When A Market Is Not Legally Defined As A Market: Evidence From Two Types of Dark Trading

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Abstract

Trading on off-exchange platforms as a whole is commonly referred to as dark trading. However, it encompasses ATSs (alternative trading systems) and Non-ATSs, each of which is subject to different regulations. Unlike Non-ATSs, ATSs are legally defined as market places and therefore must use non-discretionary methods to execute orders. In this study, we examine two exogenous transparency shocks and show that legal distinctions between ATSs and Non-ATSs can result in significant economic differences in their market quality. Specifically, we find that ATSs typically have lower market quality than Non-ATSs. Furthermore, transparency exacerbates these quality gaps, except for execution speeds. Transparency on ATSs dramatically increases price impacts and effective spreads and reduces price improvements on ATSs, while transparency on Non-ATSs significantly reduces price impacts and effective spreads and increases price improvements on Non-ATSs. Both ATS and Non-ATS Transparency enhance execution speeds on their respective platforms. This paper highlights the challenges in studying dark trading platforms as a unified entity and regulating them as a whole, as the same policy initiative can have opposing outcomes for the two types of dark trading.

Keywords: Dark Trading, ATS (Alternative Trading Systems), Non-ATS, Market Quality, Retail Trading, Transparency

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1 Introduction

The U.S. equities market is highly fragmented, consisting of 16 exchanges and 228 off-exchange trading platforms as of December 2022.[1] The trading on off-exchange platforms as a whole is generally referred to as *dark trading*.[2] However, the term *dark trading* is not legally homogeneous. From a regulatory perspective, there are two types of off-exchange trading platforms: alternative trading systems (**ATSs**) and non-alternative trading systems (**Non-ATSs**). ATSs are legally defined as market places, like exchanges, and therefore must use established "non-discretionary" methods to execute orders (Section III, 63 FR 70844). In contrast, Non-ATSs are not legally recognized as market places. A trading system that violates the "non-discretionary" condition of being a market place is considered a Non-ATS. For instance, internal broker-dealer systems, such as Citadel Securities LLC and Virtu Americas LLC, are Non-ATSs because they can have discretion over executing orders as principals or agents, as well as over order splitting and routing decisions.
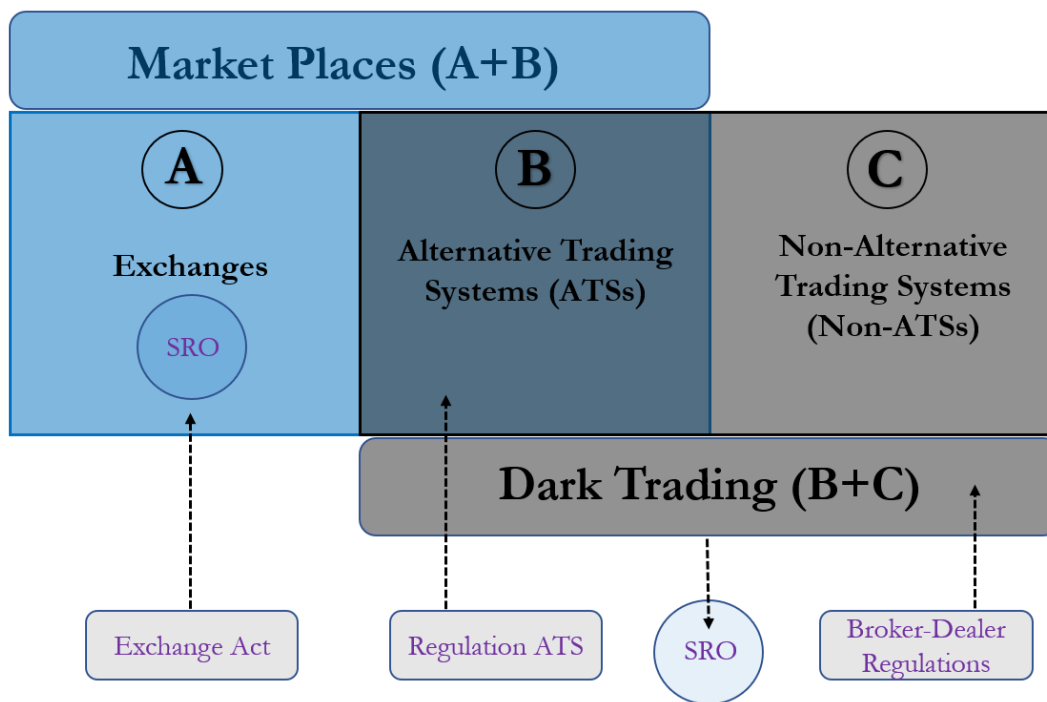

Figure 1: Breakdown of Trading Platforms and Their Regulatory Framework

Note: The diagram shows different types of trading platforms in the U.S. equities market and their regulatory framework. The regulatory framework will be discussed in detail in Section 2. Dark trading refers to trades executed outside stock exchanges. SRO denotes self-regulatory organizations.

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[1]Source: CBOE U.S. Equities Market Volume Summary and FINRA OTC Transparency Data.
[2]See (Comerton-Forde & Putniņš, 2015), (Foley & Putniņš, 2016), (Menkveld, Yueshen, & Zhu, 2017) for instance.

Despite these sharp differences in their regulatory environments, no study examines how these different regulatory treatments affect off-exchange trading platforms' market quality. Our paper fills this gap in the literature. We examine two exogenous transparency shocks and show that legal distinctions between ATSs and Non-ATSs can result in significant economic differences in their market quality (speed of executions, effective spread, price impact, and price improvements). Specifically, we find that ATSs typically have lower market quality than Non-ATSs. Furthermore, transparency exacerbates these quality gaps, except for execution speeds. Both transparency on ATSs and Non-ATSs enhance execution speeds on their respective platforms. Otherwise, transparency on ATSs dramatically reduces market quality on ATSs, whereas transparency on Non-ATSs significantly improves market quality on Non-ATSs.

Transparency on ATSs and Non-ATSs refers to two crucial policy changes in dark trading regulations implemented in 2014 and 2016. Starting from May 2014, ATSs are required to report their volume and trade information to the Financial Industry Regulatory Authority (FINRA) on a weekly and stock-by-stock basis. FINRA makes this data publicly available on its website. FINRA made a similar regulation change for Non-ATSs in April 2016. We will call the first change "ATS Trade Transparency" and the second change "Non-ATS Trade Transparency".

Prior to the implementation of ATS Trade Transparency, execution speeds were lower on ATSs than on Non-ATSs. Transparency improved the speed of executions on ATSs compared to Non-ATSs because it made it easier for investors to find and congregate in more liquid ATSs. Similarly, Non-ATS Trade Transparency had a comparable effect. Before the policy change, execution speeds were already higher on Non-ATSs. Non-ATS Trade Transparency widened these gaps by further increasing execution speeds on Non-ATSs compared to ATSs. We found similar results when comparing with exchanges: ATS (Non-ATS) Trade Transparency improved the speed of executions on ATSs (Non-ATSs) compared to exchanges.

Apart from execution speeds, ATS Trade Transparency significantly deteriorated other market quality metrics in ATSs compared to Non-ATSs. Prior to the implementation of ATS Trade Transparency, market quality was worse on ATSs regarding price impacts and price improvements, as they had higher price impacts and lower price improvements. Transparency dramatically widened these gaps in market quality, increasing price impacts by 15.4% and decreasing price improvements by 36.6% to 45.4% on ATSs compared to Non-ATSs. Transparency also adversely affected effective spreads on ATSs. Although effective spreads were

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lower on ATSs before ATS Trade Transparency, transparency increased effective spreads on ATSs by 20.3% compared to Non-ATSs. We found similar results when comparing ATSs with exchanges. Transparency increased price impacts and effective spreads by 25.8% and 9.2%, respectively, and decreased price improvements by 15.3% to 20.7% on ATSs compared to exchanges.

In contrast, Non-ATS Trade Transparency improved other market quality metrics in Non-ATSs compared to ATSs. Before Non-ATS Trade Transparency, market quality was already better in Non-ATSs in all dimensions, with lower price impacts, effective spreads, and higher price improvements. Transparency significantly widened these gaps in market quality. It decreased price impacts and effective spreads by 5.0% and 3.1%, respectively, and increased price improvements by 15.2% to 25.3% on Non-ATSs compared to ATSs. We found even stronger effects when comparing Non-ATSs with exchanges. It decreased price impacts and effective spreads by 21.0% and 19.0%, respectively, and increased price improvements by 17.5% to 46.1% on Non-ATSs compared to exchanges.

Transparency affects the market quality of ATSs and Non-ATSs in opposite ways due to their different legal treatments. Although both ATS and Non-ATS Trade Transparency allow traders to better locate and trade on more liquid venues across fragmented off-exchange trading platforms, they differently affect the incentives of informed and uninformed investors to use ATSs and Non-ATSs, which alters the ratio of informed and uninformed investors on these platforms. ATS Trade Transparency provides flexibility to informed investors, whereas Non-ATS Trade Transparency provides flexibility to uninformed investors.

In the case of ATS Trade Transparency, informed investors can freely move to more liquid ATSs. However, the movements of uninformed investors to ATSs are more limited than those of informed investors. Some uninformed investors are trapped on Non-ATSs through various practices such as preferencing and payment for order flow (PFOF).[3] Although ATSs are not legally prevented from engaging in such practices, it is more difficult for them to do so. ATSs are market places and thus must adhere to predetermined non-discretionary trading rules and procedures, even when executing orders through such practices. As a result, ATS Trade Transparency increases the incentives of informed investors to use ATSs but has a limited impact on uninformed investors' venue choices. Overall, more informed trading oc-

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[3]Preferencing refers to routing an order to a market maker who does not have the best quoted price but has agreed in advance to execute the order at the best quoted price. PFOF is the act of paying brokers to purchase their customers' orders.

curs on ATSs, which deteriorates their market quality compared to Non-ATSs and exchanges.

In the case of Non-ATS Trade Transparency, informed traders cannot move freely to Non-ATSs because Non-ATSs' trading rules and procedures are discretionary. Non-ATSs can route their customers' orders to other venues or exercise other forms of discretion when they suspect informed trading. This discretion helps them to protect themselves against informed trading and limits the movements of informed investors to Non-ATSs after transparency. On the contrary, Non-ATS Trade Transparency makes the movements of uninformed order flow to Non-ATSs through preferencing and PFOF more effective because it allows brokers to locate more liquid Non-ATSs and make better routing decisions.[4] As a result, Non-ATS Trade Transparency increases the incentives of uninformed investors to use Non-ATSs (via their brokers) but has a limited impact on informed investors' venue decisions. Overall, more uninformed trading occurs on Non-ATSs, which improves their market quality compared to ATSs and exchanges.

This paper's results can shed light on a recent debate regarding the accuracy of (Boehmer, Jones, Zhang, & Zhang, 2021)'s (hereafter BJZZ) method to identify retail trades in NYSE Trade and Quote (TAQ) data. BJZZ's method relies on a key assumption: retail orders executed on Non-ATSs generally receive small sub-penny price improvements. However, (R. Battalio, Jennings, Saglam, & Wu, 2022) and (Barber, Huang, Jorion, Odean, & Schwarz, 2022) document that BJZZ's method can fail to identify the majority of retail trades, correctly identifying only 30% to 35% of retail trades in their samples.

Our results can partially explain the disparities between BJZZ's results and their critiques. Non-ATSs might be offering minimum price improvements before Non-ATS Trade Transparency. BJZZ's sample spans from January 2010 to December 2015, which falls into the non-transparent era. Their key assumption might hold during their sampling period. However, Non-ATS Trade Transparency substantially increased price improvements on Non-ATSs. Therefore, BJZZ's key assumption is very likely to be violated during the transparent era. Both (R. Battalio et al., 2022) and (Barber et al., 2022) are using more recent data: December 2021 and December 2021 to June 2022, respectively. During these periods, price improvements are not necessarily small for retail trades. In fact, both papers report that around 40% of retail trades analyzed in their studies received non-sub-penny price improve-

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[4]Orders routed to Non-ATSs through such practices are generally uninformed because Non-ATSs generally purchase uninformed order flows ((Chordia & Subrahmanyam, 1995), (Easley, Kiefer, & O'Hara, 1996), (Weaver, 2011)), (Hu & Murphy, 2022).

ments. Our results suggest that this dynamic might be a more recent phenomenon, and therefore both BJZZ and their critiques ((R. Battalio et al., 2022) and (Barber et al., 2022)) may simultaneously be correct.

Our paper also has important policy implications. Any trade executed on an off-exchange platform is almost immediately disseminated through the consolidated tape. However, trades executed over ATSs and Non-ATSs are being published in TAQ data with the same code "D". Our paper highlights the difficulty of studying dark trading platforms as a unified entity as well as the difficulty of regulating them as a whole because the same policy initiative may lead to opposite consequences to two types of dark trading. In this context, there is still room for improvement in venue-based post-trade transparency in the U.S. equities market. We propose that trades executed on ATSs and Non-ATSs should be published under different codes instead of combining them under the same code "D". It can allow investors to extract better information from dark trading, make more informed venue choices, and accordingly accelerate price discovery processes.

