Stock Exchanges as Platforms for Data and Trading

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1. QUALIFICATIONS AND ASSIGNMENT

1. My name is Marc Rysman and I am a Professor of Economics at Boston University, where I teach courses on industrial organization, econometrics, antitrust, and regulation. I received my Ph.D. in Economics from the University of Wisconsin at Madison in 1999. My research focuses on industrial organization and competition, and the related issues of antitrust and regulation. I have investigated a variety of industries, including telecommunication, Yellow Pages directories, payment cards, and consumer electronics.

2. From 2009 to 2018, I was a Visiting Scholar at the Federal Reserve Bank of Boston. I have been a Visiting Associate Professor at MIT (2007–2008), a Visiting Scholar at Harvard University (2003–2004, 2014–2015), a Visiting Fellow at Northwestern University (2003), and a Visiting Scholar at the Federal Reserve Bank of Minneapolis (2003).

3. I have won numerous teaching and research awards, including the Neu Family Award for Teaching Excellence in Economics (2006 and 2012), Networks, Electronic Commerce and Telecommunications (NET) Institute Grants (2003, 2005, and 2009), National Science Foundation Grants (2001, 2004, 2006, and 2009), and the Christensen Award in Empirical Economics (1997, with Phil Haile).

4. I have published numerous articles in top peer-reviewed journals in the field of Economics, including in *Journal of Industrial Economics*, *International Journal of Industrial Organization*, *RAND Journal of Economics*, *American Economic Review*, *Journal of Political Economy*, *Review of Economic Studies*, and the *Journal of Economic Perspectives*. I am an Editor of the *RAND Journal of Economics*.

5. The economics of platforms have been a central focus of my research and consulting work. I have published several peer-reviewed articles in this area, and I was commissioned to write the *Journal of Economic Perspectives* article on "The Economics of Two-Sided Markets." During my ten years as a visiting scholar at the Federal Reserve Bank of Boston, I have specialized in the economics of payment networks. I was asked by the Federal Communications Commission to write a white paper on the business data services market, which has many important platform elements.

6. I have been asked by the New York Stock Exchange Group ("NYSE Group") to analyze how platform economics applies to stock exchanges' sale of market data products and trading services and to explain how this affects the assessment of competitive forces affecting its data fees. NYSE Group provided financial support for this research. I was assisted in my analysis by staff of Cornerstone Research, who worked under my direction.

2. EXECUTIVE SUMMARY

7. Platforms are firms that act as intermediaries between two or more sets of agents. Typically, the choices of one set of agents affect the payoffs to the other set(s) of agents via *externalities*. For example, credit cards are more valuable to cardholders when many merchants accept them, and credit card acceptance has greater benefits for merchants when there are many cardholders. These linkages between the different "sides" of a platform mean that one cannot understand pricing and competition for goods or services provided on one side of the platform in isolation, without accounting for the influence of the other side(s).

8. Stock exchanges are classic examples of platform companies. In fact, there are multiple senses in which exchanges are platforms. In this paper, I focus on exchanges as platforms between consumers of market data and consumers of trading services.

9. Stock exchanges offer several types of market data products, including 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 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.

10. Traders' choices about where to trade affect the value of these data products. Trading activity and order book depth enhances 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.

11. This paper focuses 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 can increase. This is 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, market data makes trading on that exchange more attractive to traders.

12. Data purchases also have externalities or indirect effects on traders that do not purchase data. For instance, increased trading by traders that purchase data from an exchange generates more liquidity on that exchange, creating value for traders that do not purchase data. These externalities further confirm that stock exchanges are platforms between consumers of market data and consumers of trading services.

13. I confirm 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. I show 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 launch proportion of total trading of 11.6%.

14. Using data on firm-level data purchases and trading obtained from NYSE Group, I was further able to test for the direct and indirect effects of access to NYSE IF that characterize platform markets. This firm-level data covers only trading at NYSE, NYSE Arca, NYSE National, and NYSE MKT/American ("NYSE Group Exchanges").[1] Because of this data limitation, I cannot study the shift of firms' overall (i.e., at all trading venues) trading toward NYSE that followed the introduction of NYSE IF as I do in the exchange-level analysis. Rather, I study the impact of the introduction of NYSE IF on two outcomes. First, I 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 – I test whether gaining access to NYSE IF makes trading on NYSE more attractive relative to other NYSE Group Exchanges, such as NYSE Arca. Second, I look at firms' total trading volume (measured by the number of shares traded) on NYSE.

15. I 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 4.4 and 7.5 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 17.7% to 40.4%. 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 – that is, it is consistent with NYSE being a platform for data and trading.

[1] The data does not cover the NYSE Chicago exchange.

16. The platform nature of stock exchanges has important implications for public policy towards exchanges. For instance, it means that data fees cannot be analyzed in isolation, without accounting for the competitive dynamics in trading services. Competition is properly understood as being between platforms (i.e., stock exchanges) that balance the needs of consumers of data and consumers of trading services. Competition between platforms can be consistent with prices that deviate from marginal costs on one or both sides of the market, and often does not lead to prices that reflect costs in the way that traditional models of competition predict. But such platform competition would discipline stock exchanges' overall pricing and profitability.

3. THE ECONOMICS OF PLATFORM COMPETITION

17. The economics of platforms focuses on firms that act as *intermediaries* between two or more sets of agents.[2] Common examples of platform firms are Internet search engines, which bring together consumers and content providers (often advertisers), and payment card networks, which facilitate interactions between consumers and retailers. Media companies, such as newspapers, are platforms for interactions between consumers and advertisers even though consumers may primarily use the newspaper for information other than advertising.

18. Typically, a feature of a platform firm is that the choices of one set of agents affect the payoffs to the other set of agents. For instance, when many merchants sign up to accept a payment card, the card becomes more valuable to a consumer. In this sense, there is an *externality* that runs from one side of the platform to the other, and often in both directions.

19. In theory, not all firms are platform firms. For instance, consider a grocery store that buys food from a manufacturer and then retails the food to consumers. The manufacturer is paid when the food is delivered to the grocery store, so it does not matter to the manufacturer whether any consumers ever buy the food or not – the manufacturer collects its wholesale price regardless. There is no interaction between consumers and manufacturers. However, in practice, grocery stores may have buy-back provisions that force manufacturers to buy back some product if it does not sell, or a grocer and manufacturer may develop a long-term relationship with explicit or tacit agreements that increase the value of their relationship. These factors would make the manufacturer care about how many consumers use the grocery store, generating linkages between the grocery store's interactions with manufacturer and shoppers that are best understood through the lens of platform economics.

20. In this sense, almost every firm has some elements of a platform to it. My view is that it is not generally useful to try to distinguish whether firms are platforms or not, as we can most often find platform elements in a firm. The more interesting question is how important platform issues are in understanding a particular firm's activities. The answer may change based on what question we ask. For instance, car manufacturers can be interpreted as platforms between dealers and consumers, as dealers value consumers that are interested in their cars and consumers value dealers that deliver cars. Understanding the platform nature of a car manufacturer may reasonably be ignored when studying some issues, such as

[2] The discussion in this section draws from Rysman, Marc. 2009. "The Economics of Two-Sided Markets." *Journal of Economic Perspectives* 23(3): 125–143.

innovation to meet fuel economy standards, but might be important for other issues, such as understanding contracts with dealers.

21. The "sides" of the market served by platforms need not be distinct sets of agents, such as merchants and cardholders or advertisers and newspaper readers. For example, sports card conventions are two-sided platforms that bring together enthusiasts to buy and sell sports cards.[3] Some participants pay an entrance fee whereas some, the dealers, pay a table fee, which allows them to set up a table at the convention. We can think of the convention as a platform that brings together these participants. While we might think of dealers as the "sellers" and regular entrants as the "buyers," in practice, both sets of agents buy, sell, and trade cards with each other. Some participants may substitute between being a dealer and non-dealer based on the convention fees.

22. Stock exchanges are classic examples of platform companies. In fact, there are multiple senses in which exchanges are platforms: Some studies reference stock exchanges' role in bringing together buyers and sellers of shares[4] or providers and takers of liquidity.[5] In this paper, I explain that exchanges are platforms between consumers of market data and consumers of trading services and I present empirical evidence to support this conclusion and confirm the importance of these linkages.

23. Understanding competition in platform markets requires an analysis of how prices to all sides of the market are interrelated. For example, even if competition between platforms is intense and overall profits are low, it could be that prices are relatively high on one side of

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[3] Jin, Ginger Zhe, and Marc Rysman. 2015. "Platform Pricing at Sports Card Conventions." *The Journal of Industrial Economics* 63(4): 704-735.

