Journal of Financial Economics 155 (2024) 103818

Contents lists available at ScienceDirect

Journal of Financial Economics

journal homepage: www.elsevier.com/locate/jfec

Price ceilings, market structure, and payout policies☆

Xiongshi Li [a], Mao Ye [b,*], Miles Zheng [c]

[a] Guangxi University of Finance and Economics, China
[b] Cornell University and NBER, 349 Sage Hall, 106 E Ave, Ithaca 14853, NY, United States
[c] Texas Christian University, United States

ARTICLE INFO

Original content: Replication Package for Price Ceilings, Market Structure, and Payout Policies (Original data)

JEL classification:
G14
G32
G35

Keywords:
Market Structure
Share Repurchase
Queue Competition
Dark Pool
Regulation

ABSTRACT

To prevent issuers from inflating their share prices, SEC Rule 10b-18 sets price ceilings on share repurchases through open markets. We find that market-structure reforms in the 1990s and 2000s dramatically increased share repurchases because they relaxed constraints on issuers competing with other buyers under price ceilings. The Tick Size Pilot Program, a controlled experiment that partially reversed previous reforms, significantly reduced share repurchases. We estimate that price ceilings and reduced market-structure frictions explain 18% of the secular increase in share repurchases. Meanwhile, these two frictions still exist, which explains why share repurchases have not crowded out dividends entirely.

1. Introduction

Miller and Modigliani (1961) demonstrate that, in a frictionless market, it does not matter whether firms pay out through dividends or share repurchases. If dividends are taxed at a higher rate than capital gains, shareholders should prefer share repurchases to dividends. Surprisingly, dividends dominated share repurchases until the 1990s despite the tax advantage that repurchases provided (Fig. 1). More surprisingly, even though this tax advantage of repurchases has gradually diminished over recent decades, Farre-Mensa et al. (2014) show a secular increase in share repurchases over dividends. This secular increase in share repurchases presents a significant challenge to the payout literature, as explaining this puzzle must address three questions. First, why does the economic driver of this trend begin by favoring dividends? Second, why does this economic driver continue to move in the same direction, favoring share repurchases to an increasingly greater extent? Third, why does this economic driver lead to gradual change rather than inflicting a one-time shock on the market?

☆ Philipp Schnabl was the editor for this article. We gratefully acknowledge helpful comments from the editor and an anonymous referee. We thank Heitor Almeida, Jim Angel, Dion Bongaerts, Eric Budish, John Campbell, Raj Chetty, Tarun Chordia, Gregory Eaton, Amy Edwards, Harry Feng, Slava Fos, John Friedman, Robin Greenwood, Gustavo Grullon, Sam Hanson, Joel Hasbrouck, Jiekun Huang, Steven Ho, Mathias Kronlund, Pete Kyle, Mark Leary, Yoon Kang Lee, Mark Loewenstein, Neil Pearson, George Pennacchi, Joshua Pollet, Jeffrey Pontiff, Jim Poterba, Amir Rubin, Gideon Saar, Martin Schmalz, Antoinette Schoar, Paul Schultz, Beibei Shen, Ji Shen, Andriy Shkilko, Jeff Smith, Elvira Sojli, Chester Spatt, Adi Sunderam, Alexei Tchistyi, Anjan Thakor, Kumar Venkataraman, Theo Vermaelen, Scott Weisbenner, Russell Wermers, Ingrid Werner, Toni Whited, Yufeng Wu, Yuhai Xuan, Liu Yang, Chen Yao, Bart Yueshen, and participants at Arrowstreet Capital, Boston College, Case Western Reserve University, Emory University, the George Washington University, Harvard Business School, INSEAD, the University of British Columbia, the University of Hong Kong, the University of Illinois, the University of Iowa, the University of Maryland, the University of Michigan, the Cornell University Market Microstructure Ph.D. Seminar, Microstructure Exchange, Guanghua International Symposium, CICF, EFA, NFA, the WRDS Advanced Research Scholar Program, the SAFE Market Microstructure Meeting, the Sydney Market Microstructure Meeting, and the ITAM Finance Conference for helpful suggestions. Ye acknowledges support from National Science Foundation grant 1838183 and the Extreme Science and Engineering Discovery Environment (XSEDE). We remain responsible for all errors and omissions.

* Corresponding author.
E-mail address: my87@cornell.edu (M. Ye).

https://doi.org/10.1016/j.jfineco.2024.103818
Received 24 February 2022; Received in revised form 26 February 2024; Accepted 27 February 2024
Available online 1 April 2024

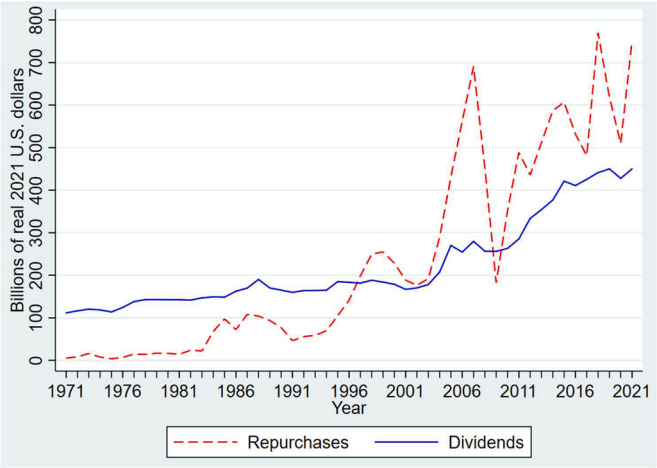


Fig. 1. The secular increase in share repurchases over dividends. In this figure, we plot aggregate repurchases made and dividends paid by publicly listed U.S. companies from 1971 through 2021. The units are reported in billions of real 2021 U.S. purchasing power dollars. Repurchases are calculated as total expenditures for the purchase of common and preferred stocks (PRSTKC) minus any reduction in the value of the net number of preferred stocks outstanding (PSTKRV). Dividends are calculated as the total dollar amounts of dividends declared on a company's common/ordinary capital.

In this paper, we show that two frictions on share repurchases—price ceilings and market structure—provide an explanation for the secular increase in share repurchases over dividends. The current price ceiling on share repurchases stems from Rule 10b-18, which asks firms to buy their shares at prices that do not exceed the highest independent bids or the most recent transaction prices.[1] As issuers cannot buy back shares in the open markets by outbidding other traders, price competition becomes secondary to share repurchases. The market structure then emerges as the first-order effect because competition at the same price depends crucially on market structure. Of particular importance is whether the market structure allows issuers effectively to buy at the bid price.[2] The friction issuers buying at the bid was surprisingly severe before 1994, when dealers enjoyed execution priority over issuers at the bid price. Dealers were able to step ahead of issuers at the bid price because the dealers were intermediaries who enjoyed the privilege of buying at the bid price and selling at the ask price, whereas other traders were entitled only to buy at the ask price and sell at the bid price. Such dealer priority imposes significant constraints on issuers, preventing them from buying at the price ceiling while also explaining why dividends were favored over repurchases before the 1990s.

One main purpose of market-structure reforms in the U.S. over the past several decades has been to provide *"an opportunity to obtain execution without dealer intervention."*[3] These reforms have gradually, over several waves, relieved frictions that constrain issuers from buying at the price ceilings. The first reform wave increased issuers' execution priority at the bid price. The Manning Rule of 1994 repealed dealer priority and the Order Handling Rules of 1997 further strengthened customers' execution priority (Hasbrouck, 2007). The second wave reduced the intensity of competition at the price ceiling: the minimum price variation (the tick size) dropped from $1/8 to $1/16 in 1997 and then to 1 cent in 2001. A more continuous price grid relaxes the price ceiling and reduces competition to buy at the same price. The third wave reduced monitoring and compliance costs at the price ceiling. For example, the NYSE installed autoquotes in 2003, allowing issuers to use computer algorithms to buy back shares.

Nowadays, an issuer or its broker can buy back shares using designated repurchase algorithms or adding Rule 10b-18 compliance instructions to a general-purpose algorithm. In addition to sending orders to traditional stock exchanges, these algorithms can also send orders to dark pools, which are market-structure innovations that have emerged in recent decades. Although dark pools are not designed exclusively for share repurchases, their execution mechanism, which matches orders passively using reference prices set by stock exchanges, dovetails with the principle underlying Rule 10b-18. For example, if a dark pool matches orders using the bid price, it automatically complies with Rule 10b-18.

To establish the causal impact of market structure on share repurchases, we begin our empirical analysis using a controlled experiment—the 2016 Tick Size Pilot Program—followed by event studies that focus on market-structure reforms implemented in the 1990s and 2000s. The Tick Size Pilot serves as our primary test because of its two unique features. First, it included randomly selected treatment and control stocks. The SEC increased the tick size for 1,200 treatment stocks from 1 cent to 5 cents, whereas the tick size for the 1,199 control stocks remained at 1 cent. Second, the Tick Size Pilot was designed to partially undo the market-structure reforms. This shock enables us to show that the increase in share repurchases is not necessarily secular: reversing the previously established market-structure reforms significantly reduced share repurchases. We find that the Tick Size Pilot reduced the treatment firms' share repurchases by 21% relative to control firms.

To provide further evidence, we partition treatment firms into two subgroups. The tick-constrained group includes firms whose pre-Pilot quoted spreads were below 5 cents, for which the Tick Size Pilot imposed a binding constraint on price competition. We find that share repurchases in tick-constrained treatment firms dropped by 45%, whereas share repurchases in tick-unconstrained treatment firms barely changed. As the bid–ask spreads of the tick-constrained treatment firms increased by 3 cents while the bid–ask spreads of tick-unconstrained treatment firms barely changed, an increase in the bid–ask spread may have contributed to the reduction in share repurchases. A small increase in the bid–ask spread alone is unlikely, however, to explain a dramatic reduction in share repurchases.[4] The main contributor to such a reduction comes from the price ceiling under Rule 10b-18, which affects share repurchases through two channels: the queuing channel and the dark-pool channel.

The idea of the queuing channel follows Yao and Ye (2018). An increase in the tick size imposed a binding constraint on price competition. Consequently, we find that market depth has increased by 214%, as more traders are willing to quote the same price at the wider tick sizes. As order executions at the same price follow time priority in stock exchanges, queuing—or early arrival to the market to beat rivals at the same price (Yao and Ye, 2018)—became more important.

[1] The purpose of a price ceiling is to prevent firms from inflating their share prices. Although Rule 10b-18 is a safe-harbor provision, the SEC (2002) states that *"issuers generally are reluctant to undertake any repurchases without the certainty that their repurchases come within the Rule's safe harbor."*

[2] Although a price ceiling can be either the independent bid or the most recent transaction prices, the independent bid price plays the dominant role under normal market conditions, to the extent that the SEC even tried to eliminate the last independent transaction price while keeping only the independent bid price as the price ceiling (SEC, 2002). This idea was pushed back based on extreme market stress, such as the 1987 Market Break and market reopening after September 11, 2001, when the bid price for other market participants disappeared (Merrill Lynch Comment Letter on Proposed Amendments to Rule 10b-18, available at https://www.sec.gov/rules/proposed/s75002/cjplohn1.htm).

[3] Exchange Act Section 11A(a)(1), 15 U.S.C. 78k-1(a)(1).

[4] Using a proprietary NYSE dataset, Li et al. (2023) show that the limit price for repurchasing orders is significantly higher than the ask price, meaning that issuers are willing to buy immediately at ask prices if they can. Therefore, the friction that prevents them from buying back shares is the price ceiling imposed by Rule 10b-18, which prevents their aggressive orders from being executed immediately or even results in non-execution.

Unfortunately, issuers are unlikely to achieve front-of-the-queue positions because they are not as fast as high-frequency traders (HFTs). Even if issuers could use the same technology as HFTs, the extra step needed to confirm Rule 10b-18 compliance would still make issuers slower than HFTs. Consistent with the queuing channel, we find that, among the tick-constrained treatment firms, firms that experienced above-median increases in bid depth reduced share repurchases 24% more than below-median firms did.

Firms can bypass queues in stock exchanges using dark pools, which usually do not follow the time-priority rule. The Tick Size Pilot imposed an additional Trade-at Rule on 400 firms in test group 3 to prevent the execution of dark orders that do not improve National Best Bid and Offer (NBBO) by more than 2.5 cents. Yet Rule 10b-18 regards buying above the best bid as an indicator of price manipulation. The contradiction between the Trade-at Rule and Rule 10b-18 unintentionally banned repurchases through dark pools. We find that tick-constrained firms in test group 3 reduced repurchases by 55%, while those in test groups 1 and 2 reduced repurchases by only 36%.

After analyzing the Tick Size Pilot, we travel back in history and conduct event studies on major market-structure reforms identified in the literature (Hasbrouck, 2007). These events involved quasi-treatment and quasi-control groups because they affected some stocks severely but barely affected others. Decades ago, Nasdaq dealers enjoyed much higher execution priority than HFTs do today. Before 1994, a Nasdaq dealer could step ahead of issuers at the bid price even if the dealer arrived later. The Manning Rule prohibits dealers from executing ahead of their customers at the same price. Using matched non-Nasdaq stocks as the control group, we find that share repurchases in Nasdaq firms increased 60% relative to control firms after the 1994 Manning Rule granted execution priority to customers' limit orders. The 1997 Order Handling Rules, which extended issuers' execution priority over all dealers in the market, led to another 38% increase in share repurchases by Nasdaq firms relative to control firms.

As tick size reductions reduce the number of competitors with which issuers must contend at the same price, we find that share repurchases increased when the SEC reduced the tick size. We assign stocks exhibiting above-median decreases in quoted spreads to treatment firms and matched remaining stocks to the control group (Fang et al., 2014). Treatment firms increased share repurchases by 41% relative to control firms following the 1997 tick-size reduction from \$1/8 to \$1/16. The relative increase in share repurchases for treatment firms was 32% in 2001 when decimalization further reduced the tick size from \$1/16 to 1 cent.

We examine the impact of automated trading in share repurchases using the installation of autoquotes by the NYSE in 2003 as a quasi-natural experiment, where we use NYSE firms as treatment firms and matched non-NYSE stocks as control firms. The transition from manual to automated execution reduced monitoring and compliance costs. Issuers can now use computer algorithms to compete with exchange specialists even when issuers are not physically present on an exchange floor. Computer algorithms also make compliance with Rule 10b-18 easy and automated. In addition, specialists lost their last-mover advantage because order executions no longer needed their approval (MacKenzie, 2017). We find that NYSE firms increased their share repurchases by 25% relative to control firms following the installation of autoquotes.

We find that the Tick Size Pilot and historical events do not affect tender offers, which are exempted from Rule 10b-18 because they are conducted outside the open market. This result again indicates that frictions in secondary markets—price ceilings and market structure—are the drivers of changes in share repurchases. Our back-of-the-envelope calculations show that these historical market-structure reforms contribute ~18% of the secular increase in share repurchases from 1995 through 2021.

Our paper contributes to the literature on taxes on payouts. Poterba and Summers (1985) and Chetty and Saez (2010) assume exogenous costs for repurchases to explain why firms pay dividends despite the tax advantage that repurchases provide. Chetty and Saez (2010) point out that *"understanding the microeconomic foundations of the cost of share repurchases is an issue of great importance for future work, independent of its potential implications for taxation."* We show that price-ceiling and market-structure frictions provide a micro-foundation for such costs. Chetty and Saez (2005) show that the 2003 dividend tax cut increased dividend payouts. A notable puzzle that arises in Chetty and Saez (2005, Fig. IX), however, is that share repurchases increased to a greater extent than dividends following the dividend tax cut. The transition from manual to automated executions of share repurchases during the same period provides one interpretation of this puzzle.

