stuffing," and "spoofing."

Stale Quote Arbitrage

Some HFTs can use their speed advantage to pick off stale limit orders. This can raise the adverse selection costs of market makers and lead to them quoting wider spreads. Academic studies have found evidence of HFTs being able to trade against stale quotes. For example, Brogaard, Hendershott and Riordan (2016) find that HFTs adversely select limit orders and this affects liquidity negatively.[286] Aquilina, Budish, and O'Neill (2020) attempt to empirically estimate the costs they believe these arbitrage opportunities impose on investors and other market participants.

Even with their speed advantage, HFT market makers cannot completely avoid being adversely selected on their limit orders. Menkveld (2013) and Brogaard, Hendershott and Riordan (2014) find that HFT market makers are adversely selected on their quotes.[287] Budish, Cramton and Shim (2015) argue that this creates incentives for HFTs to overinvest

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[285] Anand and Venkataraman (2016) find that HFT liquidity suppliers scale back when there are large order imbalances. They also find that HFTs earn higher profits and supply more liquidity during periods of higher stock volatility.

[286] *See also* Brogaard, Hendershott and Riordan (2014) and Van Kervel (2015).

[287] *See also* Biais, DeClerck and Moinas (2016).

in speed to be able to react the fastest. This competitive dynamic, which the authors refer to as a technological "arms race," may not benefit market participants or market efficiency.

Order Anticipation

A number of academic studies show that HFTs are able to predict the order flow of other traders. For example, Hirschey (2018) finds that the aggressive buying and selling of HFTs is correlated with the aggressive buying and selling of non-HFTs in the next 30 seconds. He interprets this finding as anticipatory trading by HFTs. Similarly, Clark-Joseph (2013) also suggests that HFTs employ order anticipation strategies in the E-mini S&P 500 futures market by submitting small aggressive marketable orders and observing the responses.[288]

Yang and Zhu (2019) provide a model of "back-running," where strategic traders use order anticipation strategies based on past order flows to predict the order flow of institutional investors. Empirical evidence suggests that HFTs are able to back-run on the long-lasting informed orders of institutional investors, which may increase institutional investors' transaction costs. For example, Van Kervel and Menkveld (2019) find that HFTs initially trade in the opposite direction of large institutional orders, but eventually change direction and take positions in the same direction for the most informed institutional orders, which increases the execution costs for these orders.[289]

Quote Stuffing

One harmful market strategy HFTs may engage in is "quote stuffing," which refers to an HFT strategy in which a very large number of orders to buy or sell securities are placed in quick succession and then canceled almost immediately.[290] Davies and Sirri (2018) discuss that this type of activity can be used to take advantage of orders that are based on the best bid and offer and can also impact market integrity by clogging message traffic and delaying other traders with slower connections from updating or submitting their orders.[291]

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[288] *See also* Breckenfelder (2019) and Raman, Robe and Yadav (2014).

[289] Korajczyk and Murphy (2019) find that during larger institutional trade executions, HFTs submit more same-direction orders. They find this leads to higher transaction costs for large, informed trades and lower transaction costs for small, uninformed trades.

[290] The Concept Release discusses other forms of HFT directional strategies that may adversely affect some market participants, including order anticipation and momentum ignition strategies.

[291] Quote stuffing can be difficult to detect. Periods of excessive quoting could be a part of a manipulative trading strategy. Alternatively, Hasbrouck (2018) also discusses that periods of excessive quoting could also be the result of HFTs competing with each other to undercut prices. Gai, Yao, and Ye (2013) identify potential quote stuffing in NASDAQ by

Egginton, Van Ness, and Van Ness (2016) look at intense episodic spikes in quoting activity and find that they have a negative impact on market quality, with targeted stocks suffering decreased liquidity, higher trading costs, and increased short-term volatility.

Spoofing

Another harmful strategy HFTs may engage in is "spoofing," which involves the submission and cancellation of buy and sell orders without the intention to trade in order to manipulate other traders.[292] Lee, Eom, and Park (2013) examine spoofing in the Korea Exchange. They find that investors strategically placed spoofing orders to create the impression of substantial order book imbalances in order to manipulate subsequent prices. They find that the stocks targeted for spoofing had higher return volatility, lower market capitalization, lower price level, and lower managerial transparency.

c. HFT Competition

Academic studies provide mixed evidence about how competition among HFTs affects liquidity. A number of these studies generally find that more competition between HFTs seems to decrease spreads and improve price resiliency, *i.e.*, a quicker narrowing of the spread after it widens. For example, Brogaard and Garriott (2019) examine how the entry of new HFTs affects competition among HFTs and find that bid–ask spreads decrease and effective and realized spreads for non-HFTs narrow when new HFTs enter the market.[293] In contrast, Yao and Ye (2018) find that competition among HFTs can increase the costs of

examining abnormally high levels of co-movement of message flows for stocks in the same data channel.

[292] It should be noted that to the extent that any trading activity, including order activity, is manipulative it is subject to legal and regulatory sanction. The Commission has brought several actions based on alleged "spoofing" and the inspections and enforcement staff of the Commission review trading activity for possible violations of anti-manipulation laws and regulations. *See*, *e.g.*, "SEC Charges Firms Involved in Layering, Manipulation Schemes" (Mar. 10, 2017) (noting filing of charges against individuals and a securities firm for engaging in and facilitating layering and other market manipulation) (*available at*: https://www.sec.gov/news/pressrelease/2017-63.html); "SEC Charges 18 Traders in $31 Million Stock Manipulation Scheme" (Oct. 16, 2019) (noting an emergency action and asset freeze against defendants allegedly engaged in a market manipulation scheme creating the false appearance of trading interest and activity) (*available at:* https://www.sec.gov/news/press-release/2019-216).

[293] *See also* Hasbrouck (2018).

non-HFTs.[294] They find that when the relative tick size, *i.e.* the minimum tick size increment divided by the stock price, is larger, HFTs compete more intensely to be the first one to the front of the limit order book queue in order to supply liquidity. This increases the difficulty of establishing time priority for non-HFT limit orders and compels them to submit more market orders as the relative tick size increases, which increases their trading costs.[295]

d. HFT Speed

Academic studies provide mixed evidence regarding how an increase in the speed of HFTs affects liquidity.[296] Brogaard, Hagströmer, Nordén, and Riordan (2015) find that HFT market makers were most likely to take advantage of an optional speed upgrade offered by an exchange. When they did, it improved liquidity because it allowed them to reduce their adverse selection costs, which allowed them to quote tighter markets. In contrast, Shkilko and Sokolov (2016) examine instances of bad weather disrupting microwave trading networks between Chicago and New York and reducing the speed advantages of certain HFTs who rely on these networks. When this occurs, they find that adverse selection risk imposed by HFTs falls, which causes trading costs to decline and liquidity to improve.[297]

More speed heterogeneity among HFTs can lead to intermediation chains that improve liquidity. Menkveld (2016) discusses how differences in the trading speed and inventory holding periods of market makers can lead to the creation of intermediation chains, with a series of financial intermediaries passing along shares between end users. He argues that intermediation chains can be useful in completing trades between end users, either by forcing intermediaries to line up in a productive sequence, or by having intermediaries

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[294] Breckenfelder (2019) also examines HFT competition and finds that when HFTs compete, their speculative, *i.e.* directional, trading increases, which causes market liquidity to deteriorate.

[295] They find that a smaller relative tick size makes it easier for non-HFTs to execute their limit orders.

