Stock Exchanges as Platforms for Data and Trading*

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Abstract: We study linkages between stock exchanges' proprietary data sales and trading activity by analyzing the introduction of a new data product, New York Stock Exchange's Integrated Feed (NYSE IF). Consistent with trading and information on trading being complements, firms that subscribed to NYSE IF increased their share of trading on NYSE. In principle, firms subscribing to NYSE IF could impose a negative externality on non-subscribing firms due to increased information asymmetry. However, consistent with information purchases having a positive network externality due to increased liquidity, non-subscribing firms also increased their share of trading on NYSE. These findings are relevant to our understanding of competition among stock exchanges, complementarity between market data and trading, and policy questions relating to the pricing of market data.

Keywords: stock exchanges; proprietary market data; platform competition; multi-sided markets; externalities

JEL Codes: G10, L50

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I. Introduction

Stock exchanges are textbook examples of multi-sided platforms (Evans and Schmalensee (2011)). Their core business is to provide a venue, infrastructure, and rules that enable buyers and sellers of stock to transact with each other. In that sense, a stock exchange is a platform that brings together buyers and sellers of stock. To be successful, stock exchanges must attract sufficient numbers of market makers, who provide liquidity by quoting prices and stand ready to buy or sell, as well as traders pursuing other strategies, who often take the liquidity market makers provide by "hitting" their offers to buy (bids) or sell (offers or asks). These two "sides" of the platform are linked by externalities as liquidity takers benefit if more liquidity providers are active on an exchange, and vice versa.

Stock exchanges are *also* multi-sided platforms in another sense: they are platforms for users of trading and data. To facilitate trading, exchanges provide information on the trading process. Stock exchanges charge for both trading services and the data that trading-related activity generates. These trading and data services are used by overlapping sets of firms (some use both, some only one) and the value of these services is interconnected. Data from a stock exchange, for example, are more valuable when the exchange carries more trading activity.

Many firms that consume data do so in order to trade, so they are naturally on "both sides" of this platform. Platform economics applies to cases like this, just as platform economics helps us understand platforms like eBay where sellers also purchase from other vendors, or credit card networks where merchants are often also cardholders who regularly use corporate or small business cards. What is critical is that access to data affects trading volumes by attracting both traders that do and do not purchase data and, conversely, that trading activity by traders that do not purchase data affects the value of market data.

The effect of the provision of exchange data on trading is theoretically unclear. Purchasers of data may trade more on that exchange, which creates liquidity on the exchange that can further attract traders that do not purchase data. In contrast, because not all traders purchase all data, the sale of market data has the potential to create information asymmetry among traders.[1] Such asymmetry can impose negative externalities on non-purchasers of market data, leading to less overall trading.

[1] Throughout this paper, when we refer to firms or traders, we mean firms or traders that place orders and trade directly on stock exchanges (or other trading venues). These traders that interact directly with exchanges are

Understanding the interaction between market data and firms' trading decisions is fundamental to understanding competition among stock exchanges and, therefore, for effective regulation of stock exchanges. The 1975 Congressional mandate for a national market system for financial securities encourages competition among financial markets and stock exchanges. Financial market regulators must manage this competition, including the dissemination and pricing of stock exchanges' data. For example, the U.S. Securities and Exchange Commission organized a roundtable discussion on these issues in the fall of 2018 (SEC (2018)) and issued a rule in December 2020 expanding the set of "core" data that is distributed by stock exchanges at regulated prices (SEC (2020b)).

How the pricing of exchanges' proprietary (non-core) data products affects exchange competition depends in part on whether externalities linking trading and data services exist. If such linkages are weak or non-existent, the pricing of data products can be understood independently of the competitive dynamics of the market for trading services.[2] If these externalities are large, joint analysis of trading and market data competition is important, as the literature on platform economics prescribes (Rochet and Tirole (2003), Rysman (2009), and others). In this case, stand-alone analysis of data pricing can lead to fundamental misunderstandings of market dynamics and potentially counterproductive regulatory intervention.[3]

This paper provides new empirical evidence of the linkages between trading services and market data products offered by exchanges. We document that some firms subscribe to proprietary data products from exchanges while others do not. Our first headline empirical result is that, consistent with trading and data being complements, firms that subscribe to proprietary data from an exchange tend to trade more on that exchange. Our second main empirical result is that the additional trading by the subscribers to the proprietary data also leads to more trading by non-subscribers. This shows that data and trading are linked via externalities between firms that subscribe to proprietary data and those that do not, and that these externalities are positive so that access to these proprietary data tends to generate more

specialized proprietary trading or market making firms, investment banks, and brokers that trade on behalf of their clients.

[2] Exchanges' trading fees have been studied theoretically (Colliard and Foucault (2012) and Foucault, Kadan, and Kandel (2013)) and empirically (Park and Malinova (2015)).

[3] Guidelines issued by the U.S. Securities and Exchange Commission (SEC (2019)) argue that such joint analysis of data and trading services is appropriate when there is evidence of the externalities linking these two. Foucault and Cespa (2014) and Easley, O'Hara, and Yang (2016) theoretically study the impact of access to market data on past trades has on liquidity, price discovery, and the cost of capital. Glosten (2020) theoretically discusses competition among exchanges and market data pricing. Glosten asserts that if an exchange reduces its price of data, it is unlikely to increase its trading volume. This is inconsistent with our empirical findings, see Rysman (2020) for further discussion.

trading on the exchange by all firms. That is, these results show that stock exchanges are platforms for data and trading.

We begin with a survey of the types of data products that exchanges provide (Section II). These include best bid and offer (BBO), order book, and full order-by-order depth of book. BBO data report the highest price at which there is buying interest on the exchange (the best bid) and lowest price at which there is selling interest (the best offer). Order book depth data reports information about the aggregate share quantity and number of buy orders available at prices equal to or lower than the best bid and sell orders at prices equal to or higher than the best offer. Full order-by-order depth of book data provide a more granular, order-by-order view of changes to the exchange's order book, showing how each trade or order, and each order cancellation or modification affects the order book. With this type of data, users can determine the number and type of orders that make up the order book and where their own limit orders would be in the electronic order book queue at a given level of the order book. Firms use this information to better predict the likelihood that their marketable orders will be executed on the exchange in question at their desired prices. Firms also use order-by-order depth of book data to make strategic order routing decisions for their liquidity-providing limit orders.

Traders' choices about where to trade affect the value of these data products. Trading activity and order book depth enhance the informational content of the data; the best bid and offer change more frequently and there are more orders beyond the top of the book. The effect of trading activity on the value of data is one set of linkages between "sides" of the market that make stock exchanges platforms for data and trading.

The main focus of this paper is on the externality that runs in the reverse direction, from data purchases to trading. As traders buy more market data from a particular exchange, the overall volume of trading on that exchange may increase or decrease. Trading activity may increase because traders use market data to make order routing decisions (among other uses). That is, the information in market data is an input to traders' decisions about where to send their orders. Market data can enter these decisions in a variety of ways, but a common theme is that market data reduces uncertainty about the price, likelihood, or timing of execution for an order. By reducing the uncertainties around order execution on an exchange (or across multiple exchanges), market data makes trading on that exchange more attractive to traders. Appendix B discusses in detail different ways that higher-quality market data reduces uncertainty and affects traders' decisions about where to route orders.

Data purchases also have externalities or indirect effects on traders that do not purchase data. The literature has identified potential positive and negative externalities.[4] Negative externalities arise when some traders purchase the data, acquiring an informational advantage over non-purchasing traders. This possibility has led some market participants to believe that not purchasing the available proprietary data from exchanges means "trading at a disadvantage" (SEC (2018)). Positive externalities can arise from increased trading by traders that purchase data from an exchange generating more liquidity on that exchange, creating value for traders that do not purchase data (see Barclay and Hendershott (2004) for evidence on related positive liquidity externalities). These externalities highlight the importance of stock exchanges acting as platforms between consumers of market data and consumers of trading services.

In Section III, we test for the existence and relevance of these linkages between market data and trading through an empirical analysis of the introduction of a new data product for the New York Stock Exchange (NYSE) in early 2015: the NYSE Integrated Feed (NYSE IF), a full order-by-order depth of book product. We find that the introduction of NYSE IF led to an increase in the proportion of total U.S. equities trading that took place on NYSE of 1.0 percentage point; that was an increase of 8.6% over NYSE's pre-NYSE IF proportion of total trading of 11.6%.

Using new data on firm-level data purchases and trading obtained from NYSE Group, we are further able to test for the direct and indirect effects of access to NYSE IF that characterize platform markets. This firm-level data cover trading at NYSE, NYSE Arca, NYSE National, and NYSE MKT/American (which we refer to as NYSE Group Exchanges).[5] Because these data cover only trading on NYSE Group exchanges, we cannot study the shift of firms' overall (i.e., at all trading venues) trading toward NYSE that followed the introduction of NYSE IF as we do in the exchange-level analysis. Rather, we study the impact of the introduction of NYSE IF on two outcomes. First, we look at the proportion of firms' trading on NYSE Group Exchanges that took place on NYSE; this measures shifts in the mix of trading within NYSE Group Exchanges. We test whether gaining access to NYSE IF makes trading on NYSE more attractive relative to other NYSE

[4] Consistent with asymmetric information about the trading process imposing negative externalities, Shkilko and Sokolov (2020) study exogenous weather episodes that temporarily remove fast traders' speed advantages in receiving information by disrupting their microwave networks. For positive externalities, Boehmer, Saar, and Yu (2005) and Easley, Hendershott, and Ramadorai (2014) study changes to the NYSE that provide more information about the trading process and find that liquidity improved.

[5] The therefore covers all NYSE Group exchanges except NYSE Chicago, which became part of NYSE Group only in 2018.

Group Exchanges, such as NYSE Arca. Second, we look at firms' total trading volume (measured by the number of shares traded) on NYSE.

We find that access to NYSE IF led firms to increase the proportion of their trading on NYSE Group Exchanges that took place on NYSE by between 6.8 and 7.7 percentage points. Estimates of the effect of subscribing to NYSE IF on the total number of shares that firms traded on NYSE are less precise and indicate an increase of 31.4% to 61.0%. Firms that did not subscribe to NYSE IF increased the proportion of their trading on NYSE Group Exchanges that took place on NYSE by 2.7 percentage points. These results are consistent with access to NYSE IF having both a direct effect on subscribers and an indirect effect on non-subscribers through externalities. Thus, our results are consistent with a positive spillover from data purchases to trading at NYSE.

I.a. Related Literature

This paper is closest to three studies of discrete changes in access to market data.[6] Consistent with our findings, these papers find evidence of a positive relationship between the availability of market data for a given exchange and increased trading activity on that exchange. This paper differs from this previous work in that it documents the direct and indirect linkages between data and trading and studies the linkage of data and trading at the firm level, rather than only at the market level.

Hendershott and Jones (2005) study Island ECN's decision in September 2002 to "go dark" by ceasing to display its limit order book for three exchange-traded funds. Island went from publicly displaying its full order book in real-time on its website to not displaying any orders, even to its subscribers (i.e., firms authorized to trade on Island). Island opted to "go dark" to avoid complying with the obligations, imposed by Regulation ATS, to display its quotes on the national market system and route orders to other exchanges if better prices were available there (and receive orders from other exchanges).[7]

Hendershott and Jones (2005) document that trading volume on the Island ECN dropped following its "going dark," although a considerable amount of trading activity continued to take place on Island. Specifically, Island's share of trading volume for the three

[6] A fourth paper, Easley, Hendershott, and Ramadorai (2014), is similar in spirit. It studies an event that reduced asymmetry between traders on and off the trading floor: a technology upgrade to the NYSE specialist posts that reduced the latency in reporting trades and quotes. They find the change significantly raised stock prices and improved liquidity and trading volume.

[7] According to Island, this would have prevented it from "maintain[ing] the system performance our subscribers expect."

affected ETFs dropped from 36%, 36%, and 21% to 16%, 22%, and 12%, respectively. Consistent with less informed traders valuing information/transparency more, Hendershott and Jones (2005) also find that the mix of traders at Island changed after it went dark, with a greater proportion of liquidity traders, who they interpret as relatively uninformed, switching to other exchanges while a greater proportion of informed traders continued to trade on Island.

Boehmer, Saar, and Yu (2005) study the introduction of NYSE's OpenBook product in January 2002. OpenBook allowed subscribers to see aggregate volume available at each level of NYSE's order book, for a fee. Boehmer, Saar, and Yu (2005) find that, following the introduction of OpenBook, volume shifted from floor brokers to NYSE's electronic limit order book as traders' "new ability to see depth in the book seems to make self-management of the trading process more attractive" relative to delegation to floor brokers. While the authors did not analyze the effect on trading volume on NYSE relative to other exchanges, their findings suggest that access to OpenBook made trading on NYSE's electronic limit order book more attractive as order book information reduced uncertainty about the likelihood, price, or timing of execution.

