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 classified as market places and therefore must adhere to pre-determined non-discretionary methods for executing 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 disparities in their market quality. Specifically, we find that ATSs generally demonstrate inferior market quality compared to Non-ATSs. Moreover, transparency magnifies these disparities in market quality, except for execution speeds. Transparency leads to improved execution speeds on both ATSs and Non-ATSs. However, it notably diminishes other market quality metrics on ATSs, while remarkably enhancing them on Non-ATSs. Our results provide insight into an ongoing debate surrounding the accuracy of (Boehmer, Jones, Zhang, & Zhang, 2021)'s (BJZZ) method in identifying retail trades, partially elucidating the disparities between BJZZ's findings and its critiques. Additionally, our paper is closely tied to a recent SEC proposal aimed at enhancing the disclosure of order execution information, thereby carrying significant policy implications.

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

1   Introduction

Off-exchange trading has significantly increased over the past decade in the U.S. equities market. Its share in the U.S. consolidated volume grew from 37% in 2014 to 44% in 2023.[1] The trading on off-exchange market centers as a whole is generally referred to as *dark trading.*[2] The existing literature has a tendency to study dark trading as a unified entity. However, it encompasses both alternative trading systems (**ATSs**) and non-alternative trading systems (**Non-ATSs**), each of which is subject to different regulations. ATSs are legally classified as *market places*, like exchanges, and therefore must bring together orders of "multiple" buyers and sellers and execute these orders using pre-determined "non-discretionary" methods, with subscribers agreeing to these predefined terms of trade (Section III, 63 FR 70844). In contrast, Non-ATSs are not legally recognized as market places. A market center that violates the "multilateral" or "non-discretionary" condition of being a market place is considered a Non-ATS.

Similar to ATSs, Non-ATSs must comply with the Best Execution Rule (FINRA 5310), mandating them to execute customers' trades at the most favorable terms reasonably available under prevailing market conditions. However, as being non-market places, they have the flexibility to exercise discretion for order handling and execution practices on an order-by-order basis, without the requirement to pre-determine their trading rules and procedures. Additionally, Non-ATSs have the option to be bilateral, allowing them to exclusively engage in trading with their customers as the sole counterparty. This distinction influences the business models adopted by ATSs and Non-ATSs. The former primarily engage in agency trading, matching orders and collecting fees in return. In contrast, the latter often commit capital and engage in direct trading with their customers as principals in a bilateral manner.

Despite these stark differences in their regulatory environments, there has been no study to date that has explored how these varied regulatory treatments impact the market quality of off-exchange market centers. Our paper fills this gap in the literature. We examine two identical and exogenous transparency shocks—one implemented on ATSs and another on Non-ATSs—and show that legal distinctions between ATSs and Non-ATSs can lead to significant economic differences in their market quality. In May 2014 (April 2016), the Financial Industry Regulatory Authority (FINRA) began to require ATSs (Non-ATSs) to publicly report their volume and trade information on a weekly and stock-by-stock basis. These

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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 instances.

policy changes provide a unique opportunity to scrutinize the market quality of ATSs and Non-ATSs, given their identical and exogenous nature.

Specifically, our findings indicate that ATSs generally exhibit lower market quality compared to other market centers. ATSs display slower execution speeds, greater adverse selection, and smaller price improvements. Furthermore, transparency tends to exacerbate disparities in market quality between ATSs and Non-ATSs. Whether implemented on ATSs or Non-ATSs, transparency increases execution speeds on their respective platforms because it allows investors to better locate and trade on more liquid platforms across fragmented off-exchange market centers. However, in other dimensions, transparency significantly reduces market quality on ATSs while substantially enhancing it on Non-ATSs.
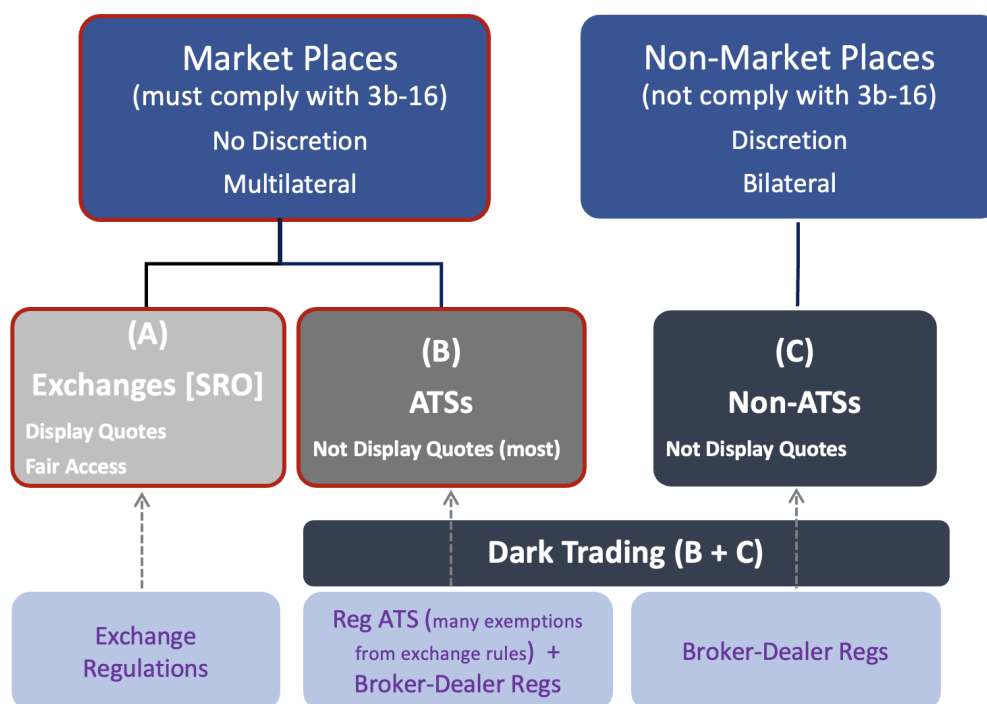

Figure 1: Breakdown of Market Centers and Their Regulatory Framework

This diagram shows different types of market centers in the U.S. equities market and their regulatory framework. The regulatory framework will be discussed in detail in Section 2. The diagram includes only **market centers**: exchanges, ATSs and Non-ATSs. Market centers, under Regulation NMS, are trading centers that present themselves as ready to receive and carry out orders. Trading centers that receive orders from customers for execution and subsequently direct them to different execution venues, rather than executing them directly, are typically not being classified as market centers. For example, entities like **retail brokers**, including Robinhood Securities, belong to this category and therefore are not legally categorized as market centers. In other words, retail brokers do not fall under the classifications of exchanges, ATSs, or Non-ATSs. Dark trading refers to trades executed outside national securities exchanges and associations. SRO denotes self-regulatory organization. **ATSs (Non-ATSs)** denote alternative (non-alternative) trading systems. Exchanges, such as the New York Stock Exchange and Nasdaq Stock Exchange, serve as examples within this category. Some instances of ATSs encompass UBS ATS, Barclays ATS and ITG Posit. Non-ATSs include, among others, wholesalers such as those operated by Citadel Securities and Virtu Americas, traditional trading desks such as UBS Securities, Barclays Capital Inc., and single dealer platforms like Virtu VEQ Link.

To begin with, transparency has different impacts on traders' transaction costs, measured by effective spreads. It increases transaction costs on ATSs by 12.8%, while reducing them on Non-ATSs by 11.7%. Transaction costs consist of the profits derived from liquidity provision, measured by realized spreads, along with adverse selection risk, measured by price impacts. The primary driver influencing changes in transaction costs is the alterations in price impacts. Transparency has no impact on realized spreads. However, it causes notable changes in price impacts, increasing them on ATSs by 8.8% and decreasing them on Non-ATSs by 12.0%.

Transparency affects price impacts on ATSs and Non-ATSs in contrasting ways due to their distinct legal treatments. Increased transparency on both ATSs and Non-ATSs makes more liquid options appealing to both informed and uninformed investors in their respective domains. However, informed investors are more likely to independently make routing decisions to leverage their informational advantage, making them inclined to connect directly to both ATSs and Non-ATSs. In contrast, uninformed investors generally delegate routing decisions to their brokers, avoiding the expenditure of resources on developing infrastructure and routing algorithms. That is, while transparency leads uninformed investors to shift towards more liquid market centers as well, informed investors can more effectively capitalize on transparency initiatives due to their typical direct access to these platforms and autonomous decision-making. In this context, the impact of transparency on price impact primarily depends on the extent to which ATSs and Non-ATSs welcome informed orders, i.e., the ability of ATSs and Non-ATSs to exclude informed orders and their incentive to include them.

In the case of ATS transparency, informed investors can easily transition to liquid ATSs. Firstly, although ATSs also prefer to avoid dealing with informed orders, they face limitations in their legal capacity to resist them. This restriction arises from the legal obligation for ATSs to adhere strictly to predefined non-discretionary trading rules. Secondly, ATSs primarily execute multilateral orders on an agency basis. They match orders and charge access fees in return. Therefore, they have weaker economic incentives to completely exclude informed orders.[3] These market dynamics cause additional informed order flow to outweigh additional uninformed order flow following transparency on ATSs, resulting in more sub-

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[3]For instance, ATS-N forms reveal that out of 29 ATSs, 20 have hedge funds as subscribers, 21 have principal trading firms as subscribers, and 18 have issuers as subscribers. The utilization of ATSs by informed investors has also been studied in the literature. (Brogaard & Pan, 2022) analyze earnings announcements and demonstrate that higher trading volumes on dark pools, a type of ATSs, encourage investors to acquire information, as it allows them to hide their orders in dark pools before execution.

stantial price impacts on these platforms.

In the case of Non-ATS transparency, a comparable transition is more restricted since Non-ATSs possess both the ability and incentive to exclude informed orders. They can exercise discretion on a per-order basis, deciding which ones to execute internally and which ones to route out. This discretionary authority hinders the migration of informed investors to Non-ATSs following transparency. Additionally, Non-ATSs typically have knowledge of the identities of the counterparties, enabling them to better leverage their discretion. Their strong economic incentives to exclude informed orders arise from their frequent commitment of capital and engagement in bilateral trading as principals. As a consequence of these market dynamics, additional informed order flow is overshadowed by additional uninformed order flow following transparency on Non-ATSs, leading to reduced price impacts on these platforms.[4]

The results for market shares are consistent with the changes in market quality. Transparency leads to a more concentrated inflow of informed orders on ATSs, clustering predominantly on one side of the market. Consequently, transparency leads to a significant decrease in market shares for ATSs, that provide high liquidity for a stock, by 27% to 32%. In contrast, transparency increases the influx of uninformed orders on Non-ATSs, which are less likely to cluster on the same side of the market. As a result, transparency increases market shares for Non-ATSs, that supply high liquidity for a stock, by 5%. These findings align with the long-term consolidation trends: Non-ATSs have consolidated into two major players, while ATSs have remained fragmented.