Our paper contributes to the literature on the transaction costs of payouts, which aims to explain why firms pay dividends despite their tax disadvantage when compared with capital gains (Allen and Michaely, 2003). One challenge of the literature is to find transaction costs that are high enough to overcome the tax disadvantage of dividend payouts, as the transaction costs investors pay to sell their shares are much lower than the tax difference between dividends and capital gains. We contribute to the literature by examining the "transaction costs" that issuers (buyers) face instead of traditional transaction costs to investors (sellers). Our paper indicates that price ceilings and market structure create substantial friction when issuers buy back their shares. In this sense, we contribute to the market-microstructure literature by showing that the impacts of microstructure on corporate policies go beyond traditional channels such as liquidity and price discovery. Combined with other frictions, such as price ceilings, the market microstructure can impose first-order frictions as severe as implicit bans.

Our paper provides one explanation of the secular increase in share repurchases over recent decades. One major goal of market-structure reforms in recent decades is to provide executions without dealer intervention. This direction consistently makes it easier for issuers to compete with other traders at the price ceilings. The increase in share repurchases has been secular over decades because regulators did not and could not institute full market-structure reforms in one step. In fact, the market-structure reforms are ongoing. In showing that price ceilings and market structure are important frictions affecting share repurchases, our paper explains why firms, brokers, and trading venues encourage the SEC to raise the price ceiling for share repurchases. One proposal is to increase the price ceiling to the Volume Weighted Average Price (VWAP) and the other is to increase the price ceiling to the midpoint of the bid–ask spread. We predict that these two higher price ceilings, if adopted, would lead to another wave of share repurchases.

2. Institutional background

In this section, we begin in Subsection 2.1 by describing the price ceilings on share repurchases established by SEC Rule 10b-18. In Subsection 2.2, we outline the market-structure innovations adopted by issuers, brokers, and trading venues to comply with Rule 10b-18. The first two subsections provide the background for understanding Subsection 2.3, where we summarize policy proposals that were designed to further relax frictions on share repurchases.

2.1. Price ceilings under SEC Rule 10b-18

In 1982, the SEC enacted Rule 10b-18, which provides a "safe harbor" that shields issuers from liability for manipulation when repurchases are consistent with the Rule's four conditions. These four conditions impose binding constraints on share repurchases in practice, as "*no one is going to feel safe trading outside of the current safe harbor rules.*"[5]

[5] See Letter from NBT Bancorp Inc. Available at https://www.sec.gov/rules/proposed/s75002/mjchewens1.txt.

(1) Manner condition: A firm should use only one broker or dealer on any single day.
(2) Timing condition: A firm should not repurchase during the opening or last half-hour before the closing of the market.
(3) Price condition: A repurchase price should not exceed the highest independent bid or the previous independent trade price, whichever is higher, that is quoted or reported in the consolidated system at the time the Rule 10b-18 purchase is effected.
(4) Volume condition: The total volume of purchases effected on any single day must not exceed 25 percent of the average daily trading volume in the preceding four weeks.

Before the adoption of Rule 10b-18, share repurchases could easily expose a firm to charges of market manipulation under the Securities and Exchange Act of 1934 Section 9(a)(2) and Section 10(b). Repurchase programs were rare until the rule came into effect because of the threat of being charged with manipulation for inflating stock prices.[6] Therefore, although the establishment of Rule 10b-18 created constraints on share repurchases, this constraint was looser than the constraint that was in place before the Rule was adopted. Grullon and Michaely (2002) find that share repurchases increased after the adoption (1983–2000) over the repurchase volume before the adoption (1972–1982). At the same time, Grullon and Michaely (2002) leave two interesting questions open: 1) Why did the one-time shock that Rule 10b-18 created lead to a *gradual* increase in share repurchases over 20 years (their sample period)? 2) Why did most of the increase in share repurchases occur in the later period (after the 1990s)?

Our paper addresses these questions. Rule 10b-18 has replaced the previous constraint on share repurchases (the threat of manipulation charges) with a looser constraint (there are no manipulation charges if issuers buy at the price ceilings). Therefore, share repurchases began increasing in the 1980s. Still, firms complain that Rule 10b-18 "*limits ability to make any significant purchases over a realistic time frame.*"[7] Therefore, the major increase in share repurchase happened much later, when the market-structure reforms gradually reduced frictions for issuers seeking to buy back shares at the price ceiling.

2.2. Modern plumbing for share repurchases and Rule 10b-18 compliance

Decades ago, when share repurchases were executed manually, the costs of complying with Rule 10b-18 were high. Humans incur high costs when continuously monitoring the price condition, and they risk unintentionally violating the condition (Cook et al., 2003).[8] Over the years, market-structure innovations and reforms have dramatically reduced the monitoring and compliance costs involved in share repurchases. In this subsection, we introduce the current plumbing through which U.S. open-market share repurchases are executed.[9]

2.2.1. Brokers and their algorithms

Brokers provide the gateway through which issuers can access stock exchanges and dark pools. In past decades, share repurchases were "high-touch" transactions, as human brokers executed orders manually. Nowadays, share repurchases are "low-touch" transactions and brokers typically buy back shares using computer algorithms. We use Interactive Brokers Jefferies Algos as an example. The first method for buying back shares is to use designated buyback algorithms. Fig. A.1 Panel A shows that firms need only to specify the "Start Time," the "End Time," and "Max % Vol," and then the "Buyback" algorithm automatically buys back shares in compliance with Rule 10b-18.[10]

The other common method for repurchasing shares is to add a "Buy Back" option to a generic algorithm. For example, the VWAP algorithm automatically manages transactions to achieve the all-day or intra-day VWAP; the "DarkSeek" algorithm searches for liquidity only in dark pools. Fig. A.1 Panel B shows that issuers and their brokers can add the "Buy Back" option to these algorithms that allow them to generate only trades that are consistent with Rule 10b-18.[11]

In summary, algorithms make it easier for issuers to buy back shares and serve as gatekeepers for Rule 10b-18, thereby reducing monitoring and compliance costs for issuers.

2.2.2. Stock exchanges and dark pools

Brokers and their algorithms provide issuers with access to stock exchanges or dark pools.

Stock exchanges. Stock exchanges have also designed mechanisms to facilitate compliance with Rule 10b-18 for issuers and brokers. One such mechanism involves designing special order types. For example, the NYSE designed a buy-minus-zero-plus (BMZP) order type, which buys only when the price is not higher than the current bid and the most recent trade price. The NYSE states: "*The BMZP instruction is designed to assist member organizations in their compliance with the 'safe harbor' provisions of Rule 10b-18 under the Act ('Rule 10b-18') for issuer repurchases.*"[12] Li et al. (2023) show that the limit price for BMZP orders is on average 18 bps higher than the ask price. Such aggressive prices would lead to immediate execution if BMZP orders were not constrained by Rule 10b-18. Yet Li et al. (2023) find that it takes considerable time for BMZP orders to execute, and BMZP orders execute only less than half of their specified sizes across their lives. Therefore, traditional transaction costs such as bid–ask spreads are unlikely to be the major constraint on share repurchases; the main friction is created by the price ceilings imposed by Rule 10b-18.

BMZP orders delegate responsibility for compliance with Rule 10b-18 to stock exchanges. Certainly, issuers and their brokers can also check Rule 10b-18 compliance. Computer algorithms make it easy to check the Rule 10b-18 conditions, but this extra step adds latency. As all major U.S. stock exchanges follow price/time priority, share-repurchase algorithms are unlikely to achieve front-of-the-queue positions. First, share-repurchase algorithms represent one type of agency algorithm; such algorithms are slower than proprietary HFT algorithms. Second, even if issuers used the same technology as HFTs, the extra step needed to check Rule 10b-18 compliance would still make them slower than HFTs.

Dark pools. Brokers can also send repurchase orders to dark pools. We hand-collect dark pools' ATS-N filing data. Part III ("Manner of Operations") in an ATS-N filing discloses detailed information about how a given dark pool operates, such as the types of subscribers, the

[6] The SEC has charged companies with illegally manipulating their stock prices during repurchase programs. See, for example, Genesco, Inc., (May 10, 1966), [1964-66 Transfer Binder] CCH Fed. Sec. L. Rep. 77,354; and SEC v. Georgia-Pacific Corporation, [1964-66 Transfer Binder] CCH Fed. Sec. L. Rep. 91,692, (S.D.N.Y. 1966). In the early 1960s, both corporations acquired other businesses using stocks as payments. The number of shares to be paid was made contingent on stock prices during specified periods. During these periods, both corporations repurchased stocks in the open market. The SEC alleged that these repurchases resulted in elevated stock prices and reduced the number of shares to be paid. See Thel (1988) and Davis v. Pennzoil Co., 438 Pa. 194, 264 A.2d 597 (Pa. Sup. Ct. 1970).

[7] See supra note 5.

[8] Cook et al., (2003) use daily aggregate repurchase data for 1993 and 1994 provided by 54 firms. They acknowledge that they may overestimate the actual level of non-compliance because they do not have transaction-level data on share repurchases.

[9] In our context, plumbing means "*major institutional arrangements connecting participants in core financial markets that are fixed in the short run*" (Duffe, 2003).

[10] Available at https://www.interactivebrokers.com/en/software/tws/usersguidebook/algos/jeffbuyback.htm.

[11] Available at https://www.interactivebrokers.eu/en/index.php?f=41864. Certainly, not all algorithms offer a "Buy Back" option. Two examples are the "opener" and "finale" algorithms, as the time condition under Rule 10b-18 prevents firms from repurchasing shares at market open or close.

[12] Available at https://www.sec.gov/rules/sro/nyse/2016/34-78679.pdf.

order-execution priority rules, and the order types provided by the dark pool. The results reported in Table A.1, column (4) indicate that 20 of 32 dark pools explicitly report that issuers are among their customers. For example, CrossStream states that they provide "*services to assist issuers repurchasing their own stock*."

Three economic incentives encourage issuers and their brokers to use dark pools. First, many brokers own dark pools. Anand et al. (2021) find that institutional brokers prefer routing orders to affiliated dark pools. Second, the results reported in Table A.1, column (5) indicate that many dark pools do not follow strict price/time priority. For example, MS POOL ATS-4 (Morgan Stanley's largest dark pool) employs price/capacity/size/time priority, which encourages large order sizes and deemphasizes speed. The priority rules in dark pools are thus friendlier to issuers because issuers may have large orders but are not as fast as HFTs. Finally, dark pools usually do not create their own prices; they passively match orders using stock exchange prices. Such passive executions dovetail nicely with the anti-manipulation principle behind Rule 10b-18. Many dark pools, such as UBS ATS and SIGMA X2, offer the "primary peg" option to match buy orders using bid prices, a practice that automatically complies with Rule 10b-18. The results reported in Table A.1, column (6) indicate that 21 dark pools provide the "primary peg" option. Some dark pools also offer a "Buyback Instructions" option, which permits an order only "*for execution consistent with the price conditions of Rule 10b-18*."[13]

2.3. Proposals to increase price ceilings under Rule 10b-18

Because price ceilings and market structure are important frictions for share repurchases, issuers and brokers continue to lobby the SEC to "*update the Rule to take account of market developments.*" One proposal is to increase the price ceiling to the Volume Weighted Average Price (VWAP). For example, ExxonMobile *"strongly endorses the proposal to include purchases effected on the basis of VWAP pricing within the express safe harbor provisions of the Rule. VWAP pricing ensures that issuers are passive price takers, rather than active market makers. As a result, we believe VWAP pricing represents an ideal methodology for purposes of the Rule."*[14] The other proposal is to increase the price ceiling to the midpoint of the NBBO. The IEX "*has petitioned the* SEC *to let firms buying back shares using hidden orders that only execute at the midpoint between the best bid and the best offer.*" This initiative has been supported by firms such as UPS.[15]

In 2010, the SEC considered increasing the price ceiling to the VWAP and stated that an increase in the price ceiling could increase share repurchases: *"[T]he proposed VWAP exception from the Rule's price condition would provide issuers and their brokers with flexibility and greater certainty in effecting qualifying VWAP transactions within the safe harbor. The proposed VWAP exception to the Rule's price condition also may increase the likelihood that firms would engage in open market repurchases since the price condition would be less restrictive for such transactions"* (SEC 2010). The same proposal also considers increasing the price ceiling to the midpoint of the NBBO, as *"some issuers may effect repurchases through electronic trading systems that use passive or independently-derived pricing mechanisms."* This proposal was finally tabled by the SEC because of resource constraints, as noted in the Reuters news coverage: "*But the proposal was dropped in the wake of the May 2010 stock market flash crash, which, along with Dodd-Frank rulemaking following the financial crisis, overwhelmed the regulator's resources.*" As a result, *"Eight years later, UPS's Barth (assistant treasurer at UPS) said he is still waiting for the* SEC *to take action."*[16]

3. The controlled experiment

We begin our analysis with a unique controlled experiment: the U.S. Tick Size Pilot Program. In Subsection 3.1, we introduce the Pilot and the sample-construction process. In Subsection 3.2, we analyze the impact of the Tick Size Pilot Program on payout policies. In Subsection 3.3 and Subsection 3.4, we show evidence of two main economic channels: the queuing and dark-pool channels. In Subsection 3.5, we present robustness checks.

3.1. The U.S. Tick Size Pilot Program and sample construction

In 2012, The Jumpstart Our Business Startups Act ("JOBS Act") directed the SEC to study whether reductions in U.S. stock tick sizes in the late 1990s and early 2000s could be driving the decline in the number of initial public offerings (IPOs). In 2014, the SEC ordered national securities exchanges (NSEs) and the Financial Industry Regulatory Authority (FINRA) to develop a pilot program. On May 6, 2015, the SEC issued an order approving the plan to implement the Tick Size Pilot Program. The Program began on October 3, 2016 and ended on October 1, 2018.

The Program included 2,399 stocks, comprising all Regulation National Market System (Reg NMS) stocks that satisfied the following criteria during a three-month measurement period before Program implementation: a share price of at least $1.50 each day, a volume-weighted average price of at least $2, average sales volume of fewer than one million shares, market capitalization below $3 billion, and a closing price above $2 on the last day of the period.[17] NSEs and the FINRA then divided these stocks into 27 categories based on three criteria: (1) low, medium, or high share prices; (2) low, medium, or high market capitalization; and (3) low, medium, or high volume. Stocks were then randomly drawn from each category to form three test groups such that each test group contained 400 stocks. The remaining 1,199 stocks were assigned to the control group.

Stocks in the control group continued to be quoted and traded at the 1-cent tick size; stocks in test group 1 could be quoted only in $0.05 increments but could still be traded at $0.01 increments; stocks in test group 2 could be quoted and traded only at $0.05 increments. Stocks in test group 3 adhered to all the same requirements as those in test group 2 but were also subject to an additional Trade-at Rule, which granted execution priority to displayed orders unless non-displayed orders could improve prices by at least 2.5 cents, with certain exceptions (SEC, 2015).