[4] Although market participants may be willing to switch between being a buyer and seller of a given security as the price changes, within any trade, an exchange is matching a buyer to a seller. In general, sellers prefer markets with many buyers and buyers prefer markets with many sellers, which generates a platform dynamic. *See*, Evans, David S. and Richard Schmalensee. 2011. "The Industrial Organization of Markets with Two-Sided Platforms." In *Platform Economics: Essays on Multi-Sided Businesses*, edited by David S. Evans, Competition Policy International, p. 5 ("Exchanges have two groups of customers, who can generally be considered "buyers" and "sellers." The exchange helps buyers and sellers search for feasible contracts—that is where the buyer and seller could enter into a mutually advantageous trade.").

[5] U.S. stock exchanges are organized as central limit order books, in which traders post offers to buy or sell at a particular price. Traders that post non-marketable limit orders (i.e., buy/sell limit orders with a limit price below/above current interest on the opposite side) are referred to as *providers* of liquidity. Traders that take those offers by submitting market orders (to buy/sell at the best available price) or marketable limit orders (where the buy/sell limit price is at or above/below current interest on the other side) are *takers* of liquidity. A provider of liquidity may be either a buyer or seller of the stock (and similarly for liquidity takers). *See*, Evans, David S. and Richard Schmalensee. 2011. "The Industrial Organization of Markets with Two-Sided Platforms." In *Platform Economics: Essays on Multi-Sided Businesses*, edited by David S. Evans, Competition Policy International, p. 5 ("In organized exchanges such as the New York Stock Exchange, it is often more useful to think of the two sides as liquidity providers—specialists or market-makers who quote prices to both buyers and sellers and thus bring liquidity to the market—and liquidity consumers—ordinary customers who accept liquidity providers' offers."); Foucault, Thierry, Ohad Kadan, and Eugene Kandel. 2013. "Liquidity Cycles and Make/Take Fees in Electronic Markets." *The Journal of Finance*, 68(1): 299-341, p. 300 ("Our model is designed to analyze the determinants of this rate when market monitoring is costly. It features a trading platform with two types of traders: 'market makers,' who post quotes, and 'market takers,' who hit quotes.").

the market and low or even negative on the other side. In such a situation, analyzing competition on one side of the market in isolation can lead to incorrect conclusions. For instance, sports card conventions typically charge much higher fees to dealers than to regular participants. An analyst focusing only on table fees at sports card conventions might conclude that convention organizers have market power, whereas an analyst considering both sides might conclude that the convention organizers do not have market power. Policy decisions based on overly narrow analyses can have unintended consequences; for example, regulating table fees could lead to reduced benefits such as free parking or "door prizes" (i.e. gifts for attendees) for non-dealer enthusiasts.

4. STOCK EXCHANGES ARE PLATFORMS FOR INTERACTIONS BETWEEN CONSUMERS OF MARKET DATA AND CONSUMERS OF TRADING SERVICES

24. In this section, I discuss exchanges as platforms for interactions between consumers of data and consumers of trading services. In fact, many firms that consume data do so in order to trade, so they are naturally on "both sides" of this platform. Platform economics still applies to cases like this, just as platform economics helps us understand platforms like eBay where sellers also purchase from other vendors. 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. I go through these points in detail below.

25. In Section 4.1, I give an overview of market data products offered by stock exchanges. Section 4.2 describes 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. Section 4.3.1 describes how trading makes data more valuable and explains that these externalities make stock exchanges platforms for data and trading. Section 4.3.2 describes externalities running in the opposite direction, from data to trading that reinforce the conclusion that stock exchanges are platforms for data and trading. This discussion draws on the ideas developed in Section 4.2. Finally, Section 4.4 reviews academic studies that present empirical evidence regarding whether access to market data for a given exchange makes trading on that exchange more attractive.

26. Throughout this paper, when I refer to firms or traders, I 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 specialized proprietary trading or market making firms, investment banks, and brokers that trade on behalf of their clients. Institutional and retail investors do not trade directly on exchanges – only registered broker-dealers can be members of exchanges, and only exchange members can trade directly on exchanges.[6] Institutional investors trade through brokers who route their trades to various trading centers and do not typically have direct control (or even real-time visibility) into where their orders are routed and executed. Marketable retail orders that come, for example, through an

[6] Securities Exchange Act of 1934, Section 3(a)(2)(A) ("The term 'member' when used with respect to a national securities exchange means (i) any natural person permitted to effect transactions on the floor of the exchange without the services of another person acting as broker, (ii) any registered broker or dealer with which such a natural person is associated, (iii) any registered broker or dealer permitted to designate as a representative such a natural person, and (iv) any other registered broker or dealer which agrees to be regulated by such exchange and with respect to which the exchange undertakes to enforce compliance with the provisions of this chapter, the rules and regulations thereunder, and its own rules. For purposes of sections 78f(b)(1), 78f(b)(4), 78f(b)(6), 78f(b)(7), 78f(d), 78q(d), 78s(d), 78s(e), 78s(g), 78s(h), and 78u of this title, the term "member" when used with respect to a national securities exchange also means, to the extent of the rules of the exchange specified by the Commission, any person required by the Commission to comply with such rules pursuant to section 78f(f) of this title.").

online retail broker, are generally routed to over-the-counter ("OTC") market makers – broker-dealers that offer liquidity primarily in a principle capacity and execute trades off the public exchanges.[7]

4.1. Overview of market data

27. Market data is often divided into two categories: core (securities information processor ("SIP") or consolidated feed) data and non-core (or proprietary) data.[8]

28. 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.[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

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[7] "Concept Release on Equity Market Structure," U.S. Securities and Exchange Commission, Release No. 34-61358, January 14, 2010, pp. 20–21; O'Hara, Maureen. 2015. "High Frequency Market Microstructure." *Journal of Financial Economics*, 116(2): 257-270, p. 260 ("A large fraction of US retail trades are either directly internalized or delivered via purchased order flow agreements to broker-dealer firms."); "SEC Rule 606 Report, Percentages of Total Non-Directed Orders Routed to Individual Market Venues, Third Quarter 2019" TD Ameritrade, https://www.tdameritrade.com/retail-en_us/resources/pdf/AMTD2054.pdf, accessed November 15, 2019 (showing that non-directed orders were routed to Citadel Execution Services, Virtu Americas LLC, G1 Execution Services, and UBS Securities LLC); "Report on Routing Customer Orders for Quarter Ending June 30, 2019," Charles Schwab, https://www.schwab.com/public/schwab/nn/legal_compliance/important_notices/order_routing.html, accessed November 15, 2019 (showing that 99% of non-directed orders were routed to Citadel Execution Services, VIRTU, G1X, UBS Securities LLC, and Two Sigma).

[8] "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, p. 4.

[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, accessed November 27, 2019.

[11] "Concept Release on Equity Market Structure," U.S. Securities and Exchange Commission, Release No. 34-61358, January 14, 2010, p. 63. 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.

[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]

29. 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.

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.

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

[13] "Providing Stock Quotations to Customers," FINRA Regulatory Notice 15-52, December 2015, p. 1, https://www.finra.org/sites/default/files/Regulatory-Notice-15-52.pdf, accessed November 15, 2019 ("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.

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

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

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

31. 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]

32. However, other market participants believe that proprietary data feeds are not necessary for their business models. Jeff Brown, Senior Vice President and Head of Schwab 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 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."[16]

33. NYSE's data confirms that not all market participants need all data. 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.[17] 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

[15] "Roundtable on Market Data Products, Market Access Services, and Their Associated Fees," U.S. Securities and Exchange Commission, October 25, 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." *See*,"Roundtable on Market Data Products, Market Access Services, and Their Associated Fees," U.S. Securities and Exchange Commission, October 25, 2018, pp. 65, 136.

[16] "Roundtable on Market Data Products, Market Access Services, and their Associated Fees," U.S. Securities and Exchange Commission, October 25, 2018, p. 170.

[17] Note that I 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.

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.[18]

34. 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 5.2).

TABLE 1
Data Purchases by Firms Trading 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%

Source: NYSE

Note: Proportion of firms who subscribed to each combination of data products is calculated as the number of firms that traded on NYSE/NYSE Arca and subscribed to that unique combination of data products for NYSE/NYSE Arca in December 2018 divided by the total number of firms that traded on NYSE/NYSE Arca in December 2018. 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/NYSE Arca in December 2018 divided by the total number of shares traded on NYSE/NYSE Arca in December 2018.