The shifts in the nature of order flows after transparency also impact price improvements on ATSs and Non-ATSs. After transparency, ATSs provide 12.1% to 24.3% lower price improvements, aiming to partially offset the increased influx of informed order flow. Conversely, Non-ATSs can offer 15.3% to 20.0% higher price improvements, benefiting from interacting with a greater amount of uninformed order flow. These changes in price improvements can shed light on a recent debate regarding the accuracy of (Boehmer et al., 2021)'s (hereafter BJZZ) method to identify retail trades in NYSE Trade and Quote (TAQ) data. BJZZ's method hinges on a key assumption: retail orders, but not institutional orders, executed

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[4]Another contributing factor to this domination is retail order flow. Retail brokers have direct access to wholesalers, in contrast to their indirect access to ATSs (and exchanges) through wholesalers. In this environment, unlike ATS transparency, retail brokers can respond to Non-ATS transparency by sending more orders to more liquid wholesalers. This movement contributes to the dominance of uninformed order flow over informed order flow following transparency on Non-ATSs.

on off-exchange market centers (mainly wholesalers) receive minuscule price improvements. Consequently, BJZZ argues that off-exchange trade prints with negligible price improvements in TAQ likely pertain to retail investors. 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. Wholesalers may have been providing minimal price improvements prior to the implementation of Non-ATS transparency. BJZZ's sample period, spanning from January 2010 to December 2015, falls within the non-transparent era. However, Non-ATS transparency significantly increased price improvements on Non-ATSs, resulting in retail trades bearing a greater resemblance to institutional trades (type-II error). Both (R. Battalio et al., 2022) and (Barber et al., 2022) utilize more recent datasets: December 2021 and December 2021 to June 2022, respectively. During these periods, price improvements do not necessarily remain small for retail trades. In fact, both studies report that approximately 40% of the retail trades in their samples received significant price improvements. In addition to the type-II error, our results also indicate that BJZZ's method can falter in identifying retail trades due to a type-I error—mistakenly categorizing institutional trades as retail. ATS transparency significantly curtailed price improvements on ATSs, causing institutional trades to resemble retail trades more closely. Consequently, BJZZ's fundamental assumption is very likely to be invalidated during the transparent era due to both type-I and type-II errors. Our findings suggest that this phenomenon might represent a more recent trend. As a result, both BJZZ's assertion and the perspectives of their critics could simultaneously hold true.

Our paper also carries significant policy implications. On December 14, 2022, the Securities and Exchange Commission (SEC) proposed to amend the information required to be reported under Rule 605 of Regulation NMS.[5] These reports are mandatory standardized monthly disclosures on order execution quality for all market centers (exchanges, ATSs and Non-ATSs). Our paper underscores the complexities associated with treating dark trading platforms as a single entity and the challenges of regulating them collectively. A single policy initiative can yield contradictory outcomes for the two types of dark trading, emphasizing the intricate nature of these platforms.

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[5]See the original proposal here: Disclosure of Order Execution Information, Release No. 34-96493.

In light of our findings, we also propose a new policy. While trades executed on off-exchange market centers are promptly disseminated through the consolidated tape, trades carried out on ATSs and Non-ATSs are posted under the same code 'D'. It might be worth considering assigning distinct codes to trades executed on ATSs and Non-ATSs instead of grouping them using a uniform code, given their distinct legal and economic characteristics. This adjustment could enable investors to derive more refined insights from dark trading, make more informed venue choices, and consequently can improve overall market quality in the U.S. equities market.

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).[6] 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 economically.[7] Second, we show that whether post-trade 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 BJZZ's method to identify retail trades in TAQ data.

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[6]In the U.S. equities markets, ATSs used to consist of dark pools and electronic communication networks (ECNs) until 2016. 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.

[7](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.

We also contribute to the literature that studies execution quality in the U.S. equities market. In this literature, (Bessembinder & Kaufman, 1997) study execution quality of NYSE and NASD (A and A+B in Figure 1, respectively); (Huang, 2002) and (Goldstein, Shkilko, Van Ness, & Van Ness, 2008) study NASDAQ and ECNs (A+B and B in Figure 1, respectively).[8] (Boehmer, 2005), (Boehmer, Jennings, & Wei, 2007) and (O'Hara & Ye, 2011) study execution quality and include market centers from all 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 on Non-ATSs than on ATSs, transparency widens these gaps in market quality, and the differences in the results are related to different legal treatments of ATSs and Non-ATSs.

Our paper is also 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 demonstrates that transparency, even at a low frequency and with a significant delay, can have a substantial impact on market quality. We also highlight the challenges in regulating dark trading platforms as a whole, as the outcomes of policy initiatives, such as post-trade transparency, can vary significantly depending on whether they are 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 presents data and introduces our empirical model. We present the results for execution speeds and effective spreads in Section 4, realized spreads and price impacts in Section 5, market shares in Section 6, price improvements in Section 7, and overall market quality in Section 8. Section 9 discusses policy implications and concludes.

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[8]Although the Nasdaq Stock Market (NASD or NASDAQ) had been legally treated similarly to a national securities exchange before officially becoming a registered exchange in 2006, categorizing Nasdaq Stock Market as either A or B before 2006 is challenging. This difficulty arises because Nasdaq Stock Market acquired and operated ECNs as well. That is why we choose to label it as A+B in papers analyzing Nasdaq Stock Market before 2006. See (Anderson & Dyl, 2007) for more details.

2   Institutional Details

The U.S. equities market is highly fragmented, consisting of 16 exchanges, 29 ATSs and around 200 Non-ATSs as of November 2023. The past decade featured two important trends in the U.S. equities market. The first one is well-known. Off-exchange market centers' share of U.S. consolidated volume increased from 37% in 2014 to 44% in 2023. The current chairman of the Securities and Exchange Commission (SEC), Gary Gensler, has constantly expressed his concerns about the rapid growth of dark trading and its lack of sufficient transparency. For instance, in an interview with Marketwatch in February 2022, he stated that "when just under half the market goes to wholesalers or dark pools, then the investing public says, that limited transparency, it's harder to have that confidence..."[9]

The second trend is less well-known. The distribution of trades among off-exchange market centers changed significantly. ATSs' share of U.S. consolidated volume steadily decreased from 16% in 2014 to 11% in 2023, while Non-ATSs' share gradually rose from 21% in 2014 to 33% in 2023.[10] One reason for these trends is that six ATSs paid over $150 million in penalties to the SEC for violating federal securities laws from 2014 to 2016.[11] These violations eroded the confidence of some investors in ATSs, prompting them to trade more on exchanges and Non-ATSs (SEC, 2015). Our paper offers suggestive evidence that transparency can also play a partial role in these trends by diminishing market quality on ATSs while enhancing market quality on Non-ATSs.

2.1   Exchange and Off-Exchange (Dark) Trading Regulations

Figure 1 presents a summary of the regulations that govern trading on U.S. equities markets, including exchanges (A) and off-exchanges (B+C). Legally, market centers can be categorized into two main groups: market places and non-market places. According to Rule 3b–16 of the Exchange Act, a market center is considered a market place if it brings together the orders of '*multiple*' buyers and sellers and uses pre-determined '*non-discretionary*' methods...under which subscribers agree to the terms of the trade" (Section III, 63 FR 70844). Market places consist of exchanges (A in Figure 1) and ATSs (B in Figure 1). Market centers that violate any of the aforementioned "italicized" conditions for being a market place cannot register as

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[9]Other examples include but not limited to: his remarks at the Global Exchange and FinTech Conference in June 2021; SEC's press release in December 2022.

[10]Please see Figure 2 in Appendix C. The data on total consolidated volume and ATS volumes are extracted from the CBOE U.S. Equities Market Volume Summary and FINRA OTC Transparency Data, respectively. Non-ATS market share is calculated by subtracting the combined market shares of exchanges and ATSs from one.

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

neither exchanges nor ATSs. These centers are classified as non-market places and consist only of Non-ATSs (C in Figure 1).

Under the Exchange Act, to be considered an exchange, a market center must register with the SEC as a 'national securities exchange', subjecting it to the strictest regulations. As part of these regulations, exchanges must establish their own self-regulatory organizations (SROs). SROs are required to publicly file with the SEC any proposed rule change (15 U.S. Code § 78s(b)). Therefore, in addition to being required for pre-setting non-discretionary trading rules, exchanges must make them publicly available.[12] Besides, market centers registered as exchanges are required to display quotes and trading interests (pre-trade transparency) and cannot exclude any person from trading on their platforms unless this exclusion is deemed necessary in the public interest (the Fair Access Rule, 15 U.S. Code § 78f(c)).

A market center can choose not to register as a national securities exchange. In this case, it can choose to become an ATS or a Non-ATS. ATSs and Non-ATSs are jointly called off-exchanges. Similar to exchanges, ATSs are legally defined as market places. They must provide a multilateral trading platform (i.e., multiple buyers and sellers) and execute orders under pre-determined, written, non-discretionary trading rules and procedures. However, ATSs are subject to weaker regulations. ATSs fall under Regulation ATS, providing them with exemptions from certain rules that exchanges must adhere to. Firstly, ATSs are not obligated to establish their own SROs; instead, they register and operate as broker-dealers, and join FINRA, an SRO. Secondly, although ATSs are required to submit amendments to the SEC at least twenty days prior to implementing any material changes to their operations, including trading rules and procedures (17 CFR 242.301(b)(2)(i)), unlike exchanges, they do not publicly share detailed documents regarding their trading rules and procedures.[13] Thirdly, they are generally not required to and do mostly not display quotes.[14] Finally, ATSs are exempt from the Fair Access Rule unless they have 5% or more of the total consolidated trading volume for a stock persistently in the past six months. In practice, ATSs seldom surpass the 5% threshold for any stock. Therefore, unlike exchanges, ATSs are allowed to

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[12]You can find some examples on the following links: NYSE, NASDAQ, IEX, and SRO Filings.

[13]Since February 2019, ATSs have been required to publicly file Form ATS-N with the SEC and update these forms in the event of any material changes to their operations. Form ATS-N contains some information about the manner of operations of ATSs, such as subscribers, order types, and priorities. Nevertheless, compared to the publicly available information about trading rules on exchanges, ATS-N forms provide only a tiny fraction of the overall picture.

[14]There are two types of ATSs: electronic communication networks (ECNs) and dark pools. The former are required to display quotes and trading interests, while the latter have flexibility and generally choose not to display them. ECNs ceased to exist after 2015. Therefore, in the current U.S. equities market, unlike exchanges, ATSs lack pre-trade transparency.

exclude traders as subscribers under almost all circumstances.