Brogaard, Brugler, and Rosch (2023) study three instances where stock exchanges increased data fees. They find that the fee increases led to decreases in these exchanges' shares of equity trading volumes. This result echoes our finding that NYSE's market share increased following the introduction of NYSE IF and is consistent with some traders reacting to data fee increases by cancelling their subscriptions and routing more of their trading to other venues.

This paper also contributes to the literature on competition between stock exchanges by documenting links between data and trading services. This implies that competition, demand, and pricing for proprietary data and for trading services are interconnected. Cantillon and Lin (2011) survey the research on exchange competition. More recent work by Budish, Lee, and Shim (2024) argues that competition between exchanges can lead to inefficient investment in "speed technology," which they define to include both proprietary data products and co-location services. Pagnotta and Philippon (2018) and Cespa and Vives (2022) model competition between exchanges via investments to provide faster trading. Chao, Yao and Ye (2017, 2019) highlight the role of tick-size frictions and trading fee schemes in explaining competition and fragmentation among stock exchanges. Foucault and Menkveld (2008) and Battalio, Corwin, and Jennings (2016) examine brokers' and traders' order routing decisions.

II. Overview of Market Data Products

As of late 2024, equity trading in the U.S. takes place on 16 stock exchanges, 30 alternative trading systems (ATS), as well as through broker-dealer internalizers and wholesalers. Stock exchanges account for nearly half of U.S. equity shares traded. The 16 stock exchanges can be classified into four groups according to their ownership: Intercontinental Exchange controls NYSE, NYSE American, NYSE Arca, NYSE Chicago, and NYSE National;[8] NASDAQ controls NASDAQ, NASDAQ BX, and NASDAQ PSX; Cboe controls BYX Equities, BZX Equities, EDGA Equities, and EDGX Equities; Investors Exchange (IEX), Members Exchange (MEMX), MIAX Pearl, and Long-Term Stock Exchange (LTSE) are independent. To facilitate trading, each stock exchange provides data on trades and orders, which are referred to as "market data." Market data is often divided into two categories: core (securities information processor ("SIP") or consolidated feed) data and non-core (or proprietary) data.

Consolidated feed data are assembled by the SIPs, which aggregate data from all exchanges to provide (1) last sale reports, including the price and amount of the latest sale of a security and the exchange where it took place; and (2) best bid and best offer (also known as *top of book*) price quote information across all exchanges.[9] The best bid and offer information reported by the SIPs is limited to "round lots," which for most stocks means orders for blocks with multiples of 100 shares;[10] the consolidated feeds do not report "odd lot" quotes of less than 100 shares (SEC (2010)).[11] SIP data services collect the required data from each stock exchange and distribute it to subscribers for a fee. By regulation, exchanges must supply the necessary data to the SIP no later than they distribute the data to their proprietary data customers.[12] Among other uses, brokers access the consolidated feed in order to comply with Rule 603(c) of Regulation NMS, known as the Vendor Display Rule, which requires broker-dealers, in a context in which a trading or order-routing decision can

[8] Our primary data source covers four of these exchanges (NYSE, NYSE Arca, NYSE National, and NYSE MKT/American), which we refer to collectively as NYSE Group Exchanges. Intercontinental Exchange acquired NYSE Chicago only in 2018, over three years after the launch of NYSE IF.

[9] "Self-Regulatory Organizations; NYSE Arca, Inc.; Order Setting Aside Action by Delegated Authority and Approving Proposed Rule Change Relating to NYSE Arca Data," Securities Act Release No. 34-59039, December 2, 2008, pp. 42–43.

[10] In some cases, exchanges apply alternative definitions of round lots. *See*, e.g., "Rule 55. Unit of Trading—Stocks and Bonds," NYSE, https://nyseguide.srorules.com/rules/document?treeNodeId=csh-da-filter!WKUS-TAL-DOCS-PHC-%7B4A07B716-0F73-46CC-BAC2-43EB20902159%7D--WKUS_TAL_5665%23teid-134.

[11] As of December 2013, the SIP does report odd lot trades. *See*, "Consolidated Tape Association; Order Approving the Eighteenth Substantive Amendment to the Second Restatement of the CTA Plan," U.S. Securities and Exchange Commission, Release No. 34-70794, October 31, 2013. See O'Hara, Yao, and Ye (2014) for a study of odd-lot trading and price discovery.

[12] "Dissemination of Quotations in NMS Securities," 17 CFR § 242.602 (2014).

be implemented, to provide a consolidated display of market data when they are providing equity quotation or trade information to customers.[13]

Proprietary data products, in contrast, are offered by individual exchanges and contain data about only that exchange, not about the market as a whole. Exchanges offer a variety of proprietary data products, some of which provide only top of book data while others provide varying levels of depth-of-book information:

a. Best bid or offer ("BBO"): Shows the best prices available at the exchange, and the quantities available at these prices. This provides the same data as the SIP, but only for the single exchange in question.

b. Order book: Shows quantities available at each price level at and beyond the top of the book. NYSE Group offers this type of data through its OpenBook products for NYSE and American exchanges and as ArcaBook for NYSE Arca.[14] NYSE's order book products include information on odd lot orders.

c. Full order-by-order depth of book: Shows order book information along with detailed information about the nature of each adjustment to the order book. That is, it provides data on each trade, new order, order cancelation, or order modification, providing additional detail about movements in the order book. NYSE Group Exchanges offer this data through their Integrated Feed products. NYSE was the last major exchange to introduce a full order-by-order depth of book product – NYSE Arca offered an Integrated Feed product since 2011 (SEC (2011)); NYSE MKT/American introduced an Integrated Feed product in late 2015 (SEC (2015)) and NYSE National introduced its Integrated Feed product in 2020 (SEC (2020)). As noted above, with this type of data, users can determine the number and type of orders that make up the order book and where their own limit orders would be in the electronic order book queue at a given level of the order book. Firms use this information to better predict the likelihood that their

[13] FINRA (2015), p. 1 ("FINRA is issuing this Notice to remind firms and registered representatives of their obligations under Rule 603(c) of Regulation NMS (Vendor Display Rule) when providing quotation information to customers. The SEC staff recently made clear its view that if a registered representative provides a quotation to a customer that can be used to assess the current market or the quality of trade execution, reliance on non-consolidated market information as the source of that quotation would not be consistent with the Vendor Display Rule. In light of the SEC staff's statements, firms should review whether they are in compliance with the requirement in the Vendor Display Rule that broker-dealers provide a consolidated display of market data when they are providing quotation information to customers.").

[14] NYSE National and NYSE Chicago do not offer an order book only data product. They do, however, offer a full order-by-order depth of book product, Integrated Feed, which contains order book information.

marketable orders will be executed on the exchange in question at their desired prices. Firms also use order-by-order depth of book data to make strategic order routing decisions for their liquidity-providing limit orders.

d. Order imbalance: Information about aggregate quantities and prices submitted during auction periods.

e. Trade data: Reports all transactions executed on the exchange. This information is also reported in the SIP.

Different market participants may use proprietary data for a number of purposes, including:

f. To inform investment decisions by enhancing their understanding of liquidity and likely price movements.

g. To inform order routing decisions by enabling them to assess the likelihood of execution at various venues.

h. To enable the operation of trading platforms (dark pools or alternative trading systems (ATS)).

Some market participants have argued that they must purchase the most sophisticated and complete data feeds from all exchanges in order to be competitive. For example, Doug Cifu, co-founder and chief executive officer of Virtu Financial, has remarked that: "Without proprietary data feeds, there's not a firm today, either as a market maker or an institutional agency broker or prop trading firm that can exist. It's just that simple."[15] Many market participants believe that not subscribing to the available proprietary data would mean they are "trading at a disadvantage."[16]

However, other market participants believe that proprietary data feeds are not necessary for their business models. Jeff Brown, Senior Vice President and Head of the Office of Legislative and Regulatory Affairs at Charles Schwab asserted that "one of the questions we've looked at is, you know, if they use a SIP for pricing or do they use the direct

[15] SEC (2018), p. 58. Mehmet Kinak, global head of systematic trading and market structure at T. Rowe Price made a similar remark: "[A]s far as brokers having a choice of whether or not they can use the SIP or direct feeds, that doesn't exist. There is no choice there. If a broker is routing using SIP data, they are not routing my flow." Similarly, Simon Emrich, head of market structure strategies at Norges Bank Investment Management, claimed that "brokers can't really be competitive for our sort of trading just using the SIP. They need to have the full depth of book. We depend on them to slice up our orders and trade them over time. We need them to have a full view of the market, not just the top of the book." SEC (2018), pp. 65, 136.

[16] SEC (2018), p. 64. This remark was from Brad Katsuyama, CEO and cofounder of IEX.

feeds for pricing, does that impact our clients' execution? And so we've studied that. And the result is that it's an insignificant difference between the use of them, which is odd because we've heard so much about how, you know, the direct feeds are necessary for execution."[17]

NYSE's data confirms that not all market participants purchase all data (we describe our data in Section III.a). Table 1 shows the percentage of firms that purchased each combination of data products from NYSE in December 2018. It also reports the proportion of trading volume on NYSE that these firms account for. Notably, 20.4% of firms that traded on NYSE during that month did not purchase data specific to NYSE.[18] The most common choice was for firms to purchase only OpenBook data (49.5% of firms), but such firms accounted for only 9.4% of trading volume. In contrast, the most active firms purchased all three types of data (BBO, OpenBook, and Integrated Feed) – just 8.7% of firms that traded on NYSE fall into this category, but those firms accounted for 34.4% of trading volume.[19]

[17] SEC (2018), p. 170.

[18] Note that we cannot rule out that firms that traded on NYSE and did not purchase data were trading on behalf of a firm that did purchase data. However, some of the firms in question are proprietary trading firms, and would not typically be routing other firms' orders.

[19] The patterns are also similar for NYSE Arca, NYSE National and NYSE American, though National does not offer an order book only product. See, "NYSE Exchange Data: Real-Time Data," NYSE, https://www.nyse.com/market-data/real-time.

TABLE 1
Data Purchases by Firms Trading on NYSE in December 2018

This table presents statistics on the proportion of firms that subscribed to each combination of data products offered by NYSE. BBO is NYSE's best bid and offer (top of book) data; OpenBook is NYSE's order book product, which reports all bid and offer prices quoted on NYSE and corresponding aggregate limit order volumes at each price level; and Integrated Feed is NYSE's full order-by-order depth of book, which shows order book information along with detailed information about the nature of each adjustment to the order book (i.e., trades, new orders, order cancelations, and order modifications). The proportion of firms subscribing to each combination of data products is calculated as the number of firms that traded on NYSE and subscribed to that unique combination of data products for NYSE in December 2018 divided by the total number of firms that traded on NYSE in December 2018 (103). Proportion of volume is calculated as the total combined number of shares traded by firms that subscribed to that unique combination of data products for NYSE in December 2018 divided by the total number of shares traded on NYSE in December 2018.

Subscriptions	Proportion of Firms	Proportion of Volume
BBO Only	0.0%	0.0%
OpenBook Only	49.5%	9.4%
Integrated Feed Only	2.9%	3.3%
BBO and OpenBook	7.8%	23.7%
BBO and Integrated Feed	0.0%	0.0%
OpenBook and Integrated Feed	10.7%	27.6%
OpenBook, Integrated Feed, and BBO	8.7%	34.4%
None	20.4%	1.6%

But these are not the only buyers of NYSE data: there are hundreds of firms that do not trade directly on NYSE but purchase its market data products. Those firms are not reflected in the figures reported in Table 1. These firms may use NYSE data for a variety of purposes, including to develop trading strategies or to operate a dark pool or ATS. These firms may also trade on NYSE through brokers – it is theoretically possible that the firms that do not purchase the data are simply executing orders under the direction of clients who do purchase it. However, our empirical work identifies significant differences in behavior between these groups (see Section III.c).

Firms obtain market data from NYSE by subscribing for a monthly fee.[20] Among firms that traded on NYSE in December 2018, the median bill for NYSE market data was $1,320. If we limit attention to firms that traded on NYSE and paid for NYSE data, the median data bill was $5,580. There is considerable variation in the data fees paid, with the

[20] Users pay an access fee as well as several use-related fees. Fee levels are publicly available. See, NYSE (2018).

firm at the 95th percentile among those both trading on NYSE and purchasing NYSE data paying $81,350.

Stock exchanges make different choices regarding if and how much to charge customers for market data. It is common for new stock exchanges or exchanges focused on increasing their share of trading to offer their data free of charge. Established stock exchanges typically charge for their data, as the NASDAQ exchanges, the Cboe exchanges, and most NYSE Group Exchanges do.[21] Stock exchanges may choose to transition from a no-fee model to one where they charge for their data as NYSE Arca did in 2009 and the BATS exchanges (BZX and BYX) did in 2013.[22] Pricing strategies such as these are natural outcomes in platform markets where building a base of users on all "sides" of the market is crucial for a platform's viability. For example, Rysman (2009) reports that the independent Yellow Pages publisher "Yellow Book" had a policy of offering advertising for free in the first year it entered a new city. Yellow Book did this to increase the number of advertisers that appeared in their books, since having more advertisers would, in turn, drive more consumers to use its books.