35. Firms obtain market data from NYSE by subscribing for a monthly fee.[19] 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

[18] 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, accessed November 15, 2019.

[19] Users pay an access fee as well as several use-related fees. Fee levels are publicly available. See, "Market Data Pricing," NYSE, January 1, 2018, https://www.nyse.com/publicdocs/nyse/data/NYSE_Market_Data_Pricing.pdf, accessed November 15, 2019.

bill was $5,580. There is considerable variation in the data fees paid, with the firm at the 95th percentile among those both trading on NYSE and purchasing NYSE data paying $81,350.

36. 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.[20] 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.[21] 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, the independent Yellow Pages publisher "Yellow Book" had a policy of offering advertising for free in the first year it entered a new city.[22] 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.

4.2. How market data affects order routing decisions

37. Before turning to platform issues, I provide some simple examples of 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. I provide three examples that highlight different ways in which market data can reduce uncertainty for traders. After going through these examples, I explain two additional ways in which access to market data reduces uncertainty and may thereby drive order flow to an exchange.

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[20] "Market Data Pricing," NYSE, January 1, 2018, p. 19, https://www.nyse.com/publicdocs/nyse/data/NYSE_Market_Data_Pricing.pdf, accessed November 15, 2019; "Price List – U.S. Equities," NasdaqTrader.com, https://www.nasdaqtrader.com/Trader.aspx?id=DPUSdata#tv, accessed November 15, 2019; "Cboe Data Services, Market Data Product Price List," Cboe, July 25, 2018, http://cdn.batstrading.com/resources/membership/US_Market_Data_Product_Price_List.pdf, accessed November 15, 2019.

[21] "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.

[22] Rysman, Marc. 2009. "The Economics of Two-Sided Markets." *Journal of Economic Perspectives* 23(3): 125–143, p. 131.

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

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

39. 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.

40. 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.

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

41. 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.

42. 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.

43. 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.

44. 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 favourable to the trader than what is available at the top of the book at other

exchanges.[23] 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 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.

45. 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 cancelled during the routing delay and lead the trader to miss out on the possibility of trading its second 100 shares at $20.02.

46. The prevalence of non-routable order types offered by exchanges confirms that some market participants are concerned about both reducing execution uncertainty and

[23] "Concept Release on Equity Market Structure," U.S. Securities and Exchange Commission, Release No. 34-61358, January 14, 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.").

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.[24] 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.[25]

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

47. 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.[26] 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.[27]

48. 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.

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[24] "NYSE Arca Pillar Order Types and Modifiers," NYSE, https://www.nyse.com/publicdocs/nyse/markets/nyse-arca/NYSE_Arca_Order_Suite.xlsx, accessed November 27, 2019. The term ISO limit order encompasses IOC ISO and Day ISO order types.

[25] "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, accessed November 25.

[26] "Concept Release on Equity Market Structure," U.S. Securities and Exchange Commission, Release No. 34-61358, January 14, 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, accessed November 27, 2019.

[27] "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, accessed November 25.

4.2.4. Uncertainty regarding the timeliness of market information

49. My examples so far assume that a trader can perfectly observe the state of the market at the top of the order book, and thus my 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 that unconsolidated data from a single exchange may reach subscribers more quickly. That is a primary reason why some traders subscribe to BBO feeds.[28]

4.2.5. Uncertainty regarding the likelihood of execution of non-marketable orders

50. 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.[29] 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.[30]

51. 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

[28] Jones, Charles M. 2018. "Understanding the Market for U.S. Equity Market Data." Working Paper, p. 46 ("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."); "A Financial System That Creates Economic Opportunities: Capital Markets," U.S. Department of the Treasury, 2017, p. 63 ("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.")

[29] 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, accessed November 15, 2019.

[30] Moallemi, Ciamac C. and Kai Yuan. 2017. "A Model for Queue Position Valuation in a Limit Order Book." Working Paper, Columbia Business School, p. 3 ("In practice, certain classes of market participants expend significant effort trying to take obtain better queue positions in the limit order book.").

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.

4.3. Linkages between access to market data and order routing decisions make stock exchanges platforms for data and trading

52. For the reasons outlined in Section 4.2, I expect that, on average, a trader with a data subscription from a particular exchange will be more likely to trade on that exchange. Having data from an exchange reduces uncertainty regarding orders sent to that exchange and, on average, should make trading on that exchange more profitable. Thus, I expect that traders that subscribe to data from a particular exchange trade more often on that exchange than they would if they did not subscribe to that exchange's data, both in the sense of allocating a higher share of their trades to the exchange and in the sense of being willing to trade more often overall.

53. Platform markets are characterized by *externalities* that run from one side of the platform to the other, and often in both directions (see Section 3). In the case of stock exchanges, externalities exist running from trading to data and vice-versa. In Section 4.3.1, I describe how trading activity and liquidity on a particular exchange affect the value of data from that exchange. In Section 4.3.2, I describe externalities running in the opposite direction, from data to trading. The first link in this chain are the direct effects of subscribing to data from an exchange on subscribers' trading activity on that exchange that I describe in detail in Section 4.2. This increase in trading activity makes trading on that exchange more attractive to traders that *do not* subscribe to its data.

4.3.1. Increased trading activity and liquidity on an exchange increase the value of data from that exchange

54. First, I discuss the effect of trading on the value of data. An exchange with a deep order book provides more data than one with little liquidity available on its order book. 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.[31]

55. In this sense, traders create value for data consumers, a form of externality that makes stock exchanges platforms between consumers of market data and consumers of trading services. Typically, economists define a firm as a platform if it mediates externalities in at least one direction, and in some cases, platform effects are very strong even with a single direction of externality.[32] However, it is still interesting to consider whether an externality running in the other direction exists, that is from data consumption to trading activity, in order to assess the strength of the platform features of this market.

4.3.2. Increased consumption of data from an exchange makes trading on that exchange more attractive

56. Data consumption can make trading more valuable. As a general rule, traders prefer exchanges with more liquidity and trading activity. Even under Regulation NMS's order protection rule, where trades are routed across exchanges to find the best available price, routing orders to an exchange with a deep order book and significant trading activity is more likely to yield execution at better prices for marketable orders and is more likely to lead to execution for non-marketable orders. Some reasons for this are:

a. Active exchanges are more likely to provide the best prices and thus minimize routing delay, which exposes traders to potential price changes (see Section 4.2.2).

b. Marketable orders are more likely to be executed at prices better than the best bids and offers reported by the SIP as a more active exchange is more likely to have resting odd lot orders or non-displayed orders that are not advertised on the SIP (see Section 4.2.3).

c. Conversely, non-marketable odd lot orders are observed only by traders that subscribe to proprietary data (and thus are not considered by exchanges when evaluating whether a trade price complies with Regulation

[31] Brief Amicus Curiae, By Consent, Of Better Markets, Inc. In Support of Respondent, *New York Stock Exchange LLC, et al. v. Securities and Exchange Commission*, October 11, 2019, p. 14 ("the value of that information depends on the number of orders that are routed to the exchange—the more orders routed to the exchange, the more valuable that exchange's information becomes.")

[32] For example, newspapers are a canonical example of a two-sided market, providing a platform for communication from advertisers to consumers. Advertising space is worth more to advertisers when more consumers read the newspaper. But consumers may be indifferent to advertiser participation on the platform (or even assign it a negative value). *See*, Rochet, Jean-Charles and Jean Tirole. 2003. "Platform Competition in Two-Sided Markets." *Journal of the European Economic Association* 1(4): 990-1029.

NMS's order protection rule), so exchanges with more data subscribers are more attractive to traders placing odd lot orders.

d. Non-displayed non-marketable orders, in which a trader instructs the exchange not to advertise its order and which are not reported to the SIPs or proprietary data,[33] are more likely to be executed on an active exchange where traders seeking immediate execution route marketable orders more frequently. In particular, I understand that non-displayed orders at the mid-point of the consolidated best bid and offer reported by the SIP are often used by institutional investors and their agents, who may not subscribe to proprietary market data products or may otherwise not use data-intensive trading strategies. According to the SEC's MIDAS tool, non-displayed limit orders, including mid-point orders, accounted for over 14% of trades and 15% of exchange trading volume in NMS stocks in Q3 2019.[34]

57. For the reasons outlined in Section 4.2 (and as is shown empirically in Section 5.2), sales of data subscriptions can lead data consumers to trade more often on an exchange, leading to increased liquidity on the exchange, which makes trading on that exchange more valuable even to traders that do not purchase data.

