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How does transaction cost affect price discovery?

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Résumé

Cette thèse étudie le Tick Size Pilot Program de la SEC, qui constitue une quasi-expérience naturelle en augmentant la taille minimale des cotes pour un ensemble d'entreprises traitées, passant d'un cent à cinq cents. Plus précisément, nous examinons comment des coûts de transaction plus élevés ont affecté l'informativité relative des transactions sur actions et sur les options. Nous constatons que le programme pilote a accru les coûts de transaction sur les actions, rendant les stratégies sur options moins attrayantes et plus dispendieuses pour les négociateurs informés dont les stratégies reposent sur la couverture simultanée avec l'action sous-jacente. Conformément au modèle VAR et à la décomposition de la variance proposés par (Joel Hasbrouck 1991) avec l'aide d'un modèle de différences-en-différences (DinD), on conclut qu'une partie de l'information s'est redéplacée vers les flux d'ordres sur actions, augmentant ainsi l'informativité des transactions sur actions entre la période pré et celle de l'intervention. Cependant, l'avantage informationnel des actions par rapport aux options ne s'est pas significativement élargi, ce qui suggère que tout gain en informativité des actions a été compensé par du bruit résiduel ou des frictions limitant la migration complète de l'information privée entre les marchés.

Mots clés

Information relative, coût de transaction, Hasbrouck, Tick Size Pilot Program, modèle VAR, différences-en-différences

Méthodes de recherche

Modèle VAR, différences-en-différences, décomposition de la variance

Abstract

The SEC has a long history of implementing reforms that directly shape market structure. Among these reforms, changes to tick size have played a central role in influencing trading costs, liquidity, and information flow across asset markets. This thesis studies the SEC's Tick Size Pilot Program implemented in 2016 and terminated in 2018, which provided a quasi-natural experiment by increasing the minimum tick size for a set of treatment firms from one cent to five cents. More precisely, we examine how higher transaction costs affected the relative informativeness of stock and option trades. We find that the Pilot Program increased stock transaction costs, making options strategies less attractive and making them costlier for informed traders whose strategies rely on simultaneously hedging with the underlying stock. Using (Joel Hasbrouck's 1991) VAR and variance decomposition framework and through a difference-in-differences model (DinD), some information migrated back into stock order flow, raising the informativeness of stock trades pre vs. implementation period. However, the total percentage in price change is insignificant, suggesting that any gains in stock informativeness were offset by residual noise or frictions that limited an overall increase in price discovery.

Keywords

Relative informativeness, transaction costs, Hasbrouck, Tick Size Pilot Program, VAR model, difference-in-differences

Research methods

VAR model, difference-in-differences, variance decomposition

Contents

List of Tables

List of Figures

List of Acronyms

SEC Securities and Exchange Commission

VAR Vector Autoregression

DinD Difference-in-Differences

BIC Bayesian Information Criterion

IRF Impulse Response Function

CRSP Center for Research in Security Prices

TAQ Trade and Quote

WRDS Wharton Research Data Services

VIX Volatility Index (Chicago Board Options Exchange)

G1 / G2 / G3 Tick Size Pilot Program Treatment Groups 1, 2, and 3

ITM In-the-Money for option terminology

S&P 500 Standard & Poor's 500 Index

OOI Option Order Imbalance

OLS Ordinary Least Squares

ECN Electronic Communication Networks

NASDAQ National Association of Securities Dealers Automated Quotations

MIDAS Market Information Data Analytics System

HFT High Frequency Trading

ATM At the money

DTE Days to expiration

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Introduction

This thesis investigates how transaction costs affect price discovery. Specifically, it examines whether the tick-size changes implemented under the SEC Tick Size Pilot Program altered the relative informativeness of stock and option trades, thereby influencing the overall contribution of informed trading to price formation. Informed traders often rely on exploiting mispricing between an underlying stock and its derivatives, with option positions hedged through trades in the stock. If the cost of trading the stock leg rises because wider tick sizes increase transaction costs, informed traders face a higher cost of hedging and may adjust where they reveal their information. More precisely, the Pilot Program effects on tick size influence informed traders through its impact on their optimal portfolio allocation between stock and option positions. Because private information is often expressed through option trades that require dynamic hedging in the underlying equity, higher stock-trading costs alter the balance between these positions. Consequently, informed traders adjust their allocation and the resulting shift in where information is revealed simply reflects the consequences of that allocation change.

The U.S. Securities and Exchange Commission (SEC) provided a unique setting to examine this question through the Tick Size Pilot Program, which ran from October 3rd, 2016, to September 28th, 2018. The Pilot Program targeted a set of small-cap common stocks that met specific eligibility criteria, including market capitalization below $3 billion, a share price above $2, and an average daily trading volume of at least one million shares. From this eligible universe, securities were assigned to three test groups and one control group, with the assignment stratified to ensure balance across firm size and liquidity characteristics. Stocks in the control group continued to trade under the standard one-cent minimum tick, while treated stocks were instead subject to a wider five-cent increment, which raised both quoting and trading costs relative to the control group.

The stated purpose of the program was to evaluate whether larger tick sizes would improve liquidity and market quality for less liquid securities by increasing dealer incentives to provide depth. In practice, however, the program also created a quasi-natural experiment. Some stocks were exogenously subject to higher trading frictions due to the tick-size constraints, while otherwise comparable stocks in the control group continued to trade under the standard tick size regime. This institutional design makes the program a powerful empirical setting for studying how modest regulatory frictions affect not only liquidity and trading costs, but also the cross-market allocation of private information between stocks and options.

In this thesis, we exploit the Pilot Program to test whether higher stock trading costs shifted the relative informativeness of stock and option order flows. We apply a (Hasbrouck 1991)-style vector autoregression (VAR) with variance decomposition to quantify the share informativeness of stock and option order imbalances to the permanent component of stock return variance at the firm-year level. We then embed these informativeness measures within a difference-in-differences (DinD) framework to assess whether the tick size increase changed the allocation of private information across markets. To complement this analysis, we also examine whether execution costs rose for treated firms by estimating regressions on effective spreads, and we conduct robustness checks using a noise-share model that isolates the non-informational component of variance while controlling for market-wide conditions. To further understand whether higher trading costs translated into costlier hedging for informed traders, we construct a measure of at-the-money (ATM), 30-day straddle prices as a proxy for short-term hedging costs. The straddle price captures the cost of holding a delta-neutral position and thus reflects how expensive it is to hedge option exposures with the underlying stock. By comparing average straddle costs before and during the Pilot period, we assess whether the wider tick-size regime materially increased the cost of implementing informed, cross-market strategies.

Our findings show that the SEC Tick Size Pilot Program did raise execution costs, making option strategies dependent on stock hedging less attractive. Consistent with (Hasbrouck's

1991) framework, some information migrated back into stock trades, raising the informativeness of stock order flow relative to options. However, the total permanent price change remained statistically insignificant, suggesting that gains in stock informativeness were offset by residual noise or frictions that limited an overall increase in price discovery. To support the claim that option strategies became less attractive and more costly for informed traders, our analysis of 30-day straddle prices shows that hedging became more expensive during the Pilot Program. The evidence indicates that the wider tick-size regime was associated with a tangible rise in the cost of maintaining delta-neutral positions, reinforcing the view that higher stock trading costs made cross-market hedging less efficient for informed traders. This increase in hedging costs supports the idea that transaction-cost shocks constrained the precision of informed traders' strategies and shifted information revelation more directly toward the equity market.

The broader importance of these results lies in what they reveal about market design and regulatory trade-offs. If widening tick sizes shifts where information enters prices, it underscores that seemingly small structural rules can alter how informed trading and liquidity provision function across linked markets. For regulators, this suggests that interventions aimed at improving liquidity in one market may unintentionally reshape price discovery in related markets. For market participants, it highlights that execution costs not only affect trading profitability but also the channels through which information is transmitted into asset prices. In this sense, the thesis contributes both to academic literature in market microstructure and to practical questions of regulatory design.

Situating this research within the broader literature, the relationship between market structure and the allocation of private information across trading venues has long been central to market microstructure research (Hasbrouck, 1991; Madhavan, 2000; O'Hara, 2003; Bessembinder, 2003). Some empirical literature demonstrates that small adjustments in trading frictions, such as tick size, can meaningfully affect liquidity, transaction costs, and the behavior of informed traders (Goldstein and Kavajecz, 2000; Bessembinder, Jones, and Maxwell, 2008; Chung and Chuwonganant, 2012). For example, decimalization in 2001 reduced the minimum tick size to one cent, narrowing bid-ask spreads but raising concerns about reduced depth and diminished incentives for liquidity provision, particularly in thinly traded stocks (Jones and Lipson, 2001).

In contrast, more recent studies of the SEC Tick Size Pilot Program analyzed the reverse experiment, an exogenous increase in tick size to examine how wider quoting increments affect trading behavior and market quality. These studies show that larger ticks altered market-making incentives and shifted activity toward non-exchange venues (Bartlett and McCrary, 2019), increased percentage bid-ask spreads but with smaller increases when options were actively traded (Griffith, Roseman, and Shang, 2020), and affected liquidity across order sizes (Chung, Lee, and Rösch, 2019). Yet, despite this literature, relatively little attention has been paid to whether tick-size reforms reshape the allocation of private information across stocks and options, the central contribution of this thesis.

The remainder of this thesis is organized as follows. The following section develops the literature review in greater depth. Then, Chapter 1 outlines the methodology, including the construction of stock and option order imbalance measures, the Hasbrouck-style VAR with variance decomposition, and the difference-in-differences (DinD) regression framework. Chapter 2 describes the data sources, the criteria for sample selection, and the construction of the variables used in this thesis Chapter 3 presents empirical results, focusing first on the relative contributions of stock and option trades to permanent price variance, followed by the analysis of effective spreads, noise share and hedge costs. The thesis concludes with a discussion of the main findings and their implications.

Literature Review

1.1 Variance decomposition and market informativeness

(Hasbrouck 1991) introduced the information-share (IS) approach to price discovery, defining a market's relative trade informativeness as the proportion of the efficient price innovation variance attributable to that market's innovations. His framework allows researchers to decompose total price variance into permanent (informational) and transitory (noise) components, identifying which market contributes more to permanent price changes. (Yan and Zivot 2010) provide a structural interpretation of this framework, showing that the Information Share (IS) captures both permanent and transitory shocks, whereas the Component Share (CS) isolates transitory effects. They conclude that IS, rather than CS, is the appropriate measure of relative informativeness across markets, as it reflects the long-run impact of order flow on prices. Accordingly, this thesis employs the information-share measure to evaluate how regulatory changes shift informational efficiency across equity and option markets.

Subsequent applications of Hasbrouck-style models have expanded their empirical relevance. (Barclay, Hendershott, and McCormick 2003), for instance, examined how market structure influences trade informativeness, finding that electronic communication networks (ECNs) attract a higher proportion of informed traders compared to traditional exchanges. While their focus was on competition between different trading platforms or marketplaces, this thesis extends the approach to a cross-asset context, analyzing whether changes in equity trading frictions lead to a reallocation of informed trading between stocks and options. Similarly, (Eun and Sabherwal 2003) investigated cross-listed equities and showed that price discovery can occur simultaneously across worldwide markets, with order flow in one market helping resolve information asymmetries in another. The present study shares this cross-market perspective but focuses on U.S. stocks and options rather than international listings. Building on these insights, this thesis further examines how information asymmetry itself evolves across linked markets when trading frictions change. (Chakravarty, Gulen, and Mayhew 2004) were among the first to explicitly compare the informativeness of stock and option markets through a priced base VAR, finding that options typically contribute less to price discovery but play a larger role for volatile or low-liquidity stocks. Building on their insight, (Hu 2014) proposed a delta-adjusted signed option volume measure through an order flow model as a more accurate proxy for informed option trading. We incorporate this refinement into our variance decomposition framework and variables, capturing how information embedded in option order flow influences the permanent component of stock returns.

1.2 Tick size reforms and market frictions

To continue in that direction, the theoretical foundation for studying tick size and trading frictions stems from (Glosten and Milgrom 1985), who model bid–ask spreads as compensation for adverse selection risk, the risk that liquidity providers face when trading against better-informed counterparties. In their framework, market makers widen spreads to protect themselves from potential losses to informed traders, such that any factor altering information asymmetry or market design directly affects trading costs. Building on this logic, (Madhavan 2000) formalizes how market design parameters, including tick size, shape equilibrium spreads, order submission strategies, and liquidity provision. These models imply that widening tick sizes can increase quoted spreads and execution costs for liquidity demanders but may also improve displayed depth and quote stability by raising the minimum profit margins for liquidity providers and discouraging fleeting quotes. This thesis builds on these theoretical foundations by examining the informational dimension of adverse selection across markets.