III. The Effect of the Introduction of NYSE IF on Trading Activity

We next turn to empirical analysis of the link between market data and trading activity following the launch of a new market data product for NYSE. NYSE Group introduced a full order-by-order depth of book data product for the NYSE (NYSE Integrated Feed or NYSE IF) in early 2015. NYSE IF offers an order-by-order view of the evolution of NYSE's order book. With NYSE IF users can determine the number and type of orders that make up the order book and where their own limit orders would be in the electronic order book queue at a given level of the order book. Firms use this information to better predict the likelihood that their marketable orders will be executed on NYSE at their desired prices. Firms also use NYSE IF to make strategic order routing decisions for their liquidity-providing limit orders.

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[21] NYSE (2018); "Price List – U.S. Equities," NasdaqTrader.com, https://www.nasdaqtrader.com/Trader.aspx?id=DPUSdata#tv; "Cboe Data Services, Market Data Product Price List," Cboe Global Markets (2018).

[22] "Self-Regulatory Organizations: Notice of Filing and Immediate Effectiveness of Proposed Rule Change by NYSE Arca, Inc. Relating to Fees for NYSE Arca Depth-of-Book Data," Securities Exchange Act Release No. 34-63291, November 9, 2010, pp. 7–8; John McCrank, "BATS Exchanges To Start Charging for Market Data," Reuters, April 18, 2013; "Self-Regulatory Organizations; BATS Exchange, Inc.; Notice of Filing and Immediate Effectiveness of a Proposed Rule Change to Impose Fees for Market Data," Securities Exchange Act Release No. 34-69936, July 3, 2013, pp. 1–25.

NYSE IF's launch gave firms access to new data about activity on NYSE that, in principle, would lead firms to increase the amount of trading they did on NYSE. For reasons discussed above, this could either attract or deter volume from other market participants without access to NYSE IF. After analyzing the effect of NYSE IF on NYSE market share, we will analyze trading by subscribing and non-subscribing firms (that we also refer to as adopters and non-adopters).

III.a. Data Sources and Description of Uptake of NYSE IF

We use three data sources to study the impact of NYSE IF's launch. The first is data on the monthly total number of shares traded, by trading venue.[23] The data report trading volume for each public exchange as well as aggregated volumes for ATS and dark pools reported by NYSE and NASDAQ trade reporting facilities or TRFs. We use these data to examine the impact of the introduction of NYSE IF on NYSE's share of overall trading below.

The other two data sources are proprietary: NYSE data on monthly trading volumes and data purchases by NYSE-member firms. Our firm-level data present trading volumes in terms of the number of shares traded, not dollar volume. Because trading fees are charged on a per-share basis, this is a better measure of revenue-generating trading activity for stock exchanges than dollar volume would be. Unlike our data on total volumes by exchange, which cover all equities trading in the U.S., the firm-level data on data purchases and trading volumes are limited to activity on NYSE Group Exchanges (NYSE, NYSE Arca, NYSE National, and NYSE MKT/American[24]). They cover the period from January 2013 to May 2019. The data are comprehensive in that they cover all 167 firms that traded on NYSE during this period. However, the data identify only the firm placing orders on NYSE Group Exchanges and not their clients who they may be trading on behalf of. As discussed in Section II above, some of these clients may have subscribed to NYSE IF and may have instructed their brokers on what trading venue to route their orders to. This feature of the data could lead us to overestimate the effect of NYSE IF on non-adopters in Table 6 below.

Analyzing the nexus between data purchases and trading activity required matching records of data purchases with trading volume statistics. We grouped firm names that, in some cases, were recorded differently in each dataset. We did this using a fuzzy matching

[23] This data was provided by NYSE, but is essentially identical to publicly available data published by Cboe Global Markets.

[24] NYSE MKT became NYSE American in July 2017.

algorithm followed by manual review. We also grouped together accounts for subsidiaries of the same parent company.[25]

Table 2 presents descriptive statistics for our firm-level dataset. Of the 167 firms that traded on NYSE during the period covered by our data, 31 subscribed to NYSE IF at some point in time. Firms that subscribed to NYSE IF (which we refer to as adopters) were more active; their average monthly trading volume on NYSE Group Exchanges was ten times higher than that of firms that did not subscribe to NYSE IF (non-adopters). The standard deviations on monthly trading volumes indicate significant heterogeneity across firms. Adopters were also more consistently active, on average trading during 71 of the 77 months covered by our data, compared to an average of 55 months for non-adopters. Perhaps counterintuitively, adopters relied less on NYSE than non-adopters – they did 48% of their trading on NYSE, on average, compared to 72% for non-adopters.[26] Adopters were more likely to be users of other NYSE proprietary data products (BBO and OpenBook) and were more likely to have traded on other NYSE Group Exchanges. It is notable that most firms, both adopters and non-adopters, traded on NYSE Arca and NYSE MKT/American as well as on NYSE.

[25] Both the matching of firm names and the grouping of firms and subsidiaries was independently reviewed by two research assistants. We then worked with them to resolve all discrepancies.

[26] When calculating the proportion of firms' trading on NYSE Group Exchanges that took place on NYSE, we conservatively calculate trading volume on NYSE (the numerator) using only trading in Tape A shares (and excluding trading in Tape B and C shares) to avoid accounting for changes due to the introduction of Tape B and C trading to NYSE in April 2018, toward the end of the period covered by our data.

TABLE 2
Summary Statistics on Firm-Level Data on Data Subscriptions and Trading on NYSE Group Exchanges

This table presents summary statistics on our firm-level dataset, which contains information on firms' monthly trading volumes on NYSE Group Exchanges (NYSE, NYSE Arca, NYSE National, and NYSE MKT/American) and their purchases of proprietary data products from these exchanges. The dataset contains information on NYSE member firms that traded on NYSE between January 2013 and May 2019. Adopters are firms that subscribed to NYSE IF during any month in our data; non-adopters are firms that never subscribed to NYSE IF. All means and standard deviations are across firms; that is, they are calculated in two stages: first the mean value for each firm and then the mean and standard deviation across firms. The number of months with trading activity on NYSE Group Exchanges is out of a maximum of 77 months. BBO is NYSE's best bid and offer (top of book) data. OpenBook is NYSE's order book product, which reports all bid and offer prices quoted on NYSE and corresponding aggregate limit order volumes at each price level. Traded on NYSE Arca (at least one month) reports the proportion of firms that traded on NYSE Arca during at least one month in the period covered by our data. Traded on NYSE National and Traded on NYSE MKT/American report analogous information for those exchanges.

	NYSE IF Adopters	NYSE IF Non-Adopters	All Firms
Number of Firms	31	136	167
Monthly trading volume on NYSE Group Exchanges (millions of shares)			
Mean	1588.20	145.35	413.19
Standard deviation	1675.09	464.45	999.57
Number of months with trading activity on NYSE Group Exchanges			
Mean	71.03	54.91	57.90
Standard deviation	13.80	25.93	24.91
Proportion of trading on NYSE Group Exchanges that took place on NYSE			
Mean	0.48	0.72	0.67
Standard deviation	0.19	0.30	0.29
Subscribed to NYSE BBO (at least one month)	0.77	0.09	0.22
Subscribed to NYSE OpenBook (at least one month)	0.97	0.82	0.85
Traded on NYSE Arca (at least one month)	1.00	0.69	0.75
Traded on NYSE National (at least one month)	0.68	0.09	0.20
Traded on NYSE MKT/American (at least one month)	0.97	0.96	0.96

The first firms to subscribe to NYSE IF started doing so in April 2015.[27] As shown in Figure 1, take-up of NYSE IF was gradual. Four firms started subscribing to NYSE IF in April 2015. That rose gradually to 22 firms in December 2015 and stabilized between 24 and 27 firms thereafter. The proportion of trading volume on NYSE by firms subscribing to NYSE IF increased in tandem with the number of firms subscribing, starting at 4.4% in April

[27] We classify a firm as subscribing to NYSE IF in a given month if NYSE reports any fees relating to NYSE IF during the month in question. Reported fees may be $0 during trial periods – firms charged $0 fees for NYSE IF are also considered to be subscribed to NYSE IF.

2015 and rising to 45.9% in December 2015. The proportion of trading volume at NYSE accounted for by NYSE IF subscribers continued to grow until stabilizing at levels between 62% and 66% in mid-2017.

We learned through conversations with NYSE Group staff that both the timing of the launch of NYSE IF and the differences in adoption dates across firms were idiosyncratic and not driven by other factors related to trading activity on NYSE. NYSE was the last major exchange to introduce a full order-by-order depth of book product – NYSE Arca offered such a product since 2011 (SEC (2011)). The gradual uptake of NYSE IF was related in part to logistical issues related to setting up access.

A variety of firms subscribed to NYSE IF, including:[28]

a. Proprietary trading firms and market makers trading for their own accounts. According to NYSE's data use client classifications, 29 of 31 adopters were in this category (18 of these are also listed under other categories). These firms include NYSE Designated Market Makers and Supplemental Liquidity Providers. The prominent participation of these firms suggests the introduction NYSE IF would have enhanced liquidity on NYSE.

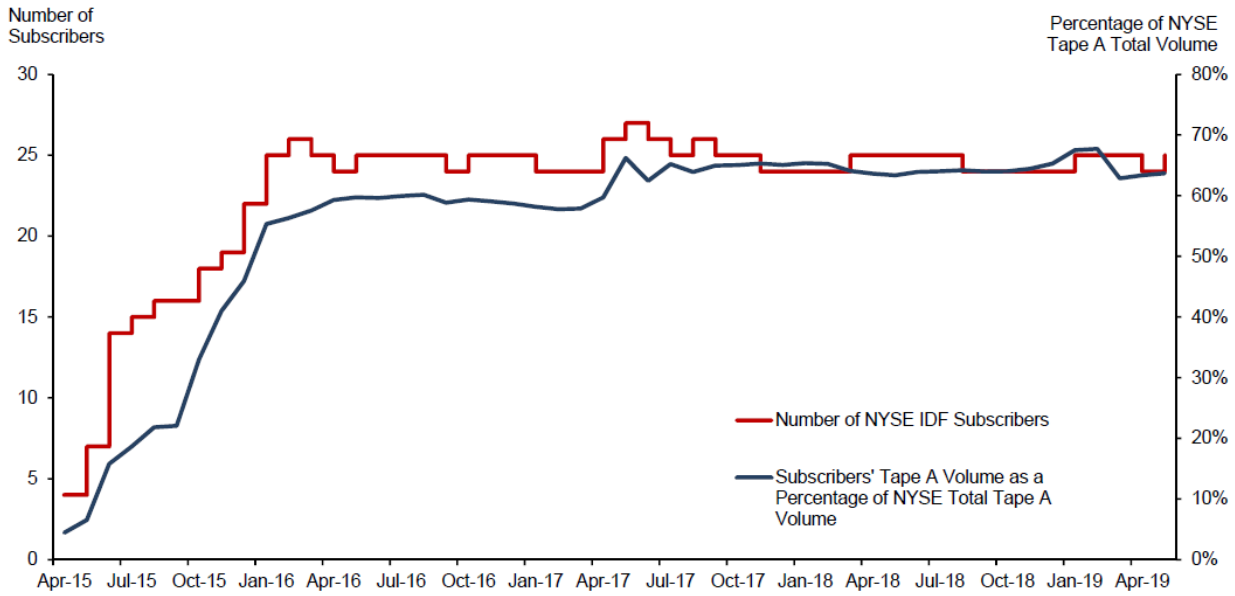
b. Brokers that act as agents, executing trades on behalf of their clients (16 adopters, all of whom are also listed under other categories).

c. Firms that use market data to run dark pools or ATS (16 adopters, all but one of whom are also listed under other categories).

[28] While we had access to firm names that enabled us to make these classifications, we do not mention any NYSE client by name or provide more detailed breakdowns of subscribers due to confidentiality restrictions. Five firms that traded on a NYSE Group Exchange but not on NYSE also subscribed to NYSE IF, as did 39 firms that did not trade directly on any NYSE Group exchange. These firms may have traded on NYSE through intermediaries, but this cannot be observed in our data.

FIGURE 1
Number of Subscribers to NYSE IF and Proportion of Total Trading on NYSE Accounted for by NYSE IF Subscribers, April 2015 to May 2019

We plot the number of firms subscribing to NYSE's Integrated Feed (NYSE IF) (red line), NYSE's full order-by-order depth of book data product, which shows order book information along with detailed information about the nature of each adjustment to the order book (i.e., trades, new orders, order cancelations, and order modifications). We also plot the proportion of NYSE's Tape A volume (i.e., volume in NYSE-listed stocks) that subscribers account for (blue line). The first firms to subscribe to NYSE IF and trade on NYSE started doing so in April 2015. Trading on NYSE was limited to Tape A stocks until April 2018.