58. We could hypothesize reasons why this chain of causality would not hold. For instance, although more volume and liquidity is desirable by itself, traders without data subscriptions may perceive a disadvantage in trading with informed traders and prefer to go elsewhere. We cannot be sure which factors will be more important in practice. Because of this, it is important to check empirically whether we observe outcomes that support my hypothesis about the platform nature of data provision. I provide new empirical evidence of this relationship in Section 5. However, I first review existing empirical evidence regarding whether access to market data for a given exchange makes trading on that exchange more attractive.

[33] "Concept Release on Equity Market Structure," U.S. Securities and Exchange Commission, Release No. 34-61358, January 14, 2010, p. 23 ("[T]he Commission's rules do not require the display of a customer limit order if the customer does not wish the order to be displayed. Customers have the freedom to display or not display depending on their trading objectives.").

[34] "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, accessed November 25, 2019.

4.4. Existing research supports the view that access to market data increases trading activity

59. Existing research documents a relationship between market data and trading activity. The studies described below analyze discrete changes in access to market data and document the consequences of these changes on trading activity and other measures of market quality. In particular, they find evidence that increased availability of market data for a given exchange increases trading activity on that exchange.

60. A particularly clear empirical case study documenting the relationship between the availability of market data and trading activity is the Island ECN's decision in September 2002 to "go dark" by ceasing to display its limit order book for three exchange-traded funds ("ETFs").[35] That is, 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). According to Island, this would have prevented it from "maintain[ing] the system performance our subscribers expect."[36]

61. Hendershott and Jones (2005) document that trading volume on the Island ECN dropped following its "going dark," but that a considerable amount of trading activity continued to take place on Island. Specifically, Island's share of trading volume for the three affected ETFs dropped from 36%, 36%, and 21% to 16%, 22%, and 12%, respectively.[37] This shows that access to market data affects trading decisions; in this case, lack of access to order book data led traders to shift roughly half of the trading that had been taking place on Island to other exchanges. It also shows that some traders, at least, did not consider access to market data to be essential for trading as they continued to execute trades on Island after it went dark for these ETFs. Hendershott and Jones (2005) also find that effective spreads for these ETFs increased on Island and decreased on other exchanges after Island went dark.

62. Notably, Hendershott and Jones (2005) 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

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[35] This description is based on Hendershott, Terrence, and Charles M. Jones. 2005. "Island Goes Dark: Transparency, Fragmentation, and Regulation." *The Review of Financial Studies* 18(3): 743-793.

[36] Email from Island ECN to subscribers, September 19, 2002. Cited in Hendershott, Terrence, and Charles M. Jones. 2005. "Island Goes Dark: Transparency, Fragmentation, and Regulation." *The Review of Financial Studies* 18(3): 743-793, p. 751.

[37] Hendershott, Terrence, and Charles M. Jones. 2005. "Island Goes Dark: Transparency, Fragmentation, and Regulation." *The Review of Financial Studies* 18(3): 743-793, Table 1.

traders continued to trade on Island. This further strengthens the conclusion that different traders value access to market data differently, and adapt their trading behavior differently to changes in its availability.

63. The introduction of NYSE's OpenBook product in January 2002 is another helpful case study.[38] OpenBook allowed subscribers to see aggregate volume available at each level of NYSE's order book, for a fee. Boehmer et al. (2005) find that the introduction of OpenBook affected trading strategies. In particular, 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.[39] While the authors did not analyze the effect on trading volume on NYSE relative to other exchanges, this is consistent with the hypothesis 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. The introduction of OpenBook also affected traders' strategies: limit orders were placed and canceled more frequently, and were smaller on average, after OpenBook became available. Boehmer et al. (2005) also find that market quality improved: liquidity increased and the price impact of trades decreased.

[38] Boehmer, Ekkehart, Gideon Saar, and Lei Yu. 2005. "Lifting the Veil: An Analysis of Pre-Trade Transparency at the NYSE." *The Journal of Finance* 60(2): 783-815.

[39] Boehmer, Ekkehart, Gideon Saar, and Lei Yu. 2005. "Lifting the Veil: An Analysis of Pre-Trade Transparency at the NYSE." *The Journal of Finance* 60(2): 783-815, p. 796.

5. EMPIRICAL EVIDENCE THAT ACCESS TO MARKET DATA INCREASES TRADING ACTIVITY

64. I now turn to newly-developed empirical evidence about 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. As described in Section 4.1 above, NYSE IF offers an order-by-order view of the evolution of NYSE's order book. Users can thus 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.

65. 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. The resulting increase in trading volumes on NYSE, in turn, would have attracted additional volume from other market participants without access to NYSE IF. As I show below, there is robust evidence that this was indeed the case and that the magnitude of the effect was large.

66. The first firms to subscribe to NYSE IF started doing so in April 2015.[40] 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 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.

67. I understand from 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 at least 2013. The gradual uptake of NYSE IF was related in part to logistical issues related to setting up access.

68. A variety of firms subscribed to NYSE IF, including:

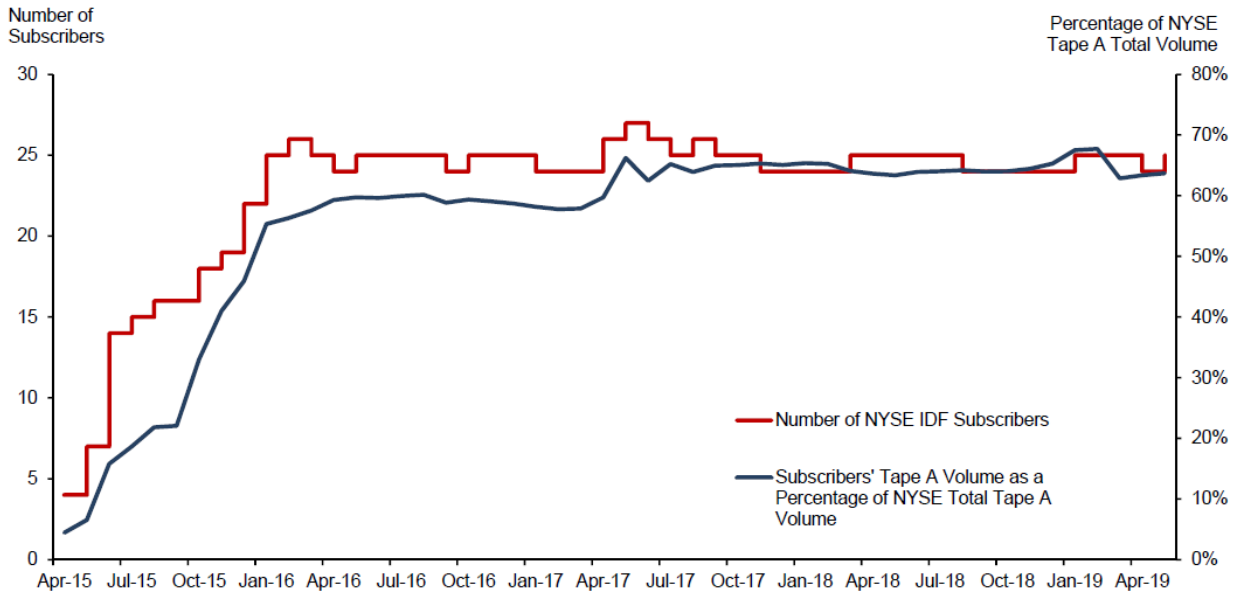
[40] I classify a firm as subscribing to NYSE IF in a given month if NYSE reports any fees relating to NYSE IF during the month in question. Reported fees may be $0 during trial periods – firms charged $0 fees for NYSE IF are also considered to be subscribed to NYSE IF.

a. Proprietary trading firms and market makers trading for their own account.

b. Brokers that act as agents, executing trades on behalf of their clients.

c. Multi-use firms acting as brokers for their clients, as proprietary traders managing the risk positions of their trading desks, and that also use market data to run dark pools or ATS. Investment banks are the most common examples of multi-use firms.

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



Source: NYSE

Note: The first firms to subscribe to NYSE IF and trade on NYSE started doing so in April 2015. Tape A refers to NYSE-listed stocks. Trading on NYSE was limited to Tape A stocks until April 2018. Subscribers' Tape A Volume as a Percentage of NYSE Total Tape A Volume is calculated as the total combined number of Tape A shares traded on NYSE by firms that subscribed to NYSE IF in a given month divided by the total number of Tape A shares traded on NYSE in that month.