We obtained the list of test and control stocks from FINRA's website. We obtained quarterly share repurchases, dividends, and other firm-level financial information from Compustat's North America Fundamentals Quarterly files. We define our payout variables following existing conventions (Almeida et al., 2016; Fama and French, 2001): *repurchase payouts* equal total expenditures in common stock repurchases divided by lagged assets; *dividend payouts* equal common stock dividends divided by lagged assets.[18] *Total payouts* equal the sum of repurchase payouts and dividend payouts. *Payout structure* equals (repurchase payouts + 1)/(dividend payouts + 1).[19] *Size* is the natural

[13] One example is BIDS ATS, https://www.sec.gov/Archives/edgar/data/1368727/000095012321000929/xslATS-N_X01/primary_doc.xml#partIIIItem1.

[14] Available at https://www.sec.gov/comments/s7-04-10/s70410-10.pdf.

[15] Available at https://www.reuters.com/article/us-usa-stocks-buybacks/old-rules-algorithmic-traders-add-costs-to-u-s-share-buybacks-idUSKBN1HY0GD.

[16] See supra note 15.

[17] Reg NMS stocks are listed on stock exchanges such as the NYSE and Nasdaq.

[18] Following the previous literature, our share-repurchase measure is based on quarterly data. On Dec 15, 2021, the SEC proposed amendments to the disclosure rules for repurchases. The proposed new Form SR requires daily disclosure of any amount purchased on the open market and the amount that is in compliance with the safe harbor provisions in Rule 10b-18. See https://www.sec.gov/news/press-release/2021-257.

[19] We add 1 to both the numerator and the denominator because the latter often equals zero (Fama and French, 2001).

log of book assets. *Profitability* is income before extraordinary items plus depreciation and amortization divided by lagged assets. *Growth opportunity* is the market value of assets divided by lagged assets. Following Holden and Jacobsen (2014), we calculate spread, turnover, and depth measures using Daily TAQ data: *percent quoted spread* is the time-weighted difference between the national best offer and the national best bid divided by their midpoint. *Total turnover* is the average daily total share volume divided by shares outstanding. *Market depth* is the average of the displayed best-bid depth and best-offer depth.

Our sample-selection process runs as follows. We drop stocks with missing information in the Compustat database and the Daily TAQ database. Following other Tick Size Pilot studies (Albuquerque et al., 2020; Rindi and Werner, 2019), we retain only common stocks (CRSP share codes 10 or 11) that remained in the Pilot throughout the Tick Size Pilot period. Following the payout literature, we exclude regulated utility and financial firms (SIC codes 4200–4299 and 6000–6999) because companies operating in these industries face additional regulations that might generate divergent payout behavior (Chetty and Saez, 2005; Fama and French, 2001). Our final sample includes 602 firms in the three test groups and 654 firms in the control group.

Our difference-in-differences (DiD) specification is as follows:

$$y_{i,t} = \eta_i + \lambda_t + \beta \times \ Treatment_i \times Post_t + \zeta' \times Controls_{i,t} + \varepsilon_{i,t}, \quad (1)$$

where i indexes firms, t indexes time, and $y_{i,t}$ is the dependent variable. η_i are firm fixed effects and λ_t are year-quarter fixed effects. $Treatment_i$ is a dummy variable that equals one if a firm is in a test group and zero if it is in the control group. $Post_t$ is a dummy variable that equals one if an observation is from the post-treatment period and zero if it is from the pre-treatment period. $\varepsilon_{i,t}$ is an error term. The main coefficient of interest is β, which estimates the average treatment effects. All variables are winsorized at the 1% and 99% levels. *t*-statistics based on standard errors are robust to heteroskedasticity and are clustered at the firm level.[20]

3.2. The effects of the Tick Size Pilot Program on payout policies

In Table 1, we report the average effects of the Tick Size Pilot on corporate payouts where $Treatment_i$ equals one if a stock is in one of the three test groups and zero if the stock is in the control group, while $Post_t$ equals one if the observation is from the post-treatment period (2016 Q4–2018 Q3) and zero if it is from the pre-treatment period (2014 Q4–2016 Q3). *Controls* include size, profitability, and growth opportunity, as in Fama and French (2001).

The results reported in Table 1 indicate that, in the Tick Size Pilot Program, treatment firms reduce repurchase payouts by 0.092 percentage points relative to control firms, representing a 21% decline from the pre-treatment average repurchase payout of 0.43 percentage points. Results reported in column (2) of Table 1 indicate that the Tick Size Pilot Program does not lead to a relative change in dividend payouts. Total payouts by treatment firms decrease by 0.096 percentage points relative to control firms, representing a 14% decline over the pre-treatment average total payouts of 0.67 percentage points. In addition, the payout structures of the treatment firms decrease by 0.083 relative to control firms, a 6.64% decrease over the pre-treatment mean of 1.25. Therefore, the Tick Size Pilot Program, an initiative that was designed to reverse market structure reforms enacted in previous decades, also reversed the secular increase in repurchases.

Next, we examine whether the reduction in repurchases came from the intensive or extensive margin. The Tick Size Pilot might reduce share repurchases at the extensive margin based on two factors. First, issuers may cancel or delay share repurchases if they are selected for one of the test groups. Second, as buyback algorithms were designed and optimized for a 1-cent tick size, they need to be updated for each test group during this two-year pilot window. Therefore, some brokers may simply avoid buying back shares if the cost of updating the codes outweighs the revenue. In Table 2 we present the DiD results for the *Repurchase dummy*, which equals one if a firm repurchases shares during the quarter and zero otherwise. We find no significant changes at the extensive margin. The results show that the Tick Size Pilot does not reduce the number of repurchasing firms. Therefore, the decrease in share repurchases comes from the intensive margin: treatment firms buy back fewer shares after the Pilot.

[20] In Table A.2, we present summary statistics for the main sample for the Tick Size Pilot Program with a breakdown by event year.

Table 1
Tick Size Pilot Program and payout policies. In this table, we report the average effects of the Tick Size Pilot on the corporate payout variables. We report the DiD regression results for the payout variables: *repurchase payouts, dividend payouts, total payouts,* and *payout structure. Treatment* is a dummy variable that equals one if a stock is in one of the three test groups and zero if it is in the control group. *Post* is an indicator variable that equals one if the year-quarter falls into the post-treatment period (2016 Q4–2018 Q3) and zero if it falls into the pre-treatment period (2014 Q4–2016 Q3). *Controls* include size, profitability, and growth opportunity, as in Fama and French Fama and French (2001). All variables are winsorized at the 1% and 99% levels. *t*-statistics based on standard errors that are robust to heteroskedasticity and clustered at the firm level are shown in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Difference-in-Differences Regression Results	Repurchase Payouts (1)	Dividend Payouts (2)	Total Payouts (3)	Payout Structure (4)
Treatment × Post	−0.0918***	−0.00463	−0.0964***	−0.0831***
	(−2.72)	(−0.32)	(−2.66)	(−2.74)
Controls	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Year-quarter FE	Yes	Yes	Yes	Yes
Cluster by firm	Yes	Yes	Yes	Yes
N	19,633	19,633	19,633	19,633
R^2	0.382	0.702	0.486	0.396

Table 2
Tick Size Pilot Program: extensive vs. intensive margins. For this table, we test whether the effects of the Tick Size Pilot on share repurchases come from the extensive or intensive margin. We report the DiD regression results for *Repurchase dummy*, which equals one if a firm repurchases shares during the quarter and zero otherwise. *Treatment* is a dummy variable that equals one if a stock is in one of the three test groups and zero if it is in the control group. *Post* is an indicator variable that equals one if the year-quarter falls into the post-treatment period (2016 Q4–2018 Q3) and zero if it falls into the pre-treatment period (2014 Q4–2016 Q3). *Controls* include size, profitability, and growth opportunity, as in Fama and French Fama and French (2001). All variables are winsorized at the 1% and 99% levels. *t*-statistics based on standard errors that are robust to heteroskedasticity and clustered at the firm level are shown in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

	Repurchase Dummy (1)
Treatment × Post	−0.00641
	(−0.43)
Controls	Yes
Firm FE	Yes
Year-quarter FE	Yes
Cluster by firm	Yes
N	19,633
R^2	0.564

3.3. The queuing channel

To identify the economic forces that drive the intensive margin, we partition treatment firms into tick-constrained and tick-unconstrained subsamples based on their average dollar-quoted spreads one quarter before the launch of the Pilot (2016 Q3). Tick-constrained firms had pre-Pilot quoted spreads that were lower than 5 cents, and we define the other firms as tick-unconstrained firms. Because the firms are partitioned into two subsamples, we create matched control samples for the treatment tick-constrained and tick-unconstrained subsamples based on pre-treatment repurchase payouts, dividend payouts, and the three control variables (size, profitability, and growth opportunity).[21] In Panel A of Table 3, we report the summary statistics and the mean differences between the treatment and matched control sample for the payout variables in the pre-treatment period. The *t*-test results show that the mean differences are not statistically significant.

In columns (1)–(4) of Table 3 Panel B, we report the results for tick-constrained firms, while in columns (5)–(8) we report the results for tick-unconstrained firms. The results show that the treatment effects of the Tick Size Pilot are concentrated in tick-constrained firms. Results reported in column (1) indicate that tick-constrained treatment firms reduce their repurchase payouts by 0.183 percentage points relative to their control firms, representing a 45% decline over the average pre-treatment level of 0.41 percentage points. Results reported in column (2) indicate that tick-constrained treatment firms did not experience significant changes in dividend payouts points relative to their control firms. Tick-constrained treatment firms' total payouts decline by 0.187 percentage points relative to control group, representing a 30.4% decline over their average pre-treatment total payouts. In addition, the payout structure decreased by 0.146, about 11.6% of the pre-treatment average. In comparison, none of the payout variables changed significantly for the tick-unconstrained firms relative to their control group. The results are also consistent with our finding that the decrease in share repurchases does not come from the extensive margin. If the main results are driven by issuers who cancel or delay share repurchases or brokers who refuse to buy back shares, we expect the Tick Size Pilot to affect tick-unconstrained firms as well.

The next step in our analysis is to refine the economic forces that drive the dramatic decrease in share repurchases for tick-constrained firms. Panel C of Table 3 presents the results for the three standard liquidity measures: percentage quoted spreads, share turnover, and market depth. For tick-constrained firms, the Tick Size Pilot caused an 84% increase in percentage quoted spreads (0.32/0.38), a 16% decrease in total share turnover (0.14/0.92), and a 214% increase in market depth (12.90/6.01), whereas the changes for tick-unconstrained firms are much smaller.

We first rule out share turnover as the main driver of the decrease in share repurchases. The volume condition in Rule 10b-18 prohibits firms from purchasing more than 25% of the preceding four-week average daily volume on any trading day, but we find that the repurchase program represents only less than 5% of the volume in our sample. In addition, Rule 10b-18 exempts firms from one block trade each week, which further relaxes the 25% volume constraint. Therefore, the volume constraint is unlikely to be binding.

The increase in the proportional bid–ask spread is equivalent to a three-cent increase in the nominal bid–ask spread. Although a three-cent increase in the bid–ask spread may contribute to reducing share repurchases, it is also unlikely to be the main driver. First, Li et al. (2023) find evidence that issuers and their brokers are willing to pay much higher prices than ask prices if they can execute their orders. Therefore, a three-cent increase in the bid–ask spread is unlikely to disincentivize share repurchases. Second, issuers often cannot buy at the ask price because of the price ceilings. Instead, a safer strategy is to use limit orders to buy at the bid price. As a wider tick tends to increase the bid–ask spread by increasing the ask price and decreasing the bid price (Li and Ye, 2022), an issuer can buy at lower prices instead of higher prices.

Surprisingly, an increase in depth is the most likely driver of the reduction in share repurchases. The depth increases because a wider tick constrains price competition and forces traders with heterogenous valuations to quote the same price (Yao and Ye, 2018). Such an increase in depth, in turn, crowds out share repurchases because issuers face more intense competition at the same price. We can express the same economic intuition alternatively by noting that a wider tick mechanically reduces the best bid price (Li and Ye, 2022). Therefore, a wider tick reduces the price ceilings for share repurchases but imposes tighter constraints on issuers under Rule 10b-18.

The following hypothetical example provides intuition. Suppose the tick size is $0.01, the best ask for a stock is at $10.01 for 100 shares, and the best bid is at $10.00 for 100 shares. An issuer can submit a limit order to buy at $10.00. There are also two less aggressive bids: 100 shares at $9.99 and 100 shares at $9.98. The issuer's limit order then establishes price priority over the quotes at $9.99 and $9.98. A wider five-cent tick size tends to increase the ask price and reduce the bid price.[22] Suppose that the ask price increases to $10.03 and the bid price decreases to $9.98. Then the price ceiling for the issuer becomes $9.98. The lower price ceiling intensifies the competition at the same price, as the issuer now needs to compete with 300 shares at $9.98.

Consistent with this intuition, we find that the depth at the best price increases by 214% for tick-constrained treatment firms relative to control firms. As stock exchanges use the time to determine the execution priority among orders at the same price, queuing—or early arrival to the market to beat rivals at the same price (Yao and Ye, 2018)—becomes more important. Unfortunately, issuers cannot trade as quickly as HFTs (SEC, 2018). Even if an issuer hires an HFT for share repurchases, the algorithms cannot run as rapidly as other HFTs because of the additional latency caused by checking for compliance with Rule 10b-18. Therefore, the queuing channel predicts that an increase in depth reduces share repurchases, the opposite of the prediction based on liquidity in general. Generally, a market with greater depth is considered more liquid, particularly for large traders. Jones and Lipson (2001) find, for example, that the 1997 tick-size reduction decreased transaction costs for small orders but increased these costs for large orders because of the reduction in depth.

To examine whether a longer queue discourages share repurchases, we partition tick-constrained firms into two subgroups based on their increased bid-side depth and re-run the DiD analyses. In Table 3 Panel D we report the results. We find that firms that experience a greater increase in bid-side depth reduce share repurchases to an even greater extent: firms with an above-median increase in depth reduce share repurchases by 56% relative to control group (0.264/0.469), whereas firms with a below-median increase in the depth reduce share repurchases by only 32% relative to their control group (0.115/0.357). The 24% difference is statistically significant (p-value < 0.01). In summary, our results are consistent with the queuing channel: a longer queue harms issuers because a lengthy queue makes speed competition at the price ceiling more important, and issuers are unlikely to win the speed competition.

3.4. The dark-pool channel

Issuers can avoid queues by using dark pools. Many dark pools do not enforce time priority. For example, SIGMA X2 follows broker priority,

[21] Our results are similar when we use an unmatched sample. All of our matching variables are measured prior to the treatment to ensure that they are unaffected by the treatment (Roberts and Whited, 2013).

[22] Li and Ye (2022) provide a formal model of this widening effect under varying tick sizes.