Related Literature. Our paper is related to three strands of literature: dark trading, execution quality, and post-trade transparency. In the literature that examines dark trading, some papers focus on the combined effects of dark trading (B+C in Figure 1) and treat ATSs and Non-ATSs as equal: among others, (Degryse, De Jong, & Kervel, 2015), (Comerton-Forde & Putniņš, 2015), (Hatheway, Kwan, & Zheng, 2017) and (Thomas, Zhang, & Zhu, 2021). Some other papers study only ATSs (B in Figure 1) by focusing on either dark pools or electronic communication networks: (Hendershott & Jones, 2005), (Fink, Fink, & Weston, 2006), (Foley & Putniņš, 2016), (Menkveld et al., 2017), (Comerton-Forde, Malinova, & Park, 2018), (Brogaard & Pan, 2022), (Buti, Rindi, & Werner, 2022).[5] There are also papers studying only Non-ATSs without explicitly mentioning it (C in Figure 1). Many of these papers call Non-ATSs wholesalers. Among others, (Kelley & Tetlock, 2013), (Boehmer et al., 2021), (Barber et al., 2022), (R. Battalio et al., 2022), (R. Battalio & Jennings, 2022), (Ernst & Spatt, 2022). Non-ATSs have some other names in other papers. For instance, (Anand, Samadi, Sokobin, & Venkataraman, 2021) use firms; (R. H. Battalio, 1997) and (O'Hara, 2015) use broker-dealers; (Hu & Murphy, 2022) use internalizers.

We make three contributions to this literature. First, our paper is the first to compare ATSs with Non-ATSs, demonstrating that dark trading is not harmonious either legally or

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[5]In the U.S., ATSs used to consist of dark pools and electronic communication networks (ECNs) until 2015. Since then ECNs either got closed or have become exchanges. See Craig Viani's article in TabbFroum for more details about how dark pools and ECNs evolved over time.

economically.[6] Second, we show that whether opaqueness is a desirable property of dark trading depends on the legal characteristics of the venue where dark trading occurs. Finally, we contribute to a recent debate regarding the accuracy of (Boehmer et al., 2021)'s method to identify retail trades in TAQ data. Our results suggest that improved transparency on Non-ATSs may reconcile (Boehmer et al., 2021)'s paper with the findings of their two critiques ((R. Battalio et al., 2022) and (Barber et al., 2022)).

We also contribute to the literature that studies execution quality in the U.S. equities market. (Huang & Stoll, 1996) and (R. Battalio, Corwin, & Jennings, 2016) compare execution quality among several exchanges (A in Figure 1). (Bessembinder & Kaufman, 1997) study execution quality of NYSE and NASD (A and C in Figure 1, respectively). (Huang, 2002) and (Goldstein, Shkilko, Van Ness, & Van Ness, 2008) study Nasdaq and ECNs (B and C in Figure 1, respectively). (Boehmer, 2005), (Boehmer, Jennings, & Wei, 2007) and (O'Hara & Ye, 2011) study execution quality and include trades from exchanges, ATSs and Non-ATSs (A, B, and C in Figure 1, respectively). (Kothari, Johnson, & So, 2021), (R. Battalio & Jennings, 2022), (Eaton, Green, Roseman, & Wu, 2022), (Hu & Murphy, 2022), (Dyhrberg, Shkilko, & Werner, 2022), (Jain, Mishra, Donoghue, & Zhao, 2023) examine execution quality in wholesalers (C in Figure 1). Our paper documents three novel results about execution quality: execution quality tends to be better in Non-ATSs than in ATSs, transparency widens these gaps in quality, and these differences in the results are related to different legal treatments of ATSs and Non-ATSs.

Our paper is also (remotely) related to the literature examining post-trade transparency. This literature tends to focus on post-trade transparency without considering heterogeneity across dark trading platforms: see (Gemmill, 1996), (Porter & Weaver, 1998), (Board & Sutcliffe, 2000), (Aghanya, Agarwal, & Poshakwale, 2020) for instance. Our paper highlights the difficulty of regulating dark trading platforms as a whole because the outcome of policy initiatives, such as post-trade transparency, can be very different depending on whether they would be implemented on ATSs or Non-ATSs.

Organization. The rest of the paper is organized as follows. Section 2 discusses institutional settings of the U.S. equities market and regulation changes. Section 3 develops

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[6](Comerton-Forde & Putniņš, 2015) and (Menkveld et al., 2017) also split dark trading into categories. The former divides dark trading into categories where all categories still include trades from B+C in Figure 1. The latter divides dark trading between dark pools (parts of B) and retail broker-dealers (parts of C). However, they mainly focus on the differences between exchanges (A) and different types of dark pools (B) regarding cost and immediacy of executions.

hypotheses. Section 4 presents data and introduces our empirical model. Section 5 presents the main results. Section 6 discusses policy implications and concludes.

2 Institutional Details

The U.S. equities market has 16 exchanges, 32 ATSs and 196 Non-ATSs as of December 2022. The past decade featured an important trend in the U.S. equities market. The distribution of trades among off-exchange platforms changed significantly. ATSs' share of U.S. consolidated volume steadily decreased from 16% in 2014 to 10% in 2021 while the market share of Non-ATSs gradually rose from 21% in 2014 to 34% in 2021.[7] One reason for these trends is that 6 ATSs had to pay more than $150 million in penalties to the SEC for violating federal securities laws.[8] These violations induced some investors to lose their confidence in ATSs and trade more on exchanges and Non-ATSs (SEC, 2015). Our paper provides suggestive evidence that transparency can also be partially responsible for these trends by deteriorating market quality on ATSs and improving market quality on Non-ATSs.

2.1 Exchange and Off-Exchange (Dark) Trading Regulations

Figure 1 summarizes exchange (A) and off-exchange (B+C) trading regulations governing U.S. equities markets. Exchanges are subject to the Securities Exchange Act of 1934. Exchanges are defined as market places under the Exchange Act. The Rule 3b–16 of the Act considers a trading platform a market place if it *"brings together* the orders of *multiple* buyers and sellers, and uses established, *non-discretionary* methods...under which such orders interact with each other"* (Section III, 63 FR 70844). Exchanges meet all these *"italicized"* conditions of being a market place.

Off-exchange trading platforms are regulated differently from exchanges. Every off-exchange trading platform, regardless of whether it is an ATS or Non-ATS, must be registered as a broker-dealer. In addition, with a few exceptions, an off-exchange trading platform is required to register with the SEC and join a self-regulatory organization (SRO), such as FINRA. Therefore, off-exchange trading platforms are subject to broker-dealer regulations

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[7]Please see Figure 2 in Appendix C. Source: the data on total consolidated volume is extracted from CBOE U.S. Equities Market Volume Summary, and the data on ATS volumes is extracted from FINRA OTC Transparency Data Quarterly Statistics. Non-ATS market share is calculated as one minus exchange and ATS market shares. The data starts from 2014Q2 since FINRA started to disclose ATS data in May 2014.

[8]Source: https://www.sec.gov/news/press-release/2016-16

set forth by both the SEC and their affiliated SROs.[9] Off-exchange trading platforms that meet the requirements of being a market place, set forth by Rule 3b–16, have the option of becoming part of A or B. If they choose the former, they must register as exchanges and establish their own SROs. If they choose the latter, they can continue to operate as registered broker-dealers, but must also comply with additional requirements under Regulation ATS and will be considered ATSs. Off-exchange trading platforms that violate any of those aforementioned "*italicized*" conditions are legally considered Non-ATSs and fall into C in Figure 1.[10] For instance, internal broker-dealer systems, such as Citadel Securities LLC and Virtu Americas LLC, fail to meet the "non-discretionary" part as they can have discretion over executing orders as principals or agents and order routing/splitting decisions.

In this legal framework, like exchanges, ATSs must also comply with Rule 3b–16 and hence they are legally defined as market places. Being a market place requires them to use pre-determined and established "non-discretionary" methods to execute orders. In addition, ATSs need to file amendments with the SEC at least 20 days prior to implementing material changes to their operations, such as trading rules and procedures (17 CFR 242.301-b2i). In contrast, Non-ATSs are not legally recognized as market places. They can have discretion when executing trades and adopt different trading rules and procedures from one trade to another. This discretion results in important economic differences in the operations of ATSs and Non-ATSs, which will be discussed in Section 3.

Regardless of whether they are executed on exchanges, ATSs, or Non-ATSs, trades in the U.S. equities market are disseminated to market participants almost immediately. Post-trade transaction data include execution price, size, and venue information for trades executed on exchanges, with each exchange having a unique code in the disseminated data. That is, the post-trade data can uniquely identify trades on each exchange under A. In contrast, all trades executed on off-exchange trading systems (B+C) are published under the same code ("D"). Although market participants can observe off-exchange trades' size and price information, they do not have access to venue information identifying the specific off-exchange trading system where the trade occurred. Therefore, trades executed in B and C cannot be separately identified in the post-trade data.

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[9]Some of these regulations are part of the Exchange Act. We prefer to use different names to emphasize that exchanges and broker-dealers are subject to different regulations.

[10]Source: Section III, 63 FR 70844. There are also other requirements that a trading platform must meet when choosing between exchange and ATS. This is not the main focus of our paper.

2.2 Regulation Changes: ATS and Non-ATS Trade Transparency

In an effort to increase post-trade transparency and enhance investor confidence, the Financial Industry Regulatory Authority (FINRA) has implemented two crucial changes in off-exchange (dark) trading regulations in recent years. Starting in May 2014, in accordance with FINRA Rule 4552, Alternative Trading Systems (ATSs) are required to report their volume and trade information to FINRA on a weekly and stock-by-stock basis. In April 2016, FINRA made a similar regulation change for Non-ATSs. FINRA make these two datasets publicly available on a two-week and four-week delayed basis for Tier 1 (more liquid) and Tier 2 (less liquid) National Market System stocks, respectively. Unlike intraday post-trade TAQ data, which labels all off-exchange trades as "D", these new datasets include venue information in addition to volume and trade. As a result, investors can now have a better understanding of the liquidity breakdown among trading platforms under B and C, as well as the liquidity breakdown between B and C.[11]

3   Hypothesis Development

Legal terms are binding for both ATSs and Non-ATSs. ATSs must execute orders using predetermined, established, and non-discretionary methods, while Non-ATSs have discretion in handling customer orders, including but not limited to order routing and splitting decisions, and executing as principal or agent. Additionally, Non-ATSs can choose to handle order flow as a single dealer in their trading systems. These legal differences create different trading environments for ATSs and Non-ATSs and therefore they are attracted to informed and uninformed investors at varying levels. Post-trade transparency heterogeneously changes informed and uninformed traders' incentives to use ATSs and Non-ATSs, which alters the ratio of informed and uninformed investors on these platforms.

Both ATS and Non-ATS Trade Transparency allow investors to better locate and trade on more liquid venues across fragmented off-exchange trading platforms. However, ATS Trade Transparency provides flexibility to informed investors, whereas Non-ATS Trade Transparency provides flexibility to uninformed investors in terms of switching to more liquid venues. With ATS Trade Transparency, informed investors can freely move to more liquid

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[11]Source: For ATS and Non-ATS regulation changes, please see the following notices for more details, respectively: FINRA Regulatory Notice 14-07 and FINRA Regulatory Notice 15-08. For the Non-ATS regulation change, there are some *de minimis* exceptions aiming to protect illiquid stocks. Please refer to the following documents for additional information: Federal Register, Vol. 84, No. 164, Release No. 34–86706.

ATSs.[12] On the contrary, the movements of uninformed investors to ATSs are limited because some of them can be trapped on Non-ATSs through practices such as preferencing and PFOF. It is more difficult for ATSs to engage in such practices because effective usage of them requires discretionary trading rules and the ability to change them quickly. As a result, ATS Trade Transparency makes ATSs more attractive to informed investors but has a limited impact on uninformed investors' venue choices. The rise of informed trading activity on ATSs deteriorates their market quality compared to Non-ATSs and exchanges. Specifically, due to increased intensity of informed trading, investors face higher price impacts and effective spreads and receive lower price improvements on ATSs compared to Non-ATSs and exchanges.

With Non-ATS Trade Transparency, the movements of informed investors to Non-ATSs are limited. Informed traders cannot move freely because Non-ATSs' trading rules and procedures are discretionary. Non-ATSs typically try to determine if a customer is informed and, if they suspect informed trading, can exercise their discretion to: (i) charge higher spreads and execute the order as principals, (ii) find a counter-party and execute it as agents, or (iii) route it to other venues.[13] This discretion helps them to protect themselves against informed trading and limits the movements of informed investors to Non-ATSs after transparency. Besides, trading on Non-ATSs is not entirely anonymous due to their partially bilateral nature. This characteristic allows Non-ATSs to exercise their discretion more effectively, making it more difficult to conceal information-based trading on Non-ATSs over time.