[296] Baron et al. (2019) also investigate how differences in latency effect competition between HFTs. They find that there are differences in relative speed across HFT firms and that the fastest firms tend to earn the largest trading revenues and remain in the market longer. New HFT entrants tend to be slower, underperform, and more likely to exit the market.

[297] Gai, Yao and Ye (2013) examine the impact of two speed upgrades on NASDAQ and find that the speed improvements led to substantial increases in the number of cancelled orders but did not lead to improvements in quoted spreads, effective spreads, trading volume or price efficiency. The authors argue that these results indicate that only relative speed matters.

effectively share the burden of an information asymmetry, or by having faster intermediaries trading more aggressively, thereby revealing information early and thus reducing information asymmetry later. Weller (2013) presents direct evidence on intermediation chains in commodity futures trading, where high-frequency market makers provide rapid execution to investors and effectively consume inventory risk-bearing services from slower market makers. Brogaard, Hagstroomer, Nordoen and Riordan (2015) show that after an exchange offered a richer menu of colocation services, HFTs sorted themselves across the various options (not all bought the fastest service). Bid-ask spreads declined and depth improved after the event, consistent with intermediation chains benefiting liquidity.

2. Price Efficiency

Academic papers also examine how algorithmic trading and high frequency trading affect the price discovery process and price efficiency.[298] The majority of these studies find that algorithmic trading and high-frequency trading improve price efficiency and decrease the time it takes for prices to incorporate new information. For example, Brogaard, Hendershott and Riordan (2014) find that, overall, HFTs facilitate price efficiency by trading in the direction of permanent price changes and in the opposite direction of transitory pricing errors.[299]

On the other hand, Weller (2018) finds evidence that algorithmic trading may reduce price efficiency by reducing the incentives for market participants to engage in costly research to learn more about companies. He finds that increased algorithmic trading leads to greater price jumps on earnings announcements. This implies increased algorithmic trading decreases the research market participants conduct to predict company earnings, which results in more surprise when earnings announcements are released.

Academic papers also generally find that algorithmic trading and high frequency trading cause quotes to contribute more to the price discovery process, as opposed to trades. For example, Hendershott, Jones, and Menkveld (2011) find that an increase in algorithmic trading caused quotes to become more informative and contribute more to price discovery as opposed to trades.[300] Brogaard, Hendershott and Riordan (2019) more closely examine

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[298] Price efficiency refers to the degree to which the price of a security incorporates all available information about the security. Price discovery refers to the process through which new information is incorporated into the price of a security.

[299] *See also* Benos, Brugler, Hjalmarsson and Zikes (2017), Boehmer, Fong, and Wu (2018), Brogaard, Hendershott and Riordan (2019), Carrion (2013), Conrad, Wahal, and Xiang (2015), Hendershott, Jones, and Menkveld (2011), Hendershott and Riordan (2011), and Riordan and Storkenmaier (2012).

[300] *See also* Hendershott and Riordan (2011) and Riordan and Storkenmaier (2012).

the contribution of HFT and non-HFT limit and market orders to price discovery and find that the majority of price discovery occurs predominately through limit orders submitted by HFTs. They also find that the contribution to price discovery from limit orders decreases and the contribution from market orders increases when volatility increases and that this change is correlated with and may be due to changes in HFT behavior.

A number of academic papers look at the speed at which HFTs process public information and how quickly they incorporate it into stock prices. Hu, Pan and Wang (2017) examine a small group of fee-paying HFTs who receive the Michigan Index of Consumer Sentiment two seconds before its broader release and find that most of the index-futures price discovery happens within 0.2 seconds after HFTs had their early peek. Chordia, Green, and Kottimukkalur (2018) examine trading around macroeconomic announcement surprises and find that prices respond to the surprises within 5 milliseconds, but that profits from trading quickly around the announcements are relatively small.

3. Volatility

Drawing connections between algorithmic trading and high-frequency trading and rapid changes in prices would seem to be a straightforward argument given the immense speed at which they trade. It would also appear a small step further to conclude that rapid and significant changes (*i.e.*, increased price volatility) would be driven by algorithmic trading. However, academic research has cast some doubt on this conclusion. Although some studies argue otherwise, a number of academic papers study the effects of algorithmic trading and high-frequency trading on volatility in equity markets and find evidence that, under normal market conditions, they reduce short term volatility. However, there is some evidence, mostly from the Flash Crash, that in certain instances algorithmic trading and high-frequency trading may exacerbate price movements during periods of uncertainty or market stress.

a. Short Term Volatility

Most academic studies find that algorithmic trading and high-frequency trading reduce short term volatility. For example, Brogaard, Hendershott and Riordan (2014) find that HFTs trade against transitory price movements, which can reduce volatility.[301] Additionally, Boehmer, Li and Saar (2018) find evidence that increased competition between HFT market makers contributes to lower volatility.

However, in contrast to the previous studies, Boehmer, Fong, and Wu (2018) find that algorithmic trading increases short-term volatility and that the effects are stronger in small

[301] *See also* Groth (2011) Hagströmer and Nordén (2013), Hasbrouck and Saar (2013) Hendershott and Riordan (2011), and Hendershott and Riordan (2013).

stocks.[302] The authors note that the increase in volatility cannot be attributed to faster price discovery or to the penchant of algorithmic traders for entering volatile markets.

Some academic studies also find that algorithmic trading and high-frequency trading continue to reduce volatility during periods of heightened volatility. For example, Hendershott and Riordan (2013) find that algorithmic trading contributes to volatility dampening in turbulent market phases because algorithmic traders do not retreat from or attenuate trading during these times.[303] Brogaard, Carrion, Moyaert, Riordan, Shkilko and Sokolov (2018) also find that HFTs trade against extreme price movements and thus stabilize prices during periods of heightened volatility. However, as discussed below in the section on the Flash Crash, there is evidence that in certain periods of market stress HFTs can exacerbate volatility, including because they may withdraw from the market en masse.

b. The Flash Crash

Generally, it appears algorithmic trading and HFTs improve market quality and reduce volatility during "normal" market periods. However, it is possible that such strategies and market participants may impact the market differently during periods of uncertainty and market stress. One area of concern has been whether high-frequency trading promotes sudden and unexpected price dislocations. Some researchers suggest that the ability of HFTs to leave the market rapidly has made the markets more fragile and could exacerbate periods of market stress. Kirilenko and Lo (2013) suggest that, under certain market conditions, the automated execution of large orders can create a "feedback-loop" or vicious cycle effects. These could in turn generate systemic destabilizing market events, such as the May 2010 "Flash Crash."

The "Flash Crash" occurred on May 6, 2010, when an algorithm rapidly sold 75,000 S&P500 e-mini futures contracts. Major equity indices in both the futures and securities markets were already down over 4% from their prior-day close by the time the large sell order hit at 2:30 PM. Indices moved down a further 5-6% in a matter of minutes before rebounding almost as quickly. The CFTC and SEC (2010) joint report finds that many of the almost 8,000 individual equity securities and ETFs traded that day suffered similar price declines and reversals within a short period of time, falling 5%, 10% or even 15% before recovering most, if not all, of their losses. However, some equities experienced even more severe price moves, both up and down. Over 20,000 trades across more than 300 securities were executed at prices more than 60% away from their values just moments before.

The CFTC and SEC (2010) joint report attributes the price declines to a sequence of events, including the exhaustion of the liquidity supply by HFTs, traditional buyers, and cross market arbitrageurs who spread the price pressure to other markets. Eventually a "hot potato" effect developed where blocks of futures contracts rapidly moved among the same

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[302] *See also* Bershova and Rakhlin (2013) and Malceniece et al. (2019).