69. Of the 31 firms that subscribed to NYSE IF at some point in time between its launch in April 2015 and May 2019 (when my data ends) and traded on NYSE, 11 were proprietary traders or market makers, 11 were multi-use firms, and 9 were a mix of other data use categories.[41]

[41] 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 the data.

70. 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 I have this information)[42] 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.

71. 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%.

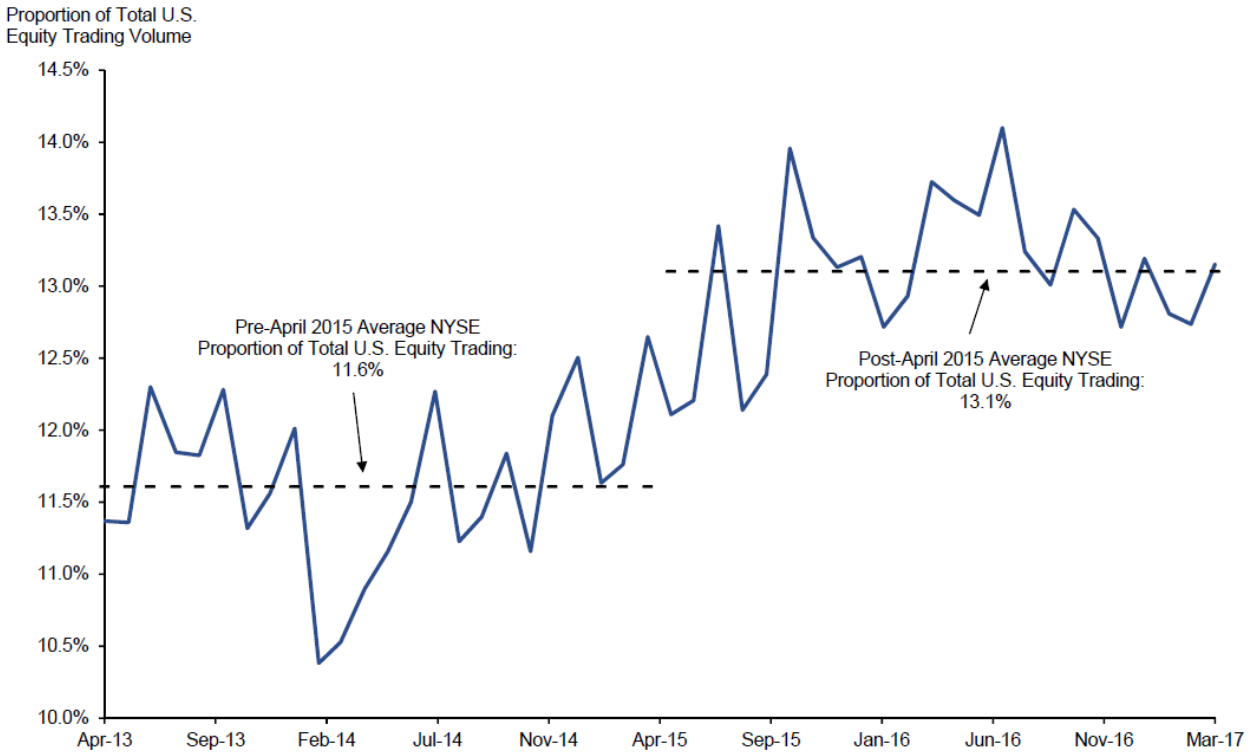
5.1. The introduction of NYSE IF increased the proportion of trading taking place on NYSE

72. 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.[43]

[42] The firm-level data available to me covers trading only on NYSE Group Exchanges (NYSE, NYSE Arca, NYSE National, and NYSE MKT/American). *See* Section 5.2.

[43] 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 2.

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



Source: NYSE

Note: The first firms to subscribe to NYSE IF and trade on NYSE started doing so in April 2015.

73. Regression analysis confirms that the introduction of NYSE IF led to an increase in the proportion of trades executed on NYSE. Table 2 presents results from four regression specifications. The coefficient of interest, 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).[44]

74. 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.

[44] This assessment of statistical significance relies on Newey-West standard errors, which allow for autocorrelation and heteroscedasticity, reported in Table 2. I also computed conventional and heteroscedasticity-robust (White) standard errors. My conclusions are the same under these alternatives.

75. Specifications 2–4 in Table 2 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. I 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.

76. Controlling for these factors reduces the estimated effect of introducing NYSE IF to 1.0 percentage point (specifications 2–4).[45]

77. 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.[46]

[45] 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 2.

[46] 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

TABLE 2
Regression Estimates of Impact of NYSE IF on Trading on NYSE

	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		0.000	0.000	0.000
		(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
R^2	0.600	0.650	0.667	0.645

Source: NYSE

Note: 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.

5.2. Evidence at the firm-level confirms that access to NYSE IF led to increased trading on NYSE

78. Data at the firm-level further confirm that access to NYSE IF made it more likely that firms would route orders to NYSE. The dataset contains monthly data on purchases of data

difference between actual trading volume in 2016 and my 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.

products and on trading on NYSE Group Exchanges (NYSE, NYSE Arca, NYSE National, and NYSE MKT/American[47]) from January 2013 to May 2019.[48] This information is provided for all 167 firms that traded on NYSE during this period.[49]

79. Because this firm-level dataset is limited to trading on NYSE Group Exchanges, I cannot study the shift of firms' overall (i.e., on all trading venues) trading toward NYSE that followed the introduction of NYSE IF as I do in the exchange-level analysis. Rather, I study the impact of the introduction of NYSE IF on two outcomes. First, I 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 – I hypothesize that gaining access to NYSE IF makes trading on NYSE more attractive relative to other NYSE Group Exchanges, such as NYSE Arca. Second, I look at firms' total trading volume on NYSE (measured by the number of shares traded).

80. 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.

81. 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

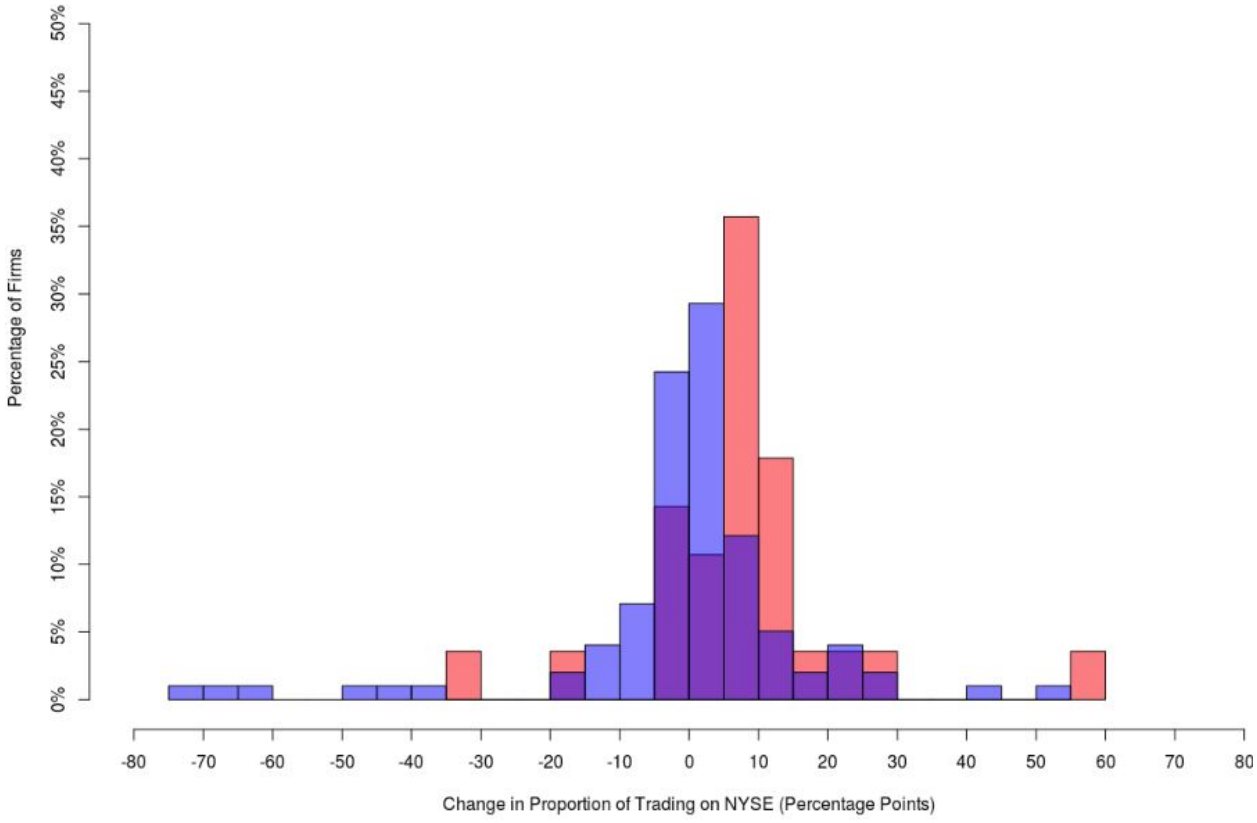
[47] NYSE MKT became NYSE American in July 2017.