On the contrary, Non-ATS Trade Transparency makes the movements of uninformed order flow to Non-ATSs through preferencing and PFOF more effective because it allows brokers to locate more liquid Non-ATSs and make better routing decisions. As a result, Non-ATS Trade Transparency increases the incentives of uninformed investors to use Non-ATSs (via their brokers) but has a limited impact on informed investors' venue decisions. The rise of uninformed trading on Non-ATSs improves their market quality compared to ATSs and exchanges. Specifically, due to increased intensity of uninformed trading, investors face lower price impacts and effective spreads and receive higher price improvements on Non-ATSs compared to ATSs and exchanges.

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[12]Although ATSs can restrict certain investors' access to their platforms, ATSs are unlikely to make major changes in these policies after transparency.

[13](Anand et al., 2021) document that not all Non-ATSs route some orders to their affiliated ATSs. It indicates that Non-ATSs select strategically which orders they want to execute as principals or agents.

4 Data and Empirical Framework

We use Rule 605 of Regulation NMS ("Dash-5") reports to obtain execution quality statistics. Dash-5 reports are mandatory standardized monthly disclosures on order executions for all trading platforms. Dash-5 reports are extracted through various channels such as TAG/Audit, Vista One Solutions and several others. The original data has a separate record for each combination of stock, order type and order size. There are five (four) order types (size): market orders, marketable, inside-the-quote, at-the-quote and near-the-quote limit orders (100-499, 500-1999, 2000-4999, 5000-9999 shares). We use 4 market quality statistics: speed of executions, effective spreads, price impacts and price improvements. Except for speed of executions, they are available only for market orders and marketable limit orders.[14]

We first determine which trading platform falls into which region in Figure 1: exchanges (A), ATSs (B) and Non-ATSs (C). Then, for each region, we aggregate these statistics over order types and sizes by using Dash-5 trading volume as the weighting variable. The final data includes one observation for each month and stock for each region. We also use two other data sources: the Center for Research in Securities Prices (CRSP) and NYSE Trades and Quotes (TAQ). We obtain daily stock prices and shares outstanding from CRSP, and daily total market volume (number of shares traded), daily total number trades and intraday volatility from TAQ. We include all CRSP ordinary common stocks (CRSP share code 10-11) that are listed on major exchanges (CRSP exchange codes 1-3). We match CRSP and TAQ using WRDS Daily TAQ CRSP Link, and use tickers to merge this combined data with Dash-5.

Let m denote the type of a trading platform, where $m \in \{\text{ATS, Non-ATS, Exchange}\}$. Let's write the model for ATS Trade Transparency. We use a difference-and-difference setup and include either Non-ATSs or exchanges to control for general market trends in market quality. The market quality statistic MarketQuality$_{itm}$ for stock i in month t in type m can be written as,

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\begin{aligned}
\text{MarketQuality}_{itm} = {} & \alpha + \beta_{ATS} \times \text{ATS} + \lambda_1 \text{POST}_{1t} + \lambda_2 \text{POST}_{2t} \\
& + \beta_1 \left(\text{ATS} \times \text{POST}_{1t} \right) + \beta_2 \left(\text{ATS} \times \text{POST}_{2t} \right) \\
& + \text{Security Fixed Effects} + \text{Controls} + \varepsilon_{itm}
\end{aligned}
$$

Dependent Variables. We use four monthly (share-weighted) MarketQuality statistics: effective spreads, price impacts, price improvements, and speed of executions. Effective

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[14]More details on Dash-5 are available on https://www.sec.gov/rules/final/34-43590.htm.

spread is considered a proxy for the overall cost of executing a trade from the trader's point of view (O'Hara & Ye, 2011). It is defined for buy (sell) orders as double the (negative) difference between the execution price and the midpoint of the consolidated best bid and offer at the time that the order is received. Price impact is not directly reported in Dash-5. Instead, realized spread is reported, which is defined for buy (sell) orders as double the (negative) difference between the execution price and the midpoint of the consolidated best bid and offer five minutes after the time of order execution. Price impact is calculated as effective spread minus realized spread. We will also use percentage effective spreads and price impacts, which are calculated by dividing effective spreads and price impacts by stocks' average monthly prices.

Price improvement is defined for buy (sell) orders as execution at a price lower (higher) than the consolidated best offer (bid) at the time the order is received. We use two price improvement variables, which we call Price Improvement (Ave) and Price Improvement (VolA). The former does not take into account aggregate trading volumes (reported in Dash-5) in trading platforms and calculate average price improvement among shares executed with price improvements. It is calculated as the share-weighted average of price improvements for shares that have been executed with price improvement, expressed in dollars. The latter takes into account aggregate trading volumes and calculates average price improvement for each share executed in a trading platform. It is calculated for a given stock as Price Improvement (Ave) times the total number of price-improved shares divided by the total trading volume reported in Dash-5.

We refer to the first (second) variable as unadjusted (adjusted) price improvement to ease communication. The first variable measures the conditional average price improvement: given that a trader receives a price improvement, they expect an improvement of "Price Improvement (Ave)" dollars on average. The second variable measures the unconditional average price improvement: a trader expects an improvement of "Price Improvement (VolA)" dollars on average, before knowing whether they will receive an improvement or not.

We also calculate three variables for execution speeds: Speed (0-9) (0-29) (0-59) which represent the ratio of shares executed within 9 (29) (59) seconds to the total trading volume reported in Dash-5 executed in the first five minutes. We multiply all dependent variables by 100 to express effective spreads, price impacts, and price improvements in cents, and express execution speeds as percentages.

Independent Variables. ATS is equal to 1 if m is an ATS, and 0 if m is in control group (either Non-ATSs or exchanges).[15] We include 9 months into our sample for each transparency change: 3 months before the change and 6 months after the change. $POST_{1t}$ and $POST_{2t}$ are dummy variables for post-policy periods, defined as: $POST_{1t}$ is equal to 1 if month t is the $1^{st}, 2^{nd},$ or 3rd month after the policy change, and 0 otherwise; $POST_{2t}$ is equal to 1 if month t is the $4^{th}, 5^{th},$ or 6th month after the policy change, and 0 otherwise. For instance, for ATS Trade Transparency that became effective in May 2014, $POST_{1t} = 1$ for May-July 2014, and $POST_{2t} = 1$ for Aug-Oct 2014.
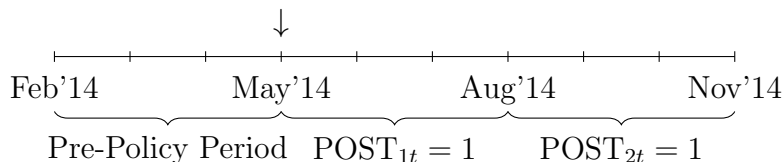
We compare the market quality over the first 6 months after the regulation change with the market quality over the last 3 months before the regulation change. β_1 and β_2 measure impacts of regulation changes and hence they are our coefficients of interest. β_1 (β_2) measures how much average market quality differs in the first (second) 3 months after the regulation change compared to the last 3 months before the change. We include all ATSs, Non-ATSs, and exchanges whose Dash-5 reports are available during the sample period under analysis. For ATS Trade Transparency, we compare ATSs with Non-ATSs and with exchanges. For Non-ATS Trade Transparency, we compare Non-ATSs with ATSs and with exchanges.

The controls include standard control variables in the literature[16]: log market capitalization and inverse of price from CRSP; log number of trades and average intraday volatility from TAQ; average order size from Dash-5, and market volatility index (VIX). We also control stock-level fixed effects.[17] We winsorize the variables at 1% and 99% for each trading platform type separately and cluster standard errors at the stock level. Summary statistics during our sampling period for ATS (Non-ATS) Trade Transparency are presented in Appendix A.1 (B.1).

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[15]For NonATS Trade Transparency, ATS is replaced with Non-ATS. Non-ATS is equal to 1 if m is a Non-ATS, and 0 if m is in control group (either ATSs or exchanges)

[16]See (Boehmer et al., 2007) and (O'Hara & Ye, 2011) for instance.

[17]The results are also robust to inclusion of other controls such as share of institutional trading or using trade and volatility variables from CRSP instead of TAQ.

5 Main Results

We present two novel empirical findings. Firstly, ATSs generally exhibit lower market quality than non-ATSs. They experience higher price impacts, lower price improvements, and slower execution speeds. In our 2016 sample, ATSs also have higher effective spreads, while in our 2014 sample, they have lower effective spreads. Secondly, transparency exacerbates these disparities in market quality, except for execution speeds. ATS and non-ATS trade transparency improves execution speeds on their respective platforms, relative to each other and to exchanges. However, transparency has opposing effects on their market quality otherwise. ATS Trade Transparency dramatically reduces market quality, resulting in higher price impacts and effective spreads, and lower price improvements in ATSs compared to non-ATSs and exchanges. In contrast, Non-ATS Trade Transparency significantly improves market quality, resulting in lower price impacts and effective spreads, and higher price improvements in Non-ATSs compared to ATSs and exchanges.

5.1 ATS Trade Transparency

The sample spans through Feb'14 to Oct'14. There are 10 ATSs whose Dash-5 reports are available during these 9 months: Aqua Securities (AQUA), Bloomberg Tradebook (BOOK), Level ATS (EBXL), Citi Lavaflow (FLOW), IEX Services (IEXG), Barclays ATS (LATS), Millennium ATS (NYFX), PDQ ATS (PDQM), Sigma X (SGMA), Wells Fargo ATS (WELX).

5.1.1 Speed of Executions

Table 1 compares execution speeds of ATSs with Non-ATSs. Speed of executions in ATSs are initially lower. After controlling stock-specific characteristics and market volatility, ATSs execute 1.61% (1.40%) (0.89%) less shares within the first 9 (29) (59) seconds. ATS Trade Transparency improves execution speeds in ATSs. Shares executed in ATSs compared to Non-ATSs within the first 9 (29) (59) seconds increase by 1.91% (2.41%) (2.26%), which corresponds to a 2.1% (2.6%) (2.4%) increase in pre-policy average speed of executions. Because average speed of executions are already high in both ATSs and Non-ATSs, these improvements are quite large in terms of variation in execute speeds. A 1.91% (2.41%) (2.26%) increase in execution speeds within the first 9 (29) (59) seconds is equivalent to 28% (39%) (40%) of pre-policy standard deviation of execution speeds within the same time frames.

	(1)	(2)	(3)
	Speed (0-9)	Speed Ave (0-29)	Speed Ave (0-59)
ATS	-1.607***	-1.397***	-0.891***
	(0.127)	(0.111)	(0.0985)
POST1	1.030***	0.796***	0.633***
	(0.0939)	(0.0799)	(0.0714)
POST2	1.162***	0.885***	0.767***
	(0.0859)	(0.0724)	(0.0643)
ATS_POST1	1.160***	1.366***	1.270***
	(0.122)	(0.106)	(0.0937)
ATS_POST2	0.752***	1.041***	0.988***
	(0.128)	(0.108)	(0.0948)
_cons	91.58***	91.49***	91.94***
	(2.837)	(2.442)	(2.222)
N	60792	60792	60792

Table 1: **(ATS Trade Transparency) Speed of Executions for ATSs vs. Non-ATSs**
Speed (0-9) (0-29) (0-59) is the percentage of shares executed within 9 (29) (59) seconds to the total trading volume reported in Dash-5 executed in the first five minutes. **ATS** is equal to 1 for ATSs and 0 for Non-ATSs. **POST1** (POST2) is 1 for the first (second) 3 months after the regulation change and 0 otherwise. **ATS_POST1** (ATS_POST2) is interaction term, ATS × POST1 (POST2). We also **control** log market capitalization, average intraday quote-based volatility, log number of trades, inverse of stock price, average order size from Dash-5, stock-level fixed effects, and market volatility index (VIX). Those coefficients are not presented to save space. Standard errors are clustered at the stock level. **Standard errors** are in parentheses; * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$.

Table 2 compares execution speeds of ATSs with exchanges. Speed of executions in ATSs are initially higher. After controlling stock-specific characteristics and market volatility, ATSs execute 7.23% (4.57%) (2.88%) more shares within the first 9 (29) (59) seconds. ATS Trade Transparency widens these gaps: compared to exchanges, shares executed in ATSs within the first 9 (29) (59) seconds increase by 7.47% (7.08%) (6.28%), which corresponds to an 8.8% (7.9%) (6.9%) increase in pre-policy average speed of executions, and 94% (102%) (102%) of pre-policy standard deviation of execution speeds within the same time frames.