Market centers that are not registered as exchanges or ATSs are called Non-ATSs. Non-ATSs are not legally classified as market places, and consequently, they are subject to even weaker regulations than ATSs. Similar to ATSs, Non-ATSs must comply with the Best Execution Rule (FINRA 5310), requiring them to execute customer trades under the most favorable terms given prevailing market conditions. However, as being non-market places, they have the flexibility to exercise discretion and judgment on an order-by-order basis for order handling and execution practices, without the need to pre-determine their trading rules and procedures. They can also modify trading rules and procedures without prior notice, allowing them to quickly adapt to different types of order flows that may impact their trading interests. Moreover, Non-ATSs have the option to be bilateral, meaning they can exclusively trade with their customers as the sole counterparty. Non-ATSs include, among others, wholesalers such as those operated by Citadel Securities and Virtu Americas, traditional trading desks such as UBS Securities and Barclays Capital Inc., and single dealer platforms like Virtu VEQ Link.

Despite ATSs and Non-ATSs falling under distinct regulatory frameworks and being subject to different regulations, they are often collectively termed as dark trading because trades on both platforms take place outside of exchanges. An important similarity between ATSs and Non-ATSs is that, unlike exchanges, both can exclude traders. However, whether to be a market place or not influences their ability and incentive to exclude traders, leading to variations in order flows. Specifically, this current market structure gives ATSs less ability and incentive to exclude informed orders compared to Non-ATSs on two grounds.

Firstly, market places must operate under written, non-discretionary trading rules and procedures. ATSs have the option to refuse a specific trader as a subscriber. However, in comparison to Non-ATSs, they possess less ability to exclude informed orders from accepted subscribers, as they are bound by previously determined rules. Non-ATSs, on the other hand, are not obligated to adhere strictly to fixed non-discretionary rules. Therefore, they retain some discretion in determining how to execute customers' orders, which in turn provides Non-ATSs with a certain level of protection from being exposed to risky order flows. They can decide which orders to execute internally (internalize) and which orders to route to other venues (externalize) on a dynamic basis, without pre-committing to a particular trading and routing procedure. They are also not required to wait for twenty days to modify their trading rules and therefore can respond to risky order flows more promptly.

Non-ATSs consider the ability to exercise discretion and judgment as essential components of their operations. In December 2022, the SEC proposed additional best execution requirements for broker-dealers to enhance execution quality ("BestEx Proposal"). The SEC is suggesting to require broker-dealers to establish detailed written rules and procedures to ensure compliance with best execution. The expected effects on ATSs are minimal, as they are already required to establish written trading rules and procedures as market places. However, this proposal would substantially limit Non-ATSs' discretion in order routing and execution practices.[15] Strong objections to the BestEx Proposal have been raised within the financial industry. For instance, Goldman Sachs & Co. LLC, as a Non-ATS, criticizes the BestEx Proposal for reducing broker-dealers' discretion and considers it a potential threat for execution quality, particularly for institutional investors. In their comment letter to the SEC, (Goldman Sachs, 2023), it is stated that the BestEx Proposal mandates broker-dealers to provide detailed plans for "how each order will be handled and/or routed over its order life", limiting their ability to make informed decisions using their judgment and discretion.

Secondly, market places must be multilateral, which necessitates the involvement of multiple buyers and multiple sellers. In simpler terms, a market place cannot exclusively execute orders against a single counterparty, including itself.[16] This dynamic implies distinct business models for ATSs and Non-ATS. ATSs primarily engage in agency trading, where they match orders and charge access fees.[17] In contrast, Non-ATSs frequently commit capital and trade directly with their customers as principals in a bilateral manner. Therefore, they have a strong incentive to exclude informed orders to avoid risking their own capital through principal trading. They typically exercise discretion to commit capital and internalize orders that exhibit lower price impact and externalize the others without committing capital.[18]

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[15]It is worth emphasizing that this proposal covers all broker-dealers, including ATSs, Non-ATSs, as well as trading centers that are not market centers, with the last category mainly comprising brokers, defined in section 3(a)(4)(A) of the Exchange Act as any person engaged in the business of effecting transactions in securities for the account of others.

[16]This requirement automatically disqualifies single dealer platforms from being market places. For instance, Virtu VEQ Link states that Virtu...is the contra party to all trades in its platform. Please see Regulation ATS, Section III(A)(2) for a discussion of being multilateral.

[17]While one side of the fee can be negative, the total fee remains positive.

[18]This type of behavior is also observed among wholesalers when handling retail orders. For instance, in June 2021, Douglas Cifu, the CEO of Virtu Americas, stated that 'approximately 40% of retail orders, including both market orders and non-marketable limit orders, handled by Virtu interact with...exchanges and ATSs or are displayed on lit exchanges'. It indicates that wholesalers use discretion to choose which orders execute internally. Indeed, the SEC expressed its concerns on this matter: in (SEC, 2023), it is stated that wholesalers tend to internalize a larger proportion of individual investor orders from retail brokers whose clients' orders, on average, demonstrate lower price impact.

Additionally, Non-ATSs typically have knowledge of the identities of their counter-parties. It helps them exercise their discretion effectively in discriminating informed orders from uninformed ones. They utilize smart algorithms to predict price impact using this proprietary identity information along with other information any market center could obtain, such as stock characteristics and market conditions.

In this market structure, compared to Non-ATSs, ATSs have less incentive to entirely exclude informed orders from their platforms as they operate on an agency trading model. "Someone else is adversely selected" is less painful than "I am adversely selected." ATS-N forms provide support to this argument, showing that the majority of ATSs accept hedge funds, principal trading firms, and issuers as subscribers. Moreover, access fees act as a deterrent for certain traders, likely to be uninformed, preventing them from having direct access to marketplaces. For instance, many retail brokers can only access exchanges and ATSs through wholesalers. Indeed, wholesalers often pay retail brokers to receive retail order flow, which are predominantly uninformed. This market dynamic leads to further segregation of informed and uninformed orders among ATSs and Non-ATSs.

2.2   Regulation Changes: ATS and Non-ATS Trade Transparency

All trades executed on ATSs and Non-ATSs are posted under the same code ("D") in the consolidated tape. While market participants can observe size and price information of off-exchange trades, they lack access to venue information that identifies the specific off-exchange market center where the trade took place. Consequently, trades executed in B and C cannot be individually distinguished in the consolidated tape. In an effort to increase post-trade transparency and enhance investor confidence, FINRA has implemented two crucial changes in off-exchange (dark) trading regulations. Starting in May 2014, in accordance with FINRA Rule 4552, 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 data from the consolidated tape, these new datasets include venue information along with volume and trade details. As a result, investors can now have a better understanding of the liquidity breakdown among market centers under B and C, as well as the liquidity breakdown between B and C. We will call the first change "ATS Trade Transparency" and the second change "Non-ATS Trade Transparency".[19]

[19]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

3 Data and Empirical Framework

We use SEC 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 market centers. We retrieve Dash-5 reports from various channels, including TAG/Audit, Vista One Solutions, S3, market centers' own websites, as well as archived reports on the Wayback Machine. An original Dash-5 report 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 focus on five market quality statistics: speed of executions, effective spreads, realized spreads, price impacts and price improvements. The measures are available only for market and marketable limit orders except for speed of executions and realized spreads.

We first determine which market center 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 a weighting variable. The final data includes one observation for each month, stock and 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 of 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.

For ATS Trade Transparency, the sample spans through March to August 2014. There are 10 ATSs whose Dash-5 reports are available during this period: 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).[20] In the control group, our sample in 2014 includes all

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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.

[20]It is worth emphasizing that Dash-5 reports do not exist for five of the ten largest ATSs, either because they combine statistical information on ATSs with their Non-ATSs and publish a single report or because they have no eligible covered orders to report under the SEC 605 Rule. Our sample excludes only UBS ATS among the top-ten ATSs that publish Dash-5 reports. While UBS ATS reports were available at the time, the platform is required to publicly post only a limited number of months of historical data and unwilling to share this data with us. We are in the process of purchasing additional data to enhance the robustness of

major exchanges within NYSE and Nasdaq as well as major Non-ATSs including but not limited to Citadel Securities, Citigroup Global Markets, G1 Execution Services, Goldman Sachs, Merrill Lynch, Morgan Stanley and Two Sigma Securities and UBS Securities.

For Non-ATS Trade Transparency, the sample spans through February to July 2016. There are 20 Non-ATSs whose Dash-5 reports are available during this period.[21] These Non-ATSs encompass all major wholesalers, traditional trading desks and single dealer platforms, including but not limited to BNY Mellon Capital Markets (BKMM), Citadel Securities (CDRG), Citigroup Global Markets (SBSH), G1 Execution Services (ETMM), Virtu Financial Capital Markets (EWTT), Credit Suisse Securities USA (FBCO), Goldman Sachs (GSCO), Merrill Lynch (MLCO), Morgan Stanley (MSCO), Knight Capital Americas (NITE), Two Sigma Securities (SOHO), Virtu Americas (TRIM), UBS Securities (UBSS). In the control group, our sample in 2016 includes all major exchanges within NYSE, Nasdaq and CBOE as well as all major ATSs including the five ATSs in the top-ten ATSs that publish Dash-5 reports.

Let m denote a market center's type, 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 other market centers to control for general market trends in market quality. The market quality statistic $\text{MarketQuality}_{itm}$ for stock i in month t in type m can be written as,

$$\text{MarketQuality}_{itm} = \alpha + \beta_{ATS} \times \text{ATS} + \beta_{POST} \times \text{POST} + \beta \left(\text{ATS} \times \text{POST} \right)$$
$$+ \text{Controls} + \text{FE} + \varepsilon_{itm} \tag{1}$$

Dependent Variables. We use five monthly (share-weighted) MarketQuality statistics: execution speeds, effective spread, realized spread, price impact, and price improvement. We 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 number of shares submitted.

Effective 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

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our results by including more ATSs in our analysis.

[21] There are indeed 38 Non-ATSs whose Dash-5 reports are available during this period. We do not include Non-ATSs that have less than 500 observations for the entire sampling period. The results are robust to including these small Non-ATSs.

(negative) difference between the execution price and the midpoint of the consolidated best bid and offer at the time that the order is received. *Realized spread* is considered a proxy for the profits derived from liquidity provision, 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 not directly observable in Dash-5. It is calculated as effective spread minus realized spread. We will also use percentage effective spread, realized spread and price impact, which are calculated by dividing effective spreads, realized 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 market centers 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 all shares executed in a market center. It is calculated for a given stock as Price Improvement (Ave) times total number of price-improved shares divided by total Dash-5 trading volume. We refer to the first (second) variable as unadjusted (adjusted) price improvement to ease communication.

When running Regression 1, we multiply effective spread, realized spread, price impact, price improvement, and speed of executions by 100 to express effective spreads, realized spreads, price impacts and price improvements in cents, and express execution speeds as percentages. We multiply percentage effective spread, realized spread and price impact by 10,000 to express them in basis points.