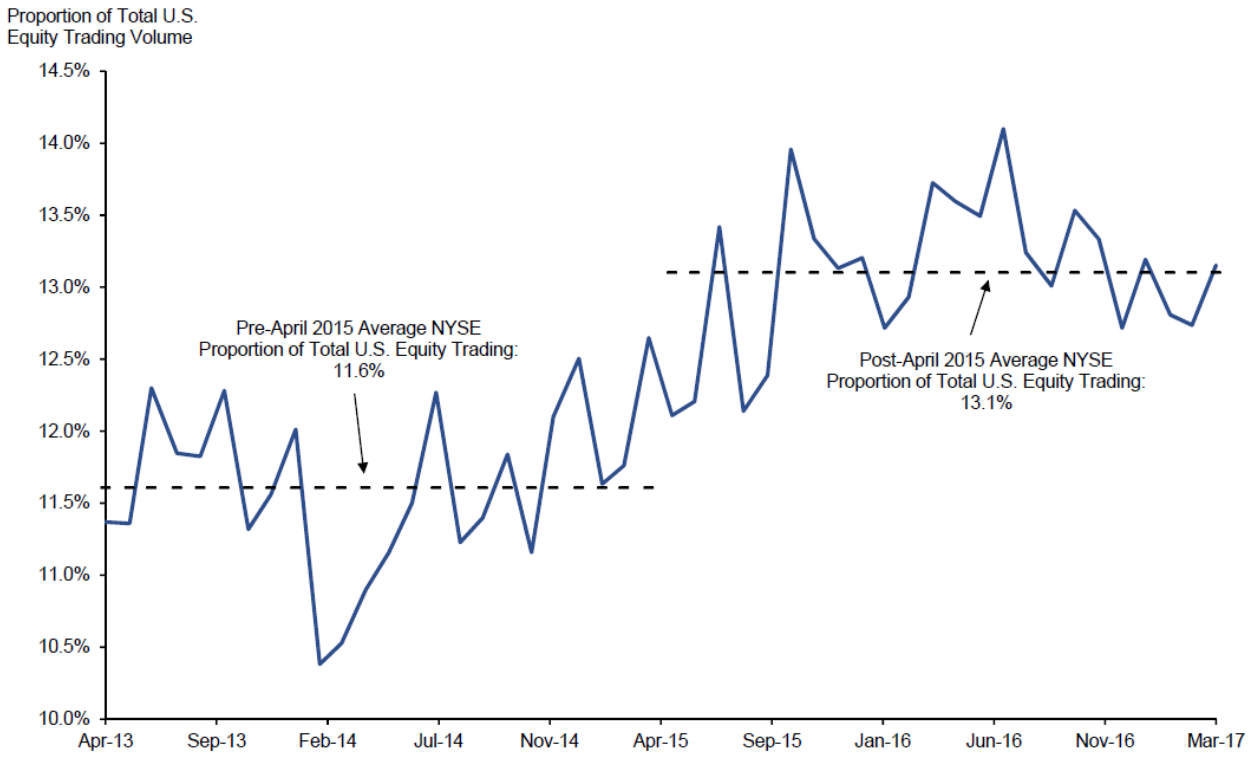
III.b. Effect on NYSE's Share of U.S. Equities Trading

The launch of NYSE IF in April 2015 had a substantial impact on NYSE's share of total U.S. equities trading. Trading on NYSE accounted for 11.6% of total U.S. equities trading, on average, during the 24 months leading up to the launch of NYSE IF. As shown in Figure 2, NYSE's share of overall U.S. equities trading increased gradually following the introduction of NYSE IF in April 2015, approaching 14.0% in September 2015 and stabilizing at levels between 12.7% and 14.1% thereafter. NYSE accounted for 13.1% of total U.S. equities volume during the 24 months following the launch of NYSE IF, an increase of 1.5 percentage points over the pre-NYSE IF period.[29]

[29] Analyzing trading on NYSE as a proportion of trading on public exchanges in the U.S. yields very similar results for both the qualitative analysis shown in Figure 2 and the regression analysis shown in Table 3.

FIGURE 2
Proportion of U.S. Equities Trading Volume on NYSE Before and After Launch of NYSE IF, April 2013 to March 2017

We plot NYSE's proportion of total U.S. equity trading volume from April 2013, two years before NYSE IF became available, through March 2017, two years after NYSE IF became available. NYSE's average proportion of trading increased from 11.6% over the two years before NYSE IF's launch to 13.1% during the two years following NYSE IF's launch.



In order to verify that the introduction of NYSE IF led to an increase in the proportion of trades executed on NYSE, we estimate a regression model of the following form:

$$NYSE\ Shr_t = \alpha + \beta X_t + \gamma NYSE\ IF_t + \varepsilon_t \quad (1)$$

$NYSE\ Shr_t$ is the share of U.S. equities trading in month t that took place on NYSE; α is a constant term, X_t is a vector of covariates, which we describe below; $NYSE\ IF_t$ is a dummy variable that takes a value of 1 after NYSE IF is launched (in April 2015) and 0 otherwise; and ε_t is an error term.

Table 3 presents results from four regression specifications, variants of Equation 1 with different covariates X. Newey-West standard errors with lag 3 are shown in parentheses.

The coefficient of interest, γ, which measures the impact of the introduction of NYSE IF, is labeled "Introduction of NYSE Integrated Feed (April 2015)". In all four specifications, this coefficient is positive and statistically significant at the 95% confidence level (indicated by two or three asterisks).[30]

The first specification does not control for any potentially confounding factors – the coefficient of interest in specification 1 is 0.015, indicating an increase of 1.5 percentage points in the proportion of trading accounted for by NYSE. This corresponds to the increase in averages shown in Figure 2.

Specifications 2–4 in Table 3 control for other potentially confounding factors:

a. Time trends: Time trends unrelated to the introduction of NYSE IF could affect the proportion of trading accounted for by NYSE. For example, the proliferation of dark pools and ATS could generate a downward trend in the proportion of trading at NYSE. In the specifications shown, the time trend is allowed to be a quadratic curve, not just a straight line.

b. Market Structure: Changes in the competitive landscape could affect the proportion of trading at NYSE. We identified four relevant events during the time period analyzed: NYSE started trading stocks whose primary listing was not on NYSE (referred to as Tape B and C stocks, as opposed to Tape A stocks which are listed on NYSE) in April 2018; IEX became a public exchange in August 2016; Cboe Stock Exchange went offline in May 2014; and NSX/NYSE National went offline during two windows between June 2014 and November 2015 and between February 2017 and April 2018.

c. Trading Volumes: Total trading volumes may be a proxy for market conditions that may favor (or hinder) trading on NYSE. Specification 2 controls for total U.S. equities trading (in logarithms); specification 3 controls for trading on public exchanges and on ATSs or dark pools separately (also in logarithms); and specification 4 controls for the proportion of trading that goes through public exchanges as opposed to dark pools or ATSs.

[30] Using conventional and heteroscedasticity-robust (White) standard errors does not alter these conclusions.

Controlling for these factors reduces the estimated effect of introducing NYSE IF to 1.0 percentage point (specifications 2–4).[31]

All of the measures of the impact of introducing NYSE IF are economically significant. An increase of 1.5 percentage points in NYSE's share of trading amounts to 12.9% of NYSE's pre-launch mean of 11.6%. The lowest estimate shown, 1.0 percentage point, is 8.6% higher than the pre-launch mean. A very rough calculation of the impact of such a change on NYSE Group's revenues confirms that it is economically significant: an 8.6% increase in trading on NYSE would have translated to roughly $11.5 million in additional revenue from net transactions fees in 2016.[32]

When interpreting these results, it is helpful to consider the extent to which different exchanges compete directly or have carved out more specific niches. For example, NYSE and NASDAQ are the primary venues for listings of large firms, NYSE Arca is known as a prominent venue for ETFs, NYSE MKT/American is known to specialize in small-capitalization companies. Nevertheless, as of 2015, NYSE-listed stocks accounted for a considerable amount of trading volume (ranging from 37% at NYSE Arca to 51% at BATS BYX) on all exchanges except NYSE MKT/American, which did not offer trading for NYSE-listed stocks. It appears that the bulk of NYSE's gains came at the expense of NASDAQ. In March 2015, on the eve of the introduction of NYSE IF, NYSE's share of U.S. equity trading volume was 12.6% compared to 16.3% for NASDAQ; a year later in March 2016, NYSE's share had grown by 1.1 percentage points to 13.7% while NASDAQ's had fallen by 2.3 percentage points to 14.0%.

[31] Inclusion of a lagged dependent variable (here, the percentage of U.S. equities trading that took place on NYSE the previous month) as a regressor does not qualitatively alter the results. Coefficients on the lagged dependent variable term are not statistically significant in any of the specifications shown in Table 3.

[32] Absent the increase due to the launch of NYSE IF, trading volume on NYSE would have been 246.2 billion shares (the actual volume traded on NYSE in 2016) divided by 1.086, or approximately 226.7 billion shares in 2016. The difference between actual trading volume in 2016 and our estimate of what trading volume would have been absent the launch of NYSE IF is 19.5 billion shares. The average net transaction fee per share traded on NYSE in 2016 was $0.000592. Multiplying this net transaction fee by the 19.5 billion affected shares yields $11.5 million.

TABLE 3
Regression Estimates of Impact of NYSE IF on Trading on NYSE

We regress NYSE's share of U.S. equities trading on several covariates, including a dummy variable for the introduction of NYSE IF in April 2015. The coefficients on this variable measure the impact of the introduction of NYSE IF on NYSE's share of U.S. equities trading, holding other factors controlled for in the regression constant. Introduction of NYSE Tape B-C (April 2018) is a dummy variable controlling for the introduction of trading of non-NYSE-listed stocks on NYSE. Time Trend and Time Trend Squared are linear and quadratic time trend terms, respectively. NSX/National Active, IEX Active, and CBOE Active are dummy variables accounting for variation in the set of stock exchanges available to traders. We control for overall trading activity with the natural logarithm of the number of shares traded on all U.S. venues (Total U.S. Equity Volume Traded (log)) or separately for the number of shares traded on public exchanges (Total U.S. Equity Volume Traded on Public Exchanges (log)) and ATS and dark pools (Total U.S. Equity Volume Traded on ATS and Dark Pools (log)). Proportion of Total U.S. Equity Trading Volume Traded on Public Exchanges is the number of shares traded on public exchanges in the month in question divided by the total number of shares traded on all U.S. venues in that month. Asterisks denote statistical significance at the 99% (***), 95% (**), and 90% (*) confidence levels. Newey-West standard errors (lag = 3) are shown in parentheses. The regressions are estimated using data covering the 78-month period from January 2013 through June 2019.

	Dependent Variable			
	Proportion of NYSE Trading Volume			
Independent Variable	(1)	(2)	(3)	(4)
Introduction of NYSE Integrated Feed (April 2015)	0.015***	0.010**	0.010**	0.010**
	(0.002)	(0.004)	(0.004)	(0.004)
Introduction of NYSE Tape B-C (April 2018)	0.001	-0.006	-0.008	-0.006
	(0.002)	(0.004)	(0.005)	(0.005)
Time Trend		-0.00001	0.0001	-0.0001
		(0.0003)	(0.0003)	(0.0003)
Time Trend Squared		0.0000	0.0000	0.0000
		(0.000)	(0.000)	(0.000)
NSX/National Active		0.004**	0.005***	0.004**
		(0.002)	(0.002)	(0.002)
IEX Active		-0.005*	-0.004*	-0.003
		(0.002)	(0.002)	(0.002)
CBOE Active		-0.007	-0.006	-0.007
		(0.005)	(0.004)	(0.005)
Total U.S. Equity Volume Traded (log)		-0.008		
		(0.007)		
U.S. Equity Volume Traded on Public Exchanges (log)			0.022	
			(0.014)	
U.S. Equity Volume Traded on ATS or Dark Pools (log)			-0.040**	
			(0.019)	
Proportion of Total U.S. Equity Volume Traded on Public Exchanges				0.043
				(0.058)
Constant	0.116***	0.321*	0.541**	0.090**
	(0.001)	(0.170)	(0.209)	(0.037)
Observations	78	78	78	78
R2	0.600	0.650	0.667	0.645

We test the robustness of these results by using an intercept-only structural break test to select a date after which the NYSE share changed. We find that June 2015, two months after the introduction of NYSE IF, is the most likely break date, and we reject the null hypothesis that the intercept does not change. Results are shown in Appendix Table A1. The proximity of the most likely break date to the introduction of NYSE IF further supports the conclusion that the data platform led to an increase in the share of equities traded on NYSE.

III.c. Firm-Level Effects on the Proportion of Trading on NYSE

We now turn to our analysis of firm-level data, with which we analyze the effects of the introduction of NYSE IF on firms' order routing decisions at a more granular level. As described above, the firm-level dataset contains monthly data on purchases of data products and on trading on NYSE Group Exchanges (NYSE, NYSE Arca, NYSE National, and NYSE MKT/American) from January 2013 to May 2019 for all 167 member firms that traded on NYSE during this period.