	(1)	(2)	(3)
	Speed (0-9)	Speed Ave (0-29)	Speed Ave (0-59)
ATS	7.226***	4.565***	2.884***
	(0.124)	(0.102)	(0.0847)
POST1	-2.814***	-2.231***	-1.803***
	(0.0962)	(0.0836)	(0.0740)
POST2	-1.507***	-1.328***	-1.161***
	(0.0891)	(0.0769)	(0.0678)
ATS_POST1	4.256***	3.875***	3.354***
	(0.120)	(0.104)	(0.0910)
ATS_POST2	3.211***	3.201***	2.926***
	(0.129)	(0.108)	(0.0946)
_cons	82.93***	83.01***	84.50***
	(2.771)	(2.527)	(2.265)
N	60570	60570	60570

Table 2: **(ATS Trade Transparency) Speed of Executions for ATSs vs. Exchanges**
Speed (0-9) (0-29) (0-59) is the percentage of shares executed within 9 (29) (59) seconds to the total trading volume
reported in Dash-5 executed in the first five minutes. **ATS** is equal to 1 for ATSs and 0 for exchanges. **POST1** (POST2) is 1
for the first (second) 3 months after the regulation change and 0 otherwise. **ATS_POST1** (ATS_POST2) is interaction term,
ATS × POST1 (POST2). We also **control** log market capitalization, average intraday quote-based volatility, log number of
trades, inverse of stock price, average order size from Dash-5, stock-level fixed effects, and market volatility index (VIX).
Those coefficients are not presented to save space. Standard errors are clustered at the stock level. **Standard errors** are in
parentheses; * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$.

5.1.2 Effective Spread and Price Impact

Table 3 presents how ATS Trade Transparency affect effective spreads and price impacts
in ATSs compared to Non-ATSs. ATSs initially have lower effective spreads and higher
price impacts. After controlling stock-specific characteristics and market volatility, ATSs
have 1.54 cents lower effective spreads and 1.89 cents higher price impacts. ATS Trade
Transparency increases both effective spreads and price impacts in ATSs. Effective spreads
in ATSs compared to Non-ATSs increases by 1.55 cents, which corresponds to 20.3% of pre-
policy average effective spread. Similarly, transparency causes dramatic increases in price
impacts in ATSs. Compared to Non-ATSs, price impacts in ATSs increase by 0.86 cents,
which is 15.4% of pre-policy average price impact. The results are robust to using percentage
effective spread and price impact. Please refer to Table 18 in Appendix A.2 for these results.

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	(1)	(2)
	Effective Spread	Price Impact
ATS	-1.537***	1.887***
	(0.0701)	(0.0874)
POST1	-0.508***	-0.213**
	(0.0700)	(0.0744)
POST2	-1.496***	-0.620***
	(0.0775)	(0.0668)
ATS_POST1	0.663***	0.494***
	(0.0652)	(0.0796)
ATS_POST2	0.891***	0.366***
	(0.0688)	(0.0796)
_cons	-9.584***	-16.01***
	(2.790)	(2.358)
N	60792	60792

Table 3: **(ATS Trade Transparency) Effective Spread and Price Impact for ATSs vs. Non-ATSs** **Effective Spread** is defined as for buy (sell) orders as double the (negative) difference between the execution price and the midpoint of the consolidated best bid and offer at the time that the order is received. **Price Impact** is effective spread minus realized spread, where realized spread is defined for buy (sell) orders as double the (negative) difference between the execution price and the midpoint of the consolidated best bid and offer five minutes after the time of order execution. Both dependent variables are multiplied by 100 to express them in cents. **ATS** is equal to 1 for ATSs and 0 for Non-ATSs. **POST1** (POST2) is 1 for the first (second) 3 months after the regulation change and 0 otherwise. **ATS_POST1** (ATS_POST2) is interaction term, ATS × POST1 (POST2). We also **control** log market capitalization, average intraday quote-based volatility, log number of trades, inverse of stock price, average order size from Dash-5, stock-level fixed effects, and market volatility index (VIX). Those coefficients are not presented to save space. Standard errors are clustered at the stock level. **Standard errors are in parentheses**; * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$.

Table 4 presents how ATS Trade Transparency affect effective spreads and price impacts in ATSs compared to exchanges. ATSs initially have higher effective spreads and price impacts. After controlling stock-specific characteristics and market volatility, ATSs have 0.594 cents higher effective spreads and 0.29 cents higher price impacts. ATS Trade Transparency widens these gaps. Compared to exchanges, effective spreads in ATSs increases by 0.60 cents, which corresponds to 9.2% of pre-policy average effective spread. Similarly, compared to exchanges, price impacts in ATSs increase by 1.58 cents, which is 25.8% of pre-policy average price impact. The results are robust to using percentage effective spread and price impact. Please refer to Table 19 in Appendix A.2 for these results.

	(1)	(2)
	Effective Spread	Price Impact
ATS	0.594***	0.291***
	(0.0515)	(0.0564)
POST1	-0.306***	-0.496***
	(0.0646)	(0.0737)
POST2	-0.839***	-1.016***
	(0.0673)	(0.0746)
ATS_POST1	0.290***	0.794***
	(0.0644)	(0.0773)
ATS_POST2	0.305***	0.789***
	(0.0639)	(0.0782)
_cons	-6.119*	-14.26***
	(2.541)	(2.634)
N	60570	60570

Table 4: **(ATS Trade Transparency) Effective Spread and Price Impact for ATSs vs. Exchanges**
Effective Spread is defined as for buy (sell) orders as double the (negative) difference between the execution price and the midpoint of the consolidated best bid and offer at the time that the order is received. **Price Impact** is effective spread minus realized spread, where realized spread is defined for buy (sell) orders as double the (negative) difference between the execution price and the midpoint of the consolidated best bid and offer five minutes after the time of order execution. Both dependent variables are multiplied by 100 to express them in cents. **ATS** is equal to 1 for ATSs and 0 for exchanges. **POST1** (POST2) is 1 for the first (second) 3 months after the regulation change and 0 otherwise. **ATS_POST1** (ATS_POST2) is interaction term, ATS × POST1 (POST2). We also **control** log market capitalization, average intraday quote-based volatility, log number of trades, inverse of stock price, average order size from Dash-5, stock-level fixed effects, and market volatility index (VIX). Those coefficients are not presented to save space. Standard errors are clustered at the stock level. **Standard errors** are in parentheses; * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$.

5.1.3 Price Improvements

Table 5 presents how ATS Trade Transparency affect price improvements in ATSs compared to Non-ATSs. Initially, there is no statistically significant difference in unadjusted price improvements between ATSs and Non-ATSs. However, after controlling stock-specific characteristics and market volatility, ATSs have 0.423 cents lower adjusted price improvements. ATS Trade Transparency reduces both price improvement measures in ATSs compared to Non-ATSs. Compared to Non-ATSs, unadjusted price improvements decrease in ATSs by 0.44 cents, which is equivalent to 36.6% of pre-policy average unadjusted price improvements. Similarly, compared to Non-ATSs, adjusted price improvements decrease in ATSs by 0.18 cents, which is equivalent to 45.4% of pre-policy average adjusted price improvements.

	(1)	(2)
	Price Improve (Ave)	Price Improve (VolA)
ATS	-0.0212	-0.423***
	(0.0163)	(0.0105)
POST1	0.0834***	0.0427***
	(0.0122)	(0.00597)
POST2	0.142***	0.0683***
	(0.0129)	(0.00663)
ATS_POST1	-0.162***	-0.0796***
	(0.0159)	(0.00655)
ATS_POST2	-0.278***	-0.101***
	(0.0183)	(0.00736)
_cons	-3.015***	-0.765***
	(0.402)	(0.159)
N	60792	60792

Table 5: **(ATS Trade Transparency) Price Improvements for ATSs vs. Non-ATSs**
Price Improve (Ave) is unadjusted average price improvement: share-weighted average amount of improvements among shares executed with price improvements, expressed in dollars. **Price Improve (VolA)** is adjusted average price improvement (adjusted for trading volumes), calculated as Price Improve (Ave) × (number of price improved shares) / (total trading volume in Dash-5). Both dependent variables are multiplied by 100 to express them in cents. **ATS** is equal to 1 for ATSs and 0 for Non-ATSs. **POST1** (POST2) is 1 for the first (second) 3 months after the regulation change and 0 otherwise. **ATS_POST1** (ATS_POST2) is interaction term, ATS × POST1 (POST2). We also **control** log market capitalization, average intraday quote-based volatility, log number of trades, inverse of stock price, average order size from Dash-5, stock-level fixed effects, and market volatility index (VIX). Those coefficients are not presented to save space. Standard errors are clustered at the stock level. **Standard errors** are in parentheses; * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$.

Table 6 presents how ATS Trade Transparency affects price improvements in ATSs compared to exchanges. Initially, ATSs have lower unadjusted price improvements and higher adjusted price improvements, indicating that ATSs offer smaller price improvements but execute more shares with price improvements. After controlling for stock-specific characteristics and market volatility, ATSs have 0.429 cents lower unadjusted price improvements and 0.061 cents higher adjusted price improvements. ATS Trade Transparency reduces both price improvement measures in ATSs compared to exchanges. Unadjusted price improvements in ATSs compared to exchanges decline by 0.29 cents, which is equivalent to 20.7% of pre-policy average unadjusted price improvements. Adjusted price improvements in ATSs compared to exchanges decline by 0.03 cents, which is equivalent to 15.3% of pre-policy average adjusted price improvements.

	(1)	(2)
	Price Improve (Ave)	Price Improve (VolA)
ATS	-0.429***	0.0614***
	(0.0124)	(0.00258)
POST1	0.114***	-0.00748***
	(0.0129)	(0.00219)
POST2	-0.0504***	-0.0215***
	(0.0126)	(0.00212)
ATS_POST1	-0.177***	-0.0110***
	(0.0160)	(0.00285)
ATS_POST2	-0.110***	-0.0146***
	(0.0161)	(0.00291)
_cons	-2.873***	-0.654***
	(0.414)	(0.0684)
N	60570	60570

Table 6: **(ATS Trade Transparency) Price Improvements for ATSs vs. Exchanges**
Price Improve (Ave) is unadjusted average price improvement: share-weighted average amount of improvements among shares executed with price improvements, expressed in dollars. **Price Improve (VolA)** is adjusted average price improvement (adjusted for trading volumes), calculated as Price Improve (Ave) $\times$ (number of price improved shares) / (total trading volume in Dash-5). Both dependent variables are multiplied by 100 to express them in cents. **ATS** is equal to 1 for ATSs and 0 for exchanges. **POST1** (POST2) is 1 for the first (second) 3 months after the regulation change and 0 otherwise. **ATS_POST1** (ATS_POST2) is interaction term, ATS $\times$ POST1 (POST2). We also **control** log market capitalization, average intraday quote-based volatility, log number of trades, inverse of stock price, average order size from Dash-5, stock-level fixed effects, and market volatility index (VIX). Those coefficients are not presented to save space. Standard errors are clustered at the stock level. **Standard errors** are in parentheses; * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$.

5.2   Non-ATS Trade Transparency

The sample spans through Jan'16 to Sep'16. There are 36 Non-ATSs whose Dash-5 reports are available during these 9 months. Here are some trading platforms from our sample: BNY Mellon Capital Markets (BKMM), Citadel (CDRG), G1 Execution Services (ETMM), Virtu Financial Capital Markets (EWTT), Goldman Sachs (GSCO), Merrill Lynch (MLCO), Knight Capital Americas (NITE), Two Sigma Securities (SOHO), Virtu Americas (TRIM), UBS Securities (UBSS).

5.2.1 Speed of Executions

Table 7 compares execution speeds of Non-ATSs with ATSs. Speed of executions in Non-ATSs are initially higher. After controlling stock-specific characteristics and market volatility, Non-ATSs execute 2.74% (1.29%) (0.77%) more shares within the first 9 (29) (59) seconds. Non-ATS Trade Transparency widens these gaps. Shares executed in Non-ATSs compared to ATSs within the first 9 (29) (59) seconds increase by 1.89% (1.49%) (1.10%), which corresponds to a 2.0% (1.6%) (1.1%) increase in pre-policy average speed of executions, and 37% (39%) (32%) of pre-policy standard deviations in execution speeds within the same time frames.

	(1)	(2)	(3)
	Speed (0-9)	Speed Ave (0-29)	Speed Ave (0-59)
NonATS	2.736***	1.289***	0.766***
	(0.0713)	(0.0552)	(0.0465)
POST1	-0.667***	-0.576***	-0.488***
	(0.0777)	(0.0597)	(0.0530)
POST2	-1.131***	-0.915***	-0.721***
	(0.0989)	(0.0762)	(0.0676)
NonATS_POST1	0.340***	0.333***	0.212***
	(0.0690)	(0.0562)	(0.0485)
NonATS_POST2	1.545***	1.156***	0.889***
	(0.0752)	(0.0613)	(0.0531)
_cons	103.3***	103.6***	102.5***
	(1.644)	(1.261)	(1.138)
N	59556	59556	59556

Table 7: **(Non-ATS Trade Transparency) Speed of Executions for Non-ATSs vs. ATSs**
Speed (0-9) (0-29) (0-59) is the percentage of shares executed within 9 (29) (59) seconds to the total trading volume reported in Dash-5 executed in the first five minutes. **NonATS** is equal to 1 for Non-ATSs and 0 for ATSs. **POST1** (POST2) is 1 for the first (second) 3 months after the regulation change and 0 otherwise. **NonATS_POST1** (NonATS_POST2) is interaction term, NonATS × POST1 (POST2). We also **control** log market capitalization, average intraday quote-based volatility, log number of trades, inverse of stock price, average order size from Dash-5, stock-level fixed effects, and market volatility index (VIX). Those coefficients are not presented to save space. Standard errors are clustered at the stock level. **Standard errors** are in parentheses; * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$.