Table 3

Tick Size Pilot Program: the queuing channel. In this table, we show that the queuing channel is one underlying mechanism that drives the effects of the Tick Size Pilot on share repurchases. In Panel A, we present pre-treatment summary statistics and the mean difference test results for the treatment and matched control firms. We partition firms into two subgroups. The tick-constrained sample includes firms whose average pre-treatment (2016 Q3) dollar-quoted spreads are below 5 cents, while other firms comprise the unconstrained sample. In Panel B, we report the DiD regression results for corporate payout variables. In Panel C, we report the DiD regression results for market-liquidity measures. In Panel D, we report the DiD regression results for *repurchase payouts* when we partition the tick-constrained sample equally into two groups based on the increase in bid-side depth. Using the bootstrap method, the *p*-values reported in the bottom row are estimated based on the null hypothesis that the coefficients are equal for the two groups under consideration. All variables are winsorized at the 1% and 99% levels. *t*-statistics based on standard errors that are robust to heteroskedasticity and clustered at the firm level are shown in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Panel A: Pre-Treatment Summary Statistics for the Constrained Sample and the Unconstrained Sample

	Tick-Constrained Sample				Tick-Unconstrained Sample			
	Treatment Mean	Control Mean	*t*-test *Diff*	*p-value*	Treatment Mean	Control Mean	*t*-test *Diff*	*p-value*
Repurchase payouts	0.412	0.399	0.013	0.673	0.443	0.440	0.003	0.932
Dividend payouts	0.203	0.177	0.026	0.107	0.274	0.271	0.003	0.867
Total payouts	0.615	0.576	0.039	0.273	0.718	0.712	0.006	0.883
Payout structure	1.255	1.291	−0.036	0.233	1.241	1.216	0.025	0.375

Panel B: Regression Results for Payout Variables

	Tick-Constrained Sample				Tick-Unconstrained Sample			
	Repurchase Payouts (1)	Dividend Payouts (2)	Total Payouts (3)	Payout Structure (4)	Repurchase Payouts (5)	Dividend Payouts (6)	Total Payouts (7)	Payout Structure (8)
Treatment × Post	−0.183***	−0.00479	−0.187***	−0.146***	−0.0249	−0.0240	−0.0489	−0.0429
	(−3.46)	(−0.24)	(−3.19)	(−3.10)	(−0.46)	(−1.42)	(−0.90)	(−0.94)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-quarter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster by firm	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	8546	8546	8546	8546	10,314	10,314	10,314	10,314
R^2	0.441	0.821	0.520	0.466	0.363	0.734	0.482	0.373

Panel C: Regression Results for Market-Liquidity Variables

	Tick-Constrained Sample			Tick-Unconstrained Sample		
	Percentage Quoted Spread (1)	Total Share Turnover (2)	Market Depth (3)	Percentage Quoted Spread (4)	Total Share Turnover (5)	Market Depth (6)
Treatment × Post	0.316***	−0.144***	12.90***	0.0125	−0.0290	4.643***
	(11.98)	(−3.41)	(18.15)	(0.32)	(−1.03)	(9.28)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year-quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Cluster by firm	Yes	Yes	Yes	Yes	Yes	Yes
N	8522	8522	8522	10,299	10,290	10,299
R^2	0.756	0.587	0.611	0.848	0.600	0.702

Panel D: Results for Partitioning Samples Based on Increase in Bid-Side Depth

	Dependent Variable: Repurchase Payouts	
	Below-Median Increase in Bid-Side Depth (1)	Above-Median Increase in Bid-Side Depth (2)
Treatment × Post	−0.115*	−0.264***
	(−1.77)	(−3.21)
Controls	Yes	Yes
Firm FE	Yes	Yes
Year-quarter FE	Yes	Yes
Cluster by firm	Yes	Yes
N	4303	4243
R^2	0.438	0.443
p-value (Small=Large)	< 0.01	

JPM-X and Barclays ATS follow subscriber tier priority, and these priorities can help issuers if their brokers own a dark pool or are affiliated with a dark pool. IBKR ATS, MS POOL ATS-4, and CrossStream follow order-size priority, and this priority helps issuers if they buy back a large number of shares.

As test group 3 in the Tick Size Pilot faces an additional trade-at requirement that restricts dark-pool trading, we predict that firms in test group 3 reduce share repurchases to a greater extent than firms in other test groups. The results reported in Table 4 show that the treatment effect on repurchase payouts for tick-constrained firms in test group 3 is −0.26 percentage points (a 55% reduction under the pre-treatment mean), whereas the treatment effect on repurchase payouts for tick-constrained firms in test groups 1 and 2 is −0.14 percentage points (a 36% reduction under the pre-treatment mean). The difference is both economically (19%) and statistically significant (*p*-value < 0.01). The results also show nonsignificant effects on tick-unconstrained firms in both test group 3 and test groups 1 and 2.

Why does the 2.5-cent price improvement requirement in dark pools

Table 4
Tick Size Pilot Program: the dark-pool channel. In this table, we show that dark pools represent another mechanism that drives the effects of the Tick Size Pilot on share repurchases. The Tick Size Pilot imposed Trade-at Rule on test group 3 but not on test groups 1 and 2. The tick-constrained sample includes a firm if its average dollar-quoted spread for the quarter before the Pilot implementation (2016 Q3) is below 5 cents, while other firms comprise the unconstrained sample. All variables are winsorized at the 1% and 99% levels. *t*-statistics based on standard errors that are robust to heteroskedasticity and clustered at the firm level are shown in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively. Using the bootstrap method, the *p*-values reported in the bottom row are estimated based on the null hypothesis that the coefficients are equal for the two groups under consideration.

Dependent Variable: Repurchase Payouts				
	Test Groups 1 and 2		Test Group 3	
	Tick-Constrained (1)	Tick-Unconstrained (2)	Tick-Constrained (3)	Tick-Unconstrained (4)
Treatment × Post	−0.139**	−0.0191	−0.258***	−0.0449
	(−2.18)	(−0.31)	(−2.68)	(−0.48)
Controls	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Year-quarter FE	Yes	Yes	Yes	Yes
Cluster by firm	Yes	Yes	Yes	Yes
N	6107	7006	2433	3329
R^2	0.449	0.363	0.414	0.368

p-value (test groups 1&2= test group 3, tick-constrained samples): < 0.01.

lead to the additional 19% reduction in share repurchases? Rindi and Werner (2019) show that the Trade-at Rule has a nonsignificant impact on overall liquidity. The answer to this question again comes not from overall liquidity but from the price ceilings under Rule 10b-18. The Trade-at Rule requires dark pools to match orders at a price that is 2.5 cents above the independent bid.[23] Rule 10b-18 implies, however, that buying shares at prices above independent bids indicates price manipulation. Therefore, the conflicts between the Trade-at Rule and 10b-18 impose an implicit ban on repurchasing in dark pools. Our results imply that dark pools were important platforms for share repurchases before the implicit ban.

3.5. Robustness checks

Reversal and placebo tests. In column (1) of Table 5 Panel A, we report results that show the reversal effects following the end of the Tick Size Pilot, using the four quarters after the Pilot's end (2018 Q4–2019 Q3) as the post-Pilot-end period and the four quarters before the Pilot's end (2017 Q4–2018 Q3) as the pre-Pilot-end period. Tick-constrained firms increased their repurchases by 43% (0.122/0.285) in the post-Pilot-end period. We then run placebo tests using two years before the Pilot implementation as a placebo shock. The results in column (2) show no significant changes in repurchases.

Result sensitivity to firm size. Our controlled experiment involves only small and medium-sized stocks. To mitigate the concern that the results apply only to small stocks, we follow Yagan (2015) and split the sample equally based on pre-treatment firm size. We report the results in columns (3) and (4) of Table 5 Panel A. For small (large) firms, we find a 46.3% (44.9%) reduction in repurchases compared with the pre-treatment mean (0.155/0.335 vs. 0.220/0.490). Both reductions are statistically significant. These results suggest that price-ceiling and market-structure frictions do not concentrate in small firms and the economic mechanism revealed by the controlled experiment is likely applicable to a broader sample.

Effects on tender offers. The results reported in column (5) of Table 5 Panel A show that the Tick Size Pilot has no significant effects on corporate self-tender offers.[24] This result helps rule out alternative channels that may lead to a drop in share repurchases because tender offers are share repurchases that are not executed through the secondary market and are not regulated by Rule 10b-18. Therefore, the Tick Size Pilot, a shock to the secondary market, should not affect tender offers. The differences in results between the two alternative ways of buying back shares provide additional evidence that price ceilings under Rule 10b-18 and market-structure frictions are the main drivers of the reductions in share repurchases.

Alternative explanations. To further isolate our channel, we include control variables identified in the literature that are the main determinants of payouts to our baseline regression specification. As some explanatory variables are recorded at annual frequency, we report the results of DiD tests using annual data.[25] The results reported in Table 5 Panel B are generally consistent with the findings in the literature. For example, firms repurchase more shares when managers own more stocks or options, consistent with agency issues with repurchases (e.g., Brown et al., 2007; Fenn and Liang, 2001); when there are more exercised options, consistent with the use of repurchases to offset earnings dilution caused by exercising options (e.g., Kahle, 2002); when firms have more non-operating cash flows, consistent with the financial-flexibility benefit of repurchases to distribute temporary cash flows (e.g., Jagannathan et al., 2000); and when firms are undervalued, consistent with market timing of repurchases (e.g., Dittmar and Field, 2015).[26] Most importantly, the coefficients on *Treatment* × *Post* remain statistically significant and the economic magnitudes are almost unchanged, suggesting that our results are not driven by these alternative channels.

Where does the undistributed cash go? Our main results show that treated firms reduced repurchases while not increasing dividends, leaving a follow-on question: what did the treated firms do with the undistributed money? To address this question, we test the effects of the Tick Size Pilot Program on short-term debt, cash holdings, and investments. The results in Table 5 Panel C show that tick-constrained treatment firms reduce short-term debt relative to their control firms, while there are no significant changes in cash holdings or investments. These findings suggest firms neither hold cash nor invest but instead pay off short-term debt with the undistributed money.

4. Historical market-structure reforms and payout policies

In this section, we travel back in history and conduct event studies centered on the market-structure reforms of the 1990s and 2000s. In Subsection 4.1, we discuss our investigation of the effects of the 1994 Manning Rule and the 1997 Order Handling Rules. In Subsection 4.2, we examine the effects of the two tick-size reductions following the 1997 Common Cents Pricing Act. In Subsection 4.3, we discuss the effects of the NYSE's jumpstart of algorithmic trading in 2003. In Subsection 4.4, we present robustness checks. In Subsection 4.5, we estimate the contribution of these reforms to the secular increase in share repurchase.

These reforms are major changes in market structure identified in the literature (Hasbrouck, 2007). Also, these reforms created

[23] SEC (2015) provides a few exemptions from this requirement.

[24] We obtain self-tender-offer data from the Securities Data Company (SDC). *Tender offer* equals the value of self-tender offers divided by lagged assets (in percentages).

[25] For example, annual managerial stock and option holdings are from the Compustat Execucomp database and total exercised and exercisable option holdings are from the Compustat Fundamentals Annual database. In the analyses, *Post* equals one if the year is 2017 or 2018 and zero if it is 2015 or 2016.

[26] Allen and Michaely (2003) and Farre-Mensa et al. (2014) provide excellent reviews of the determinants of payout policy.

Table 5

Tick Size Pilot Program: robustness checks. In this table, we report the results of robustness checks related to our analysis of the Tick Size Pilot Program. The sample includes tick-constrained firms. In Panel A columns (1) and (2) we report the results of the reversal and placebo tests, respectively. In the reversal test, we define the post-treatment period as 2018 Q4–2019 Q3 and the pre-treatment period as 2017 Q4–2018 Q3. In the placebo test, we define the post-treatment period as 2014 Q4–2016 Q3 and the pre-treatment period as 2012 Q4–2014 Q3. In Panel A columns (3) and (4) we report results of tests of sensitivity to firm size by partitioning the sample equally based on pre-treatment total assets. In Panel A column (5) we report the DiD regression results for *tender offer*. In Panel B, we show that our results remain robust after controlling for the other main determinants of corporate payout choice identified in the literature. As the compensation-related variables are recorded at annual frequency, we report the results of DiD tests for repurchase payouts using annual data. *Post* equals one if the year is in 2017 or 2018 and zero if it is in 2015 or 2016. For column (1), we show the main results on repurchase payouts without additional controls. For column (2), we control for managerial stock holdings and managerial options holdings. For column (3), we control for total exercised and exercisable options. For column (4), we control for the financial flexibility advantage of share repurchases proxied by cash-flow volatility and non-operating cash flows. For column (5), we control for mispricing proxied by future one-year market-adjusted returns. For column (6), we control for financial constraint proxied by the WW index (Whited and Wu, 2006). For column (7), we control for price informativeness proxied by return non-synchronicity, defined as one minus the R^2 from a firm-specific regression of daily stock returns on value-weighted market returns for a year. For column (8), we control for these explanatory variables simultaneously. In Panel C, we report the results of the effects on short-term debt, cash holdings, and investments. *Controls* for Panels A and B include size, profitability, and growth opportunity. *Controls* for Panel C include size, profitability, and growth opportunity as well as the additional control variables used for Panel B. All variables are winsorized at the 1% and 99% levels. *t*-statistics based on standard errors that are robust to heteroscedasticity and clustered at the firm level are shown in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Panel A:	Dependent Variable: Repurchase Payouts				Tender offer
	Reversal and Placebo Tests		Result Sensitivity on Firm Size		
	Reversal Test	Placebo Test	Small Firms	Large Firms	
	(1)	(2)	(3)	(4)	(5)
Treatment × Post	0.122**	0.0539	−0.155**	−0.220***	0.00350
	(2.05)	(0.85)	(2.36)	(2.75)	(1.00)
Controls	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
Year-quarter FE	Yes	Yes	Yes	Yes	Yes
Cluster by firm	Yes	Yes	Yes	Yes	Yes
N	4027	7924	4288	4258	8546
R^2	0.539	0.400	0.472	0.412	0.064

Panel B:	Controlling for Alternative Explanations (Annual Data)							
	Dependent Variable: Repurchase Payouts							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Treatment × Post	−1.003***	−1.015***	−1.009***	−1.005***	−1.002***	−1.010***	−1.007***	−1.041***
	(−3.43)	(−3.50)	(−3.46)	(−3.44)	(−3.43)	(−3.49)	(−3.45)	(−3.62)
Manager stocks	-	1.341*	-	-	-	-	-	1.281*
		(1.79)						(1.74)
Manager options	-	0.165	-	-	-	-	-	0.287
		(0.53)						(0.90)
Exercised options	-	-	4.945**	-	-	-	-	4.848**
			(2.39)					(2.35)
Exercisable options	-	-	−0.157	-	-	-	-	−0.733
			(−0.25)					(−1.16)
Cash-flow volatility	-	-	-	−0.663	-	-	-	−0.689
				(−0.74)				(−0.67)
Non-operating cash flow	-	-	-	0.165***	-	-	-	0.163***
				(3.73)				(3.89)
Future market-adjusted return	-	-	-	-	0.0346	-	-	0.125
					(0.20)			(0.72)
WW index	-	-	-	-	-	−0.422**	-	−0.428***
						(−2.52)		(−2.68)
Price informativeness	-	-	-	-	-	-	−0.964	−1.014
							(−0.87)	(−0.91)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster by firm	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1945	1945	1945	1945	1945	1945	1945	1945
R^2	0.608	0.610	0.613	0.610	0.608	0.613	0.608	0.622

Panel C	What Did Firms Do with the Money Not Distributed? (Annual Data)		
Dependent Variable	Short-term Debt	Cash	Investment
	(1)	(2)	(3)
Treatment × Post	−0.962**	0.430	−0.386
	(−2.56)	(0.75)	(−0.74)
Controls	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Cluster by firm	Yes	Yes	Yes
N	1945	1945	1945
R^2	0.703	0.945	0.922

quasi-treatment and quasi-control groups because they affected some stocks intensely but barely affected others.[27] Comparing the quasi-treatment and quasi-control groups helps us to control for the effects of confounding events. To further control for heterogeneity across firms, we match the treatment firms with the control firms based on repurchase payouts, dividend payouts, size, profitability, and growth opportunities. Table A.3 presents the pre-treatment summary statistics and mean differences, which suggest that treatment firms and their matched controls are similar before the events. Control variables include the main determinants of corporate payout choice identified in the literature, as in Section 3.5. We also limit our sample period to one year before and one year after the events. In all these tests, we use the same sample filters that we used with the Tick Size Pilot analyses and follow the DiD regression using Eq. (1). Observations are recorded at annual frequency because firms do not report quarterly repurchase information until 2004.