One major regulatory reform was the shift to decimalization in 2001, when U.S. equity markets moved from fractional to penny pricing, effectively reducing the minimum tick size from one-eighth of a dollar ($0.125) to one cent ($0.01). (Bessembinder 2003) showed that decimalization lowered trading costs and improved execution quality for small orders, as both quoted and effective spreads narrowed. However, (Goldstein and Kavajecz 2000) and (Jones and Lipson 2001) found that smaller ticks also reduced displayed market depth, impairing execution quality for large institutional orders. (Chordia, Roll, and Subrahmanyam 2005) documented that decimalization compressed spreads but increased trading activity, with heterogeneous effects depending on firm size and liquidity. Collectively, these studies highlight the trade-off created by smaller ticks: while finer price grids enhance competition and reduce trading costs, they can also diminish displayed depth and reduce incentives for liquidity provision.

On the opposite end of the spectrum, several studies have examined the effects of increasing tick size, conditions directly relevant to the SEC Tick Size Pilot Program. (O'Hara, Saar, and Zhong 2018) showed that relative tick size influences high-frequency trading (HFT) market makers: wider ticks allow HFTs to post longer-lived limit orders and capture larger spreads, but they also heighten exposure to adverse-selection risk. (Weller 2018) further refines this perspective by demonstrating that tick-size effects are price-dependent, disproportionately burdening low-priced stocks where a fixed tick constitutes a larger fraction of the share price. His results imply that the impact of tick-size regulation is heterogeneous across firms, depending on how binding the tick constraint is relative to the stock's price level. This insight is particularly relevant to the SEC Tick Size Pilot Program, where nominally identical tick increments imposed unequal relative frictions across firms. Accordingly, this thesis accounts for such heterogeneity by comparing treated and control stocks of similar price levels and liquidity characteristics when assessing changes in price discovery and trading costs. Finally, (Bessembinder, Jones, and Maxwell 2008) and (Chung and Chuwonganant 2012) cautioned that excessive tick widening can reduce quote competition and increase execution costs. Taken together, these studies reveal that wider ticks create persistent frictions that reshape trading behavior and liquidity provision. This thesis builds on that insight by examining whether such regulatory frictions also alter how and where private information is incorporated into prices.

1.3 Evidence from the SEC Tick Size Pilot Program

The SEC Tick Size Pilot Program provides a rare quasi-experimental setting to evaluate how modest changes in market design affect trading behavior and market quality. Existing studies consistently find that widening tick sizes increased transaction costs and altered liquidity provision, though the magnitude, persistence, and mechanisms of these effects remain debated. Most literature, however, focus exclusively on within-equity-market outcomes, leaving open the question of whether such reforms also influence the cross-market allocation of private information and the behavior of informed traders.

(Bartlett and McCrary 2019) examined whether larger tick sizes achieved the Pilot's Program goal of revitalizing market making in small-cap stocks. They found that any initial liquidity benefits were short-lived, as realized spreads decayed rapidly and trading activity migrated toward taker–maker and midpoint venues, undermining the program's intent. (Griffith, Roseman, and Shang 2020) extended the analysis to both equities and options, showing that spreads widened for treated stocks but less so for firms with active options markets, where hedging activity partially absorbed higher costs. (Gao, Lin, and Liu 2022) documented that wider ticks discouraged institutional trading and reduced market-making profitability by raising adverse-selection and inventory costs, while (Barardehi, Dixon, Liu, and Lohr 2022) highlighted that the policy's impact was heterogeneous, benefiting wider-spread stocks but harming narrow-spread ones.

All four studies employ a difference-in-differences (DinD) framework to causally estimate the Pilot's Program, effects, providing strong evidence that regulatory frictions produce measurable but mostly transitory distortions in liquidity, spreads, and market-making incentives. Yet, these analyses remain limited to price and depth measures, without assessing how wider tick sizes may have reallocated the process of information assimilation between equities and derivatives.

(Chung, Lee, and Rösch 2019) take a step in this direction, showing that larger tick sizes reduced liquidity for small trades but improved execution for large orders, while also enhancing price informativeness. Their findings suggest that tick size directly influences the efficiency with which information is incorporated into prices. This thesis builds on that insight by extending the analysis beyond liquidity to the informational and behavioral dimensions of adverse selection, specifically, whether higher equity-side trading costs altered informed traders' hedging decisions.

Finally, (Ran and Ye 2024) connect the Pilot to real-economy outcomes, showing that reduced liquidity weakened green investors' exit threats and lowered firms' environmental ratings, effects that reversed once the program ended. Consistent with their design, this thesis excludes financial firms (SIC codes 6000–6999) to align with the program intended sample and ensure comparability between treated and control stocks.

1.4 Hedging costs

While prior sections have shown how price discovery can be decomposed and how tick-size regulation affects trading costs, a crucial missing link in the existing literature is how informed traders adjust their hedging behavior when equity-side frictions change. This mechanism is important to understanding why the allocation of information between stock and option markets may shift following the SEC Tick Size Pilot Program.

Empirical evidence suggests that informed traders often exploit multiple instruments rather than concentrating their activity in a single market. Option trading volume has been shown to predict future stock returns (Pan and Poteshman 2006), consistent with informed investors initiating exposure in the options market before related price adjustments occur in the underlying equity. Similarly, (Easley, O'Hara, and Srinivas 1998) provide evidence that informed order flow in equities and options is jointly determined, indicating that the two markets serve complementary roles in the information transmission process. While these studies focus on information flow rather than explicit hedging, the cross-market linkage they document implies that portfolio adjustments between derivatives and equities can act as a channel through which private information is revealed and incorporated into prices.

(Duffie and Jackson 1990) derive closed-form optimal hedge ratios in a continuous-time futures framework with margining, showing how the equilibrium hedge depends jointly on price volatility, correlation structures, and investor risk aversion. While their model assumes frictionless trading, their results establish the principle that optimal hedging intensity responds endogenously to the structure of the underlying market. (Duffie, Fleming, Soner, and Zariphopoulou 1997) extend this framework to incomplete markets with non-replicable income streams under HARA utility, demonstrating that agents optimally balance expected utility gains against the costs and limitations of dynamic rebalancing. In their model, higher effective hedging costs or imperfect replication reduce trading frequency and lead to noisier, less precise hedge positions. Together, these theoretical insights provide the mechanism central to this thesis: when equity-side trading frictions increase, as under the SEC Tick Size Pilot's wider ticks, rational informed traders reoptimize their hedge-information trade-off. The costlier stock leg discourages frequent rebalancing, reducing the precision of option-based strategies and shifting a larger share of price discovery toward the stock market.

Recent theoretical and quantitative work deepens this intuition. (Aksamit, Hou, and Obłój 2020) develop a robust mathematical framework to measure the value of information for an investor who has better information than others. They study how extra information changes pricing and hedging outcomes in markets with asymmetric information. In their model, the informed agent can act on a refined filtration (a richer information set), which allows them to form better hedging strategies and achieve tighter pricing bounds. This paper reinforces the view that informed traders express their information through hedging behavior.

Finally, (Park and Lee 2016) study how informed traders hedge in a market with asymmetric information and jump risks. In their model, an exclusive information process governs both the timing and magnitude of price jumps, and informed participants optimally adjust their hedge ratios in response to new information. The resulting local risk–minimizing strategy shows that informed traders dynamically rebalance to manage the trade-off between informational advantage and exposure to unhedgeable risk. In this framework, the unhedgeable risk arises from the jump component of prices, which reflects private information shocks that cannot be fully offset through continuous trading in the underlying asset. Interpreted in the context of this thesis, such behavior implies that when trading frictions rise, such as under the wider tick sizes of the SEC Tick Size Pilot, hedging precision declines, and the process of information revelation across markets may shift accordingly.

1.5 Contribution

Overall, prior research provides a rich understanding of how tick size affects liquidity, market-making, and trading costs, but it leaves open fundamental questions about where private information resides when trading frictions change. This thesis contributes to the literature by linking microstructure regulation to cross-market information dynamics, offering the first empirical evidence on how the SEC Tick Size Pilot Program temporarily shifted price discovery from options to equities, and how these effects fully reversed after the program's conclusion.

Methodologically, this study advances literature by integrating a Hasbrouck-style variance decomposition with a difference-in-differences (DinD) design. This hybrid approach allows for causal inference on how structural reforms redistribute information across interconnected trading venues, bridging the gap between event-based identification and structural price-discovery analysis. Substantively, the thesis connects two previously distinct strands of research: one examining tick-size regulation and market frictions, and another investigating cross-market price discovery and information transmission. By combining these perspectives, it demonstrates that even modest changes in market design can reshape not only trading costs and liquidity provision but also the channels through which information is incorporated into prices in today's fragmented market environment.

The existing literature on the Tick Size Pilot Program converges on a central insight: widening tick sizes introduced temporary frictions that distorted trading costs and liquidity, effects that generally reversed once the program ended. This thesis contributes a new dimension to this literature by incorporating the role of hedging costs in shaping informed trading behavior. By examining how wider tick sizes increase the cost of executing the stock leg of option-based strategies, the analysis captures how structural frictions can modify the hedging decisions of informed traders and, in turn, alter the channels through which private information enters prices and no prior study has directly quantified how such regulatory shocks reallocated price discovery between equities and options.

Chapter 1
Methodology

This section explains the methodology used to estimate the model parameters for the Hasbrouck-style VAR model, the variance decomposition, the difference-in-differences (DinD) regression model, stock effective spread, noise share and hedge costs.

The SEC's Tick Size Pilot Program was launched on October 3rd, 2016, and concluded on September 28th, 2018, with the goal of assessing whether widening the minimum quoting increment could improve liquidity and market quality for small-cap stocks. By SEC's definition, the first test group (G1) was to be quoted in $0.05 increments but will continue to trade at their current price increment. The second test group (G2) was to be quoted and trade in $0.05 minimum increments, but would allow certain exemptions for midpoint executions, retail investor executions, and negotiated trades and the third test group (G3) was to adhere to the requirements of the second test group but will also be subject to a "trade-at" requirement. There will also be an exemption for block-size orders. Control stocks would continue to trade at $0.01 increment. Securities that are included in the Tick Size Pilot Program are NMS common stocks that have a market capitalization of $3.0 billion or less, a closing price of at least $2.00, and a consolidated average daily volume of one million shares or less.[1] The Pilot Program was launched in response to concerns that the 2001 decimalization reform, while lowering spreads, had reduced market depth and weakened incentives to support small-cap stocks. By widening tick sizes, the SEC aimed to restore dealer profitability and improve liquidity, though at the cost of higher transaction expenses. This trade-off created a natural setting to study how increased trading frictions affect price discovery.

We carry out our analysis by separating the data into three distinct periods: the pre-Pilot period (between October 2nd, 2014, and October 2nd, 2016), the Pilot period itself (October

[1] https://www.sec.gov/data-research/tick-size-pilot-program

3rd, 2016, to September 28, 2018), and the post-Pilot period (October 2nd, 2018, to December 31st, 2019). This structure allows us to compare market behavior not only before and during the program duration, but also between the program's duration and its termination, thereby capturing both the immediate effects of widening tick sizes and their reversal once the policy was removed.

1.1 Stock order imbalance

To estimate the dynamics of price discovery, we require variables that capture both price movements and the underlying forces driving them. The stock order imbalance (SOI) serves as a key proxy for the informational content of trades. It measures the net buying pressure in the equity market, the difference between buyer and seller-initiated volumes and thus summarizes the direction and intensity of order flow. A persistently positive SOI indicates excess buying pressure consistent with favorable information being incorporated into prices, while a negative SOI reflects selling pressure often associated with adverse information or liquidity shocks. In this sense, SOI links trading activity to the price discovery process, providing a direct observable channel for how information affects returns. It is calculated as the difference between the total buy side trade volume and the total sell-side trade volume from (Lee-Ready 1991) algorithm[2]. Based off (Hu's 2014) study, it is defined as

$$SOI_{i,t} = \text{Buy Volume}_{i,t} - \text{Sell Volume}_{i,t} \quad (1.1)$$

of firm i on day t respectively.