[303] *See also* Groth (2011).

set of HFTs. Equity market prices declined and some algorithms withdrew their orders on the bid side in the equity market. These same algorithms, along with other algorithms, also drove demand for short positions in futures contracts and similarly withdrew from the futures market. This withdrawal from the equity market and of short demand in the futures market created a negative feedback loop that caused the bid side to be exhausted and virtually fall away so that sell orders were executed at distressed prices during a period of several minutes until a sufficient number of market participants recalibrated their algorithms or otherwise. When a five-second pause was triggered on the CME, prices began to recover and within minutes they had risen to almost their previous levels.

A number of academic studies examine the "Flash Crash" and the role that algorithmic trading and HFTs played in it. Most studies are consistent with the CFTC and SEC joint report and conclude that HFTs did not cause the 2010 Flash Crash, but their withdrawal from the market may have exacerbated the rapid price declines. For example, Easley, López de Prado, and O'Hara (2012) attribute the 2010 Flash Crash to the combination of automated market makers and increased order flow "toxicity," which combined to cause market makers to withdraw their quotes and liquidate positions.[304]

Aldrich, Grundfest, and Laughlin (2017) find that instability of the market data infrastructure also contributed to the May 2010 Flash Crash. A lag in the data feed caused stale prices for the SPY ETF to be disseminated to the market. The authors argue this caused uncertainty among algorithmic traders, and that uncertainty rationally caused them to withdraw liquidity, which contributed to the price collapses.

4. Regulatory Studies and Speed Bumps

a. Single-Stock Circuit Breaker Pilot and Limit-Up Limit-Down Plan

A number of studies look at the effects of the single-stock circuit breaker pilot and "limit-up, limit-down" plan.[305] Brogaard and Roshak (2016) find that the introduction of single-stock circuit breakers enhances market stability by reducing extreme events; however, this comes at the cost of reduced price efficiency in the market. Hautsch and Horvath (2019) examine trading pauses during the single-stock circuit breaker pilot and "limit-up, limit-down" plan and find that, on average, trading pauses enhance price discovery during the break but increase volatility and widen bid-ask spreads after the break. They argue there is a trade-off between the benefits of trading pauses in terms of their function as safeguards and protectors from extreme price movements and their adverse effects on volatility, price stability, and transaction costs.

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[304] *See also* Kirilenko, Kyle, Samadi, and Tuzun (2017), McInish, Upson and Wood (2014), and Menkveld and Yueshen (2018).

[305] *See supra* Section VI.B.2 and Section VI.B.3 for discussions of the single-stock circuit breaker pilot and "limit-up, limit-down" plan.

As part of the "limit-up, limit-down" plan, the Participants to the Plan were required to submit an analysis of the "limit-up, limit-down" plan's performance. The Supplemental Joint Assessment by the Participants finds that the number of trades that were cancelled decreased under the "limit-up, limit-down" plan and that the "limit-up, limit-down" plan's parameters were successful in preventing trades from occurring outside of the "limit-up, limit-down" price bands, thus avoiding the types of mispriced trades that resulted in the Flash Crash. Hughes, Ritter, and Zhang (2017) examines how the "limit-up, limit-down" plan affects extraordinary transitory volatility, as measured by the frequency of large, short-term trade-price reversals. They find evidence that is consistent with the "limit-up, limit-down" mechanisms reducing extraordinary transitory volatility. They also find some evidence that is consistent with the "limit-up, limit-down" mechanisms reducing extraordinary transitory volatility relative to the single-stock circuit breaker mechanism that was in place prior to the "limit-up, limit-down" mechanism.[306]

b. 15c3-5

In November 2011, the SEC implemented the final provision of Rule 15c3-5 curbing unfiltered market access. The provision mandated that brokers verify their clients' order flow for compliance with credit and capital thresholds before routing to market centers. Chakrabarty et al. (2019b) find that the new checks introduce latency to order flow and force some latency-sensitive strategies out of the market. As a result, liquidity providers are better able to revise their quotes in response to new information, which causes adverse selection to decline and liquidity to improve. Consistent with the notion that the market for liquidity provision is competitive, they argue that their results show that the benefit of lower adverse selection is transferred entirely to liquidity demanders in the form of lower trading costs.

c. Speed bumps

One solution that has been incorporated by some exchanges to reduce the adverse selection costs imposed by HFTs is the "speed bump," an intentional delay that slows down access and messaging to the market center. The most well-known instance of this occurs on the Investors Exchange (IEX), which was previously organized as an ATS. IEX creates a 350-microsecond delay by running all external communications through a coil of fiber-optic cable.

Hu (2019) examines the effects of IEX's speed bump and shows that when stocks are affected by IEX's speed bump, their trading costs decline on average, with larger decreases for stocks with higher historical average trading activity on IEX.[307] He also finds that adverse selection costs decrease and that the speed bump decreases the chances that

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[306] Hughes, Ritter, and Zhang (2017) note that these results vary depending on the specific methodology employed.

[307] *See also* Chakrabarty et al. (2019a).

stocks are exposed to "sweep risk," the risk of trading against large informed or "toxic" orders that may trade through multiple levels of an order book or across multiple venues.

The effects of speed bumps can vary based on whether they are applied equally to all traders or if they only slow down the orders of some traders but not others, *i.e.*, an asymmetric speed bump. Chen et al. (2017) examines the introduction of an asymmetric, randomized speed bump on the Canadian exchange TSX Alpha that slows down liquidity demanding orders. This feature is designed to allow low-latency liquidity providers to avoid order-flow driven adverse selection by reacting to activity on other venues. They observe that spreads and order cancellations increase when the exchange adds the speed bump and that it segments order flow and increases profits for fast liquidity providers on that venue at the expense of other liquidity providers and aggregate market quality.

B. Debt Securities

As noted above, academic research on algorithmic trading in debt securities is limited.[308] The literature that exists focuses largely on instruments with readily-available order-level data, such as on-the-run Treasury securities. Due to a lack of order level data, there is little literature on algorithmic trading in corporate and municipal bonds.

Similar to HFTs in the equity markets, principal trading firms (PTFs) play a prominent role as intermediaries in the interdealer on-the-run Treasuries market.[309] Using data on trades in Treasury securities reported to TRACE, Brain et al. (2018) estimate that PTFs account for about 62 percent of trading volume in the electronic/automated interdealer-broker Treasury market. The majority of electronic trading in the on-the-run interdealer Treasury market occurs on the electronic BrokerTec platform. Fleming et al. (2018) examine liquidity and price discovery in on-the-run Treasuries traded in the central limit order book on this platform. In general, they find that the BrokerTec platform offers more liquidity, greater market depth, more trading activity, and narrower bid-ask spreads than the comparable voice-assisted broker systems. Similar to equities markets, they find that order cancellation rates are high and that more price discovery occurs via quotes than executed trades.

Jiang et al. (2014) examines the effects of high-frequency trading activity, which would include PTFs, on liquidity and price efficiency in on-the-run Treasuries around pre-scheduled macroeconomic announcements. They find that high-frequency trading has a negative effect on liquidity (wider spreads) in the pre-announcement period, and that high-

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[308] *See supra* Section V.C.

[309] As discussed above, principle trading firms (PTFs) are technologically and quantitatively sophisticated firms trading as principal. In the on-the-run Treasuries market, PTFs would exhibit similar characteristics to HFTS in the equities market. *See infra* Section X.D, for a more general discussion of principal trading firms.

frequency trading lowers the depth of the order book post-announcement. However, they also conclude that price efficiency is improved both pre- and post-announcement.