Because this firm-level dataset is limited to trading on NYSE Group Exchanges, we cannot study the shift of firms' overall (i.e., on all trading venues) trading toward NYSE that followed the introduction of NYSE IF, as we do in the exchange-level analysis presented in Section III.b. Rather, we study the impact of the introduction of NYSE IF on two outcomes. First, we look at the proportion of firms' trading on NYSE Group Exchanges that took place on NYSE. This measures shifts in the mix of trading at NYSE Group Exchanges – we hypothesize that gaining access to NYSE IF made trading on NYSE more attractive relative to other NYSE Group Exchanges, such as NYSE Arca. Second, we look at firms' total trading volume on NYSE (measured by the number of shares traded). As discussed above, there was no overlap in equities traded on NYSE and NYSE MKT/American; while the introduction of data products could, in principle, affect the choice of equities traded as well as the choice of trading venue, we would not anticipate large shifts in activity between these two exchanges. This, in turn, minimizes concerns arising from NYSE MKT/American's introduction of an integrated feed data product in late 2015 (SEC (2015)). In any case, this would tend to bias our results downward, making our estimates conservative.

Our analysis of firms' proportion of trading on NYSE addresses firms' split of trading among exchanges directly – we therefore focus mainly on these results. The analysis of firms' trading volumes on NYSE offers an alternative, but more indirect, perspective on this question. Furthermore, as documented below, firms' trading volumes fluctuate considerably month-to-month, making inference more challenging.

Firms that adopted NYSE IF were more likely than those that did not to increase the proportion of their trading (among NYSE Group Exchanges) on NYSE. Figure 3 shows the distribution of changes in NYSE IF-adopting firms' proportion of trading on NYSE from the 24 months before adopting NYSE IF to the 24 months after adopting it (red bars). It also shows the distribution of changes in the proportion of trading on NYSE from the 24 months before NYSE IF's launch (in April 2015) to the 24 months after among firms that did not subscribe to NYSE IF (non-adopting firms; blue bars). Areas where red and blue bars overlap are shown in purple.

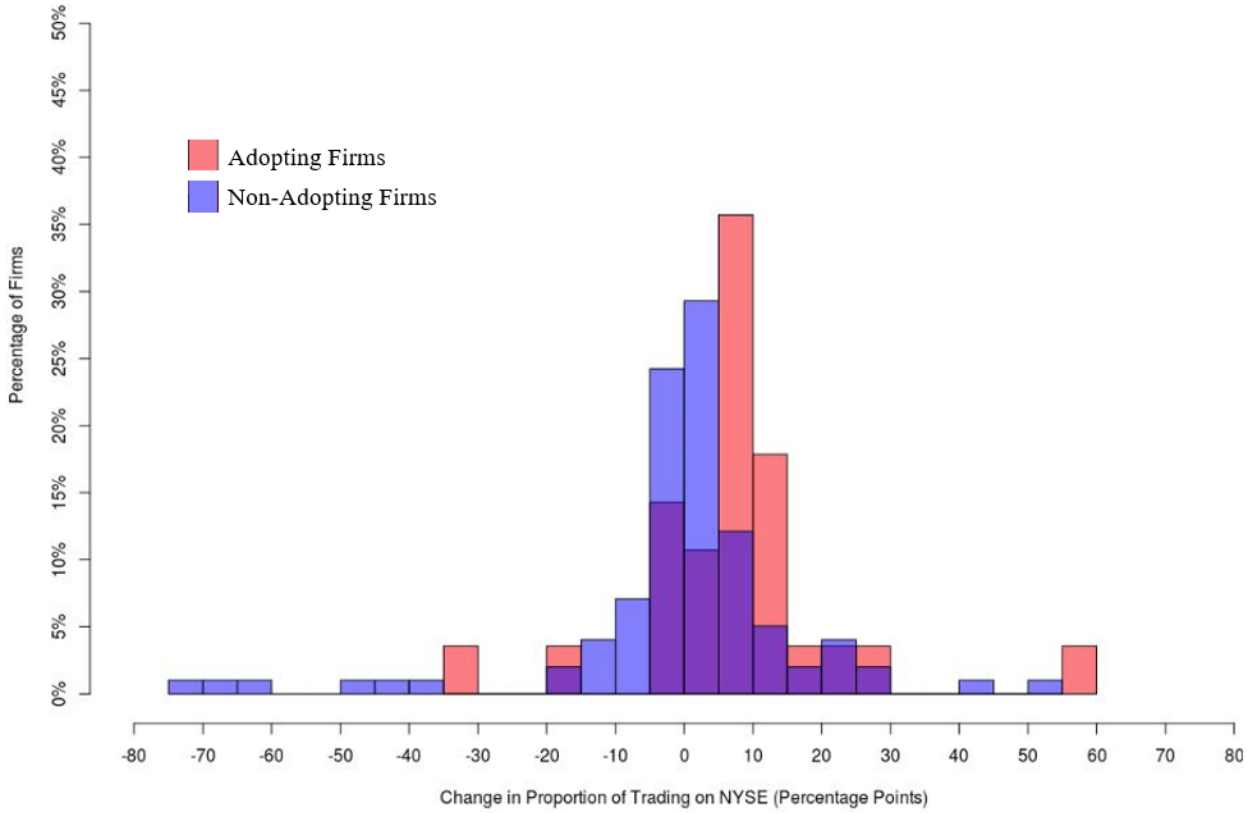
While reactions by specific firms to the availability of NYSE IF vary widely, it is evident that the distribution of red bars is to the right of the distribution of blue bars, meaning that NYSE IF adopters increased their proportion of trading more than non-adopters. Indeed, 22 of 28 adopters that traded on NYSE in both the 24 months before and the 24 months after adoption increased their proportion of trading on NYSE following their adoption of NYSE IF; most (16) of these firms increased their proportion of their trading on NYSE by between 5 and 20 percentage points.[33] More than half (56 out of 99) of non-adopters that traded on NYSE during both the 24 months before and the 24 months after the launch of NYSE IF increased their proportion of trading on NYSE after April 2015.[34]

[33] Three firms subscribed to NYSE IF from the first month they appear in the trading data. We do not account for these firms in these statistics as there is no meaningful comparison period prior to adoption for them.

[34] These statistics cover 127 firms. A total of 167 firms traded on NYSE during the period covered by the data; 37 non-adopters did not trade during either the 24 months leading to the launch of NYSE IF, the 24 months following the launch of NYSE IF, or both. Three adopters did not trade on NYSE in the 24 months before their adoption.

FIGURE 3
Distribution of Changes in the Proportion of Trading on NYSE Following Adoption (Adopting Firms) or Launch (Non-Adopting Firms) of NYSE IF

We plot firm-level changes in the proportion of trading on NYSE Group Exchanges that took place on NYSE before and after the launch of NYSE IF. Changes in the proportion of trading for firms that subscribed to NYSE IF at some point in time (adopting firms) are calculated as total shares traded on NYSE during the 24 months from the first month in which the firm subscribed to NYSE IF divided by the total number of shares traded on all four NYSE Group Exchanges during the same period minus total shares traded on NYSE during the 24 months prior to the first month in which the firm subscribed to NYSE IF divided by the total number of shares traded on all four NYSE Group Exchanges during the same period. Changes in the proportion of trading for firms that did not subscribe to NYSE IF at any point in time (non-adopting firms) are calculated as total shares traded on NYSE between April 2015 and March 2017 divided by the total number of shares traded on all four NYSE Group Exchanges during the same period minus total shares traded on NYSE between April 2013 and March 2015 divided by the total number of shares traded on all four NYSE Group Exchanges during the same period. Only firms reporting trading in both comparison periods are shown.



While the distribution of blue bars is to the left of the red bars, it is centered to the right of 0%, indicating that most non-adopters also increased their proportion of trading on NYSE following the launch of NYSE IF. This is consistent with the launch of NYSE IF having positive externalities on firms that did not subscribe to it, as one would expect in a platform.

The distribution of changes in the total number of shares traded on NYSE shows a similar, if more varied, pattern of volume increases and decreases (Figure 4).[35] The distribution of red bars (adopters) is to the right of the distribution of blue bars (non-adopters). NYSE IF adopters were more likely to increase their total volume of trading on NYSE (18 of 28 adopter firms did so) than non-adopters (35 of 99 non-adopter firms did so). Among the adopters that increased their total trading on NYSE, 13 did so by more than 20%.

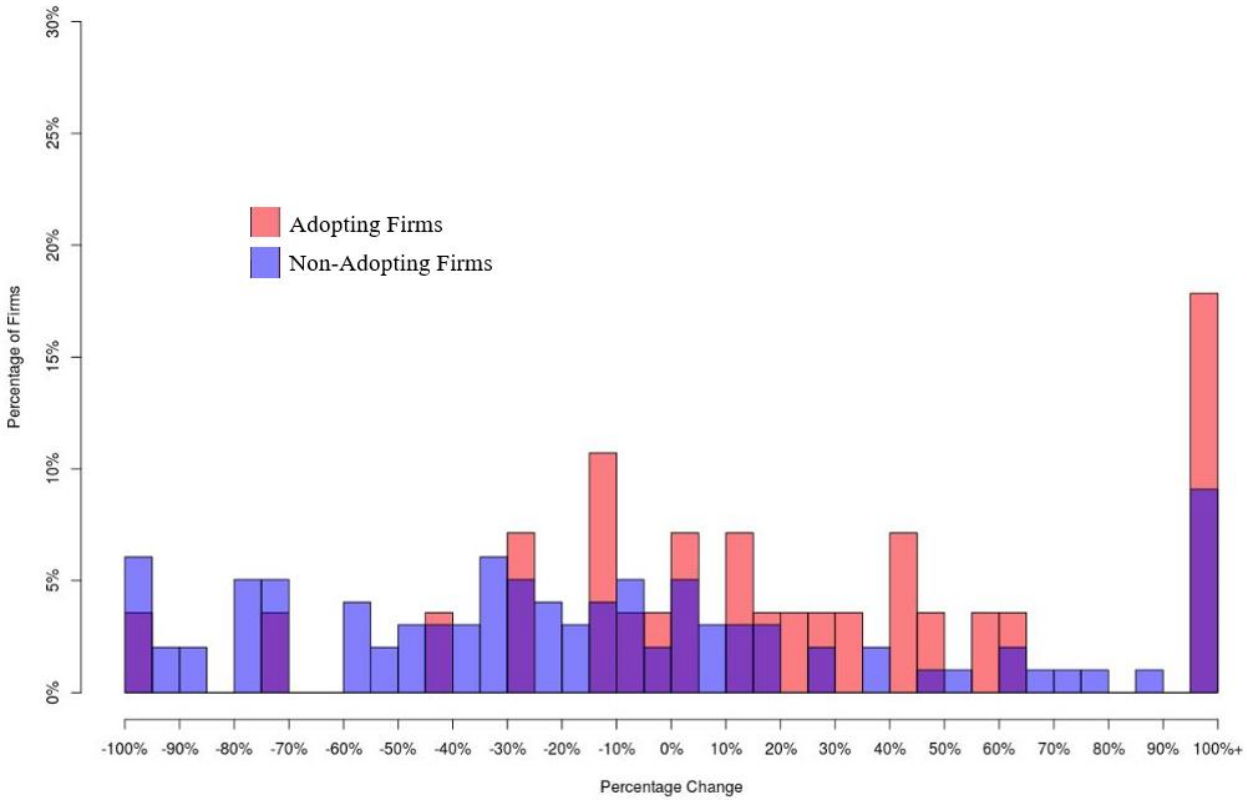
Specific examples illustrate how access to NYSE IF increased firms' trading on NYSE. A large proprietary trading firm that began subscribing to NYSE IF in June 2015 markedly increased the proportion of its trading on NYSE (as a percentage of its total trading on NYSE Group Exchanges for which we have this information) from 49.3% during the two years leading up to its adoption of NYSE IF to 54.8% during the 24 months following its adoption. The number of shares it traded on NYSE increased by 30.1% between those same time periods.

Similarly, an order routing firm related to a large stock exchange provides an example of a very different type of firm that nonetheless reacted similarly to access to NYSE IF. The firm began subscribing to NYSE IF in August 2015. NYSE accounted for 71.6% of its trades on NYSE Group Exchanges during the two years leading up to its adoption of NYSE IF. In the 24 months following this event, the share of its trading volume on NYSE Group Exchanges that went to NYSE increased to 83.1%.

[35] The large bars at 100% and over reflect the five NYSE IF adopters and the nine firms that did not adopt NYSE IF whose trading volume on NYSE increased by 100% or more.

FIGURE 4
Distribution of Percentage Changes in the Number of Shares Traded on NYSE Following Adoption (Adopting Firms) or Launch (Non-Adopting Firms) of NYSE IF

We plot firm-level changes in the number of shares traded on NYSE before and after the launch of NYSE IF. Percentage changes for firms that subscribed to NYSE IF at some point in time (adopting firms) calculated as total number of shares traded on NYSE during the 24 months from the first month in which the firm subscribed to NYSE IF divided by the total number of shares traded on NYSE during the 24 months prior to that month, minus one. Percentage changes for firms that did not subscribe to NYSE IF at any point in time (non-adopting firms) calculated as total number of shares traded on NYSE between April 2015 and March 2017 divided by the total number of shares traded on NYSE between April 2013 and March 2015 minus one. Only firms reporting trading in both comparison periods are shown.