Contrary to (Hu 2014) we do not scale by the number of common shares outstanding. We focus on the impact of transaction costs and trading frictions on informativeness, which is better captured by raw trading activity rather than firm size. This will be our signed stock volume variable in our Hasbrouck-style VAR model explained in section 1.3.

[2] https://wrds-www.wharton.upenn.edu/data-dictionary/taqm_2025/wrds_iid_2025/

1.2 Option order imbalance

The second variable in our VAR model explained in section 1.3 is the option order imbalance (OOI), which captures the informational component of trading in the options market. Similar to stock order imbalance (SOI), it reflects the direction and intensity of net buying or selling pressure but in the derivative segment of the market, where informed traders often express their views more efficiently or hedge their equity positions. Because signed option imbalance is not directly observable in any database, we construct it indirectly by inferring trade direction from daily option price changes. Specifically, if an option's price increases from one day to the next, we assign a positive return sign indicating net buying pressure, whereas a price decrease implies net selling pressure. A positive option return implies buying pressure translating in demand for options, while a negative return suggests selling pressure. This sign component captures whether option trades convey bullish or bearish information about the underlying stock. This will be our sign (option return) in equation 1.2.

However, unlike stocks, options derive their value from the underlying asset. To translate option market activity into effective pressure on the underlying stock, we adjust for delta, which measures the sensitivity of an option's price to changes in the underlying. Call options typically have positive deltas, while put options have negative deltas.

Therefore, to estimate an option's contribution to underlying price pressure, for each option contract associated with a given ticker, we multiply the return sign by the delta and trading volume of that contract. By summing across all options for the same stock, we can then compute option order imbalance (OOI). This yields a directional measure of pressure on the underlying security. Again, based off (Hu's 2014) study, we compute the option order imbalance (OOI)

$$OOI_{i,t} = \sum_{j=1}^{N} \text{sign (option return)}_{i,t,j} * \text{Volume}_{i,t,j} * \text{Delta}_{i,t,j} \quad (1.2)$$

of firm i on day t and on j[th] option contract respectively. $Delta_{i,t,j}$ represents the sensitivity of the option price to changes in the underlying stock price. Although delta values are available in our dataset, they are generally computed using the (Black–Scholes model 1973). The model estimates delta as the partial derivative of the option price with respect to the stock price, capturing how responsive the option's value is to small price fluctuations in the underlying equity. Contrary to (Hu 2014) we do not scale by the number of common shares outstanding. Again, we focus on the impact of transaction costs and trading frictions on informativeness, which is better captured by raw trading activity rather than firm size.

1.3 Hasbrouck-style VAR model and variance decomposition

Before evaluating the relative informativeness of stock and option trades within the context of the SEC Tick Size Pilot Program, it is essential to first introduce the econometric framework that guides our analysis. The vector autoregression (VAR) model offers a natural and flexible approach for capturing dynamic interactions among multiple market variables. Each variable is modeled as a function of its own past values as well as the lagged values of all other variables in the system. This enables the model to account for mutual dependencies and feedback effects across markets, recognizing that shocks in one variable can propagate to others over time. By treating all variables as jointly endogenous, the VAR framework avoids restrictive causal assumptions and instead allows the data to reveal the temporal structure of influence among trading activity and price movements.

(Hasbrouck 1991) develops this VAR-based method to measure the extent to which trades contribute to permanent price changes. By treating the efficient price as a random walk, he uses impulse response functions (IRFs) to track the long-run effect of trade shocks on prices. A Cholesky decomposition is applied to separate correlated innovations, assuming trades precede quote revisions. Multiplying this impact by the variance of trade shocks gives the contribution of trades to the variance of the efficient price. This procedure is the variance decomposition.

In this thesis, we first adopt a Hasbrouck-style vector autoregression (VAR) framework with variance decomposition. The VAR model is specified using three variables: stock return, signed stock volume, and signed option volume. The equations are:

$$
\begin{aligned}
r_t &= \alpha_r + \textstyle\sum_{k=1}^{p}(a_{rk}r_{t-k} + b_{rk}x_{t-k} + c_{rk}z_{t-k}) + v_{1,t} \\
x_t &= \alpha_x + \textstyle\sum_{k=1}^{p}(d_{xk}r_{t-k} + e_{xk}x_{t-k} + f_{xk}z_{t-k}) + v_{2,t} \\
z_t &= \alpha_z + \textstyle\sum_{k=1}^{p}(g_{zk}r_{t-k} + h_{zk}x_{t-k} + i_{zk}z_{t-k}) + v_{3,t}
\end{aligned}
\tag{1.3}
$$

Where r_t is the stock return. It measures the percentage change in the total value of a common stock position over one trading day, x_t represents the signed stock volume as explained in section 1.1 while z_t represents the signed option volume, as mentioned in section 1.2. The vector of orthogonalized disturbances is denoted by v_t.. The coefficients a_i, b_i, c_i, d_i, e_i, f_i, g_i, h_i, i_i correspond to the estimated parameters of the vector autoregression. For each eligible stock-year, we estimate the optimal lag length using the Bayesian Information Criterion (BIC) and fit the VAR model accordingly. Orthogonalized impulse response functions (IRFs) are then computed over a 30-day horizon using Cholesky decomposition to isolate the dynamic effect of structural shocks associated with stock and option trades on stock returns, with variable ordering: signed stock volume, signed option volume, and stock return. This structure reflects the assumption that innovations in signed stock volume contemporaneously influence option trading activity and option prices, while signed option volume can also affect stock returns within the same interval. The stock return equation is ordered last to capture the final adjustment of prices that absorb the combined impact of trading activity across both markets. The ordering is consistent with (Hasbrouck's 1991) where order flow innovations are treated as the primary drivers of information and returns serve as the residual variable that incorporates these shocks. To maintain comparability across specifications, this ordering is kept fixed throughout the thesis.

Also, the choice of horizon reflects a balance between capturing the dynamics of how information shocks are incorporated into prices and avoiding excessive noise from long-term extrapolation. Informed trading and order–flow–driven price impacts are typically realized over short to medium horizons. A 30–day window is therefore long enough to capture the cumulative effect of stock and option order flow shocks on permanent price changes, while ensuring that the estimated variance decomposition remains empirically stable.

We extract the residual covariance matrix from the estimated vector autoregression (VAR) model results, which captures the variance and covariance of the innovation terms across all 3 variables in the system. The diagonal elements of this matrix indicate the extent of unexplained variation for each variable after controlling for its own lagged values and those of the other variables. Meanwhile, the off-diagonal elements reflect the degree of contemporaneous correlation between the residuals of different variables. This matrix plays a central role in the subsequent variance decomposition and impulse response analysis.

Finally, we sum the impulse response functions (IRFs) over time, square the cumulative effect, and scale it by the variance of the corresponding innovations. This procedure constitutes the variance decomposition, which partitions the permanent variance of returns into the absolute contributions of stock and option order flow shocks, thereby isolating the component of permanent variance attributable to each market. Specifically, the components are defined as:

Absolute contribution of stock orders flows to permanent variance of returns:

$$\sigma^2_{\mathrm{w,x}} = \left(\sum_{t=0}^{T} \mathrm{IRF}_{\mathrm{return,stock}}(\mathrm{t})\right)^2 * \Omega_{\mathrm{stock}} \quad (1.4)$$

Absolute contribution of option orders flows to permanent variance of returns:

$$\sigma^2_{w,z} = (\sum_{t=0}^{T} \mathrm{IRF}_{\mathrm{return,option}}(t))^2 * \Omega_{\mathrm{option}} \quad (1.5)$$

Where $\mathrm{IRF}_{\mathrm{return,stock}}(t)$ is the response of stock returns at time *t* to a one-unit shock in stock order flow then summed for all IRFs, $\mathrm{IRF}_{\mathrm{return,option}}(t)$ is the response of stock returns at time *t* to a one-unit shock in option order flow and also summed across all IRFs, Ω_{stock} and Ω_{option} are the extracted variance of stock trade and option trade shocks respectively from the residual covariance matrix .

Summing across markets yields the total variance of permanent return innovations explained by order flow:

$$\sigma^2_{\mathrm{total}} = \sigma^2_{w,x} + \sigma^2_{w,z} \quad (1.6)$$

Equation (1.6) expresses the variance decomposition in its additive form, in which the total permanent variance ($\sigma^2_{\mathrm{total}}$) of returns is partitioned into the absolute contributions of stock order flow shocks ($\sigma^2_{w,x}$) and option order flow shocks ($\sigma^2_{w,z}$). This additive formulation ensures that the total informational variance in permanent returns is fully accounted for by innovations originating in both markets. In the next section, these absolute contributions are normalized by the total permanent variance of returns to yield share informativeness, which provide a relative measure of each market's role in price discovery.

1.4 The main test

The central objective of this thesis is to evaluate how transaction costs affect price discovery by altering the relative informativeness of stock and option trades. Transaction costs shape the incentives of informed traders, who may reallocate their activity across markets to minimize execution costs and maximize informational impact. Because both equities and options serve as alternative venues for informed trading, changes in relative trading costs can shift the balance of where information is first impounded into prices. The SEC Tick Size Pilot provides an ideal quasi-experimental setting to examine this mechanism by exogenously increasing transaction costs for a subset of stocks and allowing us to trace the resulting changes in stock versus option-based price discovery.

To assess price discovery, defined as the relative informativeness of stock versus option trades, we divide each trade type's absolute contribution to permanent variance of returns by the total variance of permanent return. Specifically, the informativeness of stock trades (IS_{stock}) is measured as:

$$IS_{stock} = \frac{\sigma^2_{w,x}}{\sigma^2_{total}} \tag{1.7}$$

Where $\sigma^2_{w,x}$ is the ratio of contribution of stock orders flows onto the total permanent variance of returns while the informativeness of option trades (IS_{option}) is given by:

$$IS_{option} = \frac{\sigma^2_{w,z}}{\sigma^2_{total}} \tag{1.8}$$

Where $\sigma^2_{w,z}$ is the ratio of contribution of option orders flows onto the total permanent variance of returns.

We also compute a joint informativeness measure (IS_{joint}), capturing the combined impact of stock and option order flow innovations on permanent price changes. This is defined as:

$$IS_{joint} = \frac{\sigma^2_{total}}{\sigma^2_{total} + \sigma^2_1} \tag{1.9}$$

where Sigma (σ^2_1) denotes the residual variance of the return innovation extracted from the residual covariance matrix.

We compute this joint informativeness measure to distinguish between price changes driven by informed trading and those arising from noise or non-informational shocks. While the stock and option informativeness ratios in (1.7) and (1.8) show how information is distributed across markets, they do not reveal whether the overall market became more or less efficient in incorporating information. The joint measure fills this gap. It captures the total share of return variance explained by both stock and option order flows relative to residual noise. In this thesis, we do not focus on transitory effects, namely, noise or other non-informational shocks, but rather on the permanent component of price variation that reflects information-based trading.

Then, these 3-information share (IS) metrics are compiled for each stock year and used in subsequent cross-sectional and difference-in-differences (DinD) analyses to assess the effect of the SEC's Tick Size Pilot Program on the relative price informativeness of stock versus option markets.

The difference-in-differences (DinD) leverages the program's quasi-experimental structure to identify the causal effect of higher trading frictions on price discovery. By comparing changes in informativeness over time between treated and control groups, the DinD estimator isolates the causal impact of the regulatory shock. This approach is particularly suited to settings like the Tick Size Pilot Program, where treatment assignment was exogenous and implemented at a well-defined point in time. By differencing across both groups and time periods, the method controls for unobserved, time-invariant heterogeneity across firms and common market-wide shocks, such as macroeconomic conditions or technological developments that could otherwise confound inference. Consequently, this design provides a robust empirical strategy for identifying the incremental effect of higher trading frictions on the cross-market distribution of price discovery between stocks and options.