4.1. Manning Rule and the Order Handling Rules

In this section, we discuss our investigation of the importance of execution priority using the 1994 Manning Rule and the 1997 Order Handling Rules as quasi-natural experiments. Before 1994, Nasdaq dealers could trade ahead of their customers' limit orders. For example, suppose a dealer quotes a $100 bid price and a $102 offer price. A customer who wants to buy at a bid price of $100 has lower execution priority than the dealer because the dealer can trade ahead of her customers. A dealer can even trade through her customers: a Nasdaq dealer who receives a customer order to buy at $101 does not have to display the order as a new, more aggressive quote; the dealer can buy for his own account at prices below $101, thus trading through the customer order. The customer is entitled to execution only when the market offer price drops to 101, which makes the customer order marketable (Hasbrouck, 2007). The Manning Rule, approved by the SEC on June 29, 1994, prohibited dealers from trading ahead of or trading through their customers, thereby increasing the execution priority of issuers over their own dealers.[28]

The Manning Rule applied only to Nasdaq-listed firms. Firms listed on other exchanges were not affected. For example, NYSE specialists faced order-flow competition from floor traders and public limit orders. Limit-order prices were incorporated into prices displayed on the market, and limit orders took precedence over specialists' orders (Christie and Schultz, 1994).

In the DiD analyses, $Treatment_i$ equals one for Nasdaq firms and zero for matched firms listed on other exchanges, while $Post_t$ equals one if an observation is from 1995 and zero if it is from 1993. The results reported in Panel A of Table 6 show that repurchase payouts by Nasdaq firms increased by 0.377 percentage points relative to control firms, representing a 60% increase over their pre-treatment mean (0.377/0.631). We find no significant treatment effects on dividend payouts. NASDAQ firms' total payouts increased by 0.373 percentage points relative to control firms, representing a 29% increase over their pre-treatment mean (0.373/1.267). Finally, NASDAQ firms' payout structures increased by 0.326 relative to control firms, representing a 25% increase over its pre-treatment mean (0.326/1.324).

The 1994 shock is unique because it affected repurchases at both the extensive and intensive margins, whereas we do not find that other market-structure reforms affected repurchases at the extensive margin. We find that the fraction of issuers that repurchased shares increased by 5 percentage points, representing a 21% increase over the pre-treatment level (0.048/0.224). These results suggest that the Manning Rule opened the door to other market-structure reforms that facilitate share repurchases. If dealers enjoyed execution priority at all times, issuers would find it hard to compete with dealers at the price ceilings.

Along with the Manning Rule implementation, Nasdaq also underwent another change: the odd-eighth adoption. Before 1994, Nasdaq market makers rarely quoted odd eighths. Christie and Schultz (1994) indicate that quoting only even eighths may be evidence of tacit collusion among Nasdaq market makers, such that the minimum bid–ask spread is at least one-quarter of a dollar wide. After this influential article, Nasdaq market makers began quoting odd eighths, which is equivalent to a reduction in the tick size for Nasdaq stocks. It is difficult to disentangle the Manning Rule's impact from the impact of the odd-eighth adoption because both reduced the advantage market makers enjoyed. Nevertheless, without the Manning Rule, issuers would find it hard to compete with dealers at the bid price irrespective of the tick size. Therefore, the Manning Rule relaxed the constraints on *whether* Nasdaq firms could repurchase shares, whereas tick-size reduction is related more directly to *how many* shares they can repurchase. Therefore, an increase in repurchases at the extensive margin may suggest the impact of the Manning Rule.

The 1997 Order Handling Rules further increased the execution priority for customer limit orders. Before 1997, a Nasdaq dealer did not need to display customers' limit orders. If an issuer submitted a buy limit order at the best bid or offer, the order could be invisible to other dealers and these dealers' customers. The Order Handling Rules required dealers to display all public orders when these orders were at the best bid or offer.[29] Once an issuer's limit order becomes visible, it can trade with the customers of other dealers, either because the customers choose to transact with the limit order or because these other dealers forward customers' marketable orders to the limit order to fulfill the best execution obligation. Therefore, the Order Handling Rules extended an issuer's execution priority from one dealer to all dealers.

Order Handling Rules apply to all U.S. stocks, but they are specifically targeted at Nasdaq stocks (Barclay et al., 1999). In our DiD analyses, $Treatment_i$ equals one for Nasdaq firms and zero for matched firms listed on other exchanges, while $Post_t$ equals one if an observation is from 1998 and zero if it is from 1996. The results we report in Panel B of Table 6 indicate that Nasdaq firms' repurchases increase by 0.387 percentage points relative to control firms, representing a 38% increase over pre-treatment mean (0.387/1.008). We do not find significant treatment effects for dividends. NASDAQ firms' total payouts increase by 0.414 percentage points relative to control firms, representing a 28% increase over pre-treatment mean (0.414/1.480). NASDAQ firms' payout structures increase by 0.360 relative to control firms, representing a 22% increase over pre-treatment mean (0.360 /1.639). In summary, the results reported in this subsection suggest the first-order importance of execution priority for repurchases when issuers face price ceilings.

4.2. The 1997 tick-size reduction and the 2001 decimalization

In our controlled-experiment analyses, we show that an increase in the tick size reduces share repurchases. To conduct an external validity check, we examine the effects of the 1997 tick-size reduction from $1/8

[27] Market structure continued to evolve after 2003, but it became extremely hard to find quasi-treatment and quasi-control groups because the trading mechanism across stock exchanges converged after these earlier reforms. Finding an event date for later market structure changes is also challenging. For example, the proliferation of dark pools is a gradual process and does not have a clear event day. Therefore, we rely on the implementation of the Trade-at Rule to identify the causal impact of the dark pool on share repurchases.

[28] The Manning Rule is a result of the 1988 Manning decision. A customer of a National Association of Securities Dealers (NASD) member firm, William Manning, alleged that the dealer had accepted his limit order, failed to execute it, and violated its fiduciary duty to him by trading ahead of the order (Securities Exchange Act Release No. 44357).

[29] Barclay et al. (1999) note that the Order Handling Rules include four sets of rules. The Limit Order Display Rule is the most highly relevant rule for issuers.

Table 6
Event studies: historical market-structure reforms and payout policies. In this table we report the results of event studies designed to test the effects of historical market-structure reforms on payout policies. In the event study for the 1994 Nasdaq Manning Rule, *Treatment* equals one if a firm is listed on Nasdaq and zero if it is a matched firm listed on another U.S. exchange, while *Post* equals one if an observation occurs in 1995 and zero if it occurs in 1993. In the event study for the 1997 Order Handing Rule, *Treatment* equals one if a firm is listed on Nasdaq and zero if it is a matched firm listed on another U.S. exchange, while *Post* equals one if an observation occurs in 1998 and zero if it occurs in 1996. In the event study for the 1997 tick size reduction, *Treatment* equals one if a firm experiences an above-median decrease in the spread and zero for matched firms, while *Post* equals one if an observation occurs in 1998 and zero if it occurs in 1996. In the event study for the 2001 decimalization, *Treatment* equals one if a firm experiences an above-median decrease in the spread and zero for matched firms, while *Post* equals one if an observation occurs in 2002 and zero if it occurs in 2000. In the event study for the 2003 implementation of autoquotes on the NYSE, *Treatment* equals one if a firm is listed on the NYSE and zero if it is a matched firm listed on another U.S. exchange, while *Post* equals one if an observation occurs in 2004 and zero if it occurs in 2002. *Control variables* include size, profitability, growth opportunity; managerial stock holdings and managerial options holdings; exercised and exercisable options; the financial flexibility advantage of share repurchases proxied by cash-flow volatility and non-operating cash flow; mispricing proxied by future one-year market-adjusted returns; financial constraint proxied by the WW index; and price informativeness proxied by return non-synchronicity, defined as one minus the R^2 from a firm-specific regression of daily stock returns on value-weighted market returns for a year. All variables are winsorized at the 1% and 99% levels. *t*-statistics based on standard errors that are robust to heteroskedasticity and clustered at the firm level are shown in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

	Repurchase Payouts (1)	Dividend Payouts (2)	Total Payouts (3)	Payout Structure (4)	Repurchase Dummy (5)	Tender Offer (6)
Panel A: 1994 Nasdaq Manning Rule						
Treatment × Post	0.377***	−0.00349	0.373**	0.326***	0.0477**	0.0460
	(2.68)	(−0.10)	(2.53)	(2.81)	(2.26)	(0.89)
Panel B: 1997 Order Handling Rule						
Treatment × Post	0.387**	0.0268	0.414**	0.360**	−0.00688	0.0527
	(2.21)	(0.85)	(2.33)	(2.44)	(−0.33)	(1.27)
Panel C: 1997 Tick Size Reduction						
Treatment × Post	0.354**	0.0162	0.370**	0.296**	0.0137	0.103
	(1.99)	(0.64)	(2.05)	(2.03)	(0.68)	(1.44)
Panel D: 2001 Decimalization						
Treatment × Post	0.540***	−0.00671	0.533***	0.470***	0.00200	0.00522
	(3.56)	(−0.19)	(3.41)	(3.80)	(0.09)	(0.08)
Panel E: 2003 NYSE Autoquote						
Treatment × Post	0.399**	0.0235	0.422**	0.181	−0.00359	0.0742
	(2.02)	(0.44)	(2.06)	(1.13)	(−0.14)	(1.03)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Cluster by firm	Yes	Yes	Yes	Yes	Yes	Yes

to $1/16 and the 2001 decimalization following the 1997 Common Cents Pricing Act. Goldstein and Kavajecz (2000) and Bessembinder (2003) show that these two tick-size reductions narrowed the bid–ask spread and reduced market depth. We expect to find increases in repurchase payouts following both tick-size reductions.

We follow prior literature and define $Treatment_i$ as equal to one for firms that experience above-median decreases in the bid–ask spread and zero for matched firms (Fang et al., 2014), while $Post_t$ equals one if an observation is from one year after the tick-size reduction and zero if it is from one year before the tick-size reduction. In Panels C and D of Table 6 we report the results, which show that, following the 1997 tick-size reduction, treatment firms' repurchase payouts increase by 0.354 percentage points relative to control firms, representing a 41% increase over their pre-treatment mean (0.354/0.874). We do not find significant treatment effects on dividend payouts. Treatment firms' total payouts increase by 0.370 percentage points relative to control firms, representing a 26% increase over their pre-treatment mean (0.370/1.404). The ratio of repurchase payouts to dividend payouts among treatment firms increases by 0.296 relative to control firms, representing a 20% increase over its pre-treatment mean (0.296/1.462). Following the 2001 decimalization, the treatment firms' repurchase payouts increase by 0.540 percentage points relative to control firms, representing a 32% increase over their pre-treatment mean (0.540/1.671). Again, we do not find significant treatment effects on dividend payouts. Treatment firms' total payouts increased by 0.533 percentage points, representing a 23% increase over their pre-treatment mean (0.533/2.298). The ratio of repurchase payouts to dividend payouts among treatment firms increases by 0.470 relative to control firms, representing a 23% increase over its pre-treatment mean (0.470 /2.030).

The results of tick-size reductions reflect an intuition that is similar to that associated with the Tick Size Pilot. A reduction in the tick size narrows the bid–ask spread, reduces market depth at the best bid price, and reduces the queue competition at the price ceilings. Therefore, firms can repurchase more shares under less constraining price ceilings.

4.3. 2003 NYSE autoquote installation

In this subsection, we explore the importance of automated execution for share repurchases. We use the NYSE autoquote installation as a quasi-natural experiment (Hendershott et al., 2011). In Section 3, we noted that the Tick Size Pilot added frictions for computer algorithms. The shocks imposed by the autoquote installation were much more fundamental because they reshaped the share-repurchase business in two ways.

First, autoquotes reduced monitoring and compliance costs for issuers. They broke down the physical barrier to accessing the market: issuers could use computer algorithms to compete with specialists for liquidity provision. Before the autoquote installation, share repurchases were executed manually (a high-touch process). When executions were manual, other liquidity providers could compete with specialists only when these liquidity providers were present, either on the floor or in the limit-order book. Automated execution significantly leveled the playing field for issuers and specialists. Autoquotes allowed algorithms to execute share repurchases (a low-touch process) and also made it easier for issuers to comply with Rule 10b-18.

Second, autoquotes removed the last-mover advantage that specialists enjoyed. Before the autoquotes were installed, NYSE specialists disseminated quotes manually and approved each transaction by pressing the "Enter" key. They could therefore condition their actions on incoming orders before they hit the "Enter" button (MacKenzie, 2017). For example, specialists could choose to participate in trades from their own accounts by improving quotes from existing limit orders. They could also stop executions of incoming marketable orders by promising future price improvements. In both cases, specialists stepped ahead of

other liquidity providers, including issuers. After automated execution became available, specialists lost their last-mover advantage because executions occurred in the absence of specialists' approval. The loss of specialists' execution privilege increased execution priority for issuers.

In this event study, we define $Treatment_i$ as equal to one for NYSE firms and zero for matched firms listed on other exchanges; for example, Nasdaq stocks shifted to electronic trading before 2003 because of the proliferation of Electronic Communication Networks (Barclay et al., 2003). $Post_t$ equals one if an observation is from 2004 and zero if it is from 2002. The results are reported in Panel E of Table 6 and show that the installation of autoquotes on the NYSE causes a 25% (0.399/1.628) increase in repurchase payouts in treated firms relative to control firms. This result provides one explanation of the increase in repurchases over dividends following the 2003 dividend-tax cut, as documented in Chetty and Saez (2005). The transition of repurchase execution from manual (high-touch) execution to automated (low-touch) execution reduced repurchasing frictions and thus increased share repurchases around 2003.

4.4. Robustness Checks

We next run two robustness checks on the effects of the historical events. First, we test the impact of historical events on tender offers. The results reported in column (6) of Table 6 indicate that the historical market-structure reforms have no significant effects on tender offers. As a tender offer is not made through the secondary market and therefore is not regulated under Rule 10b-18, the nonsignificant treatment effects for tender offers help to establish price ceilings and market structure as the drivers of the increases in open-market share repurchases. Second, we use event-time DiD analyses to estimate differences in changes in repurchases between the treatment and control groups from three years before the events to one year after the events, where year $t-3$ is the baseline year. Fig. A.2 plots the DiD coefficients graphically. In general, the differences in repurchase changes between the treatment and control groups are nonsignificant prior to the events, suggesting that the treated and control firms follow a similar trend in share repurchases prior to the treatment.[30] The figure also shows the main treatment effects of increases in repurchases following the reforms.

4.5. Linking micro-level evidence to the macro-level trend

In this section, we use back-of-the-envelope calculations to provide rough estimates of the contributions of the historical market-structure reforms to the secular increase in repurchases. Quantifying the contributions of any single economic factor to the secular increase in repurchases is certainly a challenging task. Existing explanations such as option dilution and financial flexibility rely on cross-sectional evidence but do not directly address how large the time-series increase in repurchases is driven by these factors (Farre-Mensa et al., 2014). Our DiD research design using historical market-structure events as quasi-natural experiments provides us with a unique setting in which to carry out the estimations. Because our DiD estimates reported in Table 6 represent the implied changes in repurchases that are attributable to market-structure reforms divided by pre-year total assets, the implied dollar increase in repurchases that is attributable to each event depends on the treated firms' total assets. Therefore, we extrapolate the dollar increase in share repurchases led by each reform by multiplying its treatment effect by the treated firms' total assets. We then sum the effects of all market-structure reforms and find that they contribute to 18% of the secular increase in share repurchases from 1995 through 2021.