[48] Separate datasets were provided by NYSE. I then merged the datasets to enable this analysis. Merging required grouping of firm names that, in some cases, were recorded differently in each dataset. I also grouped together accounts for subsidiaries of the same parent company. Both merging across datasets and grouping related subsidiaries required manual review of firm names.

[49] Note that data on trading identifies 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 4.1 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 to artificially low estimates of the effect of NYSE IF as some trading that I classify as unaffected by access to NYSE IF may have in fact been affected. This data issue is less likely to affect the regressions that are estimated on the subset of firms that traded directly on NYSE and subscribed to NYSE IF (see Tables 3 and 4).

5 and 20 percentage points.[50] 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.[51]

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



Source: NYSE

Note: Changes in the proportion of trading for firms that subscribed to NYSE IF at some point in time (adopting firms) 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.

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

[51] 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.

82. 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.

83. 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 (see Figure 4).[52] 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%.

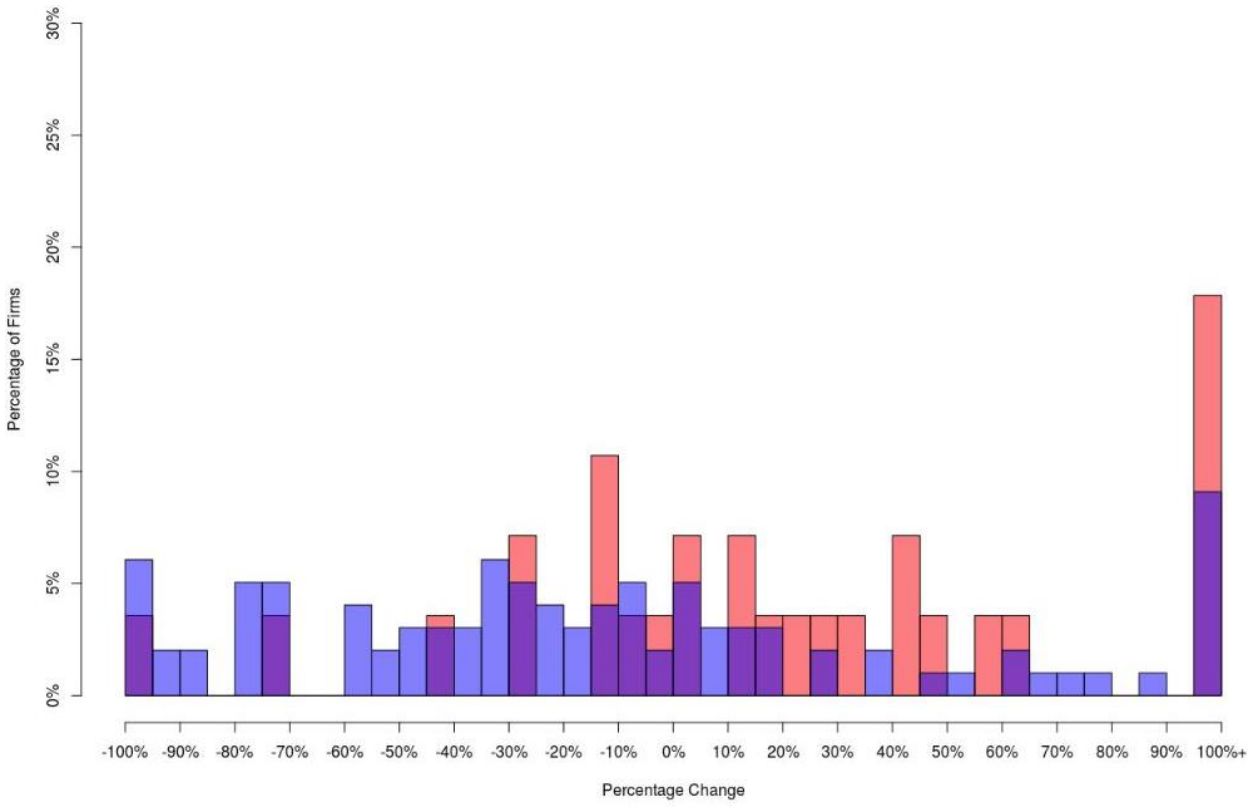
84. Regression results confirm that firms increased their trading on NYSE after gaining access to NYSE IF.[53] To make this determination, I estimate several "fixed effects" regression models. Fixed effects regression models account for the effect of all (observable and unobservable) time-invariant firm characteristics on the variable of interest (here, trading on NYSE) by including regressors or independent variables that mark observations related to each firm. Fixed effects estimators are sometimes referred to as "within" estimators because they reflect only variation within each firm's trading, not variation across firms. Due to their ability to account for unobservable firm characteristics that could otherwise contaminate regression estimates, fixed effects regressions are widely used to more reliably estimate causal relationships between variables of interest.[54]

[52] The large bars at 100% and over reflects the 5 NYSE IF adopters and the 9 firms that did not adopt NYSE IF whose trading volume on NYSE increased by 100% or more.

[53] While NYSE IF includes order imbalance information, its potential effects on continuous market trading are clearer than on auction volume. Estimating the regressions presented in Tables 3–5 while excluding auction volume from all measures of volume yields similar results.

[54] Wooldridge, Jeffrey M. 2010. *Econometric Analysis of Cross Section and Panel Data*. Cambridge: MIT Press, Section 10.5.

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



Source: NYSE

Note: 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.

85. I also control for firm-specific time trends in the outcome of interest: the proportion of trading (among NYSE Group Exchanges) on NYSE for the regressions in Table 3 or the total number of shares traded on NYSE for the regressions in Table 4. The use of firm-specific time trends avoids the potential for spurious results driven by differences in pre-existing trends rather than by the adoption of NYSE IF. For example, if firms whose trading on NYSE was increasing prior to the launch of NYSE IF were more likely to subscribe to NYSE IF, an estimate of the impact that failed to account for these pre-existing trends could overestimate the effect of NYSE IF.

86. The regressions in Table 3 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, indicating that subscribing to NYSE IF increases the proportion of firms' trading on NYSE. Five of the six reported coefficients of interest are statistically significant at the 95% confidence level, as indicated by two or three asterisks.[55]

87. The regressions in Table 3, Panel A 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", on a dataset containing all firms that traded on NYSE and covering January 2013 to May 2019 (the period for which I have data).[56] These regressions use trading activity by firms not subscribing to NYSE IF to control for market-wide shifts in activity on NYSE in each month while using changes in firms' status as NYSE IF subscribers to identify the effect of subscribing to NYSE IF relative to these market-wide shifts. As such, these regressions exploit variation between adopters and non-adopters as well as in the timing of adopters' subscriptions to NYSE IF. Specification 1 controls only for firm characteristics and firm-specific time trends and estimates that subscribing to NYSE IF increases a firm's proportion of trading on NYSE by 7.2 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 does not change the estimated effect of subscribing to NYSE IF.

88. Specification 3 controls for factors that vary across time (but not across firms) in a flexible and robust way by adding "Month-Year Fixed Effects". These additional fixed effects account for the influence of any factors (observed or unobserved) that may affect the proportion of trading on NYSE but do not vary across firms. An example could be volatility in the prices of shares for companies listed on NYSE relative to those listed at other exchanges. "Month-Year Fixed Effects" also capture the effect of changes in market structure such as the entry and exit of competing exchanges, so that controls for these events need not be included.[57] This specification estimates that subscribing to NYSE IF increases a firm's proportion of trading on NYSE by 4.4 percentage points. The large number of regressors that

[55] Statistical significance is assessed using standard errors clustered 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, Alberto, Susan Athey, Guido W. Imbens, and Jeffrey Wooldridge. 2017. "When Should You Adjust Standard Errors for Clustering?" National Bureau of Economic Research Working Paper 24003. For this reason, I also make a note of the statistical significance of some estimates when using conventional standard errors.