Independent Variables. ATS is equal to 1 if m is an ATS, and 0 if m is in control group (Non-ATSs and exchanges).[22] We include six months into our sample: three months before the change and three months after the change. POST is a dummy variable for post-policy periods, defined as: POST is equal to 1 if month t is the $1^{st}, 2^{nd},$ or 3rd month after the policy change, and 0 otherwise. For instance, for ATS Trade Transparency that became effective on June 2, 2014, POST = 1 for June-August 2014.

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[22]For Non-ATS 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 (ATSs and exchanges)

Pre-Policy ↓ Post-Policy

3 Months   3 Months
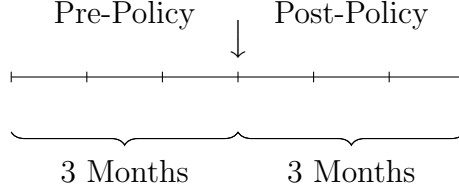
We compare the market quality over the first three months after the regulation change with the market quality over the past three months before the regulation change. β measures impacts of regulation changes and thus they are our coefficients of interest. β measures how much average market quality differs in the first three months after the regulation change compared to the last three months before the change. We include all ATSs, Non-ATSs, and exchanges whose Dash-5 reports are available during the sample period under analysis, except for some small aforementioned Non-ATSs. We include a stock in our analysis only if it is consistently traded in both the treatment and control groups. For ATS Trade Transparency, we compare ATSs with Non-ATSs and exchanges. For Non-ATS Trade Transparency, we compare Non-ATSs with ATSs and exchanges.

The controls include standard control variables in the literature: log number of trades and average intraday volatility from TAQ, and average order size from Dash-5.[23] We also include stock-level fixed effects. We winsorize the variables at 1% and 99% for each market center type separately and cluster standard errors at the stock level. Summary statistics during our sampling periods for ATS (Non-ATS) Trade Transparency are presented in Appendix A.1 (B.1). We present the results for speed of executions and effective spreads in Section 4, realized spreads and price impacts in Section 5, and price improvements in Section 7.

4   Execution Speeds and Transaction Costs

Whether implemented on ATSs or Non-ATSs, transparency increases execution speeds on their respective platforms because it allows investors to better locate and trade on more liquid market centers across fragmented off-exchange trading platforms. Table 1 (A) demonstrates how ATS Trade Transparency affects execution speeds on ATSs compared to other market centers. Execution speeds on ATSs are initially lower. After controlling stock-specific characteristics, ATSs execute 6.06% (6.52%) (6.79%) less shares within the first 9 (29) (59) seconds. ATS Trade Transparency helps ATSs narrow these gaps in execution speeds. Shares

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[23]See (Boehmer et al., 2007) and (O'Hara & Ye, 2011) for instance. The results are robust to inclusion of other controls such as share of institutional trading, inverse of stock price and market volatility index (VIX) as well as using trade and volatility variables from CRSP instead of TAQ. The results are also robust when we compare the first six months after the regulation change with the last three months before the change.

executed on ATSs compared to other market centers within the first 9 (29) (59) seconds increase by 1.24% (1.33%) (1.35%), which corresponds to 68.2% (71.0%) (70.9%) of pre-policy median speed of executions on ATSs, and 45.1% (47.2%) (47.2%) of pre-policy average speed of executions on ATSs.

(A) ATS Trade Transparency: ATSs vs. Others (Non-ATSs + Exchanges)

	(1) Speed (0-9)	(2) Speed (0-29)	(3) Speed (0-59)	(4) EfS (cent)	(5) EfS (bps)
ATS	-6.059***	-6.521***	-6.786***	-0.527***	-2.214***
	(0.0894)	(0.0930)	(0.0946)	(0.0674)	(0.410)
POST	-1.645***	-1.745***	-1.773***	-1.270***	-6.887***
	(0.0750)	(0.0790)	(0.0808)	(0.0676)	(0.491)
ATS_POST	1.239***	1.330***	1.350***	0.579***	2.636***
	(0.0820)	(0.0847)	(0.0858)	(0.0589)	(0.467)
N	40564	40564	40564	40564	40564

(B) Non-ATS Trade Transparency: Non-ATSs vs. Others (ATSs + Exchanges)

	(1) Speed (0-9)	(2) Speed (0-29)	(3) Speed (0-59)	(4) EfS (cent)	(5) EfS (bps)
NonATS	9.418***	9.524***	9.507***	2.274***	0.0797
	(0.241)	(0.250)	(0.253)	(0.148)	(0.941)
POST	0.189***	0.208***	0.221***	-0.347***	-5.205***
	(0.0369)	(0.0389)	(0.0396)	(0.0570)	(0.681)
NonATS_POST	1.995***	1.990***	1.972***	-0.175***	-2.950***
	(0.131)	(0.134)	(0.135)	(0.0505)	(0.427)
N	39790	39790	39790	39790	39790

Table 1: **Execution Speeds and Transaction Costs**
Speed (0-9) (0-29) (0-59) is the ratio of shares executed within 9 (29) (59) seconds to the total number of shares submitted. They are multiplied by **100** to express them as percentages. **EfS (cent)** is effective spread, 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, and multiplied by 100 to express them in cents. **EfS (bps)** is percentage effective spread, defined as effective spread divided by average monthly stock price, and multiplied by 10,000 to express them in basis points. **ATS** is equal to 1 for ATSs and 0 for other market centers. **POST** is 1 for transparent era and 0 for non-transparent era. **ATS_POST** is interaction term, ATS × POST. **NonATS** is equal to 1 for Non-ATSs and 0 for other market centers. **NonATS_POST** is interaction term, NonATS × POST. We also **control** average intraday quote-based volatility, log number of trades, average order size from Dash-5, and stock fixed effects. 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 1 (B) demonstrates how Non-ATS Trade Transparency affects execution speeds on Non-ATSs compared to other market centers. Execution speeds on Non-ATSs are initially

higher. After controlling stock-specific characteristics, Non-ATSs execute 9.42% (9.52%) (9.51%) more shares within the first 9 (29) (59) seconds. Non-ATS Trade Transparency widens these disparities in execution speeds. Shares executed on Non-ATSs compared to other market centers within the first 9 (29) (59) seconds increase by 2.00% (1.99%) (1.97%), which corresponds to 23.4% (23.1%) (22.7%) of pre-policy median speed of executions on ATSs, and 14.9% (14.5%) (14.3%) of pre-policy average speed of executions on Non-ATSs.

Despite these similarities in execution speeds, transparency affects traders' transaction costs, measured by effective spreads, on ATSs and Non-ATSs in opposite ways. Table 1 (A) demonstrates how ATS Trade Transparency affects effective spreads on ATSs compared to other market centers. ATSs initially have lower effective spreads. After controlling for stock-specific characteristics, ATSs have 0.53 cents (2.21 basis points) lower effective spreads (percentage effective spreads). ATS Trade Transparency increases transaction costs for traders on ATSs. Effective spreads (percentage effective spreads) on ATSs compared to other market centers increase by 0.58 cents (2.64 basis points), which corresponds to 18.4% (12.8%) [8.3% (5.2%)] of pre-policy median [average] effective spread (percentage effective spreads) on ATSs.

Transparency affects effective spreads on Non-ATSs in the opposite manner. Table 1 (B) demonstrates how Non-ATS Trade Transparency affects effective spreads on Non-ATSs compared to other market centers. Non-ATSs initially have 2.27 cents higher effective spreads, yet there is no statistically significant difference in percentage effective spreads between Non-ATSs and other market centers. Given that percentage effective spread is a better proxy for transaction costs for traders due to its immunity to stock splits, we can assert that traders face similar costs on Non-ATSs and other market centers before transparency. Non-ATS Trade Transparency reduces transaction costs for traders on Non-ATSs. Effective spreads (percentage effective spreads) on Non-ATSs compared to other market centers decrease by 0.18 cents (2.95 basis points), which corresponds to 5.1% (11.7%) [2.5% (4.1%)] of pre-policy median [average] effective spread (percentage effective spreads) on Non-ATSs.

5   Liquidity Provision Profits and Adverse Selection

Transaction costs have two components: profits derived from liquidity provision, measured by realized spreads, and adverse selection risk, measured by price impacts. Transparency affects transaction costs by changing adverse selection risks on ATSs and Non-ATSs because it has no impact on realized spreads in both cases. Table 2 (A) presents how ATS Trade

Transparency affects realized spreads and price impacts on ATSs compared to other market centers. ATSs make lower profits from supplying liquidity compared to other market centers. After controlling for stock-specific characteristics, realized spreads (percentage realized spreads) on ATSs are smaller by 1.08 cents (8.88 basis points). However, ATSs are exposed to more adverse selection. Price impacts (percentage price impacts) are higher on ATSs by 0.62 cents (6.93 basis points). Despite facing higher adverse selection risks, lower realized spreads induce traders to enjoy lower transaction costs on ATSs, as previously presented in Table 1 (A).

Transparency negatively impacts transaction costs for traders on ATSs by increasing adverse selection. It is because the introduction of transparency on ATSs primarily affects informed investors. Usually, they make their routing decisions themselves and therefore have direct access to these platforms, enabling them to more effectively adjust their venue selection criteria following transparency. ATSs face challenges in excluding these informed orders because, as market places, they must adhere to predetermined non-discretionary trading rules and procedures. ATSs also do not have strong incentives to exclude these informed orders as they match orders and collect fees on an agency basis.

In contrast, following transparency, uninformed investors have more limited movements to ATSs, often because they delegate routing decisions to their brokers. Additionally, some uninformed investors lack direct access to ATSs. For instance, many retail brokers can only access ATSs through wholesalers. As a result, ATSs see an increased influx of orders from informed investors following transparency, which outweighs additional uninformed orders and leads to larger price impacts on these platforms. Price impacts (percentage price impacts) on ATSs compared to other market centers increase by 0.57 cents (1.61 basis points), which corresponds to 19.6% (8.8%) [8.4% (3.4%)] of pre-policy median [average] price impacts (percentage price impacts) on ATSs.

Table 2 (B) presents how Non-ATS Trade Transparency affects realized spreads and price impacts on Non-ATSs compared to other market centers. Non-ATSs generate higher profits from providing liquidity compared to other market centers. This result is unsurprising given their greater ability to discriminate orders and customers. After controlling for stock-specific characteristics, realized spreads (percentage realized spreads) on Non-ATSs are higher by 2.44 cents (20.13 basis points). Additionally, Non-ATSs are exposed to less adverse selection. Price impacts (percentage price impacts) are lower on Non-ATSs by 0.24 cents (20.91 basis points). Despite lower adverse selection risks on Non-ATSs, traders cannot enjoy lower

transaction costs on Non-ATSs, as previously demonstrated in Table 1 (B), because of higher profit extractions from liquidity provision.