Table 7 details the steps in our extrapolation and Fig. 2 visualizes the results. The implied dollar increase in share repurchases that is attributable to market-structure reforms depends on three factors: 1) the number of treated firms, 2) the size of the treated firms, and 3) the treatment effect on treated firms. We therefore conduct a three-dimensional decomposition to project our micro-evidence onto the macro-trends.

Panel A of Table 7 presents the number and fraction of treated firms over time. The results reported in columns (1)–(5) indicate the number of treated firms in each market-structure reform. The 1994 Nasdaq Manning Rule led to 1096 treated firms in 1995, but this dropped to 960 in 1997 because some treated firms were delisted from the stock exchange during this period.[31] The 1997 Nasdaq Order Handling Rule led to more treated firms (1,256) because many Nasdaq firms were newly listed between 1994 and 1997. The 1997 tick-size reduction and the 2001 decimalization affected not only Nasdaq firms but also NYSE firms and led to even larger numbers of treated firms (1,662 and 1,474, respectively).[32] Finally, the 2003 NYSE autoquote installation led to a relatively lower number of treated firms (872). For column (6) we measure the number of firms that have been treated by at least one reform. We call these firms treated firms for the sake of simplicity. Column (7) presents the number of all firms (including both treated and non-treated firms) in the sample. Column (8) presents the fraction of treated firms over all firms. As Panel A of Fig. 2 illustrates, this fraction increased from 21% in 1995 to 43% in 1998 to 56% in 2002, reaching 61% in 2004 following the NYSE autoquote installation. Therefore, most firms have been treated by at least one market-structure reform after the NYSE installed autoquotes.

Panel B of Table 7 presents the pre-year total assets of treated firms over time, which is the multiplier we use to calculate the implied increase in share repurchases with our DiD estimates. The 1994 Nasdaq Manning Rule led to $632 billion in treated assets in 1995, which increased to $814 billion in 1997 because of asset growth in the treated firms. Like the pattern shown in Panel A, the 1997 Nasdaq Order Handling Rule led to greater treated assets ($913 billion), while the 1997 tick-size reduction and 2001 decimalization led to even greater treated assets ($2,180 billion and $2,167 billion, respectively).[33] Most interestingly, the great explosion in treated assets followed the 2003 NYSE autoquote installation, which led to $9,914 billion in treated assets. Panel B of Fig. 2 shows that the asset weight of treated firms increased from 7% in 1995 to 26% in 1998, 36% in 2002, and 85% in 2004 following the NYSE autoquote installation. Therefore, market-

[30] Note that there was an increase in repurchases in treated firms over control firms from year −3 to year −2 in the 2003 NYSE autoquote analyses. Perhaps the dot-com bubble burst in the early 2000s affected mainly NASDAQ firms, and therefore NASDAQ firms reduced repurchases more than NYSE firms. There was no significant change from year −2 to year −1, as the impact of the dot-com bubble stabilized. This result also highlights the importance of using short windows of one year before and one year after the treatments in our main analyses to avoid confounding events that may contaminate the estimates. There was a slight increase in repurchases in treated firms over repurchase in control firms from year −1 to year 0, as our data are reported at annual frequency and year 0 is partially treated. For the 2001 decimalization, there was a slight increase in repurchases in treated firms over repurchases in control firms from year −3 to year −1 but the relative change in repurchases was nonsignificant from year −2 to year −1.

[31] A firm may delist voluntarily or involuntarily. Voluntary delisting can occur because of mergers, takeovers, or privatization. Involuntary delisting can occur for failing to meet listing requirements (e.g., regulatory, financial, and trading standards) set by a stock exchange.

[32] The total number of treated firms in 1998 (2,275) is smaller than the sum of the number of treated firms in each of the three reforms (864+1,256+1,662) because a firm can be treated by more than one reform. For firms treated by more than one reform, we include the impact of each treatment when we compute the results in Panel C of Table 7.

[33] Like the results reported in Panel A, here the total non-overlapping treated assets in 1998 (2,833) is smaller than the sum of the treated assets in each of the three reforms (870+913+2,180) because the total non-overlapping treated firms do not double-count firms that are treated by multiple reforms.

Table 7

Event studies: linking micro-level evidence to macro-level trends. In this table we provide quantitative estimations of the contribution of the market-structure events to the secular increase in repurchases. Panel A presents the number and fraction of treated firms. Panel B presents the pre-year total assets and the asset weights of treated firms. Panel C presents the estimation results pertaining to the implied increase in repurchases attributable to the market-structure reforms and the contribution of the market-structure reforms to the secular increase in share repurchases. Columns (1)–(5) show the implied dollar changes in repurchases attributable to market-structure reforms. For each year following an event, we multiply our DiD estimates reported in Table 6 by the pre-year total assets of treated firms reported in Table 7 Panel B. We aggregate the implied increase in share repurchases across events in Column (6). Column (7) shows the aggregate repurchases of all firms from 1994 through 2021. Column (8) presents the estimation of the secular increase in share repurchases. Column (9) shows the fraction of the secular increase in share repurchases attributable to the market-structure reforms. The units in dollar amounts are reported in billions of real 2021 U.S. purchasing power.

Panel A: The Number of Treated Firms

Year	1994 Nasdaq Manning Rule (1)	1997 Order Handling Rule (2)	1997 Tick Size Reduction (3)	2001 Decimalization (4)	2003 NYSE Autoquote (5)	All Treated Firms (6)	All Firms in the Sample (7)	Fraction of Treated Firms (8)
1995	1096	-	-	-	-	1096	5232	21%
1996	1033	-	-	-	-	1033	5648	18%
1997	960	-	-	-	-	960	5675	17%
1998	864	1256	1662	-	-	2275	5308	43%
1999	772	1123	1503	-	-	2037	5076	40%
2000	709	1016	1344	-	-	1821	4920	37%
2001	665	944	1205	-	-	1636	4357	38%
2002	641	909	1115	1474	-	2228	4010	56%
2003	616	866	1040	1404	-	2098	3752	56%
2004	589	821	975	1325	872	2267	3723	61%
2005	560	773	907	1247	845	2128	3644	58%
2006	523	721	850	1166	807	1997	3572	56%
2007	497	678	778	1043	749	1827	3506	52%
2008	479	649	722	983	730	1720	3296	52%
2009	464	626	683	932	716	1634	3121	52%
2010	440	592	651	881	697	1551	3014	51%
2011	422	569	623	845	675	1484	2919	51%
2012	393	534	596	801	659	1409	2847	49%
2013	370	509	565	761	639	1347	2877	47%
2014	361	490	538	728	625	1297	2977	44%
2015	348	471	511	691	602	1237	2952	42%
2016	335	452	486	660	580	1182	2866	41%
2017	316	427	457	624	560	1125	2867	39%
2018	298	404	437	592	545	1076	2885	37%
2019	286	385	420	565	524	1031	2879	36%
2020	275	368	399	541	507	989	2971	33%
2021	255	342	373	518	489	942	3122	30%

Panel B: Pre-year Total Assets of Treated Firms

Year	1994 Nasdaq Manning Rule (1)	1997 Order Handling Rule (2)	1997 Tick Size Reduction (3)	2001 Decimalization (4)	2003 NYSE Autoquote (5)	All Treated Firms (6)	All Firms in the Sample (7)	Asset Weights of Treated Firms (8)
1995	632	-	-	-	-	632	9009	7%
1996	728	-	-	-	-	728	9365	8%
1997	814	-	-	-	-	814	10,100	8%
1998	870	913	2180	-	-	2833	10,700	26%
1999	979	1174	2495	-	-	3113	11,400	27%
2000	1123	1382	2783	-	-	3500	12,800	27%
2001	1234	1610	2834	-	-	3664	13,900	26%
2002	1209	1550	2982	2167	-	5035	13,700	37%
2003	1182	1496	2708	2268	-	4825	13,400	36%
2004	1180	1505	2844	2351	9914	11,900	14,000	85%
2005	1224	1576	2878	2503	10,400	12,400	14,700	84%
2006	1173	1473	2872	2514	10,200	12,100	14,600	83%
2007	1218	1527	2929	2533	10,300	12,200	15,000	81%
2008	1261	1568	2884	2488	10,400	12,400	15,400	81%
2009	1211	1522	2675	2411	9906	11,800	14,600	81%
2010	1255	1577	2651	2402	10,100	12,000	14,900	81%
2011	1406	1751	2709	2384	10,500	12,500	15,700	80%
2012	1557	1938	2970	2499	10,700	12,900	16,300	79%
2013	1703	2113	3174	2619	10,800	13,300	17,000	78%
2014	1819	2266	3257	2636	11,000	13,600	17,800	76%
2015	1879	2370	3392	2699	11,100	13,800	18,500	75%
2016	2038	2548	3622	2783	11,200	14,000	19,000	74%
2017	2222	2748	3711	2789	10,900	13,900	19,200	72%
2018	2318	2907	3827	2831	11,100	14,300	20,000	72%
2019	2206	2829	3636	2635	11,100	14,200	20,100	71%
2020	2229	2911	3773	2866	11,800	15,000	21,200	71%

(*continued on next page*)

Table 7 (*continued*)

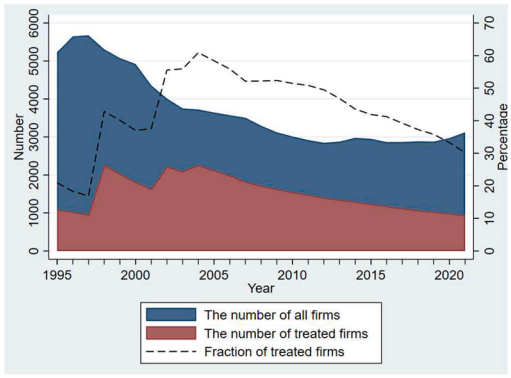
2021	2288	2998	3767	2918	11,900	15,200	21,800	70%	
Panel C: Implied Increase in Repurchases Attributable to Market-Structure Reforms									
Year	1994 Nasdaq Manning Rule (1)	1997 Order Handling Rule (2)	1997 Tick Size Reduction (3)	2001 Decimalization (4)	2003 NYSE Autoquote (5)	Sum of Events (6)	Repurchases of All Firms in the Sample (7)	Secular Increase in Repurchases (8)	Percentage Contribution of Market-Structure Reforms (9)
1994	-	-	-	-	-	-	69.53	-	-
1995	2.38	-	-	-	-	2.38	105.06	35.53	6.70%
1996	2.74	-	-	-	-	2.74	141.15	71.61	3.83%
1997	3.07	-	-	-	-	3.07	198.61	129.07	2.38%
1998	3.28	3.53	7.72	-	-	14.53	249.66	180.12	8.07%
1999	3.69	4.54	8.83	-	-	17.07	255.08	185.55	9.20%
2000	4.23	5.35	9.85	-	-	19.43	228.61	159.07	12.22%
2001	4.65	6.23	10.03	-	-	20.91	188.48	118.95	17.58%
2002	4.56	6.00	10.56	11.70	-	32.82	176.60	107.06	30.66%
2003	4.46	5.79	9.59	12.25	-	32.08	191.90	122.36	26.22%
2004	4.45	5.82	10.07	12.70	39.56	72.59	289.19	219.66	33.05%
2005	4.61	6.10	10.19	13.52	41.50	75.92	431.29	361.76	20.99%
2006	4.42	5.70	10.17	13.57	40.70	74.56	562.08	492.55	15.14%
2007	4.59	5.91	10.37	13.68	41.10	75.65	691.20	621.67	12.17%
2008	4.75	6.07	10.21	13.44	41.50	75.96	452.59	383.05	19.83%
2009	4.57	5.89	9.47	13.02	39.52	72.47	182.28	112.74	64.28%
2010	4.73	6.10	9.38	12.97	40.30	73.49	351.41	281.87	26.07%
2011	5.30	6.78	9.59	12.87	41.90	76.43	488.50	418.97	18.24%
2012	5.87	7.50	10.52	13.50	42.69	80.08	435.73	366.20	21.87%
2013	6.42	8.18	11.24	14.14	43.09	83.07	512.23	442.70	18.76%
2014	6.86	8.77	11.53	14.23	43.89	85.28	586.73	517.20	16.49%
2015	7.08	9.17	12.01	14.57	44.29	87.13	606.87	537.34	16.21%
2016	7.68	9.86	12.82	15.03	44.69	90.08	531.72	462.18	19.49%
2017	8.38	10.63	13.14	15.06	43.49	90.70	481.07	411.53	22.04%
2018	8.74	11.25	13.55	15.29	44.29	93.11	770.26	700.72	13.29%
2019	8.32	10.95	12.87	14.23	44.29	90.65	619.35	549.82	16.49%
2020	8.40	11.26	13.35	15.48	47.08	95.58	509.93	440.40	21.70%
2021	8.63	11.60	13.34	15.76	47.48	96.80	749.90	680.36	14.23%
Sum (1995–2021)	146.88	178.99	260.38	277.00	771.34	**1634.58**	-	**9110.05**	**17.94%**
Percentage Contribution by Reforms	1.61%	1.96%	2.86%	3.04%	8.47%	-			

structure reforms began by affecting a large number of firms with relatively lower assets in the 1990s, but later affected much larger firms in the 2000s. These patterns help explain the aggregate trend through which the secular increase in share repurchases begins with an increase in the number of firms that switch from paying dividends to offering share buybacks in the 1990s (Fama and French, 2001; Grullon and Michaely, 2002), while the dramatic increase in the dollar amount of share repurchases occurs after 2003 (Farre-Mensa et al., 2014).

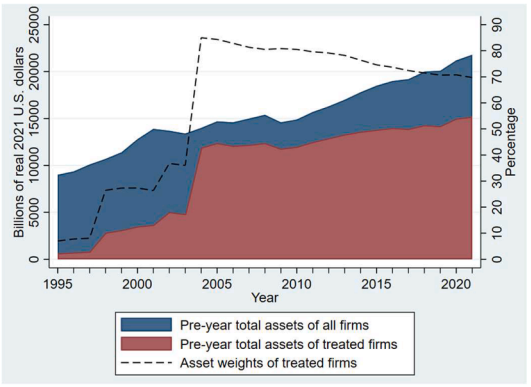
Panel C of Table 7 presents the estimation results for the treatment effect on treated firms. The results reported in columns (1)–(5) indicate the implied dollar increases in repurchases in each reform-year, where we multiply the treatment effect indicated in Table 6 by the pre-year total assets of treated firms reported in Table 7 Panel B. For example, for column (1) we extrapolate the impact of the Nasdaq Manning Rule by multiplying its treatment effect by treated firms' pre-year total assets. The implied increase in share repurchases in 1995 ($2.38 billion) that is attributable to the Nasdaq Manning Rule equals the product of the DiD coefficient reported in column (1) of Table 6 Panel A (0.377%) and the treated firms' pre-year total assets in 1995 ($632 billion). The implied increase in share repurchases in 1998 is $3.28 billion, using the same DiD coefficient multiplied by treated firms' pre-year total assets in 1998 ($870 billion).