We estimate regression models of the two outcomes discussed above, the proportion of trading on NYSE and firms' volume of trading on NYSE, to test whether the introduction of NYSE IF led both adopters and non-adopters to trade more on NYSE. When analyzing the responses of firms to subscribing to NYSE IF, we estimate within-firm comparisons of pre- and post-adoption outcomes. Our dataset enables us to account for the considerable heterogeneity among the firms in our data (as documented in Table 2) by incorporating firm fixed effects. Our regression models are of the following form:

$$Y_{i,t} = \alpha_i + \beta X_{i,t} + \gamma NYSE\ IF_{i,t} + \varepsilon_{i,t} \quad (2)$$

Subscripts *i* and *t* index firms and time periods (months), respectively. $Y_{i,t}$ is the outcome of interest (proportion of trading on NYSE or trading volume on NYSE) for firm *i* in month *t*. $NYSE\ IF_{i,t}$ is a dummy variable that takes a value of 1 if firm *i* subscribed to NYSE IF in month *t* and 0 otherwise. We classify a firm as subscribing to NYSE IF in a given month if NYSE reports any fees relating to NYSE IF during the month in question. The coefficient of interest is γ, which captures the average effect of subscribing to NYSE IF.

In order to isolate the effect of subscribing to NYSE IF (γ), we control for a series of factors that could also influence firms' trading on NYSE. The terms α_i are firm fixed effects, which capture the effect of all (observable and unobservable) time-invariant firm characteristics on the variable of interest (here, trading on NYSE). $X_{i,t}$ is a vector of covariates that includes changes in equity trading market structure as well as linear and quadratic time trends in some specifications. We include linear and quadratic time trends in some specifications to ensure that the estimated effect of adoption of NYSE IF is not contaminated with pre-existing trends in adopting firms' trading patterns. All control variables vary over time and one factor, the volume that a firm trades on other NYSE exchanges (used only in the volume regressions shown in Table 5), varies both over time and across firms.

The regressions in Table 4 estimate the relationship between the proportion of firms' trading (on NYSE Group Exchanges) that goes to NYSE and various regressors, including "Subscribed to NYSE IF". The estimated coefficients for the variable of interest, "Subscribed to NYSE IF", are all positive and statistically significant at the 95% confidence level, indicating that subscribing to NYSE IF is associated with an increase in the proportion of firms' trading on NYSE.[36]

Table 4 presents five specifications that differ in both the observations analyzed and the independent variables included in the regression. All five specifications in Table 4 are estimated on a dataset of firms that traded on NYSE and subscribed to NYSE IF during January 2013 to May 2019 (the period that our dataset covers). In specifications 1-4, we exclude the six firms that subscribed to NYSE IF at some point in the sample and then unsubscribed later on. Excluding these six firms eliminates the possibility that our estimates

[36] Statistical significance is assessed using clustered standard errors at the firm level to account for possible heteroscedasticity and serial correlation within firms. While this is common practice, it is a conservative approach and methodologies for inference in these settings are evolving. For instance, some recent research argues that clustered standard errors are used more often than is appropriate. *See*, Abadie, Athey, Imbens, and Wooldridge (2017).

mix the effects of the transition from not subscribing to NYSE IF to subscribing with the effects of going from subscribing to not subscribing, which could differ. Specification 5 includes all 31 adopter firms and shows that results are qualitatively similar. Specification 4 excludes observations during the period between the introduction of NYSE IF and the month when an individual firm started its subscription. This avoids contamination of our estimates of firms' pre-adoption NYSE trading proportion due to spillovers from other firms' earlier adoption of NYSE IF.

Specification 1 controls only for time-invariant firm characteristics using firm fixed effects. This most parsimonious specification estimates that subscribing to NYSE IF increases a firm's proportion of trading on NYSE by 7.7 percentage points. Specification 2 controls for changes in market structure due to the entry and exit of various public exchanges during the period analyzed. Controlling for these factors marginally changes the estimated effect of subscribing to NYSE IF to 7.4 percentage points. Adding linear and quadratic time trends to control for pre-existing trends in adopting firm's trading behavior again only marginally reduces the estimated effect of subscribing to NYSE IF to 6.8 percentage points, as shows in specification 3.

Specification 4 uses the same control variables as specification 2 but uses a more stringent sample definition where the period between the launch of the NYSE IF and when a firm subscribes is excluded. We do not include time trends in specification 4 because of the inconsistent sample definition across time. Since we drop observations for some firms after April 2015, a time trend may capture changes in sample composition rather than overall trends in trading behavior. The results remain largely unchanged, and the estimated coefficient implies that subscribing to NYSE IF increases a firm's proportion of trading on NYSE by 7 percentage points.

Specification 5 uses the same control variables as specifications 2 and 5 but includes all adopters. Again, the results are qualitatively unchanged, and the estimated coefficient implies that subscribing to NYSE IF increases a firm's proportion of trading on NYSE by 5.6 percentage points.

We do not pursue a differences-in-differences estimator using non-adopters as a control group because we expect the adoption of NYSE IF by some firms to affect trading activity by non-adopters through externalities; that is, spillover effects from the adoption of NYSE IF could be significant.

TABLE 4
Regression Estimates of Impact of NYSE IF Subscription on the Proportion of Firms' Trading on NYSE

We evaluate firms' responses to subscribing to NYSE IF by regressing firms' monthly proportion of trading on NYSE Group Exchanges that took place on NYSE on a dummy variable indicating whether the firm subscribed to NYSE IF in that month (Subscribed to NYSE IF) and other covariates. NSX/National Active, IEX Active, and CBOE Active are dummy variables accounting for variation in the set of stock exchanges available to traders. All specifications control for firm fixed effects. Specifications 1-5 are estimated on data for the subset of firms that subscribed to NYSE IF at some point in time (adopters). Specification 3 also controls for linear and quadratic time trends. Asterisks denote statistical significance at the 99% (***), 95% (**), and 90% (*) confidence levels. Standard errors clustered at the firm level are shown in parentheses. The regressions are estimated using data covering the 77-month period from January 2013 through May 2019.

Independent Variable	(1)	(2)	(3)	(4)	(5)
Subscribed to NYSE IF	0.077**	0.074***	0.068**	0.070**	0.056**
	(0.029)	(0.026)	(0.031)	(0.029)	(0.023)
NSX/National Active		-0.021**	-0.006	-0.022**	-0.021***
		(0.008)	(0.010)	(0.009)	(0.007)
IEX Active		-0.011	0.029*	-0.010	0.013
		(0.015)	(0.016)	(0.019)	(0.014)
CBOE Active		-0.024	0.000	-0.025	-0.017
		(0.021)	(0.015)	(0.018)	(0.017)
Time Trend			0.004*		
			(0.002)		
Time Trend Squared			-0.000**		
			(0.000)		
Constant	0.452***	0.475***	0.408***	0.474***	0.453***
	(0.016)	(0.012)	(0.037)	(0.014)	(0.010)
Firm Fixed Effects	Y	Y	Y	Y	Y
Observations	1784	1784	1784	1593	2202
Number of Firms	25	25	25	25	31
R-squared	0.710	0.717	0.728	0.686	0.768

The regressions in Table 5 estimate the relationship between the number of shares each firm traded on NYSE and various regressors, including "Subscribed to NYSE IF". We use the logarithm of the number of shares traded, which makes the interpretation of coefficients and comparisons across traders of different sizes easier than if we used the level of those variables. The specifications mirror those in Table 4. In addition to the regressors used in Table 4, specifications 2–5 use a variable controlling for firms' trading volume on other NYSE Group Exchanges (i.e., on NYSE Arca, NYSE National, and NYSE MKT/American). Adding the control variable "Volume on Other NYSE Exchanges" helps us distinguish between overall increases in trading volume and increases in trading volume

specifically on NYSE. All five estimates of the effect of subscribing to NYSE IF on firms' volume of trading on NYSE are positive, with estimates ranging from 31.4% (specification 1) to 61.0% (specification 2).[37] Shifts in overall trading volume on NYSE are more dispersed than changes in the proportion of trading on NYSE, as can be seen by inspecting Figures 3 and 4. This is reflected in the fact that only three of the five coefficients (specifications 2, 4 and 5) are statistically significant at the 95% confidence level.

[37] Per specification 1, a change from zero to one in "Subscribed to NYSE IF" will lead to a change in $100 \times (e^{0.273} - 1)\% = 31.4\%$. For specification 2, the estimated impact is $100 \times (e^{0.476} - 1)\% = 61.0\%$.

TABLE 5
Regression Estimates of Impact of NYSE IF Subscription on the Volume of Firms' Trading on NYSE

We evaluate firms' responses to subscribing to NYSE IF by regressing the natural logarithm of firms' monthly number of shares traded on NYSE on a dummy variable indicating whether the firm subscribed to NYSE IF in that month (Subscribed to NYSE IF) and other covariates. NSX/National Active, IEX Active, and CBOE Active are dummy variables accounting for variation in the set of stock exchanges available to traders. Volume on Other NYSE Exchanges (log) is the natural logarithm of a firm's total number of shares traded on NYSE Group Exchanges other than NYSE (NYSE Arca, NYSE National, and NYSE MKT/American). All specifications control for firm fixed effects. Specifications 1-5 are estimated on data for the subset of firms that subscribed to NYSE IF at some point in time (adopters). Specification 3 also controls for linear and quadratic time trends. Asterisks denote statistical significance at the 99% (***), 95% (**), and 90% (*) confidence levels. Standard errors clustered at the firm level are shown in parentheses. The number of observations varies across specifications as observations reporting zeroes for variables in logarithms are dropped. The regressions are estimated using data covering the 77-month period from January 2013 through May 2019.

Independent Variable	(1)	(2)	(3)	(4)	(5)
Subscribed to NYSE IF	0.273	0.476**	0.473*	0.340**	0.335*
	(0.166)	(0.206)	(0.255)	(0.139)	(0.196)
NSX/National Active		-0.008	0.032	-0.003	-0.016
		(0.039)	(0.054)	(0.036)	(0.061)
IEX Active		-0.248*	-0.120	-0.155	-0.069
		(0.130)	(0.125)	(0.095)	(0.114)
CBOE Active		-0.011	0.008	-0.038	-0.019
		(0.125)	(0.141)	(0.102)	(0.123)
Volume on Other NYSE Exchanges (log)		0.493**	0.518**	0.435**	0.433***
		(0.197)	(0.191)	(0.189)	(0.172)
Time Trend			0.007		
			(0.017)		
Time Trend Squared			-0.000		
			(0.000)		
Constant	19.766***	9.970**	9.362**	11.166***	11.133***
	(0.094)	(3.951)	(3.896)	(3.792)	(3.452)
Firm Fixed Effects	Y	Y	Y	Y	Y
Observations	1721	1721	1721	1547	2067
Number of Firms	25	25	25	25	31
R-squared	0.776	0.808	0.809	0.806	0.845

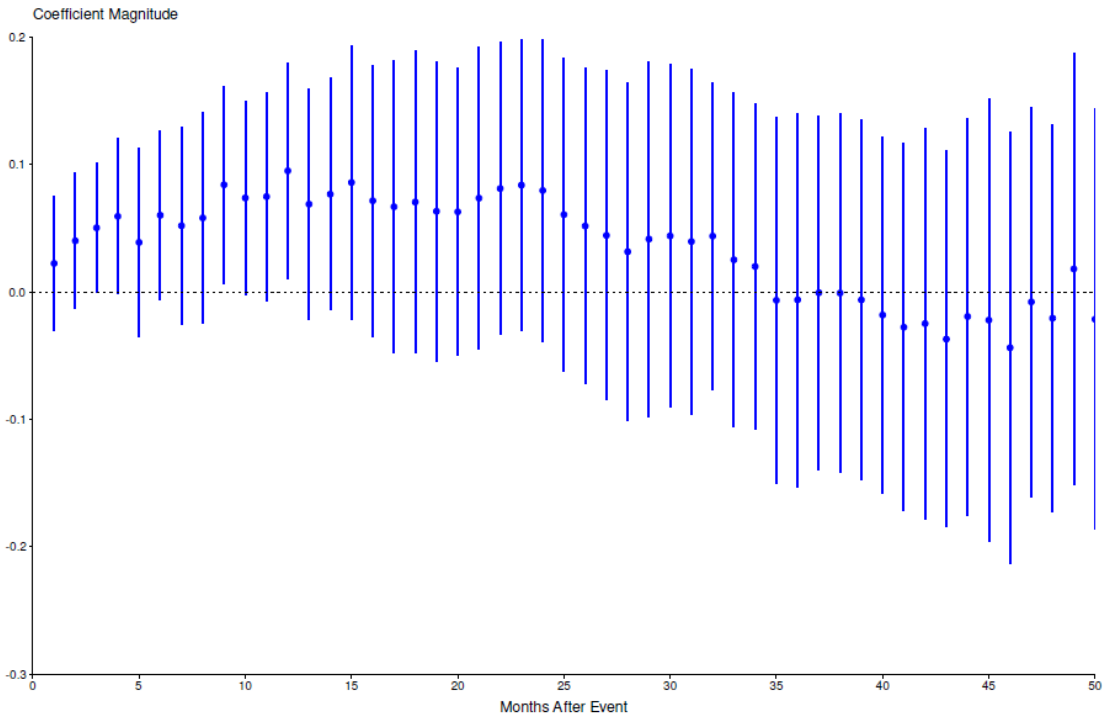
A possible concern is that firms may subscribe to NYSE IF in response to short-run trading demands, biasing our estimates due to reverse causality. For example, it is possible that some firms subscribed to NYSE IF because they anticipated trading large volumes of

NYSE-listed securities that were most liquid on the NYSE exchange. However, two pieces of evidence cut against the reverse causality story. First, most firms that subscribed to the NYSE IF platform remained subscribed for the remainder of the sample period. This suggests that firms were not simply responding to short-term shocks to their trading demands. Second, we estimate "event-study" versions of specification 4 in Tables 4 and 5 where month indicators are interacted with the NYSE IF adoption dummy. Results are shown in Figure 5. The point estimates indicate a positive (though imprecisely estimated) effect of subscription to NYSE IF which falls to zero around 3 years after subscription for the proportion of trading and four years after subscription for trading volume. This suggests that the effect of subscription is long-lived, and not simply a response to short-term trading demands.