(A) ATS Trade Transparency: ATSs vs. Others (Non-ATSs + Exchanges)

	(1) ReS (cent)	(2) ReS (bps)	(3) P.Impact (cent)	(4) P.Impact (bps)
ATS	-1.075***	-8.876***	0.619***	6.930***
	(0.0565)	(0.533)	(0.0708)	(0.537)
POST	-0.494***	-4.393***	-0.754***	-2.216***
	(0.0417)	(0.409)	(0.0668)	(0.521)
ATS_POST	0.0144	0.720	0.565***	1.611*
	(0.0614)	(0.643)	(0.0766)	(0.682)
N	40564	40564	40564	40564

(B) Non-ATS Trade Transparency: Non-ATSs vs. Others (ATSs + Exchanges)

	(1) ReS (cent)	(2) ReS (bps)	(3) P.Impact (cent)	(4) P.Impact (bps)
NonATS	2.435***	20.13***	-0.241*	-20.91***
	(0.0819)	(0.737)	(0.117)	(0.897)
POST	-0.136***	-0.252	-0.227***	-4.900***
	(0.0341)	(0.404)	(0.0582)	(0.701)
NonATS_POST	0.0560	-0.774	-0.185**	-2.013**
	(0.0517)	(0.563)	(0.0667)	(0.632)
N	39790	39790	39790	39790

Table 2: **Liquidity Provision Profits and Adverse Selection**
ReS (cent) is realized spread, 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, and multiplied by 100 to express them in cents. **ReS (bps)** is percentage realized spread, defined as realized spread divided by average monthly stock price, and multiplied by 10,000 to express them in basis points. **P.Impact (cent)** is price impact, calculated as effective spread minus realized spread, and multiplied by 100 to express them in cents. **P.Impact (bps)** is percentage price impact, defined as price impact divided by average monthly stock price, and multiplied by 10,000 to express them in basis points. **ATS** is equal to 1 for ATSs and 0 for other market centers. **POST** is 1 for transparent era and 0 for non-transparent era. **ATS_POST** is interaction term, ATS × POST. **NonATS** is equal to 1 for Non-ATSs and 0 for other market centers. **NonATS_POST** is interaction term, NonATS × POST. We also **control** average intraday quote-based volatility, log number of trades, average order size from Dash-5, and stock fixed effects. Those coefficients are not presented to save space. Standard errors are clustered at the stock level. **Standard errors** are in parentheses; * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$.

Transparency decreases transaction costs for traders on Non-ATSs by further reducing adverse selection on these platforms. In contrast to ATS Trade Transparency, the movement of informed investors to liquid Non-ATSs is constrained in the case of Non-ATS Trade Trans-

parency. Non-ATSs have the capability to individually discriminate these orders, without pre-committing to any trading rules and procedures. They can exercise discretion on a per-order basis to determine which orders to handle internally and which to execute externally. This discretionary authority limits the migration of informed investors to Non-ATSs. In addition, the fact that Non-ATSs typically have knowledge of their counter-parties' identities (i.e., their customers) also enhances their ability to use discretion effectively. Non-ATSs also have strong incentives to push back informed orders because they often commit capital and trade directly with their customers in a bilateral manner as principals.

Furthermore, unlike ATS transparency, some uninformed investors, such as retail brokers, can quickly adapt to Non-ATS transparency because they usually have direct access to Non-ATSs. Transparency enables them to identify liquid Non-ATSs and make more informed routing decisions. Consequently, Non-ATSs experience a greater influx of uninformed order flow following transparency, dominating additional informed orders and leading to reduced price impacts on these platforms. Price impacts (percentage price impacts) on Non-ATSs compared to other market centers decrease by 0.19 cents (2.01 basis points), which corresponds to 8.2% (12.0%) [3.8% (4.1%)] of pre-policy median [average] price impacts (percentage price impacts) on Non-ATSs.

6   Market Shares and Consolidation

Transparency can affect market shares through network externalities: the more liquid a market center is, the easier it becomes to trade, making it more attractive to other traders. In essence, transparency can assist investors in establishing a focal point for trading. In the presence of network externalities, following transparency, more liquid market centers gain more market power and therefore we should observe consolidation of liquidity in a few large market centers. However, whether transparency creates network externalities also depends on the types of orders attracted. If higher liquidity attracts more informed orders than uninformed orders, transparency does not necessarily assist large market centers in gaining market power, as informed orders typically cluster on the same side of the market.

In this context, transparency can affect ATSs' and Non-ATSs' market shares differently because transparency increases informed order flow on ATSs, while increasing uninformed order flow on Non-ATSs, as demonstrated in Section 5. We examine how transparency affects the market shares of the largest 'k' ATSs and Non-ATSs. Specifically, we estimate the following market share equation:

$$\text{MarketShare}_{it}^{\text{Top(k)}} = \alpha + \beta \, \text{Post}_t + \text{ControlVariables}_{it} + \text{Stock FE} + \varepsilon_{it} \qquad (2)$$

where $\textbf{MarketShare}_{it}^{\textbf{Top(k)}}$ is the logit transformation of the sum of the kth largest ATSs' (or Non-ATSs) market shares for stock i in week t. It is worth emphasizing that Top(k) ATSs (Non-ATSs) are determined on a stock-by-stock basis and for each week separately. Hence, the composition of Top(k) ATSs (Non-ATSs) may vary from one stock to another and from one week to the next. We focus on $k = 1$ or $k = 2$. We rank trading venues based on their market shares before transparency shocks. The market share of an ATS (Non-ATS) is calculated by dividing the ATS (Non-ATS) volume by the total consolidated TAQ volume. The control variables consist of lagged weekly volume-weighted averages of the total number of trades, stock price, effective spread, quoted spread, and volatility, all sourced from TAQ. We also control stock fixed effects.

FINRA discloses ATS and Non-ATS data with a 2-week (4-week) delay for Tier 1 (2) stocks. Consequently, the initial 3 (5) weeks of data for Tier 1 (2) stocks remain unaffected by transparency, enabling an analysis with complete data. For example, the first ATS Tier-1 data was published on June 2, 2014 for the week 'May 12-16, 2014'. Therefore, the weeks 'May 12-16', 'May 19-23', and 'May 26-30' were not influenced by transparency. We examine six weeks for Tier 1 stocks and ten weeks for Tier 2 stocks. For Tier 1 (2) stocks, Post$_t$ is 1 for the first 3 (5) weeks after FINRA's initial publication of ATS or Non-ATS data, and 0 for the past 3 (5) weeks before the initial publication of ATS or Non-ATS data (e.g., Post$_t$ = 1 for the weeks following June 2, 2014 for ATS Transparency).

Table 3 (left) demonstrates how ATS Trade Transparency affects (logit-transformed) market shares of Top-1 and Top-2 ATSs. After controlling for stock-specific characteristics and stock fixed effects, the market shares of Top-1 (Top-2) ATSs decrease by 0.385 (0.316), corresponding to 32% (27%) of the pre-policy median market share of Top-1 (Top-2) ATSs. In contrast to ATSs, market shares of Top-1 and Top-2 Non-ATSs increase following transparency. Table 3 (right) demonstrates how Non-ATS Trade Transparency affects (logit-transformed) market shares of Top-1 and Top-2 Non-ATSs. After controlling for stock-specific characteristics and stock fixed effects, the market shares of Top-1 (Top-2) Non-ATSs increase by 0.052 (0.052), corresponding to 5% (5%) of the pre-policy median market share of Top-1 (Top-2) Non-ATSs.

(left) ATS Trade Transparency; (right) Non-ATS Trade Transparency

	(1)	(2)			(1)	(2)
	Top-1	Top-2			Top-1	Top-2
Post	-0.385***	-0.316***		Post	0.0516***	0.0516***
	(0.0128)	(0.00978)			(0.0135)	(0.0134)
N	26156	28414		N	2398	2452

Table 3: **Market Shares**

On the **left** table, **Top-1 (Top-2)** is the logit transformation of the sum of the largest (two largest) ATSs' market shares. On the **right** table, **Top-1 (Top-2)** is the logit transformation of the sum of the largest (two largest) Non-ATSs' market shares. The **market share** of an ATS (Non-ATS) is calculated by dividing the ATS (Non-ATS) volume by the total consolidated TAQ volume. Top(k) ATSs or Non-ATSs are determined on a stock-by-stock basis and for each week separately using market shares before transparency shocks. For Tier 1 (2) stocks, **Post** is 1 for the first 3 (5) weeks after FINRA's initial publication of ATS or Non-ATS data and 0 for the past 3 (5) weeks before the initial publication of ATS or Non-ATS data. We also **control** lagged weekly volume-weighted averages of the total number of trades, stock price, effective spread, quoted spread, volatility, and stock fixed effects. Those coefficients are not presented to save space. Standard errors are clustered at the stock level. **Standard errors** are in parentheses; * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$.

The differential impact of transparency on ATSs' and Non-ATSs' market shares can be attributed to the distinct effects of transparency on adverse selection. Transparency leads to a more concentrated inflow of informed orders on ATSs. Larger ATSs are more likely to attract more informed orders, who tend to cluster on one side of the market, thereby not resulting in an increase in market shares. There exists a natural boundary for matching informed orders, and more informed orders even have the potential to decrease market shares, particularly if uninformed counterparties decide to withdraw from the market to avoid increased exposure to adverse selection. In contrast, transparency results in a more concentrated inflow of uninformed orders on Non-ATSs. Larger Non-ATSs can attract more uninformed order flow, which are less likely to cluster on the same side of the market and therefore can lead to an increase in their market shares.

Table 4: **Turnover of Most Liquid Market Centers among ATSs and Non-ATSs**

	N	Mean	SD	1st Perc.	Median	99th Perc.
ATSs	3,291	**.47**	0.12	.18	**.48**	.70
Non-ATSs	3,291	**.11**	0.10	.01	**.08**	.42

To provide further support, we analyze turnover rates of most liquid market centers among ATSs and Non-ATSs. Specifically, we define Turnover$_i$ (ATS) (Non-ATS) as the fraction of weeks that the most liquid (ATS) (Non-ATS) changes for stock i. Table 4 presents the cross-sectional turnover statistics. The average turnover rate for ATSs is 0.47, which

implies that the most liquid ATS for a stock changes approximately once every two weeks (1/0.47 weeks). Non-ATSs are quite persistent in this respect. The average turnover rate for Non-ATSs is 0.11, meaning the most liquid Non-ATS for a stock changes approximately once every two months (1/0.11 weeks).

These results are in line with the long-term consolidation trends: Non-ATSs have consolidated into two major players, while ATSs have remained fragmented. Non-ATSs can achieve growth through uninformed orders—a liquid Non-ATS is likely to attract more uninformed orders, enhancing market quality and, in turn, attracting additional uninformed orders. This positive feedback loop can lead to consolidation among Non-ATSs. For example, Citadel Securities and Virtu Americas have expanded their market shares by executing retail orders through payment for order flow. However, there is a natural boundary on ATS consolidation. A liquid ATS attracts more informed order flow, leading to a deterioration in market quality over time. As a result, traders may shift to other liquid ATSs, creating a cycle that prevents the consolidation of ATSs into a few major players.