After 1997, additional market-structure reforms kicked in, and we show results indicating their effects in columns (2)–(5) of Table 7. For example, the 1997 Order Handling Rule and tick-size reduction led, respectively, to $3.53 billion (0.387% × $913 billion) and $7.72 billion (0.354% × $2,180 billion) implied increases in repurchases in 1998. For column (6) we measure the aggregated implied increase in share repurchases across events. The aggregated implied increase in share repurchases that is attributable to market-structure reforms in 1998 is $14.53 billion, which we calculated by summing the implied increase in repurchases from these three reforms (3.28+3.53+7.72). Decimalization and the NYSE autoquote installation generated larger implied increases in share repurchases. Decimalization resulted in an $11.70 billion (0.540% × $2,167 billion) implied increase in share repurchases in 2002, while the NYSE autoquote installation resulted in a $39.56 billion (0.399% × $9,914 billion) implied increase in share repurchases in 2004. The total implied increase in share repurchases across reforms rose to $32.08 billion in 2002 and $72.59 billion in 2004. After 2004, all five reforms were implemented and the total implied increase in repurchases across reforms continued to grow, rising to $96.80 billion in 2021. We also sum the estimates of the implied increase in repurchases over the entire 1995–2021 period: the Manning Rule and the Order Handling Rule resulted in $146.88 billion and $178.99 billion increases in repurchases, respectively; the 1997 tick-size reduction and decimalization resulted in $260.38 billion and $277.00 billion increases in repurchases, respectively; and the NYSE autoquote installation resulted in a $771.34 billion increase in repurchases. The total implied increase in share repurchases due to these reforms over the 1995–2021 period is ~$1.63 trillion.

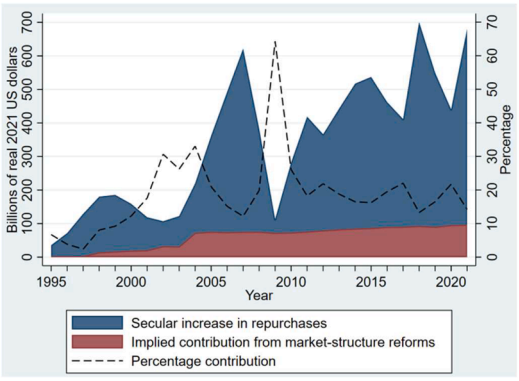
The next step in calculating the percentage contribution of the market-structure reforms to the secular increase in share repurchases is to estimate the denominator. We first calculate the increase in repurchases in each year over the 1995–2021 period over repurchases in the baseline year of 1994. To capture the secular trend during the entire sample period from 1995 through 2021 instead of a point estimate in a



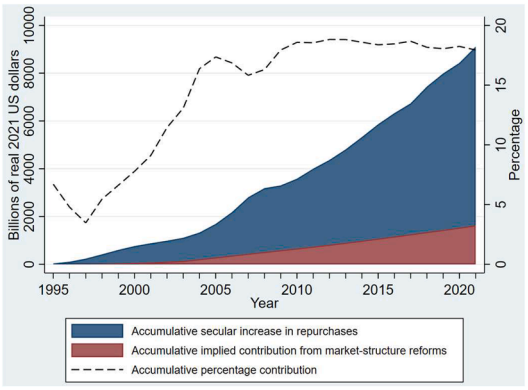
Panel A: The Number of Treated Firms



Panel B: Pre-year Total Assets of Treated Firms



Panel C: Implied Increase in Repurchases in each Year



Panel D: Accumulative Implied Increase in Repurchases

Fig. 2. Event studies: linking micro-level evidence to macro-level trends. In this figure, we plot the quantitative estimations of the contribution of the market-structure events to the secular increase in repurchases from 1995 to 2021. Panel A plots the number and fraction of treated firms. Panel B plots the pre-year total assets and the asset weights of treated firms. Panel C plots the estimation results pertaining to the implied increase in repurchases attributable to the market-structure reforms and the percentage contribution of the market-structure reforms to the secular increase in share repurchases *in each year*. Panel D plots the *accumulative* implied increase in repurchases attributable to the market-structure reforms and the accumulative percentage contribution of the market-structure reforms to the secular increase in share repurchases. For example, in 2003, the implied increase in repurchases attributable to the market-structure reforms is the implied increase in 2003 only, while the accumulative implied increase in repurchases attributable to the market-structure reforms is the sum of the implied increase from 1995 to 2003. Similarly, in 2003, the secular increase in share repurchases is the aggregate increase in repurchases in 2003 only, while the accumulative secular increase in share repurchases is the sum of the aggregate increase in repurchases from 1995 to 2003.

particular year, we accumulate these increases in repurchases. Column (7) presents the repurchases of all firms from 1994 through 2021. Column (8) presents the increase in repurchases each year over the 1995–2021 period over the baseline year of 1994. Column (9) shows the fraction of the aggregate increase in share repurchases that is attributable to the market-structure reforms, where we divide the implied increase in share repurchases reported in column (6) by the aggregate increase in repurchases reported in column (8). Panel C of Fig. 2 plots the implied increase in repurchases and the percentage contribution of market-structure reforms by year. For example, the increase in repurchases in 1995 over repurchases in 1994 is $35.53 billion, calculated by subtracting the aggregate repurchase amount in 1994 ($69.53 billion) from the aggregate repurchase amount in 1995 ($105.06 billion), and the percentage contribution of market-structure reforms in 1995 was 6.70% (2.38/35.53). Similarly, the increase in repurchases in 2021 over repurchases in 1994 was $680.36 billion (749.90–69.53), and the percentage contribution of market-structure reforms in 2021 was 14.23% (96.80/680.36). Summing the annual estimates for each year, Panel D of Fig. 2 shows that the accumulative secular increase in share repurchases from 1995 through 2021 is ~$9.11 trillion, and the total contribution of the market-structure reforms to the secular increase in share repurchases over the 1995–2021 period was ~18% (1.63/9.11).

The last row in Panel C of Table 7 presents the breakdown of the percentage contribution by event. One interesting result is that the NYSE autoquote installation made the greatest contribution to the secular increase in share repurchases (8.47%) even though it occurred last among the reforms, while the 1994 Nasdaq Manning Rule made the smallest contribution (1.61%) even though it was the first to occur. As the installation of autoquotes affects NYSE stocks while earlier reforms affect mostly NASDAQ stocks, and NYSE firms are on average larger than NASDAQ firms, this reform increased share repurchases more measurably in dollar amounts. The Order Handling Rule, the 1997 tick-size reduction, and decimalization contributed 1.96%, 2.86%, and 3.04% of the secular increase in repurchases, respectively.

To summarize the economic implications of our back-of-the-envelope analysis, the results presented in this section indicate that the historical market-structure reforms played an important role in the secular increase in share repurchases, not only qualitatively but also quantitatively. Moreover, we find that the market-structure reforms at first affected a large number of firms in the 1990s following the 1994 NASDAQ Manning Rule but had relatively smaller impacts on the dollar amounts of share repurchases, and later had much larger impacts on increasing the dollar amount of share repurchase in the 2000s after the 2003 NYSE autoquote installation. These results help explain why the secular increase in share repurchases over paying dividends begins with an increase in the number of firms (Fama and French, 2001; Grullon and Michaely, 2002) followed by an increase in dollar amounts (Farre-Mensa et al., 2014).

5. Conclusion

When U.S. firms repurchase shares in the open market, they face price ceilings established by SEC Rule 10b-18. The price ceilings, in turn, gives market structure the first-order role in share repurchases. We show that the price ceilings and reduced market-structure frictions provide one explanation of the secular increase in share repurchases over dividends. The 1994 Manning Rule and the 1997 Order Handling Rules increased issuers' execution priority at the price ceilings. Tick-size reductions in 1997 and 2001 led to finer price grids, relaxing the price ceilings and reducing queue competition at the same price. Automated execution (e.g., the 2003 NYSE autoquote installation) allows traders to use computer algorithms to monitor the market and comply with Rule 10b-18. These market-structure reforms have reduced frictions for issuers who compete with other traders at the price ceiling and have thereby increased share repurchases. The Tick Size Pilot Program, which partially reversed the market reforms by increasing the tick size, also reversed the secular increase in share repurchases for randomly selected treatment firms. Meanwhile, the frictions introduced by the price ceiling and market structure still exist, which explains why share repurchases have not crowded out dividends entirely.

Our results indicate that market structure can have first-order effects on corporate policies when firms trade directly on the open market and face regulatory constraints such as price ceilings. These two conditions suggest new directions for research at the intersection of market microstructure and corporate finance. Our results open two new research dimensions for liquidity: liquidity-for-whom and liquidity-from-where. Although a market with greater depth is generally considered more liquid, it may harm issuers because they face more intense competition when repurchasing shares at the price ceiling. Therefore, regulations can blur the definition of liquidity for distinct groups of traders, indicating the importance of liquidity-for-whom. We find that dark pools are important for share repurchases because these platforms allow issuers to avoid queues at the price ceilings. The trade-at rule, which unintentionally banned share repurchases in dark pools, reduces share repurchases, indicating the importance of liquidity-from-where.

Finally, the market-structure reforms and innovations we study did not cause just a single shock. Instead, they continued affecting markets for decades and will continue to do so well into the future. Such gradual changes not only provide an interpretation of the secular increase in share repurchases over decades but also generate out-of-sample predictions of future changes. In showing that the price ceiling from Rule 10b-18 introduces a major friction for share repurchases, our paper explains why firms lobby the SEC to increase the price ceiling to the VWAP or the midpoint of the bid–ask price. In addition, as both the midpoint price and the VWAP would further loosen the price ceilings for share repurchases, the results presented in our paper indicate that implementing these proposals could create another boost to share repurchases.

CRediT authorship contribution statement

Xiongshi Li: Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Methodology, Formal analysis, Data curation, Conceptualization. **Mao Ye:** Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Methodology, Formal analysis, Data curation, Conceptualization. **Miles Zheng:** Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Methodology, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The author declares that he has no relevant or material financial interests that relate to the research described in this paper.

Data availability

Data will be made available on request.

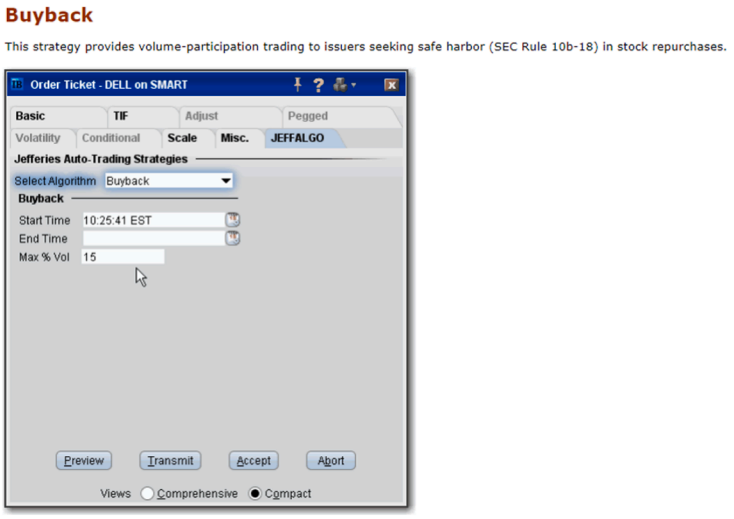
Replication Package for Price Ceilings, Market Structure, and Payout Policies (Original data) (Mendeley Data)

Supplementary materials

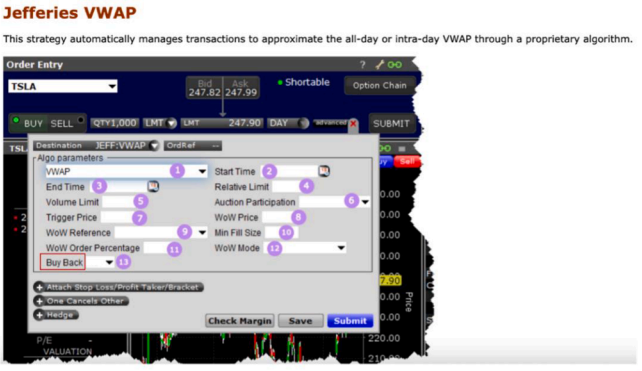
Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jfineco.2024.103818.

Appendix Additional figures and tables

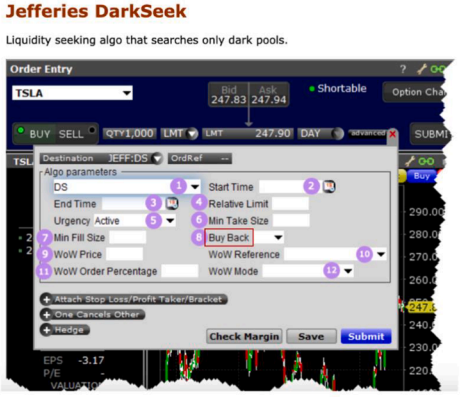
Panel A: Designated Buyback Algorithm



Panel B: Customized Buyback Algorithms



13	Buy Back -(optional) Indicates that the algo should engage SEC Rule 10b-18 restrictions for Buy Back in US instruments. Also applies local market Buy Back rules (for non-US instruments). This field cannot be modified. Value Y or N.



8	Buy Back (optional) - Indicates that the algo should engage SEC Rule 10b-18 restrictions for Buy Back in US instruments. Also applies local market Buy Back rules (for non-US instruments). This field cannot be modified. Value Y or N.

Fig. A.1. Designated and customized buyback algorithms. In this figure, we show that an issuer can buy back shares using designated repurchase algorithms or by adding a 10b-18 compliance restriction to a general-purpose algorithm (a customized buyback algorithm). Panel A shows an algorithm that is assigned to share repurchases. Firms need to specify the "Start Time," the "End Time," and "Max % Vol" and then the algorithm automatically buys back shares in compliance with Rule 10b-18. Panel B shows two examples of customized buyback algorithms. The Volume Weighted Average Price (VWAP) algorithm automatically manages transactions to achieve the all-day or intra-day VWAP. The DarkSeek algorithm searches for liquidity only in dark pools. Issuers can add the "Buy Back" option to these algorithms such that they generate only trades that are consistent with Rule 10b-18.