Table 8 compares execution speeds of Non-ATSs with exchanges. Speed of executions in Non-ATSs are initially higher. After controlling stock-specific characteristics and mar-

ket volatility, Non-ATSs execute 16.6% (11.7%) (8.51%) more shares within the first 9 (29) (59) seconds. Non-ATS Trade Transparency widens these gaps: compared to exchanges, shares executed in Non-ATSs within the first 9 (29) (59) seconds increase by 3.45% (3.84%) (3.26%), which corresponds to a 4.0% (4.3%) (3.5%) increase in pre-policy average speed of executions, and 35% (51%) (53%) of pre-policy standard deviations in execution speeds within the same time frames.

	(1)	(2)	(3)
	Speed (0-9)	Speed Ave (0-29)	Speed Ave (0-59)
NonATS	16.58***	11.67***	8.514***
	(0.134)	(0.100)	(0.0912)
POST1	-1.459***	-1.405***	-1.188***
	(0.0694)	(0.0608)	(0.0560)
POST2	-1.713***	-1.895***	-1.669***
	(0.0896)	(0.0787)	(0.0725)
NonATS_POST1	1.224***	1.380***	1.108***
	(0.0886)	(0.0720)	(0.0659)
NonATS_POST2	2.233***	2.462***	2.147***
	(0.0969)	(0.0790)	(0.0720)
_cons	76.38***	81.00***	83.44***
	(1.336)	(1.265)	(1.200)
N	59592	59592	59592

Table 8: **(Non-ATS Trade Transparency) Speed of Executions for Non-ATSs vs. Exchanges**
Speed (0-9) (0-29) (0-59) is the percentage of shares executed within 9 (29) (59) seconds to the total trading volume reported in Dash-5 executed in the first five minutes. **NonATS** is equal to 1 for Non-ATSs and 0 for exchanges. **POST1** (POST2) is 1 for the first (second) 3 months after the regulation change and 0 otherwise. **NonATS_POST1** (NonATS_POST2) is interaction term, NonATS × POST1 (POST2). We also **control** log market capitalization, average intraday quote-based volatility, log number of trades, inverse of stock price, average order size from Dash-5, stock-level fixed effects, and market volatility index (VIX). Those coefficients are not presented to save space. Standard errors are clustered at the stock level. **Standard errors** are in parentheses; * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$.

5.2.2 Effective Spread and Price Impact

Table 9 presents how Non-ATS Trade Transparency affect effective spreads and price impacts in Non-ATSs compared to ATSs. Non-ATSs initially have lower effective spreads and price impacts. After controlling stock-specific characteristics and market volatility, Non-ATSs have 0.09 cents lower effective spreads and 1.59 cents lower price impacts. Non-ATS Trade

Transparency widens these gaps. Effective spreads in Non-ATSs compared to ATSs reduces by 0.22 cents, which corresponds to 3.1% of pre-policy average effective spread. Similarly, compared to ATSs, price impacts in Non-ATSs reduces by 0.26 cents, which is 5.0% of pre-policy average price impact. The results are robust to using percentage effective spread and price impact. Please refer to Table 27 in Appendix B.2 for these results.[18]

	(1)	(2)
	Effective Spread	Price Impact
NonATS	-0.0915*	-1.594***
	(0.0438)	(0.0668)
POST1	-0.607***	-0.663***
	(0.0690)	(0.0742)
POST2	-1.084***	-1.037***
	(0.0929)	(0.0986)
NonATS_POST1	-0.0421	-0.212***
	(0.0411)	(0.0516)
NonATS_POST2	-0.175***	-0.0504
	(0.0400)	(0.0553)
_cons	-6.015***	-15.23***
	(1.817)	(1.837)
N	59556	59556

Table 9: **(Non-ATS Trade Transparency) Effective Spread and Price Impact for Non-ATSs vs. ATSs**
Effective Spread is defined as for buy (sell) orders as double the (negative) difference between the execution price and the midpoint of the consolidated best bid and offer at the time that the order is received. **Price Impact** is effective spread minus realized spread, where realized spread is defined for buy (sell) orders as double the (negative) difference between the execution price and the midpoint of the consolidated best bid and offer five minutes after the time of order execution. Both dependent variables are multiplied by 100 to express them in cents. **NonATS** is equal to 1 for Non-ATSs and 0 for ATSs. **POST1** (POST2) is 1 for the first (second) 3 months after the regulation change and 0 otherwise. **NonATS_POST1** (NonATS_POST2) is interaction term, NonATS × POST1 (POST2). We also **control** log market capitalization, average intraday quote-based volatility, log number of trades, inverse of stock price, average order size from Dash-5, stock-level fixed effects, and market volatility index (VIX). Those coefficients are not presented to save space. Standard errors are clustered at the stock level. **Standard errors** are in parentheses; * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$.

Table 10 presents how Non-ATS Trade Transparency affect effective spreads and price impacts in Non-ATSs compared to exchanges. Non-ATSs initially have higher effective spreads and lower price impacts. After controlling stock-specific characteristics and market volatility, Non-ATSs have 0.868 cents higher effective spreads and 2.40 cents lower price impacts.

[18]NonATS_POST1 and NonATS_POST2 are insignificant in Regression 1 and 2 in Table 9, respectively. However, NonATS_POST1 and NonATS_POST2 are jointly significant in both regressions.

Non-ATS Trade Transparency dramatically reduces both effective spreads and price impacts in Non-ATSs. Compared to exchanges, effective spreads in Non-ATSs decrease by 1.25 cents, which corresponds to 19.0% of pre-policy average effective spread. Similarly, compared to exchanges, price impacts in Non-ATSs decrease by 1.12 cents, which is 21.0% of pre-policy average price impact. The results are robust to using percentage effective spread and price impact. Please refer to Table 28 in Appendix B.2 for these results.

	(1)	(2)
	Effective Spread	Price Impact
NonATS	0.868***	-2.403***
	(0.0745)	(0.102)
POST1	-0.182**	-0.146*
	(0.0628)	(0.0649)
POST2	-0.368***	-0.437***
	(0.0820)	(0.0837)
NonATS_POST1	-0.425***	-0.625***
	(0.0555)	(0.0652)
NonATS_POST2	-0.822***	-0.496***
	(0.0588)	(0.0703)
_cons	-5.833***	-11.55***
	(1.652)	(1.653)
N	59592	59592

Table 10: **(Non-ATS Trade Transparency) Effective Spread and Price Impact for Non-ATSs vs. Exchanges Effective Spread** is defined as for buy (sell) orders as double the (negative) difference between the execution price and the midpoint of the consolidated best bid and offer at the time that the order is received. **Price Impact** is effective spread minus realized spread, where realized spread is defined for buy (sell) orders as double the (negative) difference between the execution price and the midpoint of the consolidated best bid and offer five minutes after the time of order execution. Both dependent variables are multiplied by 100 to express them in cents. **NonATS** is equal to 1 for Non-ATSs and 0 for exchanges. **POST1** (POST2) is 1 for the first (second) 3 months after the regulation change and 0 otherwise. **NonATS_POST1** (NonATS_POST2) is interaction term, NonATS × POST1 (POST2). We also **control** log market capitalization, average intraday quote-based volatility, log number of trades, inverse of stock price, average order size from Dash-5, stock-level fixed effects, and market volatility index (VIX). Those coefficients are not presented to save space. Standard errors are clustered at the stock level. **Standard errors** are in parentheses; * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$.

5.2.3   Price Improvements

Table 11 presents how Non-ATS Trade Transparency affect price improvements in Non-ATSs compared to ATSs. Non-ATSs initially have higher unadjusted and adjusted price improvements. After controlling stock-specific characteristics and market volatility, Non-ATSs have

0.097 cents higher unadjusted price improvements and 0.41 cents higher adjusted price improvements. Non-ATS Trade Transparency dramatically increases both price improvement measures in Non-ATSs. Unadjusted price improvements in Non-ATSs compared to ATSs increase by 0.27 cents, which is equivalent to 15.2% of pre-policy average unadjusted price improvements. Adjusted price improvements in Non-ATSs compared to ATSs increase by 0.19 cents, which is equivalent to 25.3% of pre-policy average adjusted price improvements.

	(1)	(2)
	Price Improve (Ave)	Price Improve (VolA)
NonATS	0.0973***	0.408***
	(0.0136)	(0.0120)
POST1	-0.0596**	-0.0194*
	(0.0195)	(0.00906)
POST2	0.0484	0.0662***
	(0.0267)	(0.0129)
NonATS_POST1	0.129***	0.0806***
	(0.0121)	(0.00740)
NonATS_POST2	0.142***	0.110***
	(0.0127)	(0.00877)
_cons	-3.870***	-2.365***
	(0.515)	(0.296)
N	59556	59556

Table 11: **(Non-ATS Trade Transparency) Price Improvements for Non-ATSs vs. ATSs**
Price Improve (Ave) is unadjusted average price improvement: share-weighted average amount of improvements among shares executed with price improvements, expressed in dollars. **Price Improve (VolA)** is adjusted average price improvement (adjusted for trading volumes), calculated as Price Improve (Ave) × (number of price improved shares) / (total trading volume in Dash-5). Both dependent variables are multiplied by 100 to express them in cents. **NonATS** is equal to 1 for Non-ATSs and 0 for ATSs. **POST1** (POST2) is 1 for the first (second) 3 months after the regulation change and 0 otherwise. **NonATS_POST1** (NonATS_POST2) is interaction term, NonATS × POST1 (POST2). We also **control** log market capitalization, average intraday quote-based volatility, log number of trades, inverse of stock price, average order size from Dash-5, stock-level fixed effects, and market volatility index (VIX). Those coefficients are not presented to save space. Standard errors are clustered at the stock level. **Standard errors** are in parentheses; * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$.

Table 12 presents how Non-ATS Trade Transparency affect price improvements in Non-ATSs compared to exchanges. Non-ATSs initially have higher unadjusted and adjusted price improvements. After controlling stock-specific characteristics and market volatility, Non-ATSs have 0.25 cents higher unadjusted price improvements and 0.96 cents higher adjusted price improvements. Non-ATS Trade Transparency increases both price improvement mea-

sures in Non-ATSs. Unadjusted price improvements in Non-ATSs compared to exchanges increase by 0.31 cents, which is equivalent to 17.5% of pre-policy average unadjusted price improvements. Adjusted price improvements in Non-ATSs compared to exchanges increase by 0.25 cents, which is equivalent to 46.1% of pre-policy average adjusted price improvements.

	(1)	(2)
	Price Improve (Ave)	Price Improve (VolA)
NonATS	0.250***	0.962***
	(0.0272)	(0.0230)
POST1	-0.0580***	-0.00487
	(0.0171)	(0.00481)
POST2	-0.0808***	-0.0124
	(0.0207)	(0.00713)
NonATS_POST1	0.0867***	0.0596***
	(0.0195)	(0.00920)
NonATS_POST2	0.219***	0.189***
	(0.0192)	(0.0124)
_cons	-2.974***	-1.684***
	(0.417)	(0.192)
N	59592	59592

Table 12: **(Non-ATS Trade Transparency) Price Improvements for Non-ATSs vs. Exchanges**
Price Improve (Ave) is unadjusted average price improvement: share-weighted average amount of improvements among shares executed with price improvements, expressed in dollars. **Price Improve (VolA)** is adjusted average price improvement (adjusted for trading volumes), calculated as Price Improve (Ave) × (number of price improved shares) / (total trading volume in Dash-5). Both dependent variables are multiplied by 100 to express them in cents. **NonATS** is equal to 1 for Non-ATSs and 0 for exchanges. **POST1** (POST2) is 1 for the first (second) 3 months after the regulation change and 0 otherwise. **NonATS_POST1** (NonATS_POST2) is interaction term, NonATS × POST1 (POST2). We also **control** log market capitalization, average intraday quote-based volatility, log number of trades, inverse of stock price, average order size from Dash-5, stock-level fixed effects, and market volatility index (VIX). Those coefficients are not presented to save space. Standard errors are clustered at the stock level. **Standard errors** are in parentheses; * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$.

6   Concluding Remarks and Policy Proposal

Dark trading consists of alternative trading systems (ATSs) and non-alternative trading systems (Non-ATSs), each of which is subject to different regulations. Similar to exchanges, ATSs are legally considered market places and therefore must use established non-discretionary rules and procedures to execute trades. In contrast, Non-ATSs are not legally recognized

as market places, allowing them to use discretionary methods when executing trades. In this study, we examine two exogenous transparency shocks and demonstrate that legal distinctions between ATSs and Non-ATSs can result in significant economic differences in their market quality. Our findings indicate that ATSs generally exhibit lower market quality than Non-ATSs. Moreover, transparency exacerbates these differences: it decreases market quality on ATSs, while improving it on Non-ATSs.