7   Price Improvements

The shifts in the nature of order flows after transparency influence price improvements on ATSs and Non-ATSs. A market center with a greater influx of uninformed investors is likely to offer higher price improvements compared to a market center mainly dealing with informed investors. Table 5 (A) presents how ATS Trade Transparency affect price improvements on ATSs compared to other market centers. Initially, after controlling stock-specific characteristics, ATSs have 0.23 cents lower unadjusted price improvements and 0.07 cents lower adjusted price improvements. Transparency reduces both price improvement measures on ATSs compared to other market centers. Unadjusted price improvements decrease on ATSs by 0.18 cents, which is equivalent to 24.3% (15.1%) of pre-policy median (average) unadjusted price improvement on ATSs. Similarly, adjusted price improvements decrease on ATSs by 0.01 cents, which is equivalent to 12.1% (7.0%) of pre-policy median (average) adjusted price improvement on ATSs.

Table 5 (B) presents how Non-ATS Trade Transparency affect price improvements on Non-ATSs compared to other market centers. Non-ATSs initially have higher unadjusted and adjusted price improvements. After controlling stock-specific characteristics, Non-ATSs offer 0.60 cents higher unadjusted price improvements and 0.92 cents higher adjusted price improvements. Transparency dramatically increases both price improvement measures on

Non-ATSs. Unadjusted price improvements on Non-ATSs increase by 0.15 cents, which is equivalent to 15.3% (8.3%) of pre-policy median (average) unadjusted price improvement on Non-ATSs. Adjusted price improvements on Non-ATSs increase by 0.11 cents, which is equivalent to 20.0% (10.9%) of pre-policy median (average) adjusted price improvement on Non-ATSs.

(A) ATS Trade Transparency: ATSs vs. Others (Non-ATSs + Exchanges)

	(1)	(2)
	P.Improve (Ave)	P.Improve (VolA)
ATS	-0.229***	-0.0739***
	(0.0167)	(0.00525)
POST	0.0253*	-0.0256***
	(0.0115)	(0.00308)
ATS_POST	-0.183***	-0.0146***
	(0.0165)	(0.00402)
N	40564	40564

(B) Non-ATS Trade Transparency: Non-ATSs vs. Others (ATSs + Exchanges)

	(1)	(2)
	P.Improve (Ave)	P.Improve (VolA)
NonATS	0.599***	0.923***
	(0.0374)	(0.0220)
POST	-0.0511***	-0.00355
	(0.0141)	(0.00399)
NonATS_POST	0.153***	0.105***
	(0.0158)	(0.00943)
N	39790	39790

Table 5: **Price Improvements**

P.Improve (Ave) is unadjusted average price improvement: share-weighted average dollar amount of improvements among shares executed with price improvements. **P.Improve (VolA)** is adjusted average price improvement (adjusted for trading volumes), calculated as P.Improve (Ave) × (number of price improved shares) / (total trading volume in Dash-5). Both variables are multiplied by **100** to express them in **cents**. **ATS** is equal to 1 for ATSs and 0 for other market centers. **POST** is 1 for transparent era and 0 for non-transparent era. **ATS_POST** is interaction term, ATS × POST. **NonATS** is equal to 1 for Non-ATSs and 0 for other market centers. **NonATS_POST** is interaction term, NonATS × POST. We also **control** average intraday quote-based volatility, log number of trades, average order size from Dash-5, and stock fixed effects. Those coefficients are not presented to save space. Standard errors are clustered at the stock level. **Standard errors** are in parentheses; * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$.

These changes in price improvements can shed light on a recent debate regarding the accuracy of BJZZ's method to identify retail trades in NYSE Trade and Quote (TAQ) data.

BJZZ's method relies on a crucial assumption: retail orders, but not institutional orders, executed on off-exchange market centers (mainly wholesalers) receive minuscule price improvements. This assumption implies that off-exchange trade prints with negligible price improvements in TAQ are likely to be sent from retail investors. However, (R. Battalio et al., 2022) and (Barber et al., 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. It's possible that, before the introduction of Non-ATS transparency, wholesalers were offering minimal price improvements. BJZZ's study covers the period from January 2010 to December 2015, which falls within the non-transparent era. However, the implementation of transparency on Non-ATSs significantly increased price improvements, making retail trades more closely resemble institutional trades (type-II error). Both (R. Battalio et al., 2022) and (Barber et al., 2022) use more recent data, from December 2021 and December 2021 to June 2022, respectively. During these periods, retail trades are not necessarily experiencing minimal price improvements. In fact, both studies report that approximately 40% of retail trades they analyzed received significant price improvements.

In addition to type-II error, our results also indicate the possibility of increased type-I errors in BJZZ's method—mistakenly categorize institutional trades as retail. The introduction of transparency on ATSs significantly reduced price improvements on these platforms, leading institutional trades to closely resemble retail trades. Consequently, BJZZ's fundamental assumption is likely to be invalidated during the transparent era due to both type-I and type-II errors. Our findings suggest that these dynamics could be a more recent phenomenon. Therefore, both BJZZ's assertion and the perspectives of their critics could potentially be valid at the same time, as their samples have distinct characteristics.

8   Overall Market Quality

Our final analysis aims to examine how transparency affects overall market quality. Identifying the causal impact of transparency on overall market quality is challenging because, unlike our previous analysis of ATSs and Non-ATSs, there is no control group. Although we include control variables and stock fixed effects to mitigate this problem and enhance identification, it is important to note that this analysis pertains to a single event, limiting our statistical capacity to attribute changes solely to this event (Boehmer, Saar, & Yu, 2005).

Specifically, we estimate the following market quality equation:

$$\text{MarketQuality}_{it} = \alpha + \beta\,\text{Post}_t + \text{ControlVariables}_{it} + \text{Stock FE} + \varepsilon_{it} \qquad (3)$$

We utilize three market quality metrics sourced from WRDS TAQ Intraday Indicators Data: effective spread, realized spread, and price impact.[24] The TAQ data encompasses all trades and market centers. We conduct our analysis on the same stocks and during the same sampling period as in the previous market share analysis in Section 6, defining Post_t in the same manner, with a minor difference. We estimate Equation 3 using daily data because, unlike FINRA data used in the estimation of Equation 2, TAQ data allows us to perform analyses at a daily frequency. For Tier 1 (2) stocks, Post_t is 1 if day t falls within the first 3 (5) weeks after FINRA's initial publication of ATS or Non-ATS data and 0 if it falls within the preceding 3 (5) weeks before the initial publication of ATS or Non-ATS data. Our control variables include lagged daily total number of trades, total number of shares traded, stock price, quoted spread, volatility and buy-sell order imbalance, all derived from TAQ. Additionally, we include contemporaneous VIX Index and S&P 500 returns to control for general market events, along with stock fixed effects.

(left) ATS Trade Transparency; (right) Non-ATS Trade Transparency

	(1) EfS (bps)	(2) ReS (bps)	(3) P.Impact (bps)		(1) EfS (bps)	(2) ReS (bps)	(3) P.Impact (bps)
Post	-0.301	-0.675	0.535	Post	-0.634	-1.010*	0.576
	(0.394)	(0.411)	(0.333)		(0.414)	(0.407)	(0.344)
N	151176	151176	151176	N	153098	153098	153098

Table 6: **Overall Market Quality**

EfS (bps) represents daily effective spread, **ReS (bps)** stands for daily realized spread, and **P.Impact (bps)** denotes daily price impact, all obtained directly from TAQ Intraday Indicators. Each of these variables is expressed in basis points. For Tier 1 (2) stocks, **Post** is 1 for the first 3 (5) weeks after FINRA's initial publication of ATS or Non-ATS data and 0 for the past 3 (5) weeks before the initial publication of ATS or Non-ATS data. We also **control** lagged daily total number of trades, total number of shares traded, stock price, quoted spread, volatility, all derived from TAQ, as well as control for contemporaneous daily VIX Index and S&P 500 returns, and stock fixed effects. 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 (left) illustrates the impact of ATS Trade Transparency on overall effective spread, realized spread, and price impact. Transparency on ATSs shows no significant impact on overall market quality. We previously demonstrate that transparency on ATSs increases effective spreads and price impacts on ATSs compared to other market centers. In this con-

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[24]Execution speeds and price improvements are not calculated in TAQ Intraday Indicators Data.

text, the overall market quality results suggest that some traders benefit from transparency by facing lower transaction costs and adverse selection risks at the expense of some other traders, so that overall transaction costs and adverse selection risks remain the same. Additionally, transparency appears to exert no influence on the overall profits derived from liquidity provision. This outcome aligns with our earlier finding that transparency does not alter realized spreads on ATSs when compared to other market centers.

Table 6 (right) demonstrates how Non-ATS Trade Transparency affects overall effective spread, realized spread and price impact. The results for effective spread and price impact mirror those observed for ATS transparency. However, realized spreads exhibit a decrease following the implementation of transparency on Non-ATSs. While we previously demonstrated that transparency on Non-ATSs does not influence realized spreads compared to other market centers, the observed change in overall realized spreads lacks a clear attribution to transparency without a better identification method. It leaves room for the influence of either transparency or broader market trends.

9 Concluding Remarks and Policy Implications

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 be multilateral and use predetermined non-discretionary rules and procedures to execute orders. In contrast, Non-ATSs are not legally recognized as market places, allowing them to use discretionary methods when executing trades as well as trading with their customers in a bilateral manner. In this study, we examine two identical and exogenous transparency shocks—one implemented on ATSs and another on Non-ATSs—and show that legal distinctions between ATSs and Non-ATSs can lead to significant economic differences in their market quality.

We present two novel empirical findings. First, ATSs generally exhibit lower market quality than Non-ATSs. Second, transparency tends to exacerbate these differences: it usually decreases market quality on ATSs, while improving it on Non-ATSs. Transparency unequivocally enhances execution speeds on both ATSs and Non-ATSs. However, beyond this impact, transparency exerts contrasting effects on the market quality of ATSs and Non-ATSs. It heightens transaction costs and adverse selection risks on ATSs while diminishing them on Non-ATSs. The results for market shares align with the changes in market quality. Transparency on ATSs leads to the most liquid ATSs to attract more informed orders,

experience worsened market quality, and subsequently lose market power. In contrast, transparency on Non-ATSs induces the most liquid Non-ATSs to attract more uninformed orders, enjoy improved market quality, and subsequently gain market power.

Transparency also has contrasting effects on price improvements on ATSs and Non-ATSs. It decreases price improvements on ATSs, while increasing them on Non-ATSs. These changes in the dynamics of price improvements can partially shed light on a recent debate regarding the accuracy of BJZZ's method to identify retail trades in TAQ data. Our results suggest that improved transparency on ATSs and Non-ATSs can partially explain the disparities between BJZZ's paper and the findings of their two critiques ((R. Battalio et al., 2022) and (Barber et al., 2022)), potentially reconciling them to a certain extent.