The difference-in-differences (DinD) regression used in this thesis is estimated using ordinary least squares (OLS) with standard errors clustered at the firm level (by ticker) to account for within-firm serial correlation in the residuals, we estimate the following linear DinD regression for each outcome variable of interest covering stock-level, option-level, and joint measure:

$$Y_{it} = \alpha + \beta_1 \cdot Treated_i + \beta_2 \cdot Post_t + \beta_3 \cdot (Treated_i \times Post_t) + \varepsilon_{it} \qquad (1.10)$$

where Y_{it} is the dependent variable for firm i at time t, $Treated_i$ is the treatment group indicator and equal to 1 for stocks assigned to any Pilot test group (G1–G3) and equal to

0 for control group. $Post_t$ is the post-treatment period indicator where $Post_t = 1$ for the Pilot period itself (October 2nd, 2016, to September 28th, 2018), and equal to 0 for the two-year pre-Pilot period (October 2nd, 2014, to October 2nd, 2016). ($Treated_i \times Post_t$) is the interaction term and β_3 captures the causal effect of the Pilot Program on the outcome. The same regression was done for Pilot period (October 2nd, 2016, to September 28th, 2018), versus post-Pilot period (October 2nd, 2018, to December 31st, 2019) to examine whether the observed effects persisted or reverted once the program concluded.

Hypothesis 1. The SEC Tick Size Pilot increased the relative contribution of stock order flow to price discovery, compared to options for treated stocks.

As equity-market trading costs changed, informed traders who normally split their activity across both markets adjusted their behavior, revealing a greater share of private information through stock trades. This behavioral shift increased the stock market's relative contribution to total price discovery. We test this hypothesis by estimating information shares from the Hasbrouck-style VAR and variance decomposition pre-pilot versus Pilot Program period and comparing treated group with control group.

1.5 Stock effective spread and noise share

In addition to analyzing relative informativeness through the vector autoregression (VAR) and variance decomposition, it is important to examine more direct measures of market quality that capture the consequences of wider tick sizes. Effective spreads allow us to verify whether the Pilot Program mechanically raised execution costs for the treated group, thereby testing the direct link between tick size and transaction costs. Noise share provides an additional lens on price discovery by distinguishing informational from non-informational return variance. Even if there is a change in share informativeness, overall market quality could still deteriorate if a larger share of total return variation is attributable to noise. By analyzing these two measures alongside the VAR-based informativeness results, we can assess both the direct cost implications of wider ticks and their broader impact on price efficiency.

The stock effective spread is a well-established proxy for realized transaction costs faced by investors. It captures the deviation between the transaction price and the prevailing quote midpoint, thus reflecting both liquidity provision and price impact components. Increases in effective spreads are typically interpreted as a sign of reduced liquidity or higher execution risk, both of which may deter informed or institutional trading activity.

Hypothesis 2. The Tick Size Pilot Program increased effective spreads for treated stocks, thereby creating a costlier execution environment. This rise in transaction costs is especially relevant for trades executed as part of multi-leg option strategies, such as delta hedging.

Empirical confirmation would suggest that the regulatory change had unintended cross-market consequences by indirectly making option-based strategies more expensive to implement.

To evaluate this effect, we estimate a difference-in-differences (DinD) regression on effective spreads. The linear DinD regression has the following form:

$$\text{Effective Spread}_{it} = \alpha + \beta_1 \cdot \text{Treated}_i + \beta_2 \cdot \text{Post}^t \cdot \beta_3 \cdot (\text{Treated}_i \times \text{Post}_t) + \varepsilon_{it} \quad (1.11)$$

The regression is estimated using ordinary least squares (OLS) with standard errors clustered at the firm level (by ticker) to account for within-firm serial correlation in the residuals. Effective Spread_{it} is the dependent variable, Treated_i is the treatment group indicator and equal to 1 for stocks assigned to any Pilot test group (G1–G3) and equal to 0 for control stocks. Post_t is the post-treatment period indicator where Post_t equal to 1 for the Pilot period itself (October 2nd, 2016, to September 28th, 2018), and equal to 0 for the two-year pre-Pilot period (October 2nd, 2014, to October 2nd, 2016). The coefficient on the interaction term ($\text{Treated}_i \times \text{Post}_t$) captures the causal impact of the Pilot Program on trading costs for treated firms. The same regression was done for Pilot period (October 2nd, 2016, to September 28th, 2018), versus post-Pilot period (October 2nd, 2018, to December 31st, 2019) to examine whether the observed effects persisted or reverted once the program concluded.

The SEC Tick Size Pilot Program may also have unintentionally increased the presence of uninformative or mechanical trading in treated stocks, thereby raising the non-informational, or noise component of observed returns. Measuring the noise share thus provides a complementary perspective on whether the program introduced frictions that impaired overall market quality beyond changes in spreads or share informativeness.

Hypothesis 3. The program increased return noise for treated stocks relative to control stocks, thereby reducing the informational efficiency of prices.

Return noise is defined as the proportion of return variance not explained by order-flow variables, reflecting the extent to which short-term price movements are driven by non-informational influences rather than permanent informational shocks. To test this hypothesis, we start by doing an ordinary least square (OLS) regression as follows:

$$r_{i,t} = \alpha + \beta_1 \cdot x_{i,t} + \beta_2 z_{i,t} + \varepsilon_{i,t} \qquad (1.12)$$

Where $r_{i,t}$ is the daily stock return for stock i on day t, $x_{i,t}$ is signed stock volume and $z_{i,t}$ is signed option volume. A constant is included. R square (R^2) is the share of the variation in the dependent variable that the regression above explains. Noise share is defined as 1− R square (R^2). This measures the fraction of return variation not explained by the two order-flow variables. We compute this for each ticker–month.

Then, we perform a difference-in-differences (DinD). The regression model is specified as follows:

$$\text{Noise Share}_{it} = \alpha + \beta_1 \cdot \text{Treated}_i + \beta_2 \cdot \text{Post}_t + \beta_3 \cdot (\text{Treated}_i \times \text{Post}_t) + \gamma X_{it} + \varepsilon_{it} \qquad (1.13)$$

The regression is estimated using ordinary least squares (OLS) with standard errors clustered at the firm level to account for within-firm serial correlation in the residuals. Noise $Share_{it}$ is the dependent variable. $Treated_i$ is the treatment group indicator and equal to 1 for stocks assigned to any Pilot test group (G1–G3) and equal to 0 for control stocks. $Post_t$ is the post-treatment period indicator where $Post_t$ equal to 1 for the Pilot period itself (October 2nd, 2016, to September 28th, 2018), and equal to 0 for the two-year pre-Pilot period (October 2nd, 2014, to October 2nd, 2016). The coefficient on the interaction term ($Treated_i \times Post_t$) is the interaction term capturing the treatment effect. X_{it} includes relevant controls: VIX, average daily spread of all stocks part of the Pilot Program and S&P 500 volume, which help account for macro-level volatility, market-wide liquidity, and trading intensity. Adding controls also helps us determine whether the effect originates at the firm level or simply mirrors broader market-wide trends.

We do not extend this test to the Pilot versus post-Pilot period, because the identification strategy relies on the regulatory shock created by the SEC Tick Size Pilot Program. Our analysis focuses on whether the Pilot Program introduced additional non-informational volatility during its active period, rather than on how markets behaved once the policy constraint was removed.

1.6 Hedge cost

To claim that hedging became costlier for informed traders, we construct a one-month, at-the-money (ATM) straddle measure by pairing call–put quotes for each ticker-day. Informed traders who take directional positions in options typically hedge their delta exposure in the stock market; therefore, a higher straddle cost implies that neutralizing risk through the option market became more expensive. For each stock, we select the pair closest to 30 days maturity and to the spot price. To ensure comparability of option maturities across time, we selected, for each ticker-day, the call–put pair whose time to expiration was closest to 30 calendar days. This approach standardizes the maturity horizon of the straddle measure and limits the influence of term-structure differences. Within each ticker-day, we defined the at-the-money (ATM) option as the contract whose strike price was closest to the underlying stock's spot price on that day. An option is considered at the money when its strike price is approximately equal to the current market price of the underlying asset. At this point, the option's intrinsic value is near zero, and its price primarily reflects time value and implied volatility. Focusing on at-the-money (ATM) options ensures that the resulting straddle is most responsive to small movements in the underlying stock, providing a clean and comparable measure of hedging cost across stocks and periods. We compute the straddle price per share:

$$Straddle_{it} = Call_{i,t}^{mid} + Put_{i,t}^{mid}$$

Then aggregate to ticker-level means within the Pre-Pilot (October 2nd, 2014, to October 2nd, 2016) and Pilot (October 3rd, 2016, to September 28th, 2018) windows. Overall levels are equally weighted across tickers. We then averaged this straddle measure by ticker within each period and report the difference, Pilot minus pre-Pilot for 5 random stocks.

Chapter 2
Data

This section outlines the data sources used, the criteria for sample selection, and the methodology for constructing the key variables.

2.1 Data description for Pilot Program panel

Data for SEC's Pilot Program comes from FINRA's web site. It provides information on the dates and stock assignments for both the control and treatment groups. There are 3 important dates. May 6th, 2015, was the announcement date, October 3rd, 2016, is the official start date and September 28th, 2018, is the termination date of the program.

As a first step, the data is cleaned by removing tickers labeled "TEST" or containing "ZZT" and 13 tickers are truncated to remove share class identifiers. This ensures that all stocks included in the Pilot Program are retained. Also, this allows us to have a clean merger with the other datasets explained below. Initially, the dataset contains 2,478 tickers. Then we merge the 3 test groups into 1. It becomes the treated group. If a ticker transitioned from the control group to the treatment group during the program experiment period, it is classified as treated for the full sample period. 1,187 distinct tickers are classified as treated.

Then, from Wharton Research Data Services (WRDS), more precisely from CRSP daily table, we collect daily data for stocks from January 1st, 2012, to Dember 31st, 2019. We want to start post 2008 financial crisis and end before the start of COVID-19. We calculate stock transaction cost (TC):

$$\mathrm{TC} = \frac{(\mathrm{ask} - \mathrm{bid})}{(\mathrm{ask} + \mathrm{bid})/2} \tag{1.14}$$

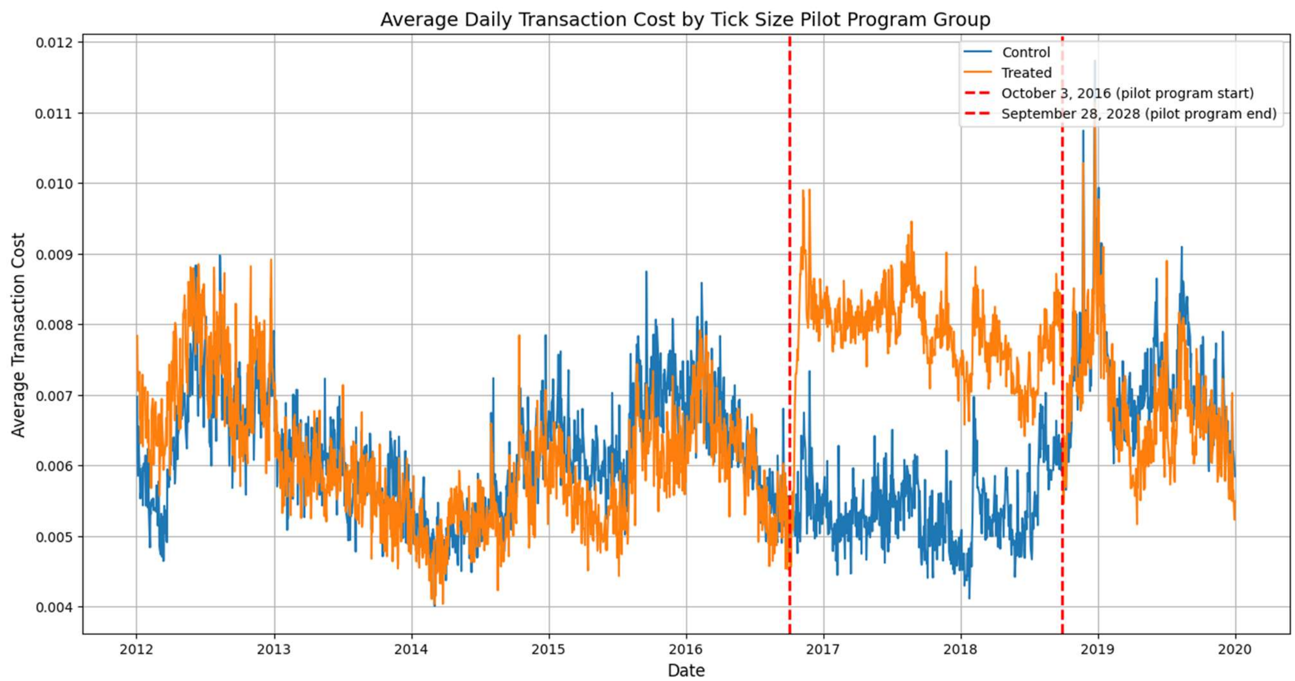
We also remove tickers that have multiple shares class to avoid duplicates and to keep only share class A. Bid and ask prices are available for all securities listed on the NYSE, AMEX, and NASDAQ exchanges. For NASDAQ, the closing bid and ask reflect the inside quotation at 4:00 PM. For NYSE and AMEX, the ask corresponds to the bid from the last available quote prior to market close[3]. We filter stocks consistent with the approach of (Ran & Ye 2024), excluding tickers from the Utilities (4200 – 4299) and Financials (6000 – 6999) sectors. Additionally, we restrict the sample to include only securities with a share code of 10 or 11, which correspond to common stocks, respectively. This ensures a focus exclusively on standard equity instruments and excludes non-voting common stocks, preferred shares, warrants, and other non-equity securities. We now have 1652 distinct tickers. 50 % are now tagged as treated.