In comparison to the Flash Crash discussion above, there is evidence to suggest that some PTFs in the on-the-run Treasury market may remain in the market and reduce the liquidity they supply, rather than withdrawal from the market, during periods of market stress. The Joint Staff Report (2015) examines the behavior of PTFs during the unusual Treasury market volatility of October 15, 2014, when there was a surge in trading activity in both the cash Treasuries and futures markets. The report finds that during the event PTFs continued to provide the majority of order book depth, and maintained a tight spread between bid and ask prices, but decisively cut back their limit order quantities. In contrast, bank-dealers widened their bid-ask spreads so that limit orders were only met at a substantial distance from the top of the book. Despite the surge in trading volume during the event window, there was no noticeable change in net positions of PTFs or bank-dealers. However, the report also finds evidence that some PTFs and bank-dealers may have contributed to the volatility. The report finds that nearly all of the large imbalance in aggressive buy orders during the early portion of the event window was attributable to PTFs and bank-dealers.[310]

VIII. Conclusion

Today's equity markets are highly interconnected and substantially, data-driven. Electronic trading and algorithmic trading (however defined) are both widespread and integral to the operation of our capital markets. We expect current trends to continue and that equity markets and various segments of our credit markets will remain highly electronic, highly reliant on computer-driven algorithms, and subject to more-rapid dissemination of information into prices and trading activity.

This increase in algorithmic trading brings with it both benefits and risks to our capital markets, including new and emerging risks. This means that continued vigilance in monitoring these advances in technology and trading, and updating of systems and expertise will be necessary in order to help ensure that our capital markets remain fair, deep, and liquid.

The Commission has undertaken various measures, and is evaluating other actions, to increase transparency, mitigate volatility, enhance stability and security and otherwise improve market integrity as summarized above. The Commission has sought input from market participants and the public more generally on these measures and potential actions. The Commission's work benefits from this input and engagement and we encourage

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[310] *See* The Joint Staff Report (2015) at 23-25.

interested parties to comment on these matters and to bring any other matters that may warrant analysis or action to our attention.

IX. Bibliography to Summary of Academic Studies

Aldrich, E.M., J.A. Grundfest, and G. Laughlin, 2017. "The Flash Crash: A New Deconstruction." Working Paper, available at SSRN: https://ssrn.com/abstract=2721922.

Anand, A. and K. Venkataraman, 2016. "Market conditions, fragility and the economics of market making." *Journal of Financial Economics* 121: 327-349.

Angel, J. J., L.E. Harris, and C.S. Spatt, 2015. "Equity Trading in the 21st Century: An Update." *Quarterly Journal of Finance* 5: 1–39.

Aquilina, M., E. Budish, and P. O'Neill, 2020. "Quantifying the High-Frequency Trading 'Arms Race': A Simple New Methodology and Estimates." UK Financial Conduct Authority Occasional Working Paper No. 50, available at: https://www.fca.org.uk/publications/occasional-papers/occasional-paper-no-50-quantifying-high-frequency-trading-arms-race-new-methodology.

Baron, M., J. Brogaard , B. Hagströmer, and A. Kirilenko, 2019. "Risk and Return in High-Frequency Trading." *Journal of Financial and Quantitative Analysis* 54: 993-1024.

Beason, T. and S. Wahal, 2020. "The Anatomy of Trading Algorithms." Working Paper, available at SSRN: https://ssrn.com/abstract=3497001.

Benos, E., J. Brugler, E. Hjalmarsson, and F. Zikes, 2017. "Interactions among High-Frequency Traders." *Journal of Financial and Quantitative Analysis* 52: 1375-1402.

Bershova, N. and D. Rakhlin, 2013, "High-frequency trading and long-term investors:

A view from the buy-side." *Journal of Investment Strategies* 2: 25-69.

Biais, B., F. Declerck, and S. Moinas, 2016. "Who Supplies Liquidity, How and When?" BIS Working Paper No. 563, available at SSRN: https://ssrn.com/abstract=2789736.

Biais B and T. Foucault, 2014. "HFT and market quality." *Bankers, Markets & Investors* 128:5-19.

Biais B and P. Woolley P, 2011. "High frequency trading." Toulouse University Manuscript.

BlackRock, 2015. "U.S. Equity Market Structure: Lessons from August 24." Viewpoint, available at: https://www.sec.gov/comments/265-29/26529-52.pdf.

Brain, D., M.D. Pooter, D. Dobrev, M. Fleming, P. Johansson, C. Jones, F.M. Keane, M. Puglia, L Reiderman, A.P. Rodrigues, and O. Shachar, 2018. "Unlocking the Treasury Market through TRACE," Federal Reserve Bank of New York *Liberty Street Economics* (blog), September 28, 2018, available at: http://libertystreeteconomics.newyorkfed.org/2018/09/unlocking-the-treasury-market-through-trace.html

Boehmer, E., K. Fong, and J. Wu, 2018. "Algorithmic Trading and Market Quality: International Evidence." Working Paper, available at SSRN: https://ssrn.com/abstract=2022034.

Boehmer, E., D. Li, and G. Saar, 2018. "The Competitive Landscape of High-Frequency Trading Firms." *The Review of Financial Studies* 31: 2227-2276.

Bollen, N. P. B., and R.E. Whaley, 2015. "Futures market volatility: What has changed?" *Journal of Futures Markets* 35: 426– 454.

Breckenfelder, J., 2019. "Competition among High-Frequency Traders, and Market Quality." ECB Working Paper No. 2290 (2019); ISBN 978-92-899-3552-4, available at SSRN: https://ssrn.com/abstract=3402867.

Brogaard, J., A. Carrion, T. Moyaert, R. Riordan, A. Shkilko, and K., 2018. "High frequency trading and extreme price movements." *Journal of Financial Economics* 128: 253– 265.

Brogaard, J. and C. Garriott, 2019. "High-Frequency Trading Competition." *Journal of Financial and Quantitative Analysis* 54: 1469-1497.

Brogaard, J., B. Hagströmer, L. Nordén, and R. Riordan, 2015. "Trading Fast and Slow: Colocation and Liquidity." *The Review of Financial Studies* 28: 3407-3443.

Brogaard, J., T. Hendershott, and R. Riordan, 2014. "High-Frequency Trading and Price Discovery." *The Review of Financial Studies* 27: 2267–2306.

Brogaard, J., T. Hendershott, and R. Riordan, 2017. "High frequency trading and the 2008 short-sale ban." *Journal of Financial Economics* 124: 22-42.

Brogaard, J., T. Hendershott, and R. Riordan, 2019 "Price discovery without trading: evidence from limit orders." *Journal of Finance* 74: 1621-1658.

Brogaard, J. and K. Roshak, 2016. "Prices and Price Limits." Working Paper, available at SSRN: https://ssrn.com/abstract=2667104.

Budish, E., P. Cramton, and J. Shim, 2015. "The high-frequency trading arms race: frequent batch auctions as a market design response." *Quarterly Journal of Economics* 130: 1547-1621.

Cappon, A., 2014. "The brokerage world is changing, who will survive?" available at: https://www.forbes.com/sites/advisor/2014/04/16/the-brokerage-world-is-changing-who-will-survive/#11d472d668a7.

Carrion, A., 2013. "Very fast money: high-frequency trading on the Nasdaq." *Journal of Financial Markets* 16: 680-711.