Additionally, our paper is closely tied to a recent SEC proposal aimed at enhancing the disclosure of order execution information, thereby carrying significant policy implications. We underscore the complexities associated with treating dark trading platforms as a single entity and the challenges of regulating them collectively. A single policy initiative can yield contradictory outcomes for the two types of dark trading. This proposal can also be viewed as an effort to enhance transparency, similar in nature to ATS and Non-ATS transparency. In this context, our paper suggests that this policy proposal could affect market quality on ATSs and Non-ATSs differently.

Our paper also has a new policy implication. 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". It might be worth considering assigning distinct codes to trades executed on ATSs and Non-ATSs instead of grouping them under a uniform code, given their legal and economic distinctions. This adjustment could enable investors to derive more refined insights from dark trading, make more informed venue choices, and improve overall market quality in the U.S. equities market.

References

Aghanya, D., Agarwal, V., & Poshakwale, S. (2020). Market in Financial Instruments Directive (MiFID), stock price informativeness and liquidity. *Journal of Banking and Finance*, *113*, 105730. Retrieved from https://doi.org/10.1016/j.jbankfin.2019.105730 doi: 10.1016/j.jbankfin.2019.105730

Anand, A., Samadi, M., Sokobin, J., & Venkataraman, K. (2021). Institutional Order Handling and Broker-Affiliated Trading Venues. *Review of Financial Studies*, *34*(7), 3364–3402. doi: 10.1093/rfs/hhab004

Anderson, A. M., & Dyl, E. A. (2007). Trading volume: Nasdaq and the nyse. *Financial Analysts Journal*, *63*, 79-86.

Barber, B. M., Huang, X., Jorion, P., Odean, T., & Schwarz, C. (2022). A (Sub)penny For Your Thoughts: Tracking Retail Investor Activity in TAQ. *SSRN Electronic Journal*. Retrieved from https://papers.ssrn.com/abstract=4202874

Battalio, R., & Jennings, R. (2022). Why Do Brokers Who Do not Charge Payment for Order Flow Route Marketable Orders to Wholesalers? *SSRN Electronic Journal*. doi: 10.2139/ssrn.4304124

Battalio, R., Jennings, R., Saglam, M., & Wu, J. (2022). Identifying Market Maker Trades as " Retail " from TAQ : No Shortage of False Negatives and False Positives.

Battalio, R. H. (1997). Third Market Broker-Dealers: Cost Competitors or Cream Skimmers? *The Journal of Finance*, *52*(1), 341. doi: 10.2307/2329567

Bessembinder, H., & Kaufman, H. M. (1997). A cross-exchange comparison of execution costs and information flow for NYSE-listed stocks. *Journal of Financial Economics*, *46*(3), 293–319. doi: 10.1016/S0304-405X(97)00032-9

Board, J., & Sutcliffe, C. (2000). The proof of the pudding: The effects of increased trade transparency in the London stock exchange. *Journal of Business Finance and Accounting*, *27*(7-8), 887–909. doi: 10.1111/1468-5957.00338

Boehmer, E. (2005). Dimensions of execution quality: Recent evidence for US equity markets. *Journal of Financial Economics*, *78*(3), 553–582. doi: 10.1016/j.jfineco.2004.11.002

Boehmer, E., Jennings, R., & Wei, L. (2007). Public disclosure and private decisions: Equity market execution quality and order routing. *Review of Financial Studies*, *20*(2), 315–358. doi: 10.1093/rfs/hhl011

Boehmer, E., Jones, C. M., Zhang, X., & Zhang, X. (2021). Tracking Retail Investor Activity. *Journal of Finance*, *76*(5), 2249–2305. doi: 10.1111/jofi.13033

Boehmer, E., Saar, G., & Yu, L. (2005). Lifting the veil: An analysis of pre-trade transparency at the nyse. *Journal of Finance*, *60*, 783-815. doi: 10.1111/j.1540-6261.2005.00746.x

Brogaard, J., & Pan, J. (2022). Dark Pool Trading and Information Acquisition. *Review of Financial Studies*, *35*(5), 2625–2666. doi: 10.1093/rfs/hhab098

Buti, S., Rindi, B., & Werner, I. M. (2022). Diving into dark pools. *Financial Management*, 961–994. doi: 10.1111/fima.12395

Comerton-Forde, C., Malinova, K., & Park, A. (2018). Regulating dark trading: Order flow segmentation and market quality. *Journal of Financial Economics*, *130*(2), 347–366. doi: 10.1016/j.jfineco.2018.07.002

Comerton-Forde, C., & Putniņš, T. J. (2015). Dark trading and price discovery. *Journal of Financial Economics*, *118*(1), 70–92. doi: 10.1016/j.jfineco.2015.06.013

Degryse, H., De Jong, F., & Kervel, V. V. (2015). The impact of dark trading and visible fragmentation on market quality. *Review of Finance*, *19*(4), 1587–1622. doi: 10.1093/rof/rfu027

Dyhrberg, A. H., Shkilko, A., & Werner, I. M. (2022). The Retail Execution Quality Landscape. *SSRN Electronic Journal*(February). Retrieved from https://www.ssrn.com/abstract=4313095 doi: 10.2139/ssrn.4313095

Eaton, G. W., Green, T. C., Roseman, B. S., & Wu, Y. (2022). Retail trader sophistication and stock market quality : Evidence from brokerage outages. , *146*, 502–528. doi: 10.1016/j.jfineco.2022.08.002

Ernst, T., & Spatt, C. (2022, mar). Payment for Order Flow And Asset Choice. *NBER Working Paper Series*. Retrieved from http://www.nber.org/papers/w29883.pdf doi: 10.3386/w29883

Fink, J., Fink, K. E., & Weston, J. P. (2006). Competition on the Nasdaq and the growth of electronic communication networks. *Journal of Banking and Finance*, *30*(9), 2537–2559. doi: 10.1016/j.jbankfin.2005.10.009

Foley, S., & Putniņš, T. J. (2016). Should we be afraid of the dark? Dark trading and market quality. *Journal of Financial Economics*, *122*(3), 456–481. doi: 10.1016/j.jfineco.2016.08.004

Gemmill, G. (1996, dec). Transparency and Liquidity: A Study of Block Trades on the London Stock Exchange under Different Publication Rules. *The Journal of Finance*, *51*(5), 1765. Retrieved from https://www.jstor.org/stable/2329537?origin=crossref doi: 10.2307/2329537

Goldman Sachs. (2023). Comment Letter on the SEC's Proposal for Regulation Best Execution. Retrieved from https://www.sec.gov/comments/s7-31-22/s73122-20162888-332491.pdf

Goldstein, M. A., Shkilko, A. V., Van Ness, B. F., & Van Ness, R. A. (2008). Competition in the market for NASDAQ securities. *Journal of Financial Markets*, *11*(2), 113–143. doi: 10.1016/j.finmar.2007.07.002

Hatheway, F., Kwan, A., & Zheng, H. (2017). An empirical analysis of market segmentation on U.S. equity markets. *Journal of Financial and Quantitative Analysis*, *52*(6), 2399–2427. doi: 10.1017/S0022109017000849

Hendershott, T., & Jones, C. M. (2005). Island goes dark: Transparency, fragmentation, and regulation. *Review of Financial Studies*, *18*(3), 743–793. doi: 10.1093/rfs/hhi013

Hu, E., & Murphy, D. (2022). Competition for Retail Order Flow and Market Quality. *SSRN Electronic Journal*, *i*. doi: 10.2139/ssrn.4070056

Huang, R. D. (2002). The quality of ECN and Nasdaq market maker quotes. *Journal of Finance*, *57*(3), 1285–1319. doi: 10.1111/1540-6261.00461

Jain, P. K., Mishra, S., Donoghue, S. M. O., & Zhao, L. (2023). Trading Volume Shares and Market Quality : Pre- and Post- Zero Commissions. (February).

Kelley, E. K., & Tetlock, P. C. (2013). How Wise Are Crowds? Insights from Retail Orders and Stock Returns. *Journal of Finance*, *68*(3), 1229–1265. doi: 10.1111/jofi.12028

Kothari, S., Johnson, T. L., & So, E. C. (2021). Commission Savings and Execution Quality for Retail Trades. *SSRN Electronic Journal*, 1–16. doi: 10.2139/ssrn.3976300

Menkveld, A. J., Yueshen, B. Z., & Zhu, H. (2017). Shades of darkness: A pecking order of trading venues. *Journal of Financial Economics*, *124*(3), 503–534. Retrieved from http://dx.doi.org/10.1016/j.jfineco.2017.03.004 doi: 10.1016/j.jfineco.2017.03.004

O'Hara, M. (2015). High frequency market microstructure. *Journal of Financial Economics*, *116*(2), 257–270. Retrieved from http://dx.doi.org/10.1016/j.jfineco.2015.01.003 doi: 10.1016/j.jfineco.2015.01.003

O'Hara, M., & Ye, M. (2011). Is market fragmentation harming market quality? *Journal of Financial Economics*, *100*(3), 459–474. Retrieved from http://dx.doi.org/10.1016/j.jfineco.2011.02.006 doi: 10.1016/j.jfineco.2011.02.006

Porter, D. C., & Weaver, D. G. (1998). Post-trade transparency on Nasdaq's national market system. *Journal of Financial Economics*, *50*(2), 231–252. doi: 10.1016/S0304-405X(98)00037-3

SEC. (2015). Shedding Light on Dark Pools The Role that ATSs Play in Our Markets Today. , 6–11.

SEC. (2023). Order Competition Rule. *Federal Register, Proposed Rules*, *88*(No 1), 128–245.