Figure 2.1 plots the average daily transaction cost for each group between January 1st, 2012, and December 31st, 2019, providing a visual assessment of the increase in execution costs caused by the Pilot Program. This pattern is consistent with Hypothesis 2. It will be examined and tested more formally in Section 3.2.

[3] https://wrds-www.wharton.upenn.edu/data-dictionary/crspsamp_all/crspdsf/

Figure 2.1: average daily transaction cost by Tick Size Pilot Program group, 1/2012–12/2019

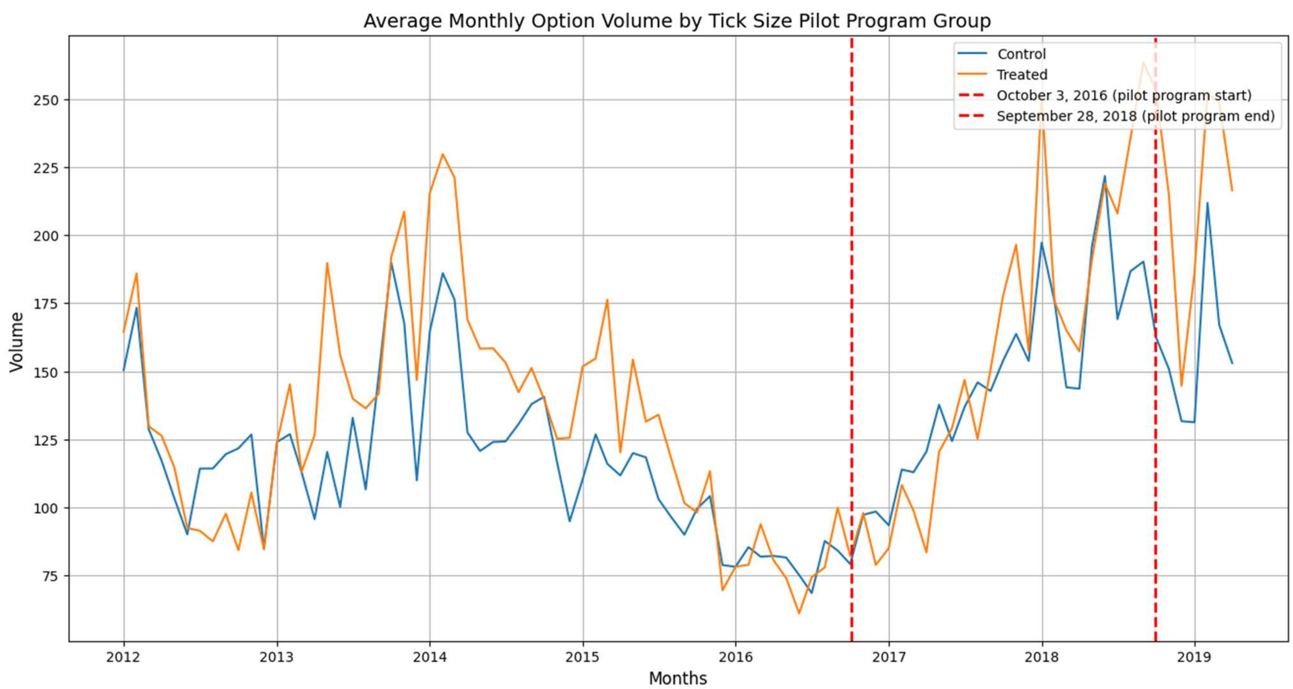
This figure illustrates the evolution of average daily transaction costs for stocks in the control and treated groups under the SEC Tick Size Pilot Program. Transaction cost is winsorized at 0.01% and 99.9% levels. The treated group exhibits a noticeable increase in transaction costs following the program's launch, suggesting potential impacts of wider tick sizes on market liquidity and trading efficiency.



Next, we utilize the OptionMetrics database to obtain options market data. We keep the same period as for stocks. Within WRDS, OptionMetrics requires year-specific queries; we loop over years, extract the required information and combine them into one comprehensive database. Then, we apply a filter to retain only call options. The option spread is computed as the difference between the best offer and the best bid. Given that multiple option contracts may exist for a single stock on a given day varying by strike price, expiration date, and other characteristics, we aggregate the data at the ticker-date level. Specifically, we sum the option volume and calculate the average option spread across all call contracts for each stock and date. This aggregation yields a single observation per stock per trading day, ensuring consistency with the structure of the data. We are now at 1316 distinct tickers. 51 % are treated stocks and 49 % are control stocks. Figure 2.2 illustrates the evolution of option volume for treated and control stocks. It plots the average monthly option volume per stock for treated and control groups from 2012 to 2019. Before the introduction of the program, treated stocks exhibiting slightly higher volatility in option activity. Following the Pilot's Program start in October 2016, option volume for treated stocks rises more sharply than for controls. After the program ended at the end of September 2018, volumes partially decrease

Figure 2.2: Average monthly option volume per stock by Tick Size Pilot Program group, 1/2012–12/2019

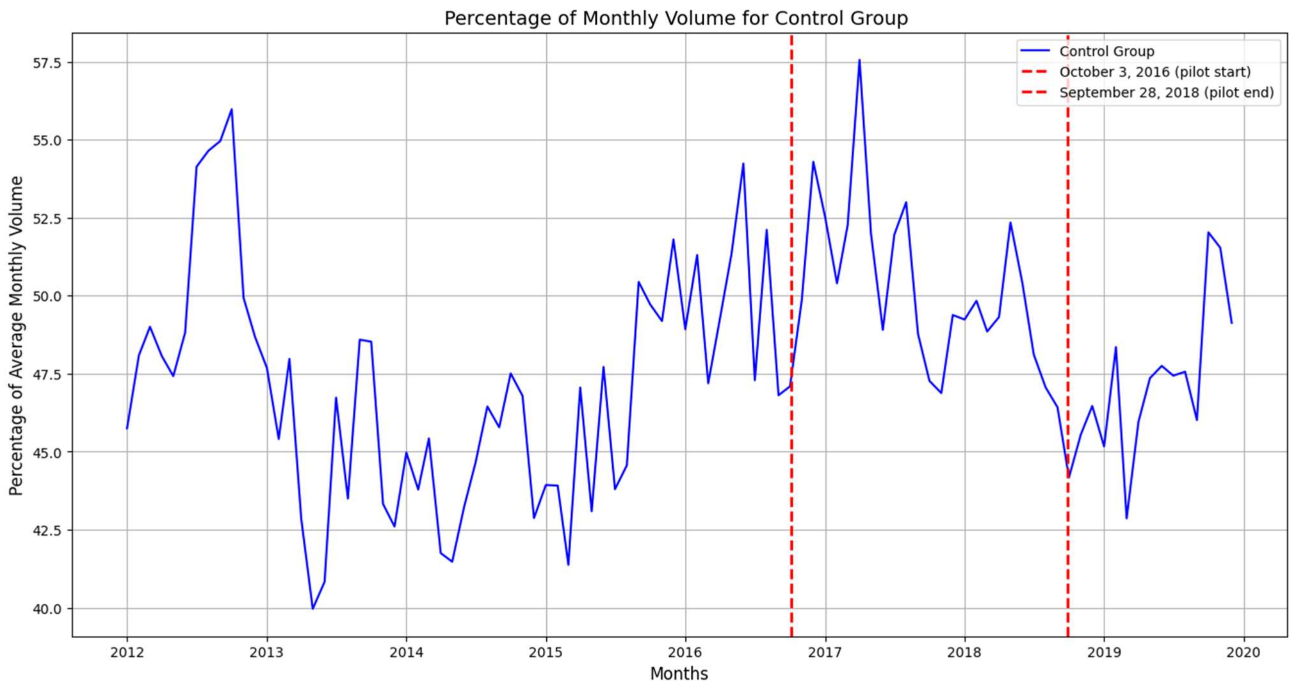
This figure shows the average daily option volume per stock, aggregated monthly for the control and treated groups. The observed increase in option volume for the treated group following the program's implementation suggests a potential shift in trading activity or information transmission associated with wider tick sizes.



To place these patterns in a broader context, we examine the share of total option trading volume accounted for by the control group. This relative measure helps to highlight shifts in aggregate market participation over the course of the program. Figure 2.3 shows the control group's share of average monthly volume. The figure tracks monthly option volume for the control group as a percentage of the overall average volume among all SEC Tick Size Pilot stocks. The series fluctuates around 45–55 percent prior to the policy and shows a noticeable increase immediately after the program's launch in October 2016. As the program progressed, volumes for the control group stabilized and then declined leading to the termination of the program.

Figure 2.3: Percentage of monthly volume for pilot program control group, 1/2012–4/2019

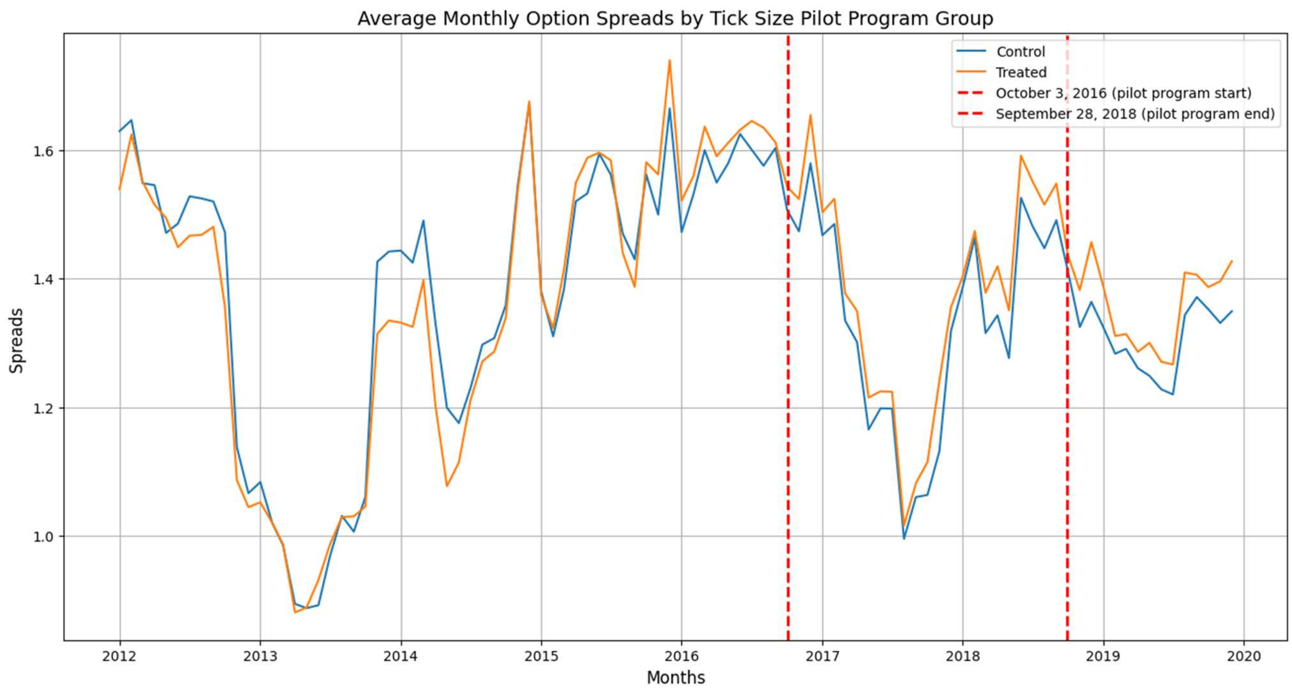
This figure presents the monthly trading volume of options in the control group as a percentage of average monthly volume across all SEC Tick Size Pilot Program stocks. The sharp rise in volume after the program's launch followed by a decline leading into its conclusion reflected expectation-driven behavior. Traders have anticipated the end of the Pilot Program and adjusted their positions accordingly, particularly as transaction costs (see Figure 2.1) began rising in mid-2018.