Chaboud, A., B. Chiquoine, E. Hjalmarsson, and C. Vega, 2014. "Rise of the machines: algorithmic trading in the foreign exchange market." *Journal of Finance* 69: 2045-2084.

Chakrabarty, B., J. Huang, and P.K. Jain, 2019. "Effects of a Speed Bump on Market Quality and Exchange Competition." Working Paper, available at SSRN: https://ssrn.com/abstract=3280645.

Chakrabarty, B., P.K. Jain, A. Shkilko, and K. Sokolov, 2019. "Unfiltered Market Access and Liquidity: Evidence from the SEC Rule 15c3-5." *Management Science*, Forthcoming, available at SSRN: https://ssrn.com/abstract=2328231.

Chordia T., A. Goyal, B.N. Lehmann, and G. Saar, 2013. "High-frequency trading." *Journal of Financial Markets* 16: 637-645.

Chordia, T., T.C. Green, and B. Kottimukkalur, 2018. "Rent Seeking by Low-Latency Traders: Evidence from Trading on Macroeconomic Announcements." *The Review of Financial Studies* 31: 4650–4687.

Chung, K.H. and A. Lee, 2016. "High-Frequency Trading: Review of the Literature and Regulatory Initiatives around the World." *Asia-Pacific Journal of Financial Studies* 45: 7-33.

Clark-Joseph, A., 2014. "Exploratory Trading." Working Paper, available at: https://pdfs.semanticscholar.org/6681/90df945037f0649c2e4cc71ea5c3128ab1a5.pdf

Clark-Joseph, A, M. Ye, and C. Zi, 2017. "Designated market makers still matter: evidence from two natural experiments." *Journal of Financial Economics*, 126: 652-667.

Committee on the Global Financial System, 2016. "Fixed income market liquidity." CGFS Papers No 55, available at: https://www.bis.org/publ/cgfs55.htm.

Conrad, J., S. Wahal, and J. Xiang, 2015. "High-frequency quoting, trading, and the efficiency of prices." *Journal of Financial Economics* 116: 271-291.

Davies, R.J. and E. Sirri, 2018. "The Economics of Trading Markets," in *Securities Market Issues for the 21st Century*, eds. M.B. Fox, L.R. Glosten, E.F. Greene, and M.S. Patel, Columbia University, 149-220.

Easley, D., M. Lopez de Prado, and M. O'Hara, 2012. "Flow toxicity and liquidity in a high frequency world." *Review of Financial Studies* 25:1457-1493.

Easley, D., M. Lopez de Prado, and M. O'Hara, 2013. *High-frequency trading*. London: Risk Books

Egginton, J., B. Van Ness, and R. Van Ness, 2016. "Quote stuffing." *Financial Management* 45: 583-608.

Fleming, M., 2016. "Is Treasury Market Liquidity Becoming More Concentrated?" *Liberty Street Economics Blog*, available at: https://libertystreeteconomics.newyorkfed.org/2016/02/is-treasury-market-liquidity-becoming-more-concentrated.html.

Fleming, M., B. Mizrach, and G. Nguyen, 2018, "The microstructure of a US Treasury ECN: The BrokerTec platform." *Journal of Financial Markets* 40: 2–22.

Frazzini, A., I. Ronen, and T. Moskowitz, 2012. "Trading Costs of Asset Pricing Anomalies." Fama-Miller Working Paper; Chicago Booth Research Paper No. 14-05, available at SSRN: https://ssrn.com/abstract=2294498.

Gai, J., M. Ye, and C. Yao, 2013. "The Externalities of High Frequency Trading." Working Paper, available at SSRN: https://ssrn.com/abstract=2066839.

Gerig, A., and K. Murphy, 2016. "The Determinants of ETF Trading Pauses on August 24th, 2015." DERA White Paper, available at: https://www.sec.gov/files/feb2016-white-paper-determinants-etftrading-pauses.pdf.

Goldstein, M.A., P. Kumar, and F.C. Graves, 2014. "Computerized and high-frequency trading." *The Financial Review* 49:177-202.

Gomber, P. and K. Zimmermann, 2018. "Algorithmic Trading in Practice." In The Oxford Handbook of Computational Economics and Finance, editors Chen, S., M. Kaboudan, and Y. Du, Oxford University Press.

Gomber, P., A. Björn, M. Lutat, and T.E. Uhle, 2011. "High-Frequency Trading." Working Paper, available at SSRN: https://ssrn.com/abstract=1858626.

Groth, S., 2011. "Does algorithmic trading increase volatility? Empirical evidence from the fully-electronic trading platform XETRA." In *Proceedings of the 10th International Conference on Wirtschaftsinformatik*.

Hagströmer, B. and L. Nordén L., 2013. "The diversity of high-frequency traders." *Journal of Financial Market* 16: 741-770.

Hagströmer B., L. Nordén, and D. Zhang, 2014. "How aggressive are high-frequency traders?" *The Financial Review* 49:395-419.

Hasbrouck, J., 2018. "High frequency quoting: Short-term volatility in bids and offers." *Journal of Financial and Quantitative Analysis* 53: 613-641.

Hasbrouck, J. and G. Saar, 2013. "Low-latency trading." *Journal of Financial Markets* 16: 646– 679.

Hautsch, N. and A. Horvath, 2019. "How Effective Are Trading Pauses?" *Journal of Financial Economics* 131: 378-403.

Hendershott, T., C.M. Jones, and A.J. Menkveld, 2011. "Does algorithmic trading improve liquidity?" *Journal of Finance* 66:1-33.

Hendershott, T., and R. Riordan, 2011. "Algorithmic trading and information." NET Institute Working Paper No. 09-08, available at: http://faculty.haas.berkeley.edu/hender/ATInformation.pdf.

Hendershott, T., and R. Riordan, 2013. "Algorithmic Trading and the Market for Liquidity." *The Journal of Financial and Quantitative Analysis* 48: 1001-1024.

Hirschey, N., 2018. "Do High-Frequency Traders Anticipate Buying and Selling Pressure?" Working Paper, available at SSRN: https://ssrn.com/abstract=2238516.

Hu, E., 2019. "Intentional Access Delays, Market Quality, and Price Discovery: Evidence from IEX Becoming an Exchange." Working Paper, available at SSRN: https://ssrn.com/abstract=3195001.

Hu, G.X., J. Pan, and J. Wang, 2017. "Early peek advantage? Efficient price discovery with tiered information disclosure." *Journal of Financial Economics* 126: 399-421.

Hughes, P., J. Ritter, and H. Zhang, 2017. "'Limit Up-Limit Down Pilot Plan and Extraordinary Transitory Volatility." DERA White Paper, available at https://www.sec.gov/comments/4-631/4631-2830173-161647.pdf.

Jarnecic, E. and M. Snape, 2014. "The provision of liquidity by high-frequency participants." *The Financial Review* 49:371-394.

Jiang, G. and I. Lo, 2014. "Private Information Flow and Price Discovery in the U.S. Treasury Market." *Journal of Banking and Finance* 47: 118–133.

Joint Staff Report, 2015, "The U.S. Treasury Market on October 15, 2014," U.S. Department of the Treasury, Board of Governors of the Federal Reserve System, Federal Reserve Bank of New York, U.S. Securities and Exchange Commission, and U.S. Commodity Futures Trading Commission. Available at: https://www.treasury.gov/press-center/press-releases/Documents/Joint_Staff_Report_Treasury_10-15-2015.pdf

Jones, C.M., 2013. "What do we know about high-frequency trading?" Manuscript, Columbia University, available at SSRN: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2236201

Kirilenko, A., A.S. Kyle, M. Samadi, and T. Tuzun, 2017. "The flash crash: High frequency trading in an electronic market." *Journal of Finance* 72: 967–998.