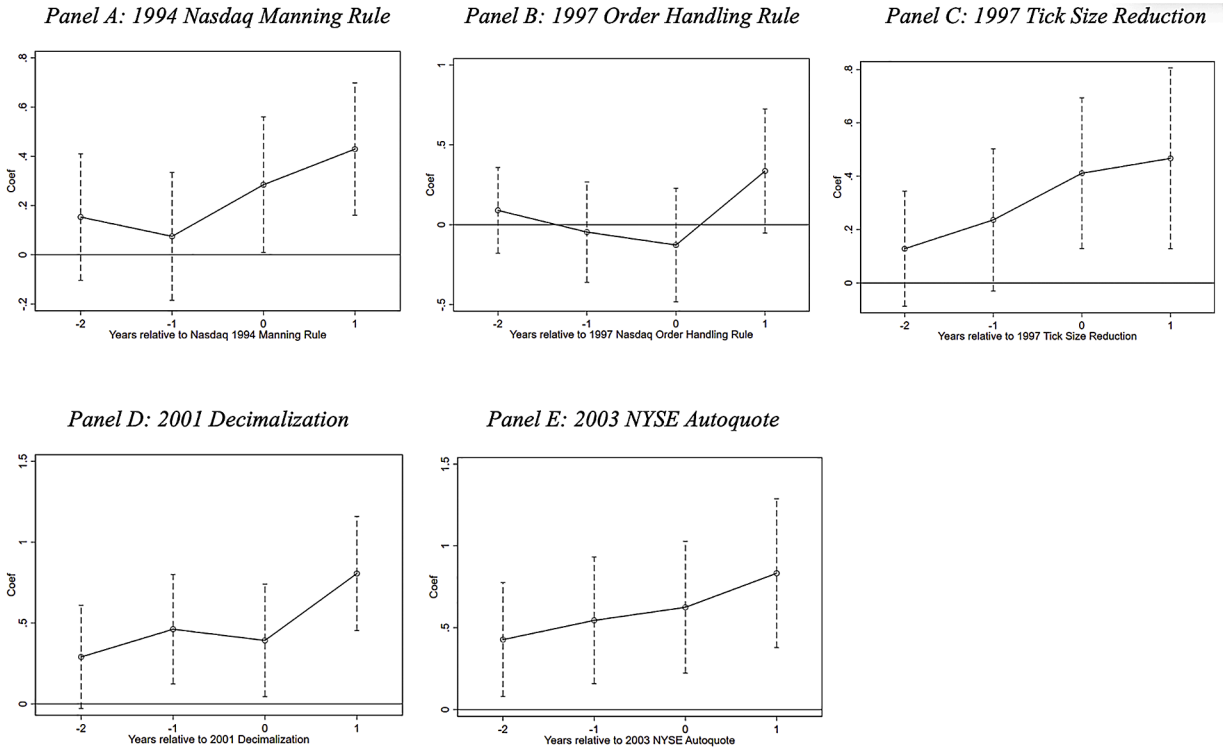


Fig. A.2. Event studies: parallel trend and treatment effects. In this figure, we graph the event-time DiD estimates. For each event-time DiD analysis, the sample period runs from t−3 to $t + 1$, where year t−3 is the baseline period. The figure shows that the differences in changes in repurchases between the treatment and control groups were in general nonsignificant prior to the events, suggesting that the treated and control firms followed similar trends prior to the treatment. As our data are reported at annual frequency, firms may be partially treated at year 0.

Table A.1
Dark pools and share repurchases: evidence from ATS-N filings. This table presents dark-pool information that we hand-collect from ATS-N filings on the SEC website (https://www.sec.gov/divisions/marketreg/form-ats-n-filings.htm), accessed on February 13, 2021. Columns (1)–(3) list the ATS name, broker-dealer operator, and Form link. In column (4) "Y" and "N" indicate whether subscribers include issuers; obtained from Part III, Item 1, "Types of ATS Subscribers." Column (5) presents priority rules, obtained from Part III, Item 7, "Order Types and Attributes" or Item 11, "Trading Services, Facilities, and Rules." In column (6) "Y" and "N" indicate whether the ATS offers primary peg orders which match the buy orders using the bid prices and automatically comply with Rule 10b-18, obtained from Part III, Item 7, "Order Types and Attributes.".

ATS Name	Broker-Dealer Operator	Form Link	Issuer as Subscriber	Priority Rule	Primary Peg
(1)	(2)	(3)	(4)	(5)	(6)
UBS ATS	UBS SECURITIES LLC	013–00069	N	Price/time for orders, price/quantity/time for CI (conditional indications)	Y
SIGMA X2	GOLDMAN SACHS & CO. LLC	013–00121	Y	Price/broker/time	Y
Crossfinder	CREDIT SUISSE SECURITIES (USA) LLC	013–00106	Y	Price/time for standard book, price/symbol score/size/time for CI	Y
JPM-X	J.P. MORGAN SECURITIES LLC	013–00110	Y	Price/tier/time	Y
LeveL ATS	EBX LLC	013–00132	N	Price/time	Y
The Barclays ATS	BARCLAYS CAPITAL INC.	013–00127	Y	Price/tier/time	Y
IBKR ATS	INTERACTIVE BROKERS LLC	013–00114	Y	Price/quantity/time	Y
MS POOL ATS-4	MORGAN STANLEY & CO. LLC	013–00117	Y	Price/capacity (tier) /size/time	Y
BIDS ATS	BIDS TRADING L.P.	013–00031	N	Price/quantity/time or quantity/price/time	Y
IntelligentCross ATS	INTELLIGENT CROSS LLC	013–00116	N	Price/display type/time	Y
Virtu MatchIt ATS	VIRTU AMERICAS LLC	013–00140	Y	Price/time for main session, price/quantity/time for CI	Y
Instinct X	BOFA SECURITIES, INC.	013–00150	Y	Price/capacity (tier) /time	Y
MS Trajectory Cross ATS-1	MORGAN STANLEY & CO. LLC	013–00115	Y	Capacity (tier) /size/time	N
SuperX ATS	DEUTSCHE BANK SECURITIES INC.	013–0052	Y	Price/time	Y
POSIT	VIRTU AMERICAS LLC	013–00175	N	Price/pro rata	Y
CrossStream	NATIONAL FINANCIAL SERVICES LLC	013–00118	Y	Price/tier/size/time	Y
JPB-X	J.P. MORGAN SECURITIES LLC	013–00109	Y	Equal split/time	N
Liquidnet H2O ATS	LIQUIDNET, INC.	013–00078	Y	Tier/time	N
MS RPOOL ATS-6	MORGAN STANLEY & CO. LLC	013–00139	Y	Type of interest (i.e., orders have priority over CI), capacity, size, and time	N
DEALERWEB	DEALERWEB INC.	013–00113	N	Price/time	N
Instinet BlockCross	INSTINET, LLC	013–00108	Y	Price/time	Y
CBX	INSTINET, LLC	013–00105	Y	Price/time	Y

(*continued on next page*)

Table A.1 (*continued*)

ATS Name	Broker-Dealer Operator	Form Link	Issuer as Subscriber	Priority Rule	Primary Peg
(1)	(2)	(3)	(4)	(5)	(6)
CODA	CODA MARKETS, INC.	013–00096	Y	Price/size/time	Y
Liquidnet Negotiation ATS	LIQUIDNET, INC.	013–00107	Y	Price/time	N
Luminex ATS	LUMINEX TRADING & ANALYTICS LLC	013–00112	N	Auto execution size/top size/time	N
CitiBLOC	CITIGROUP GLOBAL MARKETS INC.	013–00129	Y	Tier/time	N
Ustocktrade	USTOCKTRADE SECURITIES, INC.	013–00119	N	Price/time	N
Instinet Crossing	INSTINET, LLC	013–00104	Y	Pro rata for VWAP, subscriber priority for MOC	N
Aqua	AQUA SECURITIES L.P.	013–00067	N	Price/time	Y
XE	PIPER JAFFRAY & CO.	013–00160	N	Price/time	Y
tZERO ATS	tZERO ATS, LLC	013–00126	N	Price/time or price/broker/time	N
Stifel X	STIFEL, NICOLAUS & COMPANY, INCORPORATED	013–00171	N	Price/time	Y

Table A.2
Tick Size Pilot Program and payout policies: summary statistics. In this table, we present summary statistics for the main sample for the Tick Size Pilot Program with a breakdown by event year. The pre-treatment period in our analyses for the Tick Size Pilot Program is 2014 Q4–2016 Q3. The post-treatment period is 2016 Q4–2018 Q3.

	Full sample	2014Q4–2015Q3	2015Q4–2016Q3	2016Q4–2017Q3	2017Q4–2018Q3
	Mean	Mean	Mean	Mean	Mean
Repurchase payouts	0.325	0.414	0.346	0.263	0.279
Dividend payouts	0.222	0.235	0.221	0.215	0.217
Total payouts	0.547	0.649	0.567	0.478	0.496
Payout structure	1.173	1.240	1.195	1.123	1.136

Table A.3
Event studies: pre-treatment summary statistics. In this table, we present pre-treatment summary statistics and the mean differences for the treatment and the matched control firms in the event studies.

	Panel A: 1994 Manning Rule				Panel B: 1997 Order Handling Rule			
	Treatment Mean	Control Mean	*t*-test *Diff*	*p-value*	Treatment Mean	Control Mean	*t*-test *Diff*	*p-value*
Repurchase payouts	0.631	0.570	0.061	0.544	1.008	0.928	0.080	0.505
Dividend payouts	0.636	0.635	0.001	0.987	0.472	0.465	0.007	0.896
Total payouts	1.267	1.204	0.063	0.616	1.480	1.394	0.087	0.526
Payout structure	1.324	1.285	0.039	0.643	1.639	1.583	0.056	0.570
	Panel C: 1997 Tick Size Reduction				Panel D: 2001 Decimalization			
	Treatment Mean	Control Mean	*t*-test *Diff*	*p-value*	Treatment Mean	Control Mean	*t*-test *Diff*	*p-value*
Repurchase payouts	0.874	0.831	0.043	0.663	1.671	1.576	0.095	0.465
Dividend payouts	0.530	0.516	0.014	0.743	0.627	0.616	0.011	0.804
Total payouts	1.404	1.346	0.058	0.614	2.298	2.192	0.106	0.456
Payout structure	1.462	1.453	0.008	0.913	2.030	1.990	0.040	0.717

	Panel E: 2003 NYSE Autoquote			
	Treatment Mean	Control Mean	*t*-test *Diff*	*p-value*
Repurchase payouts	1.628	1.492	0.136	0.460
Dividend payouts	1.093	1.006	0.087	0.233
Total payouts	2.721	2.499	0.223	0.272
Payout structure	1.727	1.733	−0.006	0.964

References

Albuquerque, R., Song, S., Yao, C., 2020. The price effects of liquidity shocks: a study of SEC's tick-size experiment. J. Financ. Econ. 138, 700–724.

Allen, F. Michaely, R., 2003. Payout policy. Constantinides, G.M., Harris, M. Stulz, R. M. (Ed.), Handbook of the Economics of Finance. Elsevier, 1, 337–429.

Almeida, H., Fos, V., Kronlund, M., 2016. The real effects of share repurchases. J. Financ. Econ. 119, 168–185.

Anand, A., Samadi, M., Sokobin, J., Venkataraman, K., 2021. Institutional order handling and broker-affiliated trading venues. Rev. Financ. Stud. 34, 3364–3402.

Barclay, M.J., Christie, W.G., Schultz, P.H., 1999. Effects of market reform on the trading costs and depths of Nasdaq stocks. J. Finance 54, 1–34.

Barclay, M.J., Hendershott, T., Mccormick, D.T., 2003. Competition among trading venues: information and trading on electronic communications networks. J. Finance 58, 2637–2665.

Bessembinder, H., 2003. Trade execution costs and market quality after decimalization. J. Financ. Q Anal. 38, 747–777.

Brown, J.R., Liang, N., Weisbenner, S., 2007. Executive financial incentives and payout policy: firm responses to 2003 dividend tax cut. J. Finance 62, 1935–1965.

Chetty, R., Saez, E., 2005. Dividend taxes and corporate behavior: evidence from the 2003 dividend tax cut. Q J. Econ. 120, 791–833.

Chetty, R., Saez, E., 2010. Dividend and corporate taxation in an agency model of the firm. Am Econ J.: Econ. Policy 2, 1–31.

Christie, W., Schultz, P.H., 1994. Why do NASDAQ market makers avoid odd-eighth quotes? J. Finance 49, 1813–1840.

Cook, D.O., Krigman, L., Leach, J.C., 2003. An analysis of SEC guidelines for executing open market repurchases. Journal of Business 76, 289–315.
Dittmar, A., Field, L.C., 2015. Can managers time the market? evidence using repurchase price data. J. Financ. Econ. 115, 261–282.
Duffie, D., 2013. Replumbing our financial system: uneven progress. Int. J. Cent. Bank. 9, 251–280.
Fama, E.F., French, K.R., 2001. Disappearing dividends: changing firm characteristics or lower propensity to pay? J. Financ. Econ. 60, 3–43.
Fang, V.W., Tian, X., Tice, S., 2014. Does stock liquidity enhance or impede firm innovation? J. Finance 69, 2085–2125.
Farre-Mensa, J., Michaely, R., Schmalz, M., 2014. Payout policy. Annual Rev. Financial Econ. 6, 75–134.
Fenn, G.W., Liang, N., 2001. Corporate payout policy and managerial stock incentives. J. Financ. Econ. 60, 45–72.
Goldstein, M.A., Kavajecz, K.A., 2000. Eighths, sixteenths, and market depth: changes in tick size and liquidity provision on NYSE. J. Financ. Econ. 56, 125–149.
Grullon, G., Michaely, R., 2002. Dividends, share repurchases, and the substitution hypothesis. J. Finance 57, 1649–1684.
Hasbrouck, J., 2007. Empirical Market Microstructure: The Institutions, Economics, and Econometrics of Securities Trading. Oxford University Press, New York.
Hendershott, T., Jones, C.M., Menkveld, A.J., 2011. Does algorithmic trading improve liquidity? J. Finance 66, 1–33.
Holden, C.W., Jacobsen, S., 2014. Liquidity measurement problems in fast, competitive markets: expensive and cheap solutions. Journal of Finance 69, 1747–1785.
Jagannathan, M., Stephens, C.P., Weisbach, M.S., 2000. Financial flexibility and the choice between dividends and stock repurchases. J. Financ. Econ. 57, 355–384.
Jones, C.M., Lipson, M.L., 2001. Sixteenths: direct evidence on institutional execution costs. J. Financ. Econ. 59, 253–278.
Kahle, K., 2002. When a buyback isn't a buyback: open market repurchases and employee options. J. Financ. Econ. 63, 235–261.
Li, S., Ye, M., 2022. Discrete price, discrete quantity, and the optimal price of a stock. Brandeis University, Cornell University and NBER. Unpublished working paper.
Li, S., Ye, M., Zheng, M., 2023. Refusing the best price? J. Financ. Econ. 147, 317–337.
MacKenzie, D., 2017. A material political economy: automated trading desk and price prediction in high-frequency trading. Soc. Stud. Sci. 47, 172–194.
Miller, M., Modigliani, F., 1961. Dividend policy, growth, and the valuation of shares. J. Business 34, 411–433.
Poterba, J.M., Summers, L.H., 1985. The economic effects of dividend taxation. Recent Advances in Corporate Finance. Dow Jones-Irwin Publishing.
Roberts, M., Whited, T., 2013. Endogeneity in empirical corporate finance. Constantinides, G. M., Harris, M. Stulz, R. M. (Ed.), Handbook of the Economics of Finance. Elsevier, 2, 493–572.
Securities and Exchange Commission, 2002. Proposed Rule: rule 10b-18 and Purchases of Certain Equity Securities by The Issuer and Others. Washington, DC.
Securities and Exchange Commission, 2015. Plan to Implement A Tick Size Pilot Program. Washington, DC.
Securities and Exchange Commission, 2018. Assessment of The Plan to Implement A Tick Size Pilot Program. Washington, DC.
Rindi, B., Werner, I., 2019. U.S. tick size pilot. Bocconi University, and The Ohio State University. Unpublished working paper.
Thel, S., 1988. Regulation of manipulation under Section 10 (b): security prices and the text of the Securities Exchange Act of 1934. Columbia Business Law Rev. 359.
Whited, T., Wu, G., 2006. Financial constraints risk. Rev. Financial Stud. 19, 531–559.
Yagan, D., 2015. Capital tax reform and the real economy: the effects of the 2003 dividend tax cut. Am. Econ. Rev. 105, 3531–3563.
Yao, C., Ye, M., 2018. Why trading speed matters: a tale of queue rationing under price controls. Rev. Financial Stud. 31, 2157–2183.