Beyond trading volume, it is also important to evaluate how market frictions evolved in the options market itself. Option bid–ask spreads provide a direct measure of trading costs and liquidity conditions in derivative markets. Figure 2.4 reports the average monthly option spread for treated and control stocks. The plot shows that option bid–ask spreads for treated and control stocks followed similar patterns before the implementation of the program. After the Pilot Program start, spreads for treated stocks widened relative to controls and remained elevated throughout most of the Pilot period.

Figure 2.4: Average monthly option spreads per stock by Tick Size Pilot Program group, 1/2012–12/2019

This figure shows the average of daily option bid-ask spreads per stock, aggregated monthly for the control and treated groups. Option Spread is winsorized at 0.01% and 99.9% levels. The post-implementation period reveals higher option spreads compared to the control group. This post-treatment gap suggests a potential reduction in option market liquidity or increased trading frictions associated with the wider tick size regime.



Next, in table 2.1, we show descriptive statistics on the 3 variables mentioned above. For option volume, the distribution is heavily concentrated at low volumes with a few extremely active options which are common in derivatives markets, where only a handful of contracts are heavily traded. Transaction costs and option spreads are measured using end-of-day bid and ask quotes and are winsorized at the 0.01% and 99.9% levels to mitigate the influence of extreme observations. These summary statistics describe the distribution, scale, and variability of stocks and options included in the SEC Tick Size Pilot Program sample.

Table 2.1: Descriptive Statistics for key Variables, 1/2012–12/2019

This table presents summary statistics for transaction cost, option volume, and option spread variables across the years 2012 to 2019. Option Volume and Option Spread is for calls only. SIC codes Utilities and Financials (Ran & Ye (2024)) are excluded. Transaction cost and Option Spread are calculated with bid and ask at market closed and are winsorized at 0.01% and 99.9% levels. These statistics provide insight into the distribution, scale, and variability of stocks and options part of the SEC Tick Size Pilot Program.

Variables	N	Mean	Std	Min	25%	50%	75%	Max	Skew	Kurt
Transaction Cost	1,962,219	0.003	0.005	0.000	0.001	0.001	0.002	0.065	5.870	47.033
Option Volume	1,962,219	140.878	899.534	0.000	0.000	5.000	49.00	180,841.000	44.771	4,556.513
Option Spread	1,962,219	1.374	1.194	0.068	0.512	0.961	1.880	9.427	1.738	4.319

2.2 Data description for Hasbrouck-style VAR model

From the NYSE Trade and Quote (TAQ) database, we compute share imbalance to get the signed stock volume variable explained in section 1.1. Share imbalance for signed stock volume is computed from the difference of Sum of buy Trade Volume (Lee Ready) and Sum of sell Trade Volume (Lee Ready).

For signed option volume, as mentioned before, since we don't have option order imbalance directly, we start by calculating the midpoint of the option. Then we can calculate the return with the option identifier column (Option ID) which allows to calculate the percentage change between the last 2 dates for the same option. We keep the sign of this result and multiply it by option volume and delta explained in section 1.2. We have stock return directly from CRSP daily database.

Then, we filter our panel data to include observations two years before and two year after the start of the Pilot Program. 1 year is 252 days. Specifically, the pre-period covers

October 2nd, 2014, to October 2nd, 2016, and the Pilot period covers October 3rd, 2016, to September 28th, 2018. The post-Pilot covers October 2nd, 2018, to December 31st, 2019. We then exclude any ticker-year combinations with no data for an entire year. To ensure reliable estimates, we also filter out tickers with fewer than 50 daily observations and those with fewer than 5 non-zero observations for the signed option volume variable. These filters are necessary because the VAR model cannot produce meaningful results with insufficient variation or extremely sparse data. We also exclude cases with no variation in signed stock volume, as the VAR estimation requires variation to identify relationships between variables. After applying these filters, we run our VAR model as described in the methodology section, resulting in a panel with one aggregated line per ticker per year. 89.62% of tickers are present in both pre and post-Pilot periods. Signed stock volume and signed option volume are standardized using z-scores to ensure comparability and signed option volume is winsorized at 0.01% and 99.9% level. Table 2.2 reports descriptive statistics for stock returns and signed trading volumes across the pre-Pilot, Pilot, and post-Pilot periods. On average, share order imbalances are negative during the 3 periods periods, suggesting that sell-side pressure dominates buy-side activity prior to, during and after the Tick Size Pilot Program. Both signed stock and signed option volumes exhibit pronounced skewness and kurtosis, indicating highly non-normal distributions with frequent tail events. In the pre-Pilot period, the distribution of signed stock volume is slightly left-skewed, while that of signed option volume shows considerable dispersion and large outliers. These patterns intensify during the Pilot and post-Pilot periods, where the dispersion of order flow widens, as reflected by higher standard deviations and extreme values become more pronounced, suggesting more frequent or more intense trading bursts.

Notably, the skewness of signed stock volume turns positive in the post-Pilot period, indicating episodes of strong buy-side pressure, while kurtosis rises sharply. This is evidence of heavier tails and occasional extreme imbalances. The signed option volume follows a similar pattern, displaying even greater volatility and excess kurtosis above 10,000, consistent with sporadic but massive shifts in option trading activity.

Across all three periods, average stock returns remain close to zero with standard deviations around 3%, consistent with typical daily equity fluctuations. In contrast, the order-flow variables exhibit substantially higher volatility and heavy tails, indicating strong interdependence and feedback effects between markets. These properties justify the use of a vector autoregression (VAR) framework, which can capture the joint dynamics among variables and account for the mutual influence of trading activity and price movements over time.

Table 2.2: Descriptive Statistics for variables used in Hasbrouck's VAR Model, 10/2014-12/2019

This table reports daily summary statistics for the three key variables included in the Hasbrouck-style VAR model. stock return, signed stock volume, and signed option volume. Statistics are reported from 10/02/2014 to 21/12/2019. Signed Stock Volume and Signed Option Volume are winsorized at 0.01% and 99.9% levels. The lag length for the VAR model was selected based on the Bayesian Information Criteria (BIC). To capture changes around the SEC Tick Size Pilot Program, we split the sample into pre-Pilot vs Pilot and Pilot vs post-Pilot periods. These statistics highlight the distribution and variability of return and order flow measures, which are essential for capturing price discovery.

					pre-Pilot Period					
Variables	**N**	**Mean**	**Std**	**Min**	**25%**	**50%**	**75%**	**Max**	**Skew**	**Kurt**
Stock return	545,944	0.000	0.032	-0.794	-0.013	0.000	0.013	7.209	21.586	4,588.209
Signed stock volume	545,937	-1,754.099	88,125.283	-7,388,570.000	-16,516.000	-1,199.000	12,835.000	17,417,137.000	20.295	4,409.597
Signed option volume	54,5949	4.301	232.252	-31,565.700	-0.577	0.000	0.000	35,975.505	12.241	3,419.193
					Pilot Period					
Stock return	577,114	0.001	0.032	-0.929	-0.011	0.000	0.012	2.855	4.765	322.161
Signed stock volume	577,112	-2,938.120	121,196.327	-20,570,938.000	-18,105.000	-1,398.000	13,073.000	18,907,178.000	-5.291	4,198.611
Signed option volume	577,119	8.193	374.814	-90,834.612	-1.490	0.000	1.202	43,681.791	-10.491	7,921.526
					post-Pilot Period					
Stock return	296,914	0.000	0.037	-0.777	-0.014	0.000	0.014	3.099	5.467	338.692
Signed stock volume	296,914	-3,608.136	157,113.408	-14,413,468.000	-19,030.750	-1,727.000	1,2711.750	43,083,564.000	74.008	20,289.532
Signed option volume	296,914	10.115	497.991	-369,69.228	-2.579	0.000	1.933	112,299.508	56.963	10,604.944

Finally, because stationarity is a prerequisite for valid VAR estimation, we applied unit root tests such as augmented Dickey–Fuller test (ADF), the Kwiatkowski–Phillips–Schmidt–Shin test (KPSS), the Phillips–Perron test (PP) to the three series. The Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) tests assess the null hypothesis of a unit root, such that a small p-value (typically $p < 0.05$) indicates rejection of the null and supports stationarity. Conversely, the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test evaluates the null hypothesis of stationarity, where a large p-value (typically $p > 0.05$) implies failure to reject stationarity. Therefore, a series is considered stationary when the ADF and PP tests reject the null of a unit root while the KPSS test fails to reject the null of stationarity.

The results show that stock returns (ADF $p = 0.000$, PP $p = 0.000$, KPSS $p = 0.10$) and signed option volume (ADF $p = 0.000$, PP $p = 0.000$, KPSS $p = 0.10$) are stationary, while signed stock volume (ADF $p = 0.000$, PP $p = 0.000$, KPSS $p = 0.01$) is non-stationary, suggesting evidence of trend-stationarity or possible model misspecification. Accordingly, stock returns and signed option volume can be included directly in the VAR, while signed stock volume when tested in first differences, the series becomes stationary, consistent with an integrated process of order one. Documenting these properties ensures that our variance decomposition and informativeness analysis are based on stable time series. Even if signed stock volume appears non-stationary, (Hasbrouck 1991) models trades and quote revisions as stationary but strongly persistent processes, while the efficient price follows a random walk. (Eun & Sabherwal 2003) explicitly show that prices are integrated process of order one and cointegrated and estimate error-correction models. What matters for variance decomposition is not forecasting consistency but the ability to capture contemporaneous innovations and their long-run impact on returns.

2.3 Data description for information share

Table 2.3 reports descriptive statistics for the three sample periods surrounding the SEC Tick Size Pilot Program. In the pre-Pilot period (October 2nd, 2014, to October 2nd, 2016), on average, 42% of permanent return variance is attributed to stock trades and 58% to option trades based on information-share estimates. The distribution is highly dispersed, with some firms showing almost exclusive influence from one market. This is consistent with (Glosten & Milgrom's 1985) adverse selection model where small-cap equities typically exhibit wider bid–ask spreads, lower depth, and higher execution costs than large-cap stocks because of information asymmetry, making direct equity trading more costly and more visible for informed participants. These frictions can lead traders to prefer the options market, where embedded leverage allows them to achieve similar notional exposure with less capital, and where trading may be less transparent. Prior studies, including (Chakravarty, S., Gulen, H., & Mayhew, S. 2004), show that option market informativeness tends to be higher for lower-liquidity or higher-volatility stocks, whereas large, highly liquid equities often exhibit option contributions in the 10–20% range. This is in line with Table 2.3. Finally, the total return variance explained by trades averages 16.1%, suggesting that a meaningful but incomplete share of price movements is linked to observable order flow.

During the Pilot period (October 3rd, 2016, to September 28th, 2018), the relative information shares remain broadly similar, 39% for stock trades and 61% for option trades. However, the average share of return variance explained by trades increases to 19.4%, indicating that informed trading may have played a somewhat larger role in price discovery under the wider tick-size regime.

In the post-Pilot period (September 29th, 2018, to December 31st, 2019), the allocation of informativeness between stock and option trades remains relatively stable, with stock trades explaining 38% and option trades 62%. The share of return variance explained by trades averages 18.9%, slightly below the Pilot period but still above pre-Pilot levels.

Overall, the descriptive averages do not by themselves reveal a clear shift of informativeness from options to stocks. Rather, they capture broad market-wide patterns that affect both treated and control firms. Instead, these suggest that informed trading activity became generally more influential under the wider tick-size regime. This interpretation is examined more rigorously in Section 3.1, where we test whether the observed differences reflect statistically significant effects of the Pilot Program.

Table 2.3: Descriptive Statistics for trade informativeness

This table presents descriptive statistics for the three sample periods surrounding the SEC Tick Size Pilot Program. The pre-Pilot period covers the two years prior to implementation (October 2nd, 2014, to October 2nd, 2016). The Pilot period spans the duration of the Program (October 3rd, 2016, to September 28th, 2018). The post-Pilot period extends from the Program's conclusion through the end of the sample (September 28th, 2018, to December 31st, 2019). Estimates are computed at the stock-year level using (Hasbrouck's 1991) variance decomposition model and provide insight into the distribution of order flow informativeness across these distinct regulatory regimes.