Kirilenko, A. and A. Lo, 2013. "Moore's Law vs. Murphy's Law: Algorithmic Trading and Its Discontents." *Journal of Economic Perspectives*. 27: 51-72.

Korajczyk, R.A. and D. Murphy, 2019. "High-Frequency Market Making to Large Institutional Trades." *The Review of Financial Studies* 32: 1034–1067.

Lee, C.M. and B. Radhakrishna B, 2000. "Inferring investor behavior: Evidence from TORQ data." *Journal of Financial Markets* 3:83-111.
Lee, E.J., K.S. Eom, and K.S. Park, 2013. "Microstructure-based manipulation: strategic behavior and performance of spoofing traders." *Journal of Financial Markets*, 16: pp. 227-252

Malceniece, L., K. Malcenieks, and T.J. Putniņš, 2019. "High frequency trading and comovement in financial markets." *Journal of Financial Economics* 134:381-399.

Malinova, K., A. Park, and R. Riordan, 2018. “Do Retail Investors Suffer from High Frequency Traders?” Working Paper, available at SSRN: https://ssrn.com/abstract=2183806.

McInish, T., J. Upson, and R.A. Wood, R.A., 2014. “The Flash Crash: Trading aggressiveness, liquidity supply, and the impact of intermarket sweep orders.” *Financial Review* 49: 481–509.

Menkveld, A.J., 2013. “High frequency trading and the new market makers.” *Journal of Financial Markets* 16:712-740.

Menkveld, A.J., 2016. “The Economics of High-Frequency Trading: Taking Stock.” *Annual Review of Financial Economics* 8: 1-24.

Menkveld, A. and V. van Kervel, 2019. "High-Frequency Trading around Large Institutional Orders." *Journal of Finance* 74: 1091-1137.

Menkveld, A.J. and B.Z. Yueshen, 2018. “The flash crash: A cautionary tale about highly fragmented markets.” *Managment Science*, forthcoming.

National Market System Plan Assessment to Address Extraordinary Market Volatility (the “Supplemental Joint Assessment” or “Assessment”), available at https://www.sec.gov/comments/4-631/4631-39.pdf.)

O'Hara M., 2015. “High frequency market microstructure.” *Journal of Financial Economics* 116:257-270.

Raman V, M. Robe, and P.K. Yadav, 2014. “Electronic market makers, trader anonymity and market fragility.” Working Paper, available at SSRN: https://ssrn.com/abstract=2445223.

Riordan, R. and A. Storkenmaier, 2012. “Latency, liquidity and price discovery.” *Journal of Financial Markets* 15:416-437.

Shkilko, A. and K. Sokolov, 2016. “Every Cloud Has a Silver Lining: Fast Trading, Microwave Connectivity and Trading Costs.” Working Paper, available at SSRN: https://ssrn.com/abstract=2848562.

Staffs of the U.S. Commodity Future Trading Commission and the U.S. Securities and Exchange

Commission (CFTC and SEC), 2010, Findings Regarding the Market Events of May 6, 2010. Available at: https://www.sec.gov/news/studies/2010/marketevents-report.pdf

Tong, L., 2015. “A blessing or a curse? The impact of high frequency trading on institutional

Investors.” Working Paper, available at SSRN: http://ssrn.com/abstract=2330053.a

Van Kervel, V., 2015. “Competition for order ow with fast and slow traders.” *Review of Financial*

Studies 28:2097-2127.

Van Ness, B.F., R.A. Van Ness, and E.D. Watson, 2015. “Canceling liquidity.” *Journal of Financial Research* 38: 3-33.

Weller, B.M., 2014. “Intermediation Chains.” Working paper.

Weller, B.M, 2018. “Does Algorithmic Trading Reduce Information Acquisition?” *The Review of Financial Studies* 31: 2184–2226.

Yang, L. and H. Zhu, 2019. “Back-Running: Seeking and Hiding Fundamental Information in Order Flows.” *Review of Financial Studies*, forthcoming, available at SSRN: https://ssrn.com/abstract=2583915.

Yao, C. and M. Ye, 2018. “Why Trading Speed Matters: A Tale of Queue Rationing under Price Controls.” *The Review of Financial Studies* 31: 2157-2183.

X. Appendix: Market Participants, Roles, and Obligations

This summary describes broad categories of investors in U.S. capital markets, along with the central problem of liquidity they face in trading; market intermediaries and professionals, including brokers and principal trading firms; trading platforms; and some basic legal standards central to modern trading.[311]

A. Investors

As the Commission has stated, "[t]he secondary securities markets exist to facilitate the transactions of investors."[312] Investors bear the risk of holding securities for long periods of time.[313] The Commission has, for some purposes, distinguished between investors, who are the long-term bearers of investment risk, and market professionals, who bear risks of trading but may not share the same long-term risks as investors.[314] This report adopts this general approach. It is common to further classify investors as either "retail" or "institutional."[315]

The term "retail" investor is typically used to refer to natural persons. Individuals might invest in, for example, stocks, mutual funds, exchange-traded funds (ETFs), corporate bonds, Treasury bonds, municipal bonds, or options. Individuals who satisfy the

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[311] This summary is necessarily simplified, and so may not precisely describe the operations of particular firms; in a similar vein, many of the activities described in this summary may be undertaken by individual entities or groups of affiliated entities. Because of this simplification, it may be most useful to think of this section as a summary of central roles in U.S. capital markets rather than as a description of specific firms. This point applies to the schematic diagram of market participant and venue types below, *infra* Figure 3.

[312] Fragmentation Release at 10580.

[313] *See also* Concept Release at 3603 (Long-term investors "are the market participants who provide investment capital and are willing to accept the risk of ownership…for an extended period of time").

[314] *See id.*; *see also* the discussion of this distinction and its applicability in Reg NMS Adopting Release at 37499-501, where the Commission concluded that, "when the interests of long-term investors and short-term traders conflict in this context, the Commission believes that its clear responsibility is to uphold the interests of long-term investors").

[315] *See*, *e.g.*, "Order Handling Proposing Release" at 49435-41 (discussing order handling and disclosures for institutional and retail orders).

requirements of being an "accredited investor" may also have access to private investments not otherwise advertised to the public.[316]

The term "institutional" investor generally refers to a diverse range of market participants—generally organizations which may be investing on their own behalf or on behalf of others. These investors may include, for example, the registered investment companies (e.g., mutual funds and ETFs) through which many Americans invest, pension funds, insurance companies, endowments, and private investment funds such as hedge funds.[317]

B. The Problem of Liquidity

When an investor wants to trade a security, they need to find a counterparty to trade with—for a trade to be effected, someone needs to take the other side of the trade.

Finding an investor who wants to trade the same security, in a similar volume, at a mutually-agreeable price, but on the opposite side of the market, is not, in many cases, a straightforward task.[318] Moreover, investors seeking to trade generally aim to do so

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[316] *See* 17 CFR § 230.501(a) (for individuals, defining an accredited investor as someone who, either alone or with a spouse, has a net worth over $1 million (excluding the value of a primary residence), or who had an income of over $200,000 (or, with a spouse, over $300,000) in the preceding two years and reasonably expects the same for the current year).