[56] "Subscribed to NYSE IF" is equal to one if the firm subscribed to NYSE IF during the month in question and equal to zero otherwise. I 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.

[57] Indeed, such controls cannot be included in this regression specification as they would be redundant or "collinear" with the "Month-Year Fixed Effects". Coefficients cannot be estimated for perfectly collinear variables within a single regression as such variables reflect the same variation in the data. *See*, Wooldridge, Jeffery. M. 2010. *Introductory Econometrics: A Modern Approach*. Fourth Edition. Mason, OH: South-Western Cengage Learning, p. 85.

are required to estimate this model limits its statistical power, and the estimated effect of subscribing to NYSE IF is not statistically significant at conventional levels.[58]

TABLE 3
Regression Estimates of Impact of NYSE IF Subscription on the Proportion of Firms' Trading on NYSE

	Panel A: All Firms			Panel B: NYSE IF Adopters		
Independent Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Subscribed to NYSE IF	0.072***	0.072***	0.044	0.072**	0.075***	0.063**
	(0.027)	(0.027)	(0.029)	(0.027)	(0.027)	(0.030)
NSX/National Active		-0.002			-0.016*	
		(0.006)			(0.008)	
IEX Active		0.030***			0.033**	
		(0.009)			(0.013)	
CBOE Active		-0.002			-0.028	
		(0.014)			(0.021)	
Firm Fixed Effects	Y	Y	Y	Y	Y	Y
Firm-Specific Time Trends	Y	Y	Y	Y	Y	Y
Month-Year Fixed Effects	N	N	Y	N	N	Y
Observations	9,670	9,670	9,670	2,202	2,202	2,202
Number of Firms	167	167	167	31	31	31
R^2	0.482	0.485	0.501	0.454	0.472	0.508

Source: NYSE

Note: 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.

89. Table 3, Panel B presents results for the same regressions in Panel A, but estimated on a dataset consisting only of firms that subscribed to NYSE IF at some point in time. Thus, these estimates make use of variation in the timing of adopters' subscriptions to NYSE IF but does not leverage comparisons between firms that subscribed to NYSE IF and those that did not. As such, the analysis in Panel B confirms that the results in Panel A are not driven by unaccounted for differences between firms that subscribed to NYSE IF and those that did not. The specifications in Panel B estimate that subscribing to NYSE IF increases a firm's proportion of trading on NYSE by between 6.3 and 7.5 percentage points. The coefficients of interest are statistically significant at the 95% confidence level in all three specifications.

[58] The estimated effect is, however, statistically significant when using conventional standard errors rather than standard errors that are clustered by firm.

90. The regressions in Table 4 estimate the relationship between the number of shares each firm traded on NYSE and various regressors, including "Subscribed to NYSE IF". I 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 I used the level of those variables. The specifications mirror those in Table 3. In addition to the regressors used in Table 3, specifications 2–3 and 5–6 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. As in Table 3, Panel A presents results for models estimated with data for all firms that traded on NYSE while Panel B presents results for models estimated using data only for firms that subscribed to NYSE IF at some point in time. All six estimates of the effect of subscribing to NYSE IF on firms' volume of trading on NYSE are positive, with estimates ranging from 17.7% (specification 3) to 40.4% (specification 5).[59] 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 one of the six coefficients (specification 5) is statistically significant at the 95% confidence level while three others are statistically significant at the 90% confidence level (specifications 1, 2, and 4).[60]

[59] Per specification 3, a change from zero to one in "Subscribed to NYSE IF" will lead to a change in $100 \times (e^{0.163} - 1)\% = 17.7\%$. For specification 5, the estimated impact is $100 \times (e^{0.339} - 1)\% = 40.4\%$.

[60] It is worth noting, however, that all six coefficients are statistically significant at the 95% confidence level when using conventional standard errors rather than standard errors clustered by firm.

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

	Panel A: All Firms			Panel B: NYSE IF Adopters		
Independent Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Subscribed to NYSE IF	0.294*	0.287*	0.163	0.294*	0.339**	0.240
	(0.159)	(0.156)	(0.160)	(0.161)	(0.154)	(0.164)
NSX/National Active		0.058**			-0.021	
		(0.029)			(0.062)	
IEX Active		0.044			-0.057	
		(0.062)			(0.084)	
CBOE Active		-0.169***			-0.127	
		(0.064)			(0.096)	
Volume on Other NYSE Exchanges (log)		0.105***	0.101***		0.501***	0.472**
		(0.028)	(0.030)		(0.164)	(0.191)
Firm Fixed Effects	Y	Y	Y	Y	Y	Y
Firm-Specific Time Trends	Y	Y	Y	Y	Y	Y
Month-Year Fixed Effects	N	N	Y	N	N	Y
Observations	9,129	8,251	8,251	2,067	2,067	2,067
Number of Firms	167	165	165	31	31	31
R^2	0.372	0.420	0.446	0.382	0.453	0.477

Source: NYSE

Note: 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.

91. As mentioned above, a key characteristic of platform markets is that increased participation on one side (market data) generates benefits for the other side (trading). In particular, we would expect access to NYSE IF to lead to more trading on NYSE *by firms that did not subscribe to NYSE IF*. To test this hypothesis, I 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. The regressor of interest in these regressions is 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 2). Because this regressor coincides with a specific time period (i.e., it does not vary across firms), I cannot use "Month-Year Fixed Effects" as I did in specifications 3 and 6 of Tables 3 and 4. Instead, I control for potential time trends and changes in market structure. I also do not use firm-specific time trends in these specifications because identification does not come from comparisons between firms

that subscribe to NYSE IF at a point in time and those that do not – none of the firms in this analysis subscribed to NYSE IF.

92. 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 2 in Table 5 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. Specification 4 indicates that the launch of NYSE IF led firms to increase their total trading volume on NYSE by 13.2% though, as in Table 4, the coefficient is imprecisely estimated and is not statistically significant at conventional levels.[61] The magnitudes of these increases are not directly comparable to those in Tables 3 and 4: the estimates in Tables 3 and 4 measure increases in trading on NYSE by firms adopting NYSE IF above and beyond any overall increase in trading on NYSE. The results in Table 5 show that there was an increase in trading on NYSE following the launch of NYSE IF among firms that did not subscribe to NYSE IF.

[61] 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. The coefficient is statistically significant at the 95% confidence level when using conventional standard errors.

TABLE 5
Regression Estimates of Impact of Launch of NYSE IF on Firms' Trading on NYSE and not Subscribing to NYSE IF

	Dependent Variable			
	Panel A: Proportion of NYSE Trading Volume		Panel B: NYSE Trading Volume (log)	
Independent Variable	(1)	(2)	(3)	(4)
Introduction of NYSE Integrated Feed (April 2015)	0.045**	0.027**	-0.302***	0.124
	(0.020)	(0.013)	(0.089)	(0.081)
Time Trend		0.001		-0.017**
		(0.001)		(0.007)
Time Trend Squared		-0.00001		0.0001
		(0.00001)		(0.0001)
NSX/National Active		0.003		0.042
		(0.008)		(0.036)
IEX Active		0.037***		0.217***
		(0.012)		(0.082)
CBOE Active		0.032**		-0.079
		(0.013)		(0.064)
Volume on Other NYSE Exchanges (log)				0.143***
				(0.032)
Firm Fixed Effects	Y	Y	Y	Y
Firm-Specific Time Trends	N	N	N	N
Month-Year Fixed Effects	N	N	N	N
Observations	7,468	7,468	7,062	6,184
Number of Firms	136	136	136	134
R^2	0.020	0.030	0.022	0.080

Source: NYSE

Note: 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.

93. Overall, the empirical evidence I have described paints a remarkably consistent story that confirms 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 3 and 4). As is expected in a platform market, this also attracted additional trading by firms that did not subscribe to NYSE IF (Table 5). These firm-level results are mirrored in my 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 2).

6. IMPLICATIONS OF PLATFORM THEORY FOR THE ANALYSIS OF MARKET DATA FEES

94. I have presented both qualitative and empirical evidence that leads me to conclude that stock exchanges are platforms for trading and data. My new empirical results focus on the introduction of a particular data product. In combination with the basic mechanisms that I understand to be at work and the existing related literature, my conclusion is not specific to a particular exchange or a particular data product. Rather, it is broadly applicable to any exchange that offers both trading services and market data.