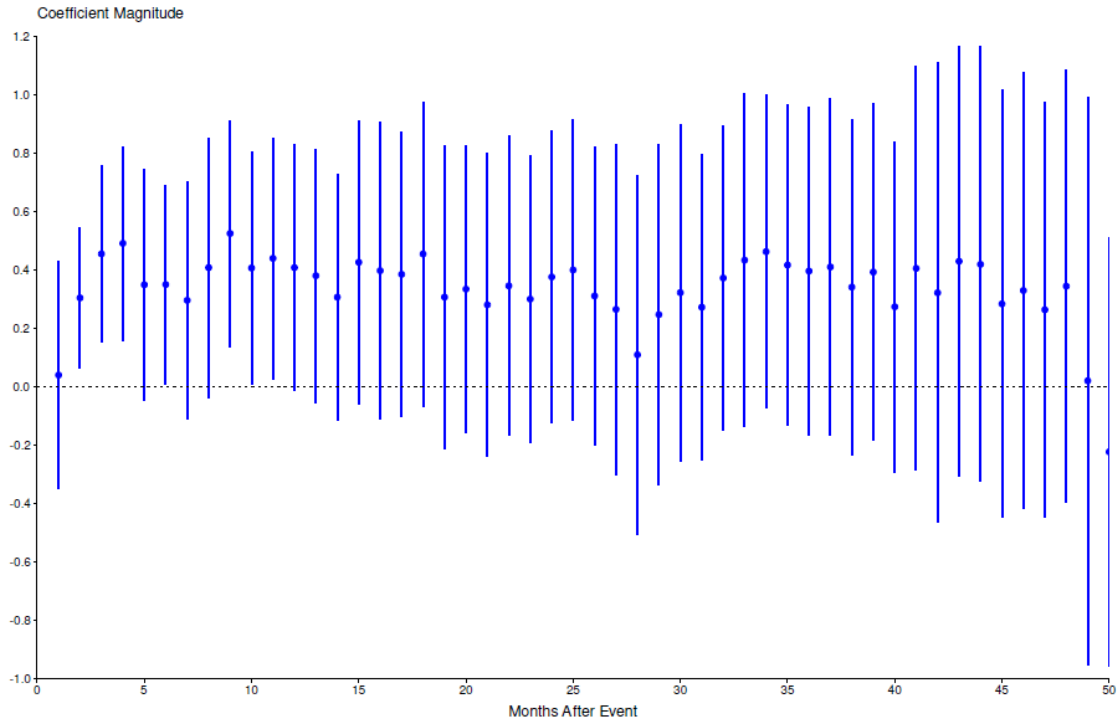
FIGURE 5
Event Study Plots for the Dynamic Impact of NYSE IF Subscription

We plot the event-study versions of our regressions in Tables 4 and 5 that measure the dynamic treatment effect of subscribing. Plots show the resulting coefficients from interacting the treatment dummy with month-year dummies with clustered standard errors. Point estimates are shown as dots and 95% confidence intervals as vertical bars.

Panel A: Proportion of Firms' Trading on NYSE



Panel B: Volume of Firms' Trading on NYSE



As mentioned above, a key characteristic of platform markets is that increased participation on one side (market data) generates benefits or costs for the other side (trading). In particular, the launch of NYSE IF may lead to more or less trading on NYSE *by firms that did not subscribe to NYSE IF* depending on whether the associated benefits in terms of liquidity outweigh the costs in terms of increased informational asymmetries. To test these duelling hypotheses, we estimate fixed effects regressions of the proportion of trading on NYSE (among NYSE Group Exchanges) and of total trading volume on NYSE by each firm on a dataset restricted to firms that did not subscribe to NYSE IF.

$$Y_{i,t} = \alpha_i + \beta X_{i,t} + \gamma NYSE\ IF_t + \varepsilon_{i,t} \quad (3)$$

As before, $Y_{i,t}$ is the outcome of interest (proportion of trading on NYSE or trading volume on NYSE) for firm i in month t and α_i are firm fixed effects. The only difference between the previous specifications is the regressor of interest, $NYSE\ IF_t$, a variable marking the time period following the launch of NYSE IF (the same variable of interest used in the exchange-level regressions shown in Table 3). This means that there is no "in-between" period for these regressions as dropped in the fourth specifications in Tables 4 and 5. Therefore, we estimate versions of specifications 1–3 in Tables 4 and 5 for non-adopters.

TABLE 6
Regression Estimates of Impact of Launch of NYSE IF on Firms' Trading on NYSE and not Subscribing to NYSE IF

We evaluate the reactions of firms that did not subscribe to NYSE IF to the launch of NYSE IF by regressing these firms' proportion of trading on NYSE (among NYSE Group Exchanges) in a given month (Panel A) and the natural logarithm of their total number of shares traded on NYSE in that month (Panel B) on a dummy variable marking the introduction of NYSE IF in April 2015 and other covariates. Time Trend and Time Trend Squared are linear and quadratic time trend terms, respectively. NSX/National Active, IEX Active, and CBOE Active are dummy variables accounting for variation in the set of stock exchanges available to traders. Volume on Other NYSE Exchanges (log) is the natural logarithm of a firm's total number of shares traded on NYSE Group Exchanges other than NYSE (NYSE Arca, NYSE National, and NYSE MKT/American). All specifications control for firm fixed effects. Asterisks denote statistical significance at the 99% (***), 95% (**), and 90% (*) confidence levels. Standard errors clustered at the firm level are shown in parentheses. The number of observations varies across specifications as observations reporting zeroes for variables in logarithms are dropped. The regressions are estimated using data covering the 77-month period from January 2013 through May 2019.

	Dependent Variable					
	Panel A: Proportion of NYSE Trading Volume			Panel B: NYSE Trading Volume (log)		
Independent Variable	(1)	(2)	(3)	(4)	(5)	(6)
Introduction of NYSE Integrated Feed (April 2015)	0.045**	0.035***	0.027**	-0.302***	-0.023	0.124
	(0.020)	(0.013)	(0.013)	(0.089)	(0.066)	(0.081)
NSX/National Active		0.001	0.003		-0.005	0.042
		(0.007)	(0.008)		(0.040)	(0.036)
IEX Active		0.036***	0.037***		-0.004	0.217***
		(0.013)	(0.012)		(0.080)	(0.082)
CBOE Active		0.021	0.032**		0.159**	-0.079
		(0.013)	(0.013)		(0.061)	(0.064)
Time Trend			0.001			-0.017**
			(0.001)			(0.007)
Time Trend Squared			-0.000			0.000
			(0.000)			(0.000)
Volume on Other NYSE Exchanges (log)					0.146***	0.143***
					(0.032)	(0.032)
Constant	0.684***	0.670***	0.647***	16.267***	14.258***	14.634***
	(0.012)	(0.011)	(0.026)	(0.053)	(0.476)	(0.510)
Firm Fixed Effects	Y	Y	Y	Y	Y	Y
Observations	7468	7468	7468	7062	6184	6184
Number of Firms	136	136	136	136	134	134
R-squared	.0196	0.030	0.030	0.022	0.073	0.080

The regression results confirm that firms that did not subscribe to NYSE IF nonetheless increased their trading on NYSE following the launch of NYSE IF. The coefficient of interest in specification 3 in Table 6 is 0.027 (statistically significant at the 95% confidence level), indicating that the launch of NYSE IF led firms that did not adopt

NYSE IF to do 2.7 percentage points more of their trading on NYSE Group Exchanges on NYSE.

The results of analysis of trading volume (Table 6, Panel B) are less precise but consistent with our main results in Panel A. The coefficient in specification 4 is negative and significant, indicating a large decrease in trading volume on NYSE by non-adopting firms. However, this appears to reflect factors unrelated to the launch of NYSE IF, notably a pre-existing downward trend in trading volumes by non-adopters. Specification 6 indicates that the launch of NYSE IF led firms to increase their total trading volume on NYSE by 13.2% though, the coefficient is imprecisely estimated and is not statistically significant at conventional levels.[38] The comparison of this estimate with that in Specification 5, which adds all the other controls besides the time trends and still returns a negative estimate, strongly suggests that the pre-existing downward trend is a source of downward bias in the estimates of Specifications 4 and 5.

Overall, the empirical evidence we have described consistently documents linkages between data subscriptions and trading, confirming that NYSE acts as a platform for data and trading. The introduction of NYSE IF led to increased trading activity by the firms adopting it (Tables 4 and 5). As discussed above, Table 6 provides evidence on whether adopters' data purchases imposed positive or negative externalities on non-adopters. Consistent with the benefits of positive liquidity externalities outweighing any negative externalities arising from information asymmetry, the NYSE IF introduction attracted additional trading by firms that did not subscribe to NYSE IF.[39] These firm-level results are mirrored in our exchange-level analysis of trading volumes on NYSE, which increased as a proportion of total U.S. equities trading following the launch of NYSE IF (Table 3).

IV. Conclusions

To understand better how stock exchanges compete, we present qualitative and empirical evidence about the importance of linkages between stock exchanges' proprietary data sales and trading activity. Empirically, we focus on the introduction of a new data product at the New York Stock Exchange and how that led to higher volumes of trading at NYSE. We present a new customer-level data set drawn from NYSE Group that matches

[38] The launch of NYSE IF in April 2015 led to a change in $100 \times (e^{0.124} - 1)\% = 13.2\%$ increase in firms' trading volume on NYSE.

[39] This result is consistent with, but does not establish, that overall externalities were positive on net. For example, in principle, it is possible that the introduction of NYSE IF drove adopters to NYSE and thereby reduced liquidity on other exchanges so that non-adopters chose to trade more on NYSE despite increased informational asymmetries.

data subscribers with traders. We show that, within NYSE Group exchanges, customers that purchased the new data product increased their trading at NYSE and, furthermore, this led non-purchasers to trade at NYSE more. This is consistent with positive externalities arising from the sale of proprietary market data. Overall, the results suggest that stock exchanges are platforms for trading and data.

These results are important because the effect of data sales on trading is theoretically unclear. Data sales can lead data purchasers to trade more on an exchange. That can lead to more liquidity on the exchange, which even traders that do not purchase data may find attractive. However, the data sales may increase the presence of well-informed traders that leads to an information asymmetry for traders that do not purchase data. Our paper finds that traders that do not purchase data are attracted to exchanges that sell data, suggesting that the liquidity effect is more important.

These results have implications for exchange regulation.[40] To the extent that the platform nature of stock exchanges is economically important, exchange competition in data fees cannot be analyzed in isolation, without accounting for the competitive dynamics in trading services. Competition is then properly understood as being between platforms (i.e., stock exchanges and other trading venues) that balance the needs of consumers of data and traders.[41] Our research stops short of quantifying the importance of these effects, but establishing the platform nature of exchanges is an important first step.

[40] While the authors find the platform nature of exchanges to be obvious, the SEC approved NYSE National Integrated Feed fees without agreeing with the proposition that "exchanges function as platforms between consumers of market data and consumers of trading services." See SEC (2020a)..

[41] Exchanges compete with dark pools for trading. However, as suggested by their name, these non-exchange venues do not provide market data. While most ATS are in this category, at least one, InteractiveCross, provides data on NMS stocks.