[317] *See*, *e.g.*, Order Handling Proposing Release at 49433 ("An institutional customer includes, for example, pension funds, mutual funds, investment advisers, insurance companies, investment banks, and hedge funds"). Certain regulations and SRO rules define thresholds and requirements to be considered an "institution" or "institutional account" for the purposes of those regulations and rules. *See*, *e.g.*, 17 CFR § 230.144A(a)(1) (defining "qualified institutional buyer" for the purpose of private resales of securities); Financial Industry Regulatory Authority (FINRA) Rule 4512(c) (defining "institutional account"—including some accounts held by natural persons—for the purposes of certain customer recordkeeping requirements); FINRA Rule 2210(a)(4) (defining "institutional investor" for the purposes of requirements with respect to communications with the public); FINRA Rule 2242(a)(7) (defining "institutional investor" for the purposes of an exemption to certain requirements related to the distribution of debt research reports). In this report, however, the term "institutional investor" is used more generically, and does not necessarily align with any of these more specific definitions.

[318] There may be, for example, practical impediments to and legal restrictions on investors' abilities to find one another for the purposes of trading. For example, only broker-dealers may be members of national securities exchanges and submit orders to exchanges; this restriction means that any investor seeking to trade on an exchange must do so, in some

without unfavorably impacting the price of the security in which they seek to trade.[319] If a long-term investor counterparty cannot be found or is not readily available, an investor seeking to trade will likely need to do so with an intermediary willing to bear the shorter-term risk of holding the security until another counterparty can eventually be found. This intermediation can be potentially risky, and, therefore, potentially costly to investors.[320] Put another way, investors who wish to trade immediately may need to pay some premium in order to do so.

A market is often said to be liquid if participants can trade immediately, even in substantial volume, without affecting the price of the instrument traded.[321] Solutions to the challenge of creating and finding liquidity reflect the nature of the securities traded, law and regulation, and the historical evolution of markets. Consequently, the markets for different

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manner, through a broker-dealer. In markets with limited publicly-available information, infrequently-traded securities, or limited centralized trading activity, investors may not know, and may have difficulty discovering, where to find an interested counterparty for a given security. An investor who trades infrequently or in small volumes may not, on their own, have an incentive to develop favorable market relationships or obtain the information necessary to effectively trade.

[319] If others in the market know that a particular security is being purchased or sold in substantial size, they are likely to adjust their ask or bid prices in response to the perceived demand, or seek to trade ahead in order to profit from rising or falling prices. Information about trading interest can be conveyed by, for example, inquiries about potential trading interest, order placement around a market, or effected trades. Public information enables participants to understand the state of a market and thereby improve investment and trading decisions, but the publication of an investor's own order or trading activity can, from the investor's perspective, negatively impact prices.

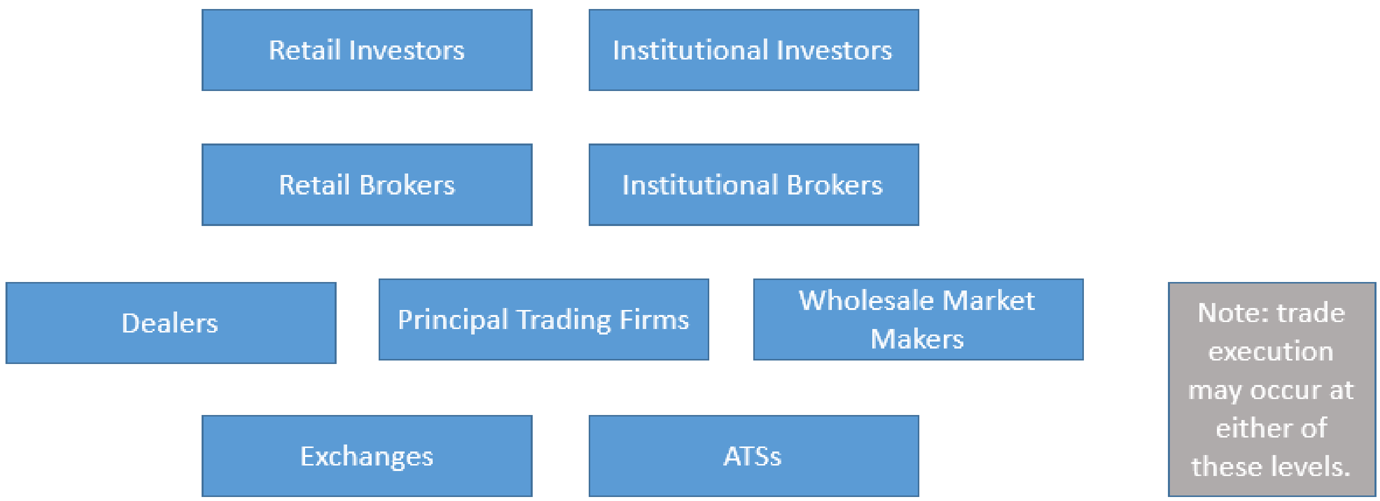
[320] "Microstructure theory broadly applied therefore implies that the costs of demanding immediate trade execution in both equity and fixed-income markets should depend on return volatility, customer arrival rates, and the likelihood of information asymmetries adverse to the intermediaries who effectively supply liquidity." Hendrik Bessembinder et al., *A Survey of the Microstructure of Fixed Income Markets at* 3 (*forthcoming*, J. Fin. & Quant. Anal.) (*available at* https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3307502). *See also The New Stock Market*, ch. 3 (describing, for modern equity markets, the role that trader information plays in shaping the provision and demand for liquidity and the management of trading risk).

[321] For a summary of approaches to evaluating liquidity, *see*, *e.g.*, Treasury Market Report at 8.

types of securities have developed unique (but, in some cases, linked) ecosystems for addressing this challenge.

The following sections describe the major types of market participants and infrastructure that have developed around this challenge, highlighting attributes that are generally common across markets. Specific activities and differences between the equity and debt markets are detailed more fully below.

Figure 3: Schematic of Key Market Role and Venue Types



C. Brokers

Generally speaking, a broker is a person engaged in the business of effecting transactions in securities for the account of others.[322] A broker effects transactions as an agent for another person—they do not trade with the order themselves, but find someone else for an order to trade with, and generally earn a commission for doing so.

Brokers may specialize in serving different types of investors, or in different types of securities. For example, a number of large retail brokers serve retail investors, and handle millions of accounts. Institutional agency brokers, on the other hand, serve the different needs of institutions, which often trade in substantial size and are particularly focused on minimizing information leakage and price impact. Institutional agency brokers may be specialized firms, or desks or departments within large, more diversified broker-dealers[323] or banks.

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[322] *See* Exchange Act Section 3(a)(4), 15 U.S.C 78c(a)(4).

[323] Many firms engage in both broker and dealer activities. A "dealer" is generally defined as any person engaged in the business of buying and selling securities for their own

D. Principal Trading Firms

Many participants in securities markets trade with their own principal ("principal trading firms" or "PTFs").[324] Principal trading firms trade in a wide variety of ways. They may, for example, act as liquidity-providing market makers, publicly displaying quotes on both sides of a market seeking to earn the difference between the bid and the ask price.[325] They may trade on trends in the markets, seeking to profit from price increases or price declines over relatively short timeframes. They may execute trades with retail orders, or hold themselves out as prepared to facilitate large block trades for institutions. Or they may perform arbitrage across products or types of securities, seeking to profit from price differentials in related instruments. In all cases, firms are using their own capital to take on market risk and seek to earn profits from their trading activity, often facilitated by the market information they are able to gather through their activities.