95. As I explain in Section 4.3.1, data is more valuable when it reflects more trading activity and more liquidity-providing orders. These linkages alone are enough to make platform economics necessary for understanding the pricing of market data.

96. As I explain in Section 4.3.2, linkages running in the opposite direction, from data to trading, are also very likely to exist. This is because market data from an exchange reduces uncertainty about the likelihood, price, or timing of execution for an order on that exchange. This reduction in uncertainty makes trading on that exchange more attractive for traders that subscribe to that exchange's market data. Increased trading by data subscribers, in turn, makes trading on the exchange in question more attractive for traders that do not subscribe to the exchange's market data. I explain some of the specific mechanisms by which market data makes trading on an exchange more attractive for subscribers to market data in Sections 4.2.1–4.2.5. These mechanisms apply to a wide assortment of market data products, including BBO, order book, and full order-by-order depth of book data products at all exchanges.

97. I also present empirical evidence that linkages running from data to trading exist and are economically meaningful. In Section 4.4, I survey existing academic research that relates to this question. In Section 5, I develop new empirical evidence that confirms the existence and importance of these linkages. In particular, I analyze the impacts of the introduction of a new data product: NYSE IF. I selected this test case not because I anticipated that this particular data product would generate particularly strong effects on trading, but because (a) the introduction of NYSE IF generated a clear change in the data available to traders whose effects can be measured empirically and (b) because I had the data required to do the analysis. I find that the introduction of NYSE IF attracted more trading to NYSE by both subscribers and non-subscribers to NYSE IF. That is, the empirical evidence confirms that stock exchanges are platforms for data and trading.

98. The platform nature of stock exchanges means that data fees cannot be analyzed in isolation, without accounting for the competitive dynamics in trading services. Competition

is properly understood as being between platforms (i.e., stock exchanges) that balance the needs of consumers of data and traders. Data fees, data use, trading fees, and order flow are all interrelated. Competition for order flow can discipline the pricing of market data, and vice-versa. Regulating the level of market data fees could have consequences for pricing and activity on the trading side of the market, and vice-versa.

99. While an assessment of the degree of competition between U.S. stock exchanges (and other trading venues for U.S. equities) is beyond the scope of this paper, it is worth noting that academics, the SEC, and the courts seem to agree that competition for order flow is "fierce."[62] For example, a recent academic article refers to trading fees as "perfectly competitive."[63] Regulators have also noted competition in the provision of data. In 2011, the DOJ stated that exchanges "compete head to head to offer real-time equity data products. These data products include the best bid and offer of every exchange and information on each equity trade, including the last sale."[64]

100. Intense competition among stock exchanges would lower the overall level of prices for data and trading, but its effect on a particular side of the market will balance the demands of data users and traders.[65] In particular, a high price-cost margin on one side of the market (for example, market data) does not imply that an exchange has market power.[66] Just as competition between credit card issuers may result in high merchant fees and high cardholder rewards, it is possible that increased competition between stock exchanges could lead to higher (or lower) data fees and lower (or higher) trading fees. As with platforms generally, overall competition between exchanges will limit their overall profitability, not margins on any particular side of the platform.[67]

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[62] *NetCoalition I*, 615 F.3d at 539 (quoting 2008 ArcaBook Approval Order, 73 Fed. Reg. at 74,782).

[63] Budish, Eric, Robin S. Lee, and John J. Shim. 2019. "Will the Market Fix the Market? A Theory of Stock Exchange Competition and Innovation." National Bureau of Economic Research Working Paper 25855. *See also*, Colliard, Jean-Edouard, and Thierry Foucault. 2012. "Trading Fees and Efficiency in Limit Order Markets." *The Review of Financial Studies* 25(11): 3389-3421, p. 3390 ("competition among markets has triggered a sharp decline in trading fees.").

[64] U.S. Department of Justice Press Release, "Assistant Attorney General Christine Varney Holds Conference Call Regarding NASDAQ OMX Group Inc. and Intercontinental Exchange Inc. Abandoning Their Bid for NYSE Euronext," May 16, 2011.

[65] Wright, Julian. 2004. "One-Sided Logic in Two-Sided Markets." *Review of Network Economics*, 3(1): 44-64, p. 49 ("competition will generally lower the total (or average) level of prices charged").

[66] Wright, Julian. 2004. "One-Sided Logic in Two-Sided Markets." *Review of Network Economics*, 3(1): 44-64, p. 47 ("A related fallacy arises from another basic principle of economics that can be misapplied to two-sided markets – the idea that competition should reduce prices to cost. Clearly, it is not true that competition, even perfect competition, will necessarily drive the price charged to each type of user to cost. As noted above, competition between nightclubs may result in men being charged above cost and women below cost. The observation that men are charged above cost does not, therefore, imply anything about the market power of the nightclub.").

[67] Wright, Julian. 2004. "One-Sided Logic in Two-Sided Markets." *Review of Network Economics*, 3(1): 44-64, p. 49 ("competition will generally lower the total (or average) level of prices charged").

101. While the effects of competition on prices on any particular side of the market are ambiguous in general, some theoretical models of platform competition suggest that competition between exchanges should keep data fees "low." One classic model of two-sided markets finds that increased competition between platforms can lead to lower prices on one side of the market (such as trading) but not affect prices on the other side (such as data).[68] However, follow-on research shows that increased competition on one side of the market will lead to lower prices on the other side of the market if prices are constrained on the side where competition intensified.[69] That is because when price on the side where competition intensified is constrained, attracting agents on the other side becomes the most effective way to compete. Constrained prices on the trading side might be a realistic description of exchanges, as setting trading fees that reward traders on net (e.g., with aggregate maker rebates that are larger than aggregate taker fees) could lead to a so-called money pump, where traders extract unlimited amounts of trading rebates from exchanges. Recent research argues that the money-pump constraint is binding for exchanges.[70]

102. Finally, evaluating stock exchanges' overall profitability using accounting measures, as some have suggested,[71] may not yield reliable assessments of competitive constraints. Accounting measures are known to be poor reflections of economic concepts such as marginal cost and, therefore, can generate misleading diagnoses of competitive conditions.[72]

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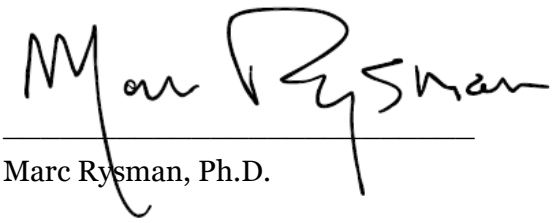

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[68] Armstrong, Mark. 2006. "Competition in two-sided markets." *The RAND Journal of Economics*, *37*(3): 668-691.

[69] Armstrong, Mark and Julian Wright. 2007. "Two-Sided Markets, Competitive Bottlenecks and Exclusive Contracts." *Economic Theory*, *32*(2): 353-380; Gomes, Renato. 2014. "Optimal Auction Design in Two-Sided Markets." *The RAND Journal of Economics*, *45*(2): 248-272; Jin, Ginger Zhe, and Marc Rysman. 2015. "Platform Pricing at Sports Card Conventions." *The Journal of Industrial Economics* 63(4): 704-735.

[70] Budish, Eric, Robin S. Lee, and John J. Shim. 2019. "Will the Market Fix the Market? A Theory of Stock Exchange Competition and Innovation." National Bureau of Economic Research Working Paper 25855, p. 26.

[71] "Guidance on SRO Filings Relating to Fees," Securities and Exchange Commission, May 21, 2019, p. 6.

[72] Fisher, Franklin and John McGowan. 1983. "On the Misuse of Accounting Rates of Return to Infer Monopoly Profits." *American Economic Review*, 73(1): 82-97; Baker, Jonathan B. and Timothy F. Bresnahan. 2008. "Economic Evidence in Antitrust: Defining Markets and Measuring Market Power." In *Handbook of Antitrust Economics*, edited by Paolo Buccirossi, Cambridge, MA: The MIT Press, 1–42, p. 19 ("The Lerner Index can be difficult to measure because of well-known problems in the measurement of marginal cost. These include conceptual difficulties in relating accounting measures to economic concepts. For example, accountants define cost categories for audit purposes that do not necessarily track economist's concepts; that present difficulties in the accounting treatment of depreciation, that may not capture opportunity costs in accounting data, and that show average variable costs not equal to marginal cost where the marginal cost curve is not horizontal. Indeed the academic literature in empirical industrial organization economics commonly treats the level of marginal cost as unobservable even when some of its determinants, like input prices and scale, can be observed.").