Variables	N	Mean	Std	Min	25%	50%	75%	Max
pre-Pilot								
Informativeness share of stock trades to permanent variance	3120	0.421	0.344	0.000	0.087	0.354	0.750	1.000
Informativeness share of option trades to permanent variance	3120	0.579	0.344	0.000	0.250	0.646	0.913	1.000
Total return variance explained by trades	3120	0.161	0.115	0.000	0.073	0.137	0.233	1.000
Pilot								
Informativeness share of stock trades to permanent variance	3404	0.393	0.336	0.000	0.079	0.310	0.682	1.000
Informativeness share of option trades to permanent variance	3404	0.607	0.336	0.000	0.318	0.688	0.921	1.000
Total return variance explained by trades	3404	0.194	0.127	0.000	0.097	0.173	0.273	0.999
post-Pilot								
Informativeness share of stock trades to permanent variance	2062	0.378	0.337	0.000	0.064	0.282	0.682	1.000
Informativeness share of option trades to permanent variance	2062	0.622	0.337	0.000	0.335	0.718	0.936	1.000
Total return variance explained by trades	2062	0.189	0.129	0.000	0.084	0.170	0.270	1.000

2.4 Data description for stock effective spread and noise share regression

This section outlines the construction of the variables used to analyze transaction costs and price efficiency. The stock effective spread (SES) captures the realized trading cost per share and serves as a key measure of execution quality in the equity market. Together with the noise share, which quantifies the proportion of transitory price variation in the variance decomposition framework, these variables allow us to assess how the Tick Size Pilot Program influenced both trading frictions and informational efficiency.

The stock effective spread (SES) is calculated like so:

$$\text{SES} = 2^* \text{ abs (stock price - (}\frac{\text{bid + ask}}{2}\text{))} \quad (1.15)$$

Where abs(•) denotes the absolute value. We use the same period as the VAR model, the pre-period covers October 2^{nd}, 2014, to October 2^{nd}, 2016, and the post-period covers October 3^{rd}, 2016, to September 28^{th}, 2018, and the data is from CRSP daily table. We have our treatment and control group from FINRA database which we merge together. Observations with negative prices were removed, as per CRSP's convention where a negative value in the price field indicates the use of a bid/ask average in the absence of a closing price[4]. These negative signs are symbolic and do not reflect actual negative values but were excluded to ensure consistency and accuracy in using true closing prices. There are 1,121,374 data points in the difference-in differences (DinD) regression. For the noise share analysis, we rely on the same three variables used in the VAR model, and we maintain the same sample period as in the effective spread analysis. However, the data is aggregated at the monthly level. That is why we have 93,390 data points. The control variable VIX is obtained from the CBOE table available through Wharton Research Data Services (WRDS) and reflects the monthly closing value of the VIX index. The market-wide bid-ask spread variable is computed as the average spread across all firms included

[4] https://wrds-www.wharton.upenn.edu/data-dictionary/crspsamp_all/crspdsf/

in the SEC's Tick Size Pilot Program for each month. Additionally, data on S&P 500 trading volume is sourced from CRSP's S&P 500 table. For each month, the total volume is calculated by summing up the trading volume of all stocks listed in the S&P 500 during that period. From Table 2.4, stock effective spread (SES) exhibits rare but very large observations indicating heavy tails consistent with episodes of severe illiquidity. Also, we see that the average noise share is 0.67, suggesting that on average, 67% of the return variance is not explained by stock and option trades. This implies that a significant portion of return variation is attributed to noise or non-informational trading, consistent with market frictions or inefficiencies. We didn't calculate pilot vs post-Pilot for this data since we are using the section for empirical evidence for the Pilot Program effects.

Table 2.4: Descriptive Statistics for stock effective spread and noise share
This table provides summary statistics for the daily effective bid-ask spread of stocks from 10/2014 to 09/2018. Only observations with strictly positive prices were retained. Noise share is also reported monthly from 01/2012 to 12/2019. The noise share reflects the proportion of return variance not explained by stock and option trades.

Variables	N	Mean	Std	Min	25%	50%	75%	Max	Skew	Kurt
Stock effective spread	1,121,374	0.035	0.048	0.000	0.010	0.020	0.050	10.100	30.245	4,497.511
Noise Share (%)	93,390	0.670	0.225	0.001	0.513	0.704	0.858	1.000	-0.541	-0.546

2.5 Data description for hedge cost

Since we already had information on call options, we complemented the dataset by obtaining the corresponding put options, the maturity dates and strike prices from OptionMetrics. The price of the underlying comes from CRSP daily table. We then restricted the sample to the Pre-Pilot period (October 2nd, 2014, to October 2nd, 2016) and the Pilot period (October 3rd, 2016, to September 28th, 2018). Using these dates, each observation was assigned to a period. The dataset now contains daily records for both calls and puts, including the bid–ask midpoint prices, strike prices, spot price of the underlying stock, and days-to-expiration. Then we aggregated the data to obtain average straddle costs per stock and per period. To obtain a balanced and reproducible subsample for the hedge cost analysis, we randomly selected five pilot stocks from the Pilot Program. Stocks were required to exhibit complete coverage across the entire period, and, for robustness, we also included tickers with at least 95% coverage to account for occasional missing days. 4 out of the 5 stocks are from the treated group. The 5 tickers are BBW, HZO, IDCC, NSIT and RGR. We then computed an equal-weighted mean across the five tickers, which serves as our benchmark measure of market-level hedge cost. This approach avoids the dominance of larger firms and gives each pilot stock the same weight in the aggregate statistics.

Table 2.5 presents the descriptive statistics for the 30-day at-the-money (ATM) option pairs used in the hedge cost analysis. On average, the total straddle cost is $3.22, corresponding to roughly 9.7 % of the underlying stock price. This indicates that purchasing an ATM straddle with one-month maturity typically costs close to one-tenth of the stock's value, reflecting moderate implied volatility levels across the selected stocks. The days-to-expiration (DTE) variable has an average of 30 days, confirming that the contracts are centered around the intended one-month horizon, with minimal variation of 5.79. The absolute moneyness averages about 3 %, indicating that the selected options are indeed close to at-the-money (ATM).

Table 2.5: Descriptive statistics for hedge costs

This table reports summary statistics for at-the-money (ATM) 30-day option pairs used to compute hedge costs. The variables include the total straddle cost, the straddle cost as a percentage of the underlying stock price, the days to expiration (DTE), and the absolute moneyness percentage

Variables	N	Mean	Std	Min	25%	50%	75%	Max	Skew	Kurt
Straddle cost	3,539	3.217	1.533	0.575	1.950	2.925	4.250	9.350	0.7393	3.108
Straddle / Stock (%)	3,539	0.0974	0.035	0.0332	0.072	0.091	0.116	0.372	1.143	5.306
Days to Expiration (DTE)	3,539	30.143	5.788	21.000	24.500	30.000	36.000	40.000	-0.012	1.724
Abs. Moneyness (%)	3,539	2.981	2.898	0.000	0.807	1.865	4.640	14.286	1.409	4.795

Chapter 3
Empirical Results

This section presents and discusses empirical findings related to the informativeness of stock and option trades, as well as stock effective spread and noise share.

3.1 Stock vs. option trade informativeness results

This section presents the results of a Difference-in-Differences (DinD) analysis aimed at evaluating how the relative share informativeness of stock and option trades evolved in response to the SEC's Tick Size Pilot Program. The analysis exploits the quasi-experimental setting of the tick size reform by comparing treated and control stocks before and after the implementation of wider tick sizes. The goal is to examine whether the change in market microstructure conditions, namely the introduction of larger minimum tick sizes, altered the dynamics of price discovery between the equity and option markets.

The results, presented in Table 3.1, show a statistically significant increase in the share informativeness of stock trades following the policy implementation for the treated group, as evidenced by the positive and significant coefficient on the interaction term (Treated × Post) in column 1. Specifically, the coefficient of 0.0611 ($p < 0.01$) suggests that the role of stock trades in price discovery increased after tick sizes were widened. This is consistent with Hypothesis 1, which predicts a reallocation of price discovery toward the equity market.

To gauge economic significance, this effect can be compared with the pre-Pilot mean share informativeness of stock trades, which was 0.421 (see Table 2.3). Dividing the estimated effect by the mean (0.0611 ÷ 0.421 =0.145) shows that the informativeness of stock trades rose by about 14.5% relative to its pre-Pilot average. This suggests that informed traders were more likely to reveal their private information through stock trades during the Pilot period, consistent with the idea that higher transaction costs made option-based strategies less attractive.

The results, reported in Table 3.1, also show a statistically significant decline in the share informativeness of option trades for the treated group, as indicated by the negative and significant coefficient on the interaction term (Treated × Post) in column 2. Specifically, the coefficient of –0.0611 ($p < 0.01$) implies that the role of options in price discovery decreased after the widening of tick sizes. Importantly, this does not mean that option share informativeness itself became negative. Rather, the coefficient reflects the average reduction relative to the pre-Pilot period. To gauge economic significance, this effect can be compared with the pre-Pilot mean share informativeness of option trades, which was 0.579 (see Table 2.3). Dividing the estimated effect by the mean (0.0615 ÷ 0.579 = 0.106) indicates that the informativeness of option trades fell by about 10.6% relative to its pre-Pilot average.

This shift implies that wider tick sizes may have inadvertently incentivized informed traders to migrate their activity back to the equity market, due to higher execution costs and greater uncertainty in options trading. It reduces the attractiveness of options as a venue for informed trading, since participating in options implies incurring higher costs via stock hedging. Equity and option markets thus act as partially substitutable venues for incorporating private information, and regulatory changes in one market can directly reallocate where price discovery takes place.

Total return variance explained by trades in column 3 from Table 3.1 confirms that the overall explanatory power of trades for return variance does not experience a statistically significant change in the treated group post-implementation (Treated × Post = -0.0027, $p > 0.05$). The negative sign on the DinD interaction term represents a relative post-treatment change for treated firms compared to control firms and should not be interpreted as indicating negative levels. In our results, this interaction effect for the overall share is small and statistically insignificant, suggesting that the aggregate contribution of informed trading remained largely unchanged during the Pilot Program. Although equity trading became relatively more informative, the total extent of informed price discovery across both markets did not rise meaningfully. A detailed discussion of these dynamics follows in Section 3.2.

Turning to the Pilot vs post-Pilot comparison, the results in the lower panel of Table 3.1 reveal the opposite pattern observed earlier: once the program ended, the relative informativeness of stock and option trades reverted toward pre-Pilot levels. The coefficient on the interaction term (Treated × Post) in column 1 is negative and statistically significant (–0.0889, $p < 0.01$), indicating that the share informativeness of stock trades declined for treated firms after the Tick Size Pilot's termination. This reversal suggests that the increase in stock-based price discovery observed during the Pilot was temporary and largely policy-driven.

To assess economic magnitude, the estimated effect can be compared with the mean stock share informativeness during the Pilot period at 0.393 (see Table 2.3). Dividing the effect by the mean (0.0889 ÷ 0.393 = 0.226) implies that the informativeness of stock trades decreased by roughly 22.6 percent relative to its Pilot-period average once the program ended.

Consistent with this shift, column 2 shows a symmetric increase in the share informativeness of option trades (Treated × Post = 0.0889, $p < 0.01$). This positive and significant coefficient indicates that option trades regained their informational role after the Pilot, offsetting the decline in stock-based informativeness. Comparing the magnitude of this change with the mean option share informativeness during the Pilot period 0.607 (see Table 2.3) yields a relative increase of 14.6 percent (0.0889 ÷ 0.607 = 0.146). These results confirm a rebalancing of information flow back toward the option market following the restoration of standard tick sizes.

Finally, the total return variance explained by trades, reported in column 3, remains statistically unchanged after the Pilot's conclusion (Treated × Post = –0.0063, $p > 0.05$). This indicates that the end of the program affected the composition of price discovery between markets rather than its overall intensity. Together, the findings show that the structural changes introduced by the Tick Size Pilot temporarily shifted the market in which price discovery primarily occurred from options to equities, but that this effect dissipated once the regulatory constraint was lifted.