This paper's results can shed light on a recent debate regarding the accuracy of (Boehmer et al., 2021)'s method to identify retail trades in TAQ data. Our results suggest that improved transparency on Non-ATSs may reconcile (Boehmer et al., 2021)'s paper with the findings by their two critiques ((R. Battalio et al., 2022) and (Barber et al., 2022)).

Our paper also has important policy implications. In the U.S. equities market, any trade executed on ATSs and Non-ATSs are disseminated to market participants through the consolidated tape under the same code "D". Our paper highlights the difficulty of studying dark trading platforms as a unified entity as well as the difficulty of regulating them as a whole because the same policy initiative may lead to opposite consequences to two types of dark trading. We show that ATS and Non-ATS trading have distinct characteristics. Therefore, they should be treated differently in terms of post-trade transparency. We propose that trades executed on ATSs and Non-ATSs should be disseminated in the U.S. consolidated tape under different codes instead of combining them under the same code "D". It can allow investors to extract better information from dark trading, make more informed venue choices, and accordingly accelerate price discovery processes.

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Appendix

A   ATS Trade Transparency

A.1   Summary Statistics

SEC 605 Statistics

	N	Mean	Std.Dev.	1st Perc.	Median	99th Perc.
Realized Spread						
Non-ATSs	30,396	0.03	0.056	-0.058	0.012	0.285
ATSs	30,285	0.001	0.034	-0.133	0.000	0.149
Exchanges	30,285	0.002	0.027	-0.107	0.000	0.140
Effective Spread						
Non-ATSs	30,396	0.077	0.106	0.006	0.038	0.602
ATSs	30,285	0.066	0.093	0.007	0.030	0.548
Exchanges	30,285	0.058	0.086	0.007	0.027	0.533
Price Impact						
Non-ATSs	30,396	0.046	0.068	-0.01	0.022	0.364
ATSs	30,285	0.064	0.093	-0.004	0.030	0.541
Exchanges	30,285	0.055	0.083	-0.001	0.026	0.513
Ave. Trade Size 605*						
Non-ATSs	30,396	1,533	920	11	1,380	4,060
ATSs	30,285	816	647	10	665	3,304
Exchanges	30,285	725	640	10	511	3,239

Market Level Statistics

	N	Mean	Std.Dev.	1st Perc.	Median	99th Perc.
Quoted Spread	90,966	0.054	0.113	0.009	0.010	0.740
Total Number of Trades (x1000)	90,966	117	241	0	36	1,106
Ave. Trade Size	90,966	158	106	1	132	657
Market Cap (million)	90,966	5,086	16,189	11	644	92,175

Table 13: **(ATS Trade Transparency) Summary Statistics Part I**
Realized Spread is defined for buy (sell) orders as double the (negative) difference between the execution price and the midpoint of the consolidated best bid and offer five minutes after the time of order execution. **Effective Spread** is defined as for buy (sell) orders as double the (negative) difference between the execution price and the midpoint of the consolidated best bid and offer at the time that the order is received. **Price Impact** is effective spread minus realized spread. *"Ave. Trade Size 605" is average order size: defined as total number of covered shares divided by total number of covered orders, and calculated using SEC 605 reports.

	N	Mean	Std.Dev.	1st Perc.	Median	99th Perc.
Price Improve (Ave)						
Non-ATSs	30,396	0.013	0.015	0.001	0.008	0.083
ATSs	30,285	0.011	0.012	0.000	0.007	0.070
Exchanges	30,285	0.016	0.013	0.000	0.013	0.080
Price Improve (VolA)						
Non-ATSs	30,396	0.006	0.007	0.000	0.004	0.035
ATSs	30,285	0.002	0.002	0.000	0.001	0.013
Exchanges	30,285	0.001	0.002	0.000	0.001	0.012
Speed (0-9)						
Non-ATSs	30,396	0.90	0.06	0.65	0.91	1.00
ATSs	30,285	0.90	0.07	0.66	0.91	1.00
Exchanges	30,285	0.80	0.07	0.62	0.80	1.00
Speed (0-29)						
Non-ATSs	30,396	0.92	0.05	0.71	0.93	1.00
ATSs	30,285	0.92	0.06	0.69	0.94	1.00
Exchanges	30,285	0.86	0.06	0.68	0.86	1.00
Speed (0-59)						
Non-ATSs	30,396	0.93	0.05	0.74	0.94	1.00
ATSs	30,285	0.94	0.05	0.72	0.96	1.00
Exchanges	30,285	0.89	0.06	0.71	0.89	1.00

Table 14: **(ATS Trade Transparency) Summary Statistics Part II**

Price Improve (Ave) is average price improvement: for shares executed with price improvement, the share-weighted average amount per share that prices were improved, expressed in dollars. **Price Improve (VolA)** is average price improvement adjusted for trading volumes, calculated for a given stock as Price Improve (Ave) × (number of price improved shares) / (total trading volume in Dash-5). **Speed (0-9) (0-29) (0-59)** is the ratio of shares executed within 9 (29) (59) seconds to the total trading volume reported in Dash-5 executed in the first five minutes.

Realized Spread

MPID	N	Mean	SD	1st Perc.	Median	99th Perc.
AQUA	4557	0.001	0.114	-0.32	0	0.502
BOOK	15562	0.006	0.131	-0.32	0.003	0.502
EBXL	28236	0.008	0.059	-0.163	0.003	0.23
FLOW	29746	-0.005	0.061	-0.245	-0.002	0.193
IEXG	28287	0.002	0.073	-0.246	0	0.284
LATS	29166	0.025	0.075	-0.143	0.009	0.372
NYFX	22141	0.01	0.101	-0.32	0.006	0.45
PDQM	29797	-0.016	0.071	-0.32	-0.007	0.187
SGMA	29774	0.023	0.073	-0.107	0.006	0.407
WELX	4384	0.011	0.112	-0.32	0.003	0.502

Effective Spread

MPID	N	Mean	SD	1st Perc.	Median	99th Perc.
AQUA	4557	0.018	0.061	-0.002	0	0.294
BOOK	15562	0.052	0.085	0	0.024	0.485
EBXL	28236	0.052	0.081	0	0.024	0.435
FLOW	29746	0.055	0.094	0	0.023	0.599
IEXG	28287	0.056	0.09	0	0.025	0.509
LATS	29166	0.07	0.105	0	0.031	0.633
NYFX	22141	0.028	0.053	-0.001	0.014	0.224
PDQM	29797	0.061	0.099	0	0.026	0.598
SGMA	29774	0.082	0.117	0.005	0.037	0.688
WELX	4384	0.001	0.011	-0.002	0	0.01

Price Impact

MPID	N	Mean	SD	1st Perc.	Median	99th Perc.
AQUA	4557	0.017	0.131	-0.482	0	0.383
BOOK	15562	0.046	0.146	-0.361	0.023	0.526
EBXL	28236	0.044	0.083	-0.067	0.02	0.393
FLOW	29746	0.059	0.108	-0.044	0.026	0.588
IEXG	28287	0.054	0.099	-0.083	0.027	0.467
LATS	29166	0.045	0.092	-0.082	0.018	0.445
NYFX	22141	0.018	0.1	-0.288	0.01	0.353
PDQM	29797	0.077	0.129	-0.055	0.036	0.681
SGMA	29774	0.059	0.094	-0.026	0.028	0.476
WELX	4384	-0.011	0.114	-0.501	-0.003	0.32

Table 15: **(ATS Trade Transparency) (Individual ATSs) Summary Statistics Part III**
Realized Spread is defined for buy (sell) orders as double the (negative) difference between the execution price and the midpoint of the consolidated best bid and offer five minutes after the time of order execution. **Effective Spread** is defined as for buy (sell) orders as double the (negative) difference between the execution price and the midpoint of the consolidated best bid and offer at the time that the order is received. **Price Impact** is effective spread minus realized spread.

Ave. Trade Size 605

MPID	N	Mean	SD	1st Perc.	Median	99th Perc.
AQUA	4557	4563.775	1645.75	136.638	5000	6202.224
BOOK	15562	1737.482	1794.867	9.671	921.966	6202.224
EBXL	28236	384.348	480.43	9.671	244.261	2543.976
FLOW	29746	759.507	862.95	9.671	430.493	3994.461
IEXG	28287	1121.417	1100.886	9.671	803.107	5342.291
LATS	29166	367.085	409.011	9.671	240.04	2004.772
NYFX	22141	539.306	742.12	9.671	273.776	3802.503
PDQM	29797	809.634	790.615	9.671	567.133	3622.009
SGMA	29774	403.88	450.333	9.671	274.646	2256.553
WELX	4384	482.381	484.439	9.671	351.799	2289.402

Price Improve (Ave)

MPID	N	Mean	SD	1st Perc.	Median	99th Perc.
AQUA	4557	0.023	0.032	0	0.01	0.187
BOOK	15562	0.007	0.014	0	0.001	0.062
EBXL	28236	0.008	0.012	0	0.005	0.052
FLOW	29746	0.011	0.017	0	0.007	0.086
IEXG	28287	0.016	0.022	0	0.01	0.124
LATS	29166	0.008	0.012	0	0.005	0.056
NYFX	22141	0.008	0.018	0	0.005	0.08
PDQM	29797	0.01	0.014	0	0.006	0.067
SGMA	29774	0.012	0.019	0	0.008	0.09
WELX	4384	0.016	0.026	0.005	0.007	0.17

Price Improve (VolA)

MPID	N	Mean	SD	1st Perc.	Median	99th Perc.
AQUA	4557	0.017	0.025	0	0.007	0.134
BOOK	15562	0.001	0.005	0	0	0.02
EBXL	28236	0.002	0.005	0	0.001	0.016
FLOW	29746	0.001	0.002	0	0	0.007
IEXG	28287	0.003	0.008	0	0.001	0.033
LATS	29166	0.003	0.005	0	0.002	0.019
NYFX	22141	0.004	0.011	0	0.002	0.05
PDQM	29797	0.003	0.004	0	0.002	0.02
SGMA	29774	0	0.002	0	0	0.005
WELX	4384	0.016	0.025	0	0.006	0.155

Table 16: **(ATS Trade Transparency) (Individual ATSs) Summary Statistics Part IV**
Ave. Trade Size 605 is average order size: defined as total number of covered shares divided by total number of covered orders, and calculated using SEC 605 reports. **Price Improve (Ave)** is average price improvement: for shares executed with price improvement, the share-weighted average amount per share that prices were improved, expressed in dollars. **Price Improve (VolA)** is average price improvement adjusted for trading volumes, calculated for a given stock as Price Improve (Ave) × (number of price improved shares) / (total trading volume in Dash-5).

Speed (0-9)

MPID	N	Mean	SD	1st Perc.	Median	99th Perc.
AQUA	4541	0.663	0.452	0	1	1
BOOK	15511	0.862	0.242	0	1	1
EBXL	28222	0.889	0.121	0.438	0.919	1
FLOW	29694	0.811	0.121	0.46	0.82	1
IEXG	28270	0.917	0.116	0.49	0.957	1
LATS	29166	1	0	1	1	1
NYFX	22141	1	0	1	1	1
PDQM	29770	0.951	0.094	0.534	0.984	1
SGMA	29769	0.872	0.109	0.5	0.897	1
WELX	4384	1	0	1	1	1

Speed (0-29)

MPID	N	Mean	SD	1st Perc.	Median	99th Perc.
AQUA	4541	0.671	0.452	0	1	1
BOOK	15511	0.887	0.221	0	1	1
EBXL	28222	0.932	0.102	0.5	0.962	1
FLOW	29694	0.856	0.112	0.5	0.875	1
IEXG	28270	0.938	0.103	0.5	0.975	1
LATS	29166	1	0	1	1	1
NYFX	22141	1	0	1	1	1
PDQM	29770	0.965	0.08	0.6	0.993	1
SGMA	29769	0.912	0.095	0.523	0.938	1
WELX	4384	1	0	1	1	1

Speed (0-59)

MPID	N	Mean	SD	1st Perc.	Median	99th Perc.
AQUA	4541	0.739	0.394	0	1	1
BOOK	15511	0.906	0.203	0.017	1	1
EBXL	28222	0.955	0.089	0.51	0.983	1
FLOW	29694	0.886	0.105	0.52	0.911	1
IEXG	28270	0.951	0.094	0.526	0.986	1
LATS	29166	1	0	1	1	1
NYFX	22141	1	0	1	1	1
PDQM	29770	0.972	0.072	0.645	0.996	1
SGMA	29769	0.935	0.085	0.6	0.962	1
WELX	4384	1	0	1	1	1

Table 17: **(ATS Trade Transparency) (Individual ATSs) Summary Statistics Part V**
Speed (0-9) (0-29) (0-59) is the ratio of shares executed within 9 (29) (59) seconds to the total trading volume reported in Dash-5 executed in the first five minutes.