E. Trading Platforms

A range of platforms have developed to allow investors, broker-dealers, and traders to meet. Some platforms allow all types of market participants to meet each other on either side of a trade; others allow smaller groups of participants to meet on either side; some allow individual market participants to seek liquidity from multiple potential counterparties; and others allow a single dealer to offer liquidity to multiple potential counterparties. Each type of platform may provide a solution to the general trading problem of finding potential counterparties and liquidity under different market conditions.

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account but not as part of a regular business. *See* Exchange Act Section 3(a)(5)(A) and (B), 15 U.S.C 78c(a)(5)(A) and (B). These firms are generally known as broker-dealers. Section 15(a)(1) of the Exchange Act makes it illegal for a broker or dealer to use the mails or any means or instrumentality of interstate commerce to effect any transaction in, or to induce or attempt to induce the purchase or sale of, any security unless the broker or dealer, absent an applicable exemption, is either registered with the Commission or a natural person associated with a registered broker or dealer. For a helpful summary of the types of functions that bring a person or entity within the regulatory category of a "broker-dealer," *see*, *e.g.*, *The New Stock Market*, ch. 9.

[324] Just as a brokerage function may be embedded within a more diversified broker-dealer, *see supra* Note 323, some firms that engage in other activities (such as brokerage) may also trade as principal.

[325] On some venues such as exchanges, "market maker" can designate a specific category of registration, with attendant privileges and responsibilities.

National securities exchanges are likely the most well-known type of platform. As described below, the exchanges are the predominant site of trading in equity markets.[326] Exchanges must register with the Commission,[327] which requires them to meet certain standards and to comply with certain obligations, and they must undertake self-regulatory responsibilities with respect to their members.[328] Importantly, exchanges must comply with and enforce standards of fair access for their members—any broker-dealer meeting standard qualification requirements must be allowed to trade, and exchanges cannot unfairly discriminate between members.[329] Exchanges generally operate through a model known as a "limit order book." A limit order is an order to buy a certain quantity of a security at a specified price or below, or to sell a certain quantity at a specified price or above. Limit orders that cannot be immediately executed upon receipt (because of a lack of orders on the opposite side meeting the price criteria) remain in the trading system and may be displayed to the broader market as quotes to indicate a willingness to trade at a given price. Together, the totality of these resting limit orders makes up the limit order "book."[330]

A number of trading venues that otherwise meet the statutory definition of an exchange operate as alternative trading systems (ATSs), through an exemption from the definition of an "exchange."[331] These venues must be operated by a registered broker-dealer, and do not undertake self-regulatory obligations over their participants or file proposed rule changes with the Commission. An ATS must comply with a range of disclosure requirements to the public and the SEC with respect to its operations and the ATS-related activities of its broker-dealer operator and affiliates.[332] Both equities and bonds trade on

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[326] Into the 20th century, bonds were actively traded on exchanges such as the New York Stock Exchange; while bonds are still traded on some exchanges, such as the New York Stock Exchange, this activity is a relatively small component of the bond market.

[327] *See* Sections 5, 6(a) of the Exchange Act, 15 U.S.C. 78e, 78f(a).

[328] National securities exchanges register with the Commission by submitting and keeping current a "Form 1" (*see* https://www.sec.gov/files/form1.pdf). Forms 1 and updates thereto are publicly available.

[329] *See* Exchange Act Section 6(b), 15 U.S.C 78f(b).

[330] Before exchange automation, specialists or market makers in each stock wrote down the collection of outstanding limit orders in a physical book.

[331] *See* Exchange Act Section 3(a)(1), 15 U.S.C. 78c(1); 17 CFR § 240.3a1-1; 17 CFR § 240.3b-16(a); 17 CFR § 242.300(a).

[332] *See Regulation of NMS Stock Alternative Trading Systems*, 83 Fed. Reg. 38768 (Aug. 7, 2018).

ATSs, and ATS subscribers do not need to be other broker-dealers. Importantly, an ATS is not required to enforce standards of fair access unless its trading exceeds certain volume thresholds.[333] In practice, this means that individual ATSs are not necessarily available to all market participants, and that ATSs are held to less stringent standards than exchanges with respect to how they treat different market participants within the platforms.

In so-called single dealer platforms, an individual dealer holds itself out to the market to trade a universe of securities off-exchange, usually at or better than the prevailing market price. Single-dealer platforms are carved out of the definition of an exchange, and so are not subject to regulation as either national securities exchanges or alternative trading systems.[334]

In markets where individual securities may be infrequently traded, request-for-quote (RFQ) platforms are common. In the U.S., RFQ platforms are used primarily in debt and swaps markets. On these platforms, a participant posts a request for dealers or other participants to provide quotes for a given security at a stated size; the participant can then elect to trade with the most favorable response received, either on or off the platform. Historically, the RFQ markets for many products have been bifurcated into customer-dealer platforms (where a customer requests quotes from multiple dealers) and inter-dealer platforms (where dealers can request quotes from each other). The registration status of RFQ platforms is largely determined by the facts and circumstances surrounding the activity of the platform.

F. Best Execution

A broker-dealer has a legal duty to seek best execution of customer orders. The duty of best execution derives from common law principles of agency and fiduciary duties, and is incorporated in rules of self-regulatory organizations and, through judicial and Commission decisions, the antifraud provisions of the federal securities laws.[335] Generally, under the rules of self-regulatory organizations, a broker-dealer must use reasonable diligence to ascertain the best market for a security, and buy or sell in that market so that

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[333] *See* 17 CFR § 242.301(b)(5).

[334] *See* 17 CFR § 240.3b-16(b).

[335] *See*, *e.g.* Reg NMS Adopting Release at 37538 (discussing cases and background); FINRA Rule 5310; Municipal Securities Rulemaking Board (MSRB) Rule G-18.

the resultant price to the customer is as favorable as possible under prevailing market conditions.[336] A range of factors should be considered in making this assessment.[337]

G. Providing and Demanding Liquidity

An important distinction in understanding some of the activities and trading strategies described in this staff report is that between providing liquidity and demanding liquidity. Providing liquidity refers to placing orders on a limit order book, whether displayed or not, or a participant otherwise indicating a willingness to trade a given instrument. A typical example of liquidity providing activity is market making, where a participant places orders on both sides of a market seeking to earn the spread between them. Demanding, or taking, liquidity is placing marketable orders to execute immediately against orders or other liquidity available at a given venue. A marketable order is an order that can be executed at current market prices—*i.e.*, either a market order intended to execute immediately at the prevailing market price or a limit order with a limit price at or better than the prevailing market price.[338] The liquidity providing party to a trade is often called the passive side, and the liquidity demanding party often called the aggressive side. Most, if not all, firms must balance providing liquidity and demanding liquidity at some point. However, some trading strategies may specialize predominantly in one or the other.

[336] *See* FINRA Rule 5310; MSRB Rule G-18.

[337] Specified factors include: the character of the market for the security, such as the price, volatility, and relative liquidity; the size and type of transaction; the number of markets checked; the accessibility of quotations; the terms and conditions of the order which results in the transaction; and, in the case of municipal securities, the information reviewed to determine the current market for the subject security or similar securities. FINRA Rule 5310(a)(1); MSRB Rule G-18(a).

[338] A "non-marketable" order is therefore an order that cannot be immediately executed at prevailing market prices. Depending on the venue, the instructions in an order, or the type of order used, the order may be, among other things, placed on a limit order book or cancelled.