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Appendix A

TABLE A1
Structural Break Tests for Regression Estimates of Impact of Launch of NYSE IF on Trading on NYSE

We evaluate three versions of an intercept-only structural break test in the time series analysis for Table 3. The tests use a supremum Wald test methodology. Time Trend and Time Trend Squared are linear and quadratic time trend terms, respectively. We control for overall trading activity with the natural logarithm of the number of shares traded on all U.S. venues (Total U.S. Equity Volume Traded (log)) or separately for the number of shares traded on public exchanges (Total U.S. Equity Volume Traded on Public Exchanges (log)) and ATS and dark pools (Total U.S. Equity Volume Traded on ATS and Dark Pools (log)). Proportion of Total U.S. Equity Trading Volume Traded on Public Exchanges is the number of shares traded on public exchanges in the month in question divided by the total number of shares traded on all U.S. venues in that month. Asterisks denote statistical significance at the 99% (***), 95% (**), and 90% (*) confidence levels. Standard errors clustered at the firm level are shown in parentheses. The number of observations varies across specifications as observations reporting zeroes for variables in logarithms are dropped. The regressions are estimated using data covering the 78-month period from January 2013 through June 2019. All specifications indicate that the most likely structural break date is June 2015, which is two months after the launch of NYSE IF.

Independent Variables	(1)	(2)	(3)
Time Trend	0.001***	0.001***	0.001***
	(0.000)	(0.000)	(0.000)
Time Trend Squared	-0.000***	-0.000***	-0.000***
	(0.000)	(0.000)	(0.000)
Total U.S. Equity Volume Traded (log)	0.001		
	(0.007)		
U.S. Equity Volume Traded on Public Exchanges (log)		0.013	
		(0.018)	
U.S. Equity Volume Traded on ATS or Dark Pools (log)		-0.016	
		(0.022)	
Proportion of Total U.S. Equity Volume Traded on Public Exchanges			0.051
			(0.074)
Structural Break Date	2015m6	2015m6	2015m6
Structural Break Wald Test Statistic	20.199	23.706	21.696
Structural Break P Value	0.000	0.000	0.000
Observations	78	78	78
R-squared	0.536	0.541	0.540

Appendix B

In this Appendix, we describe how data is used by traders to make order routing decisions and, specifically, why market data for a particular exchange would make trading on that exchange more attractive. We begin by presenting three simple examples that illustrate how investors use data and why they would be willing to pay for it. As these examples show, market data from an exchange can reduce uncertainty about the likelihood, price, or timing of execution for an order on that exchange. Such reductions in uncertainty can encourage traders to route their orders to that exchange. After going through these examples, we explain two additional ways in which access to market data reduces uncertainty and may thereby drive order flow to an exchange.

Our objectives in presenting these qualitative descriptions are twofold. First, they provide a more detailed framework for understanding our empirical results in Section III. Second, they provide a conceptual underpinning to the notion that the types of externalities that require the application of platform economics link the sale of exchanges' data and trading services. One set of linkages are self-evident: Trading and limit orders provide the information in which purchasers of data are interested, such as transaction volume, price movements, and the set of limit orders below the top of the book that allow traders to make better predictions about how new trades will cause the market to shift. Limit orders simultaneously generate both market liquidity and market data. Naturally, this value spills across firms. That is, firms that place orders on a stock exchange create value for *other firms* that purchase data. The linkages whereby data affects the value of trading are less obvious, and thus require more explanation.

Example 1: Uncertainty regarding execution of large orders on a single exchange

This simple example illustrates how seeing the limit order book can reduce uncertainty regarding likely execution prices for market orders.

An investor wishes to purchase 200 shares of a particular stock immediately. The consolidated feed is showing 100 shares available on exchange A at $20.00. No other exchange is quoting an offer. Also, there is a limit sell order for 100 shares at $20.10 on exchange A.

If the investor sees only the consolidated feed, the investor would not see the limit order at $20.10 and would face uncertainty regarding the ultimate purchase price that would result from submitting a market order for 200 shares. If the entire order book were visible,

the investor would be able to see that its second 100 shares would be executed at $20.10, for a total weighted average price of $20.05.

Example 2: Uncertainty regarding execution of large orders with two exchanges

For the second example, suppose that there are two exchanges A and B, and their sell limit orders are as follows: A1 100 shares for $20.00; A2 100 shares for $20.02; B1 100 shares for $20.04; B2 100 shares for $20.10.

A buyer is looking to buy 200 shares immediately. Assuming it subscribed to a consolidated feed, the buyer would see the top of the book at each exchange: 100 shares for $20.00 on Exchange A and 100 shares for $20.04 on Exchange B.

The buyer could consider the following three options: (1) route a market order for 200 shares to Exchange A; (2) route simultaneous orders for 100 shares to Exchange A and 100 shares to Exchange B; (3) route an order for 100 shares to Exchange A and wait to see how prices reported in the consolidated feed evolve before submitting its order for the second 100 shares.

Abstracting from the time required to process and route orders and from high-frequency changes in quoted prices, all three options would result in execution at a volume-weighted average price of $20.01. The "order protection rule" (also known as the "no trade-through" rule) stipulated by Regulation NMS prevents an exchange from executing an order at a price less favorable to the trader than what is available at the top of the book at other exchanges.[42] Under option 1, Exchange A will execute the trader's order for 200 shares immediately, as both $20.00 and $20.02 are better prices than what is available at Exchange B. Under option 2, Exchange A will execute the trader's order for 100 shares immediately and Exchange B will try to access Exchange A's top of book as observed at the time of order receipt. This will result in Exchange B sending an order to Exchange A priced at either $20.00 or $20.02, depending on whether Exchange A has already executed the trader's first

[42] SEC (2010), pp. 26–27 ("Another important type of linkage in the current market structure is the protection against trade-throughs provided by Rule 611 of Regulation NMS. A trade-through is the execution of a trade at a price inferior to a protected quotation for an NMS stock. A protected quotation … must be an automated quotation that is the best bid or best offer of an exchange or FINRA. Importantly, Rule 611 applies to all trading centers, not just those that display protected quotations. Trading center is defined broadly in Rule 600(b)(78) to include, among others, all exchanges, all ATSs (including ECNs and dark pools), all OTC market makers, and any other broker-dealer that executes orders internally, whether as agent or principal…. Rule 611 also helps promote linkages among trading centers by encouraging them, when they do not have available trading interest at the best price, to route marketable orders to a trading center that is displaying the best price. Although Rule 611 does not directly require such routing services (a trading center can, for example, cancel and return an order when it does not have the best price), competitive factors have led many trading centers to offer routing services to their customers.").

order and updated its quote. If the Exchange B order is priced at $20.00 and goes unexecuted Exchange B will likely wait to observe Exchange A's refreshed quote, resulting in Exchange B routing to Exchange A again, this time at $20.02, and receiving a fill at that price. Under option 3, Exchange A would execute the first order for 100 shares at $20.00 and then the trader would send a second order to Exchange A to be executed at $20.02 after seeing Exchange A's quote updated to $20.02. Under any of these scenarios, the trader faces the same sort of ex-ante uncertainty as it did in example 1 above: at the moment it submits its first order, it would not be sure what price it will receive for its second 100 shares.

The equivalence between the three options above falls apart when we acknowledge that processing and routing an order takes some (very small) amount of time (*routing delay*) and that available quoted prices could change during that span. Option 1, where the trader sends a market order for 200 shares to Exchange A, has the best chance of being executed at the best prices currently available. Options 2 and 3, however, require additional time before the order for the second 100 shares reaches Exchange A as either Exchange B checks for prices available on other exchanges and routes the order to Exchange A (under option 2) or the trader observes the evolution of quotes at the top of the book and sends a second marketable order to Exchange A (under option 3). In either case, order A2 may be re-priced or canceled during the routing delay and lead the trader to miss out on the possibility of trading its second 100 shares at $20.02.

The prevalence of non-routable order types offered by exchanges confirms that some market participants are concerned about both reducing execution uncertainty and minimizing the impact of routing delay. For example, an ISO limit order may be used to ensure immediate execution of the specified amount at its limit price or better as long as there are resting limit orders that it can be matched to, regardless of whether a more favorable price is advertised at another exchange.[43] A primary reason a trader would use an ISO limit order (and assume responsibility for compliance with Regulation NMS's order protection rule) is to get immediate execution rather than endure the delay and uncertainty associated with having the exchange survey other exchanges for better prices. In total, non-routable order types accounted for 68.3% of matched non-auction volume on NYSE in October 2019.[44]

[43] "NYSE Arca Pillar Order Types and Modifiers," NYSE, https://www.nyse.com/publicdocs/nyse/markets/nyse-arca/NYSE_Arca_Order_Suite.xlsx. The term ISO limit order encompasses IOC ISO and Day ISO order types.

[44] "NYSE Tape A - Order Type Usage (Percentage of Matched Volume)," NYSE, 2019, https://www.nyse.com/publicdocs/nyse/markets/nyse/NYSE-Order-Type-Usage.pdf.

Example 3: Uncertainty regarding execution of "odd lot" orders

The third example highlights uncertainty around the execution of small orders (i.e., odd lot orders, typically those less than 100 shares). One limitation of the SIP is that it reports the best bids and offers available at each exchange for "round lots" – that is, quotes to buy or sell blocks with multiples of 100 shares of a given security.[45] According to the SEC's MIDAS tool, odd lot trades accounted for over 46% of trades and 14% of exchange trading volume in NMS stocks in Q3 2019.[46]

Suppose the orders reported by the SIP are as in example 2, except that Exchange B also has an odd lot offer for 50 shares at $19.99. Consider a situation where the trader wishes to buy 45 shares immediately. With only the SIP data, the trader would likely send a market order to Exchange A to be executed at the best offer price available of $20.00. If the trader subscribed to an order book or full order-by-order depth of book data for Exchange B (or both exchanges), it would send his order to Exchange B to be executed at the more favorable price of $19.99.

Uncertainty regarding the timeliness of market information

Our examples so far assume that a trader can perfectly observe the state of the market at the top of the order book, and thus our examples highlight the value to some traders of subscribing to order book data. Why might a trader subscribe to a BBO service, when the SIP provides the same information? In practice, there is always some amount of time that passes between activity on a stock exchange and when investors can observe that activity in their data feeds (i.e. after the market update has been received, processed, and redistributed by the SIP or after an individual firm has received and processed the update via exchange proprietary feeds), and between when a trader places an order and when an order reaches an exchange. In that amount of time, the state of the market can change, which can change the economics of some orders. Thus, obtaining data more quickly can be valuable for some trading strategies as it can reduce uncertainty regarding the "current" state of the market. While exchanges provide data to the SIP no later than they do to their BBO subscribers, the time involved in processing and redistributing the data to generate the SIP data feed means

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[45] SEC (2010), p. 63. In some cases, exchanges apply alternative definitions of round lots. *See*, e.g., "Rule 55. Unit of Trading—Stocks and Bonds," NYSE, https://nyseguide.srorules.com/rules/document?treeNodeId=csh-da-filter!WKUS-TAL-DOCS-PHC-%7B4A07B716-0F73-46CC-BAC2-43EB20902159%7D--WKUS_TAL_5665%23teid-134.

[46] "Market Information Data and Analytics System (MIDAS); Market Structure; Market Activity Overview," U.S. Securities and Exchange Commission, https://www.sec.gov/marketstructure/datavis/ma_overview.html#.XdxfbehKiUk.

that unconsolidated data from a single exchange may reach subscribers more quickly. That is a primary reason why some traders subscribe to BBO feeds (Jones (2018).[47]

Uncertainty regarding the likelihood of execution of non-marketable orders

For an actively traded stock, there are typically several orders at each price in an order book. On most U.S. exchanges, orders at the same displayed price on the same exchange are executed in the order that they arrive.[48] Information about the amount offered and the relative sequence of orders at each level of an order book, provided by full order-by-order depth of book data products, can help a trader that seeks to optimize or understand its order queue placement (see Moallemi and Yuan (2017).

The detailed information provided by full order-by-order depth of book data enables traders to infer where their orders would be in the queues. Furthermore, traders can analyze the behavior of orders with different characteristics to better predict how long other participants' orders might be available. Thus, the detailed order book data reduces uncertainty regarding the likelihood of execution and makes it more likely that the trader would submit non-marketable orders at the exchange(s) for which it has visibility.

[47] Jones (2018) explains that: "Shortly after Reg NMS was adopted, there was an increase in the use of proprietary data feeds by market participants to get access to trades and top-of-book quote information faster than they could get it through SIPs." Similarly, the U.S. Department of the Treasury (2017) notes that: "Many HFT firms rely on these proprietary data feeds to inform their trading, in part by consolidating information from exchanges' proprietary feeds faster than it can be delivered by the SIP."

[48] While most markets execute non-marketable limit orders with the same limit price in the order they arrive, NYSE enforces a different priority rule whereby multiple orders at the same price point may share executions. An order's place on the electronic order book queue is nonetheless relevant for the likelihood and timing of execution. *See*, "Parity & Priority," NYSE, https://www.nyse.com/publicdocs/nyse/markets/nyse/Parity_and_Priority_Fact_Sheet.pdf.