A.2 Percentage Spreads

	(1)	(2)
	Effective Spread (P)	Price Impact (P)
ATS	-0.111***	0.0945***
	(0.00552)	(0.00638)
POST1	0.00475	-0.00458
	(0.00562)	(0.00606)
POST2	-0.0645***	-0.0239***
	(0.00552)	(0.00529)
ATS_POST1	0.0388***	0.0474***
	(0.00516)	(0.00673)
ATS_POST2	0.0605***	0.0299***
	(0.00537)	(0.00670)
_cons	3.173***	1.867***
	(0.229)	(0.233)
N	60792	60792

Table 18: **(ATS Trade Transparency) Percentage Effective Spread and Price Impact for ATSs vs. Non-ATSs** Percentage effective spread and price impact are respectively calculated by dividing effective spreads and price impacts by stocks' average monthly prices. **Effective Spread** is defined as for buy (sell) orders as double the (negative) difference between the execution price and the midpoint of the consolidated best bid and offer at the time that the order is received. **Price Impact** is effective spread minus realized spread, where realized spread is defined for buy (sell) orders as double the (negative) difference between the execution price and the midpoint of the consolidated best bid and offer five minutes after the time of order execution. **ATS** is equal to 1 for ATSs and 0 for Non-ATSs. **POST1** (POST2) is 1 for the first (second) 3 months after the regulation change and 0 otherwise. **ATS_POST1** (ATS_POST2) is interaction term, ATS × POST1 (POST2). We also **control** log market capitalization, average intraday quote-based volatility, log number of trades, inverse of stock price, average order size from Dash-5, stock-level fixed effects, and market volatility index (VIX). Those coefficients are not presented to save space. Standard errors are clustered at the stock level. **Standard errors** are in parentheses; * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$.

	(1)	(2)
	Effective Spread (P)	Price Impact (P)
ATS	0.0140***	-0.0168**
	(0.00424)	(0.00511)
POST1	0.0173**	-0.00201
	(0.00587)	(0.00689)
POST2	-0.0145**	-0.0314***
	(0.00528)	(0.00610)
ATS_POST1	0.0148**	0.0510***
	(0.00562)	(0.00708)
ATS_POST2	0.0180***	0.0350***
	(0.00522)	(0.00698)
_cons	3.042***	2.321***
	(0.217)	(0.226)
N	60570	60570

Table 19: **(ATS Trade Transparency) Percentage Effective Spread and Price Impact for ATSs vs. Exchanges**
Percentage effective spread and price impact are respectively calculated by dividing effective spreads and price impacts by stocks' average monthly prices. **Effective Spread** is defined as for buy (sell) orders as double the (negative) difference between the execution price and the midpoint of the consolidated best bid and offer at the time that the order is received. **Price Impact** is effective spread minus realized spread, where realized spread is defined for buy (sell) orders as double the (negative) difference between the execution price and the midpoint of the consolidated best bid and offer five minutes after the time of order execution. **ATS** is equal to 1 for ATSs and 0 for exchanges. **POST1** (POST2) is 1 for the first (second) 3 months after the regulation change and 0 otherwise. **ATS_POST1** (ATS_POST2) is interaction term, ATS $\times$ POST1 (POST2). We also **control** log market capitalization, average intraday quote-based volatility, log number of trades, inverse of stock price, average order size from Dash-5, stock-level fixed effects, and market volatility index (VIX). Those coefficients are not presented to save space. Standard errors are clustered at the stock level. **Standard errors** are in parentheses;
* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$.

B Non-ATS Trade Transparency

B.1 Summary Statistics

SEC 605 Statistics

	N	Mean	Std.Dev.	1st Perc.	Median	99th Perc.
Realized Spread						
Non-ATSs	29,796	0.019	0.046	-0.089	0.007	0.225
ATSs	29,778	0.008	0.038	-0.094	0.002	0.201
Exchanges	29,796	0.000	0.021	-0.083	-0.001	0.071
Effective Spread						
Non-ATSs	29,796	0.064	0.094	0.005	0.031	0.557
ATSs	29,778	0.064	0.095	0.004	0.030	0.576
Exchanges	29,796	0.058	0.084	0.005	0.029	0.506
Price Impact						
Non-ATSs	29,796	0.044	0.069	-0.002	0.020	0.395
ATSs	29,778	0.055	0.079	-0.002	0.026	0.447
Exchanges	29,796	0.058	0.080	0.003	0.030	0.457
Ave. Trade Size 605*						
Non-ATSs	29,796	1,509	888	10	1,366	3,873
ATSs	29,778	1,069	745	10	914	3,642
Exchanges	29,796	663	602	10	450	2,992

Market Level Statistics

	N	Mean	Std.Dev.	1st Perc.	Median	99th Perc.
Quoted Spread	89,370	0.052	0.117	0.002	0.010	0.740
Total Number of Trades (x1000)	89,370	132	276	0.158	36	1,315
Ave. Trade Size	89,370	153	106	1	127	677
Market Cap (million)	89,370	5,027	16,503	8	551	103,435

Table 20: (**Non-ATS Trade Transparency**) **Summary Statistics Part I**

Realized Spread is defined for buy (sell) orders as double the (negative) difference between the execution price and the midpoint of the consolidated best bid and offer five minutes after the time of order execution. **Effective Spread** is defined as for buy (sell) orders as double the (negative) difference between the execution price and the midpoint of the consolidated best bid and offer at the time that the order is received. **Price Impact** is effective spread minus realized spread. *"Ave. Trade Size 605" is average order size: defined as total number of covered shares divided by total number of covered orders, and calculated using SEC 605 reports.

	N	Mean	Std.Dev.	1st Perc.	Median	99th Perc.
SEC 605 Statistics						
Price Improve (Ave)						
Non-ATSs	29,796	0.019	0.024	0.001	0.010	0.134
ATSs	29,778	0.017	0.022	0.001	0.010	0.137
Exchanges	29,796	0.016	0.017	0.001	0.012	0.116
Price Improve (VolA)						
Non-ATSs	29,796	0.010	0.013	0.000	0.005	0.064
ATSs	29,778	0.006	0.008	0.000	0.003	0.045
Exchanges	29,796	0.001	0.003	0.000	0.000	0.013
Speed (0-9)						
Non-ATSs	29,796	0.940	0.050	0.729	0.952	0.997
ATSs	29,778	0.914	0.052	0.710	0.925	1.000
Exchanges	29,796	0.764	0.055	0.663	0.756	0.934
Speed (0-29)						
Non-ATSs	29,796	0.956	0.038	0.805	0.965	1.000
ATSs	29,778	0.943	0.041	0.784	0.952	1.000
Exchanges	29,796	0.831	0.057	0.716	0.826	0.966
Speed (0-59)						
Non-ATSs	29,796	0.963	0.034	0.829	0.971	1.000
ATSs	29,778	0.955	0.037	0.810	0.965	1.000
Exchanges	29,796	0.873	0.057	0.748	0.873	0.982

Table 21: **(Non-ATS Trade Transparency) Summary Statistics Part II**

Price Improve (Ave) is average price improvement: for shares executed with price improvement, the share-weighted average amount per share that prices were improved, expressed in dollars. **Price Improve (VolA)** is average price improvement adjusted for trading volumes, calculated for a given stock as Price Improve (Ave) × (number of price improved shares) / (total trading volume in Dash-5). **Speed (0-9) (0-29) (0-59)** is the ratio of shares executed within 9 (29) (59) seconds to total trading volume reported in Dash-5 that is executed in the first five minutes.

Realized Spread

MPID	N	Mean	SD	1st Perc.	Median	99th Perc.
ARXS	9351	0.014	0.096	-0.32	0.007	0.421
ATDF	15836	0.017	0.096	-0.275	0.005	0.502
BARD	11470	0.027	0.118	-0.32	0.012	0.502
BKMM	22005	0.026	0.089	-0.232	0.012	0.41
CANT	13173	0.023	0.127	-0.32	0.01	0.502
CDRG	22913	0.021	0.074	-0.147	0.007	0.406
CSTI	9880	0.013	0.122	-0.32	0.008	0.502
ETMM	29263	0.023	0.091	-0.219	0.008	0.502
EWTT	17191	0.036	0.114	-0.32	0.023	0.502
GSCO	13317	0.007	0.09	-0.31	0.001	0.417
MLCO	27403	0.028	0.096	-0.24	0.011	0.502
NITE	29525	0.021	0.074	-0.133	0.006	0.434
Others	16771	0.026	0.131	-0.32	0.01	0.502
SOHO	29063	0.016	0.082	-0.25	0.006	0.404
TRIM	29525	0.021	0.074	-0.133	0.006	0.434
UBSS	29475	0.018	0.081	-0.238	0.007	0.405

Effective Spread

MPID	N	Mean	SD	1st Perc.	Median	99th Perc.
ARXS	9351	0.043	0.066	0	0.021	0.338
ATDF	15836	0.061	0.092	0	0.03	0.579
BARD	11470	0.037	0.066	0	0.016	0.378
BKMM	22005	0.049	0.071	0	0.027	0.385
CANT	13173	0.048	0.079	0	0.02	0.474
CDRG	22913	0.065	0.099	0.004	0.03	0.579
CSTI	9880	0.044	0.066	0	0.022	0.36
ETMM	29263	0.052	0.092	0.003	0.021	0.579
EWTT	17191	0.092	0.089	0.004	0.068	0.579
GSCO	13317	0.013	0.048	0	0	0.23
MLCO	27403	0.048	0.089	0	0.017	0.579
NITE	29525	0.064	0.097	0.005	0.03	0.579
Others	16771	0.045	0.076	0	0.019	0.444
SOHO	29063	0.046	0.078	0	0.02	0.479
TRIM	29525	0.064	0.097	0.005	0.03	0.579
UBSS	29475	0.057	0.093	0	0.026	0.579

Table 22: **(ATS Trade Transparency) (Individual Non-ATSs) Summary Statistics Part III**
Realized Spread is defined for buy (sell) orders as double the (negative) difference between the execution price and the midpoint of the consolidated best bid and offer five minutes after the time of order execution. **Effective Spread** is defined as for buy (sell) orders as double the (negative) difference between the execution price and the midpoint of the consolidated best bid and offer at the time that the order is received.

Price Impact

MPID	N	Mean	SD	1st Perc.	Median	99th Perc.
ARXS	9351	0.031	0.087	-0.194	0.013	0.41
ATDF	15836	0.043	0.085	-0.131	0.019	0.426
BARD	11470	0.013	0.097	-0.194	0.002	0.4
BKMM	22005	0.024	0.08	-0.194	0.01	0.379
CANT	13173	0.028	0.107	-0.194	0.011	0.426
CDRG	22913	0.044	0.071	-0.014	0.019	0.426
CSTI	9880	0.034	0.11	-0.194	0.015	0.426
ETMM	29263	0.029	0.074	-0.115	0.009	0.395
EWTT	17191	0.057	0.1	-0.194	0.039	0.426
GSCO	13317	0.008	0.078	-0.194	0.002	0.32
MLCO	27403	0.02	0.084	-0.194	0.006	0.403
NITE	29525	0.043	0.068	-0.019	0.02	0.405
Others	16771	0.023	0.11	-0.194	0.01	0.426
SOHO	29063	0.029	0.07	-0.1	0.011	0.379
TRIM	29525	0.043	0.068	-0.019	0.02	0.405
UBSS	29475	0.038	0.079	-0.086	0.015	0.426

Ave. Trade Size 605

MPID	N	Mean	SD	1st Perc.	Median	99th Perc.
ARXS	9351	678.487	937.942	9.671	300	4998.667
ATDF	15836	1529.717	1205.139	9.671	1244.391	5244.522
BARD	11470	981.185	1112.621	25.7	557.577	5244.522
BKMM	22005	1416.805	1261.875	9.671	1010.07	5244.522
CANT	13173	896.703	1144.174	9.671	438.34	5244.522
CDRG	22913	1391.19	954.293	9.671	1201.422	4241.1
CSTI	9880	683.405	1074.566	9.671	190.167	5244.522
ETMM	29263	1738.556	1159.599	10.078	1591.559	5244.522
EWTT	17191	247.729	326.859	9.671	132.948	1803.911
GSCO	13317	1200.756	1259.914	46.117	696.387	5244.522
MLCO	27403	1356.713	1176.198	9.671	1000	5244.522
NITE	29525	1394.71	932.507	9.671	1214.317	4221.504
Others	16771	1056.625	1284.45	9.671	512.481	5244.522
SOHO	29063	1496.166	1122.812	9.671	1272.39	5072.08
TRIM	29525	1394.71	932.507	9.671	1214.317	4221.504
UBSS	29475	1708.562	1145.094	10.143	1537.062	5244.522

Table 23: **(ATS Trade Transparency) (Individual Non-ATSs) Summary Statistics Part IV**
Price Impact is effective spread minus realized spread. **Ave. Trade Size 605** is average order size: defined as total number of covered shares divided by total number of covered orders, and calculated using SEC 605 reports.