Thomas, J., Zhang, F., & Zhu, W. (2021). Dark Trading and Post-Earnings-Announcement Drift. *Management Science*, *67*(12), 7785–7811. doi: 10.1287/mnsc.2020.3828

Appendix

A   ATS Trade Transparency

A.1   Summary Statistics

Dash-5 Statistics

	N	Mean	Std.Dev.	1st Perc.	Median	99th Perc.
Effective Spread						
ATSs	20,172	0.067	0.097	0.007	0.031	0.560
Non-ATSs	20,172	0.079	0.108	0.006	0.039	0.605
Exchanges	20,094	0.059	0.086	0.007	0.027	0.530
Realized Spread						
ATSs	20,172	0.001	0.047	-0.167	0.001	0.150
Non-ATSs	20,172	0.033	0.068	-0.059	0.013	0.358
Exchanges	20,094	0.002	0.040	-0.112	0.000	0.134
Price Impact						
ATSs	20,172	0.064	0.090	-0.006	0.029	0.480
Non-ATSs	20,172	0.047	0.069	-0.010	0.022	0.365
Exchanges	20,094	0.057	0.085	-0.001	0.027	0.527
% Effective Spread						
ATSs	20,172	0.494%	0.713%	0.014%	0.199%	3.700%
Non-ATSs	20,172	0.587%	0.801%	0.014%	0.254%	3.899%
Exchanges	20,094	0.468%	0.708%	0.014%	0.169%	3.724%
% Realized Spread						
ATSs	20,172	0.030%	0.410%	-1.373%	0.003%	1.651%
Non-ATSs	20,172	0.232%	0.489%	-0.486%	0.081%	2.518%
Exchanges	20,094	0.022%	0.370%	-1.086%	0.000%	1.503%
% Price Impact						
ATSs	20,172	0.458%	0.683%	-0.028%	0.181%	3.414%
Non-ATSs	20,172	0.359%	0.557%	-0.048%	0.136%	2.903%
Exchanges	20,094	0.448%	0.692%	-0.001%	0.165%	3.724%

Table 7: **(ATS Trade Transparency) Summary Statistics Part I**

The sample covers six months: March – August 2014. **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. **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. **Price Impact** is effective spread minus realized spread. **Percentage effective spread, realized spread, and price impact** are respectively calculated by dividing effective spreads, realized spreads and price impacts by stocks' average monthly prices.

Dash-5 Statistics

	N	Mean	Std.Dev.	1st Perc.	Median	99th Perc.
Price Improve (Ave)						
ATSs	20,172	0.011	0.012	0.000	0.007	0.075
Non-ATSs	20,172	0.013	0.015	0.001	0.008	0.083
Exchanges	20,094	0.016	0.013	0.000	0.013	0.082
Price Improve (VolA)						
ATSs	20,172	0.002	0.003	0.000	0.001	0.013
Non-ATSs	20,172	0.006	0.007	0.000	0.004	0.035
Exchanges	20,094	0.001	0.002	0.000	0.001	0.012
Speed (0-9)						
ATSs	20,172	89%	7%	65%	91%	100%
Non-ATSs	20,172	89%	7%	63%	90%	100%
Exchanges	20,094	80%	7%	61%	80%	100%
Speed (20-29)						
ATSs	20,172	92%	6%	69%	94%	100%
Non-ATSs	20,172	92%	5%	70%	93%	100%
Exchanges	20,094	85%	6%	67%	85%	100%
Speed (30-59)						
ATSs	20,172	94%	6%	72%	95%	100%
Non-ATSs	20,172	93%	5%	73%	94%	100%
Exchanges	20,094	89%	6%	70%	89%	100%
Ave. Trade Size (605)						
ATSs	20,172	795	663	10	634	3,337
Non-ATSs	20,172	1,544	919	11	1,394	4,051
Exchanges	20,094	718	628	10	513	3,195

Table 8: **(ATS Trade Transparency) Summary Statistics Part I (cont.)**

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 number of shares submitted. **Ave. Trade Size (605)** is average order size in Dash-5. It is defined as total number of covered shares divided by total number of covered orders, and calculated using SEC 605 reports.

Market Level Statistics (TAQ)

	N	Mean	Std.Dev.	1st Perc.	Median	99th Perc.
Quoted Spread	20,172	0.055	0.113	0.010	0.010	0.740
% Quoted Spread	20,172	0.519%	1.030%	0.008%	0.108%	5.714%
Total Number of Trades (x1000)	20,172	115	229	0.2	37	1,058
Ave. Trade Size	20,172	161	126	1	133	668
Market Cap (million)	20,172	5,055	16,081	10	652	91,219

Table 9: **(ATS Trade Transparency) Summary Statistics Part II**

Market level statistics are obtained from Daily TAQ Intraday Indicators. The statistics are at the market level: TAQ calculates them using all trades in all platforms on a given day. The table presents monthly weighted averages where we use total daily number of shares traded in TAQ as the weighting variable.

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 10: **(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 11: **(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 12: **(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 number of shares submitted.

B   Non-ATS Trade Transparency

B.1   Summary Statistics

Dash-5 Statistics

	N	Mean	Std.Dev.	1st Perc.	Median	99th Perc.
Effective Spread						
ATSs	19,951	0.067	0.099	0.004	0.032	0.595
Non-ATSs	19,964	0.067	0.098	0.005	0.033	0.574
Exchanges	19,964	0.059	0.087	0.005	0.029	0.527
Realized Spread						
ATSs	19,951	0.009	0.045	-0.086	0.003	0.203
Non-ATSs	19,964	0.022	0.062	-0.085	0.008	0.319
Exchanges	19,964	-0.001	0.028	-0.085	0.000	0.076
Price Impact						
ATSs	19,951	0.056	0.080	-0.002	0.027	0.455
Non-ATSs	19,964	0.045	0.070	-0.002	0.021	0.394
Exchanges	19,964	0.059	0.082	0.003	0.030	0.466
% Effective Spread						
ATSs	19,951	0.664%	0.984%	0.016%	0.230%	4.660%
Non-ATSs	19,964	0.681%	0.996%	0.016%	0.247%	4.582%
Exchanges	19,964	0.635%	0.965%	0.019%	0.204%	4.561%
% Realized Spread						
ATSs	19,951	0.154%	0.543%	-0.862%	0.016%	2.837%
Non-ATSs	19,964	0.237%	0.556%	-0.661%	0.059%	2.800%
Exchanges	19,964	0.008%	0.317%	-1.040%	-0.002%	1.277%
% Price Impact						
ATSs	19,951	0.501%	0.737%	-0.007%	0.196%	3.790%
Non-ATSs	19,964	0.443%	0.697%	-0.007%	0.161%	3.593%
Exchanges	19,964	0.617%	0.924%	0.018%	0.205%	4.241%

Table 13: **(Non-ATS Trade Transparency) Summary Statistics Part I**

The sample covers six months: January – June 2016. **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. **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. **Price Impact** is effective spread minus realized spread. **Percentage effective spread, realized spread, and price impact** are respectively calculated by dividing effective spreads, realized spreads and price impacts by stocks' average monthly prices.

Dash-5 Statistics

	N	Mean	Std.Dev.	1st Perc.	Median	99th Perc.
Price Improve (Ave)						
ATSs	19,951	0.017	0.021	0.001	0.010	0.130
Non-ATSs	19,964	0.018	0.024	0.001	0.010	0.132
Exchanges	19,964	0.017	0.018	0.001	0.012	0.116
Price Improve (VolA)						
ATSs	19,951	0.005	0.007	0.000	0.003	0.041
Non-ATSs	19,964	0.010	0.012	0.000	0.005	0.058
Exchanges	19,964	0.001	0.003	0.000	0.000	0.014
Speed (0-9)						
ATSs	19,951	92%	5%	71%	93%	100%
Non-ATSs	19,964	94%	5%	72%	95%	100%
Exchanges	19,964	77%	6%	66%	76%	94%
Speed (10-29)						
ATSs	19,951	94%	4%	78%	95%	100%
Non-ATSs	19,964	96%	4%	80%	96%	100%
Exchanges	19,964	84%	6%	71%	83%	97%
Speed (30-59)						
ATSs	19,951	96%	4%	81%	97%	100%
Non-ATSs	19,964	96%	4%	82%	97%	100%
Exchanges	19,964	88%	6%	75%	88%	98%
Ave. Trade Size (605)						
ATSs	19,951	1,041	743	10	880	3,670
Non-ATSs	19,964	1,481	883	10	1,330	3,878
Exchanges	19,964	655	597	10	446	3,041

Table 14: **(Non-ATS Trade Transparency) Summary Statistics Part I (cont.)**
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 number of shares submitted. **Ave. Trade Size (605)** is average order size in Dash-5. It is defined as total number of covered shares divided by total number of covered orders, and calculated using SEC 605 reports.

Market Level Statistics (TAQ)

	N	Mean	Std.Dev.	1st Perc.	Median	99th Perc.
Quoted Spread	19,964	0.053	0.119	0.003	0.010	0.740
% Quoted Spread	19,964	0.678%	1.341%	0.009%	0.106%	6.202%
Total Number of Trades (x1000)	19,964	139	293	0.1	38	1,396
Ave. Trade Size	19,964	157	180	1	127	689
Market Cap (million)	19,964	4,922	16,338	8	532	103,390

Table 15: **(Non-ATS Trade Transparency) Summary Statistics Part II**
Market level statistics are obtained from Daily TAQ Intraday Indicators. The statistics are at the market level: TAQ calculates them using all trades in all platforms on a given day. The table presents monthly weighted averages where we use total daily number of shares traded in TAQ as the weighting variable.

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 16: **(Non-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 17: **(Non-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 18: **(Non-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 19: **(Non-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 number of shares submitted.

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 20: **(Non-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 number of shares submitted.
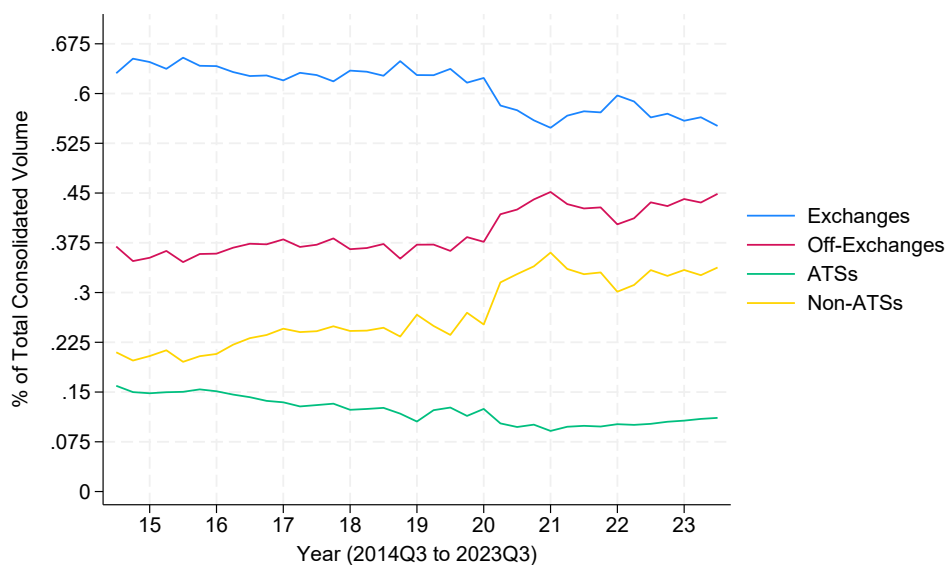
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Figure 2: Trends on ATSs' and Non-ATSs' Shares of U.S. Consolidated Volume

Note: The **y-axis** is fraction of total consolidated volume happening on exchanges, off-exchanges, ATSs or Non-ATSs. The **x-axis** is quarters spanning from 2014Q2 to 2023Q3. **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.