Price Improve (Ave)

MPID	N	Mean	SD	1st Perc.	Median	99th Perc.
ARXS	9351	0.007	0.015	0	0.002	0.078
ATDF	15836	0.013	0.023	0	0.006	0.15
BARD	11470	0.008	0.017	0	0.004	0.092
BKMM	22005	0.012	0.02	0	0.005	0.11
CANT	13173	0.003	0.009	0	0	0.035
CDRG	22913	0.017	0.025	0.001	0.009	0.161
CSTI	9880	0.004	0.011	0	0.001	0.046
ETMM	29263	0.022	0.028	0	0.011	0.161
EWTT	17191	0.007	0.016	0	0	0.08
GSCO	13317	0.02	0.027	0	0.01	0.161
MLCO	27403	0.018	0.025	0	0.01	0.152
NITE	29525	0.018	0.026	0.001	0.009	0.161
Others	16771	0.004	0.011	0	0.001	0.05
SOHO	29063	0.023	0.034	0	0.009	0.161
TRIM	29525	0.018	0.026	0.001	0.009	0.161
UBSS	29475	0.02	0.03	0.001	0.009	0.161

Price Improve (VolA)

MPID	N	Mean	SD	1st Perc.	Median	99th Perc.
ARXS	9351	0.004	0.011	0	0.001	0.059
ATDF	15836	0.008	0.014	0	0.003	0.088
BARD	11470	0.007	0.013	0	0.003	0.08
BKMM	22005	0.007	0.014	0	0.002	0.08
CANT	13173	0.001	0.005	0	0	0.02
CDRG	22913	0.009	0.014	0	0.005	0.089
CSTI	9880	0.003	0.008	0	0.001	0.038
ETMM	29263	0.017	0.021	0	0.009	0.102
EWTT	17191	0.001	0.003	0	0	0.009
GSCO	13317	0.016	0.022	0	0.008	0.102
MLCO	27403	0.01	0.016	0	0.005	0.1
NITE	29525	0.01	0.015	0	0.004	0.093
Others	16771	0.002	0.008	0	0	0.036
SOHO	29063	0.016	0.023	0	0.006	0.102
TRIM	29525	0.01	0.015	0	0.004	0.093
UBSS	29475	0.012	0.018	0	0.005	0.102

Table 24: **(ATS Trade Transparency) (Individual Non-ATSs) Summary Statistics Part V**
Price Improve (Ave) is average price improvement: for shares executed with price improvement, the share-weighted average amount per share that prices were improved, expressed in dollars. **Price Improve (VolA)** is average price improvement adjusted for trading volumes, calculated for a given stock as Price Improve (Ave) × (number of price improved shares) / (total trading volume in Dash-5).

Speed (0-9)

MPID	N	Mean	SD	1st Perc.	Median	99th Perc.
ARXS	9351	0.983	0.082	0.467	1	1
ATDF	15836	0.906	0.132	0.309	0.96	1
BARD	11470	0.963	0.131	0.309	1	1
BKMM	22005	0.903	0.145	0.309	0.966	1
CANT	13173	0.954	0.143	0.309	1	1
CDRG	22913	0.956	0.064	0.669	0.973	1
CSTI	9880	0.975	0.11	0.309	1	1
ETMM	29263	0.956	0.088	0.476	0.983	1
EWTT	17191	1	0	1	1	1
GSCO	13317	0.965	0.114	0.309	1	1
MLCO	27403	0.83	0.183	0.309	0.885	1
NITE	29525	0.949	0.059	0.716	0.966	1
Others	16771	0.946	0.157	0.309	1	1
SOHO	29063	0.969	0.077	0.562	0.994	1
TRIM	29525	0.949	0.059	0.716	0.966	1
UBSS	29475	0.891	0.107	0.451	0.917	1

Speed (0-29)

MPID	N	Mean	SD	1st Perc.	Median	99th Perc.
ARXS	9351	0.989	0.062	0.606	1	1
ATDF	15836	0.926	0.114	0.429	0.976	1
BARD	11470	0.977	0.092	0.429	1	1
BKMM	22005	0.921	0.125	0.429	0.98	1
CANT	13173	0.966	0.114	0.429	1	1
CDRG	22913	0.966	0.05	0.759	0.979	1
CSTI	9880	0.986	0.074	0.429	1	1
ETMM	29263	0.964	0.073	0.565	0.987	1
EWTT	17191	1	0	1	1	1
GSCO	13317	0.974	0.094	0.429	1	1
MLCO	27403	0.861	0.156	0.429	0.912	1
NITE	29525	0.968	0.041	0.809	0.98	1
Others	16771	0.967	0.112	0.429	1	1
SOHO	29063	0.976	0.061	0.674	0.997	1
TRIM	29525	0.968	0.041	0.809	0.98	1
UBSS	29475	0.907	0.096	0.499	0.933	1

Table 25: **(ATS Trade Transparency) (Individual Non-ATSs) Summary Statistics Part VI**
Speed (0-9) (0-29) (0-59) is the ratio of shares executed within 9 (29) (59) seconds to the total trading volume reported in Dash-5 executed in the first five minutes.

Speed (0-59)

MPID	N	Mean	SD	1st Perc.	Median	99th Perc.
ARXS	9351	0.992	0.049	0.714	1	1
ATDF	15836	0.936	0.103	0.49	0.984	1
BARD	11470	0.982	0.079	0.49	1	1
BKMM	22005	0.932	0.113	0.49	0.987	1
CANT	13173	0.973	0.097	0.49	1	1
CDRG	22913	0.972	0.04	0.811	0.984	1
CSTI	9880	0.989	0.064	0.504	1	1
ETMM	29263	0.97	0.063	0.643	0.991	1
EWTT	17191	1	0	1	1	1
GSCO	13317	0.979	0.08	0.49	1	1
MLCO	27403	0.881	0.139	0.49	0.93	1
NITE	29525	0.972	0.038	0.825	0.984	1
Others	16771	0.975	0.094	0.49	1	1
SOHO	29063	0.98	0.054	0.706	0.999	1
TRIM	29525	0.972	0.038	0.825	0.984	1
UBSS	29475	0.92	0.088	0.533	0.946	1

Table 26: **(ATS Trade Transparency) (Individual Non-ATSs) Summary Statistics Part VII**
Speed (0-9) (0-29) (0-59) is the ratio of shares executed within 9 (29) (59) seconds to the total trading volume reported in Dash-5 executed in the first five minutes.

B.2 Percentage Spreads

	(1)	(2)
	Effective Spread (P)	Price Impact (P)
NonATS	0.00746	-0.0940***
	(0.00410)	(0.00463)
POST1	-0.0689***	-0.0686***
	(0.00687)	(0.00765)
POST2	-0.132***	-0.104***
	(0.00893)	(0.00969)
NonATS_POST1	-0.00346	-0.0136**
	(0.00357)	(0.00426)
NonATS_POST2	-0.0125***	-0.00770
	(0.00351)	(0.00424)
_cons	3.411***	1.875***
	(0.217)	(0.213)
N	59556	59556

Table 27: **(Non-ATS Trade Transparency) Percentage Effective Spread and Price Impact for Non-ATSs vs. ATSs**

Percentage effective spread and price impact are respectively calculated by dividing effective spreads and price impacts by stocks' average monthly prices. **Effective Spread** is defined as for buy (sell) orders as double the (negative) difference between the execution price and the midpoint of the consolidated best bid and offer at the time that the order is received. **Price Impact** is effective spread minus realized spread, where realized spread is defined for buy (sell) orders as double the (negative) difference between the execution price and the midpoint of the consolidated best bid and offer five minutes after the time of order execution. **NonATS** is equal to 1 for Non-ATSs and 0 for ATSs. **POST1** (POST2) is 1 for the first (second) 3 months after the regulation change and 0 otherwise. **NonATS_POST1** (NonATS_POST2) is interaction term, NonATS $\times$ POST1 (POST2). We also **control** log market capitalization, average intraday quote-based volatility, log number of trades, inverse of stock price, average order size from Dash-5, stock-level fixed effects, and market volatility index (VIX). Those coefficients are not presented to save space. Standard errors are clustered at the stock level. **Standard errors** are in parentheses; * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$.

	(1)	(2)
	Effective Spread (P)	Price Impact (P)
NonATS	0.0611***	-0.255***
	(0.00640)	(0.00958)
POST1	-0.0352***	-0.0246***
	(0.00616)	(0.00708)
POST2	-0.0713***	-0.0634***
	(0.00802)	(0.00878)
NonATS_POST1	-0.0334***	-0.0471***
	(0.00492)	(0.00713)
NonATS_POST2	-0.0668***	-0.0302***
	(0.00489)	(0.00686)
_cons	3.388***	2.434***
	(0.209)	(0.204)
N	59592	59592

Table 28: **(Non-ATS Trade Transparency) Percentage Effective Spread and Price Impact for Non-ATSs vs. Exchanges**

Percentage effective spread and price impact are respectively calculated by dividing effective spreads and price impacts by stocks' average monthly prices. **Effective Spread** is defined as for buy (sell) orders as double the (negative) difference between the execution price and the midpoint of the consolidated best bid and offer at the time that the order is received. **Price Impact** is effective spread minus realized spread, where realized spread is defined for buy (sell) orders as double the (negative) difference between the execution price and the midpoint of the consolidated best bid and offer five minutes after the time of order execution. **NonATS** is equal to 1 for Non-ATSs and 0 for exchanges. **POST1** (POST2) is 1 for the first (second) 3 months after the regulation change and 0 otherwise. **NonATS_POST1** (NonATS_POST2) is interaction term, NonATS × POST1 (POST2). We also **control** log market capitalization, average intraday quote-based volatility, log number of trades, inverse of stock price, average order size from Dash-5, stock-level fixed effects, and market volatility index (VIX). Those coefficients are not presented to save space. Standard errors are clustered at the stock level. **Standard errors** are in parentheses; * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$.
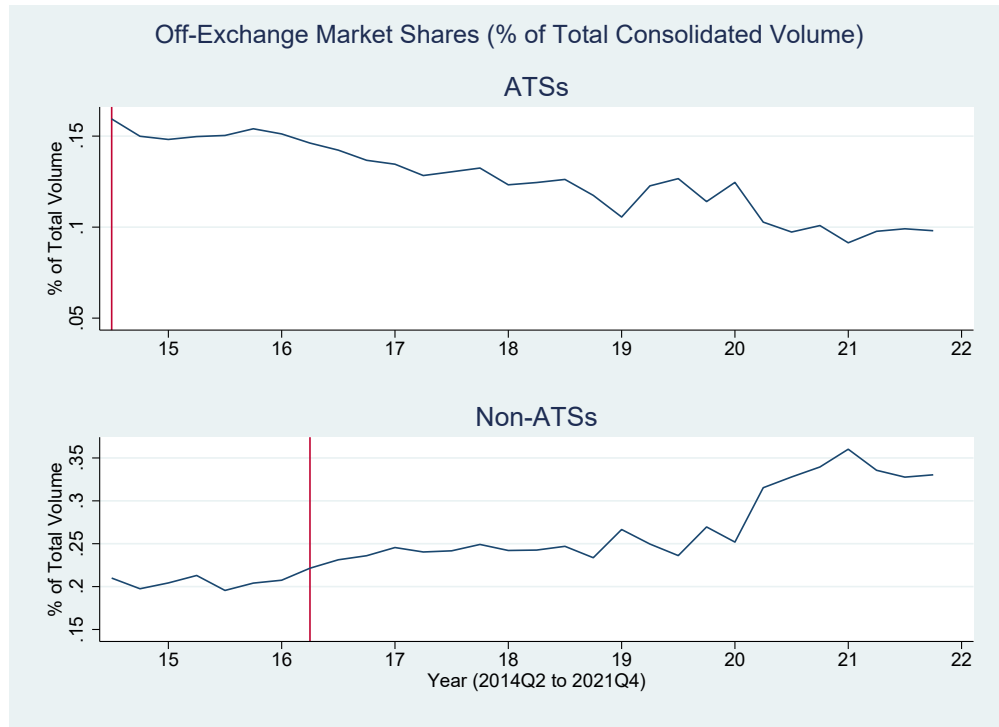
C   Figures

Figure 2: Trends in ATSs' and Non-ATSs' Shares of U.S. Consolidated Volume

Note: The **y-axis** is percentage of trading volume happening in ATSs/Non-ATSs. The **x-axis** is quarters spanning from 2014Q2 to 2021Q4. The **top** figure shows ATSs' share of U.S. consolidated volume. The vertical red line represents May 2014, the implementation time of ATS Trade Transparency. The **bottom** figure shows Non-ATSs' share of U.S. consolidated volume from 2014Q2 to 2021Q4. The vertical red line represents Apr 2016, the implementation time of Non-ATS Trade Transparency. **Source:** the data on total consolidated volume is extracted from CBOE U.S. Equities Market Volume Summary, and the data on ATS volumes is extracted from FINRA OTC Transparency Data Quarterly Statistics. Non-ATS market share is calculated as one minus exchange and ATS market shares. The data starts from 2014Q2 since FINRA started to disclose ATS data in May 2014.