The relationship between stock and option informativeness follows directly from the zero-sum property of Hasbrouck's variance decomposition framework. Since the total permanent variance of returns represents the aggregate amount of information incorporated into prices, the informativeness shares attributed to stock and option trades are normalized components of that total. By construction, these shares must sum to one:

$$IS_{stock} + IS_{option} = 1 \tag{1.16}$$

This implies that, when the overall level of permanent variance remains relatively stable, an increase in the informativeness of one market necessarily corresponds to a decline in the other. In other words, price discovery reallocates between stocks and options rather than expanding or contracting in aggregate.

Table 3.1: Difference-in-differences regression results on trade informativeness

This table reports the results of Difference-in-Differences (DinD) regressions evaluating the impact of the SEC Tick Size Pilot Program on trade informativeness. The dependent variables are the informativeness share of stock trades, the informativeness share of option trades, and the total return variance explained by trades, each derived from (Hasbrouck's 1991) variance decomposition. Informativeness shares represent the proportion of the permanent component of return variance attributable to stock or option order flow.

	Informativeness share of stock trades to permanent variance (IS_{stock})	**Informativeness share of option trades to permanent variance (IS_{option})**	**Total return variance explained by trades (IS_{joint})**
	pre-Pilot vs Pilot		
Intercept	0.4192 ***	0.5808 ***	0.1593 ***
	(0.010)	(0.010)	(0.003)
Treated	0.0041	-0.0041	-0.0043
	(0.014)	(0.014)	(0.005)
Post	-0.0582 **	0.0582**	0.0334 ***
	(0.011)	(0.011)	(0.004)
Treated × Post	0.0611 ***	-0.0611 ***	-0.0027
	(0.016)	(0.016)	(0.006)
F-statistic	12.48***	12.48 ***	42.12***
	Pilot vs post-Pilot		
Intercept	0.3610***	0.6390***	0.1928 ***
	(0.009)	(0.009)	(0.004)
Treated	0.0654***	-0.0654***	0.0017
	(0.013)	(0.013)	(0.005)
Post	0.0288**	-0.0288**	-0.0019
	(0.013)	(0.013)	(0.005)
Treated × Post	-0.0889 ***	0.0889 ***	-0.0063
	(0.018)	(0.018)	(0.007)
F-statistic	11.74***	11.74 ***	1.031***

***, **, * indicate significant at 1%, 5%, and 10% levels, respectively.
The data in parentheses are standard errors.
Errors are clustered at firm level.

Figure 3.1 provides a visual summary of how the share informativeness of stock and option trades evolved across the Pre-Pilot and Pilot periods for both treated and control groups. The left panel shows the stock share informativeness, while the right panel presents the corresponding measure for the options market. Visually, the height of each bar represents the mean share informativeness for a given group and period, allowing differences between groups and periods to be observed directly. For stock trades, the bars for treated firms remain roughly stable between the pre-Pilot and Pilot periods, increasing slightly from 0.423 to 0.426. The change for treated firms is therefore Δ Treated = 0.4263 − 0.4234 = +0.0029, whereas the change for control firms is Δ Control = 0.3610 − 0.4192 = −0.0582. The corresponding difference-in-differences estimate is Δ Treated − Δ Control = 0.003 − (−0.058) = +0.0611, consistent with the regression coefficient of 0.0611 ($p < 0.01$) reported in Table 3.1. The widening gap between treated and control firms thus illustrates a positive treatment effect: the share informativeness of stock trades increased relative to what would have occurred in the absence of the policy. Although the treated group's raw mean rose only slightly, the relative change becomes economically meaningful once the counterfactual decline in the control group is taken into account. In contrast, for option trades, the pattern moves in the opposite direction. The treated group's mean share informativeness decreases slightly from 0.5766 to 0.5737, representing a change of Δ Treated = 0.5737 − 0.5766 = −0.0029, while the control group's mean increases from 0.5808 to 0.6390, yielding Δ Control = 0.6390 − 0.5808 = +0.0582. The corresponding difference-in-differences estimate is therefore Δ Treated − Δ Control = (−0.0029) − (+0.0582) = −0.0611, consistent with the regression coefficient reported in Table 3.1 (−0.0611, $p < 0.01$). This negative treatment effect indicates that the share informativeness of option trades declined by six percentage points relative to the control group during the Pilot Program period. The result complements the positive effect observed for stock trades, reflecting the zero-sum nature of information allocation between the two markets: as the equity market's informativeness increased, the option market's relative contribution to price discovery diminished by a nearly offsetting amount. Together, the two panels illustrate a clear reallocation of price discovery from options to equities among treated firms following the implementation of the SEC Tick Size Pilot Program.

Figure 3.1: Pre-Pilot vs. Pilot period mean share informativeness of stock and option trades, 10/2014-09/2018

This figure illustrates the average share informativeness of stock and option trades, comparing treated and control firms before and during the SEC Tick Size Pilot Program. Each bar represents the mean across stock-year estimates, grouped by treatment group and time period. The left panel shows stock trade share informativeness, while the right panel shows option trade share informativeness. While the visual differences across groups and periods appear relatively small, the regression analysis in Table 3.1 reveals statistically significant shifts for the treated firms following the implementation of the SEC Tick Size Pilot Program. Specifically, the informativeness of stock trades increased, while that of option trades declined, suggesting a reallocation of informed trading toward the equity market.

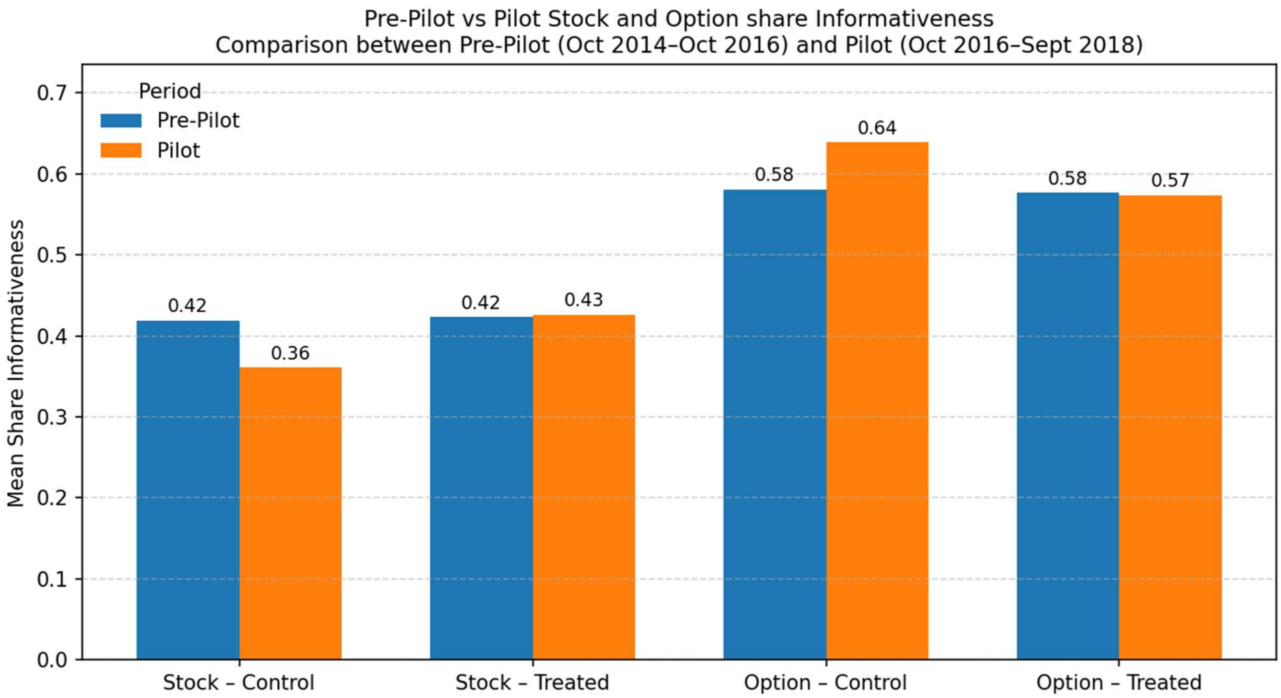


Figure 3.2 illustrates the evolution of stock and option informativeness between the Pilot and post-Pilot periods for treated and control groups. The left panel displays the share of permanent variance explained by stock trades, while the right panel shows the corresponding measure for option trades. Visually, the difference between treated and control bars narrows for stocks and widens for options once the Pilot Program concludes. This pattern reflects a reversal of the earlier policy effect observed during the Pilot phase.

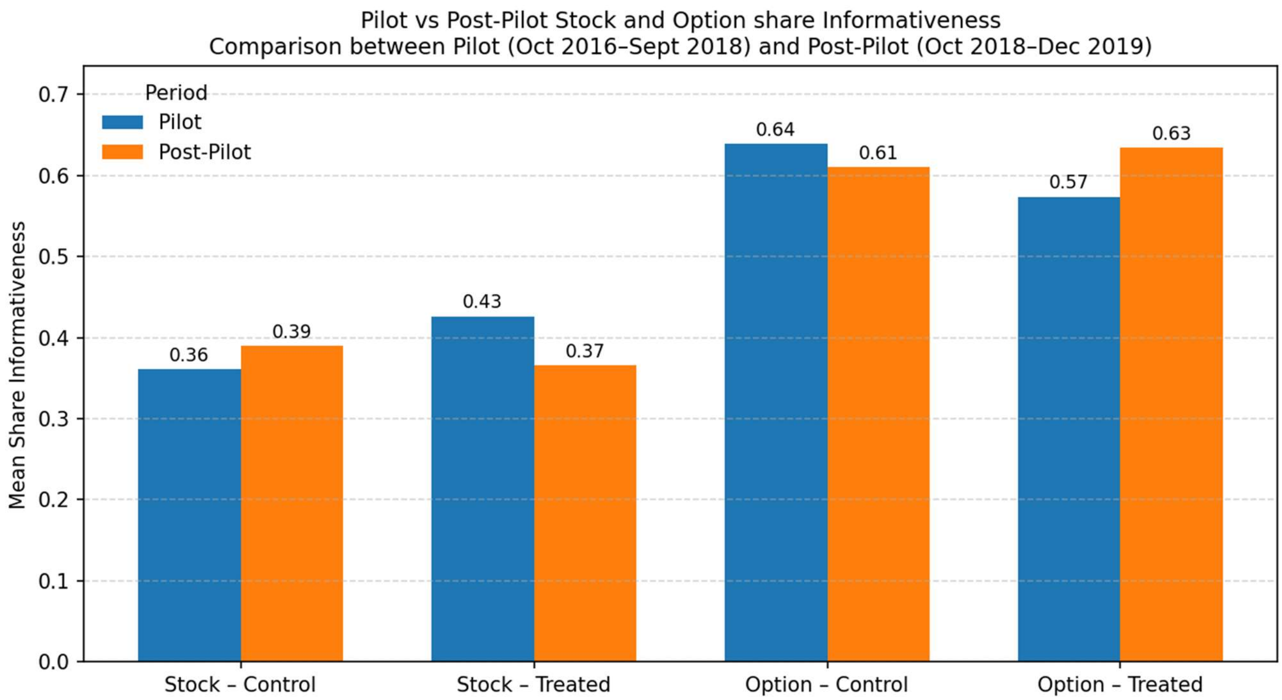
For stock trades, both treated and control groups exhibit similar levels of informativeness after the program's termination, suggesting that the earlier rise in stock informativeness for treated firms dissipated once normal tick size increments were reinstated. The gap that had widened during the Pilot effectively closes, indicating that the increase in the role of stock trades in price discovery was transitory and policy-driven rather than structural.

In contrast, the option market shows the opposite trend. The treated group's option informativeness rebounds slightly in the post-Pilot period, bringing its share of the permanent variance back in line with that of the control group. The widening of the bars on the right panel thus visually captures the restoration of informational balance across markets once the artificial trading constraint was removed.

Overall, the figure conveys a clear visual message: the Tick Size Pilot temporarily distorted the cross-market distribution of price discovery, shifting informativeness toward equities at the expense of options. Once the program ended, these effects reversed, and both markets returned to their pre-Pilot equilibrium, reaffirming that the earlier divergence was a direct consequence of the regulatory intervention rather than a lasting change in trader behavior.

Figure 3.2: Pilot vs. post-Pilot period mean share informativeness of stock and option trades, 09/2018-12/2019

This figure illustrates the average share informativeness of stock and option trades, comparing treated and control firms during and after the SEC Tick Size Pilot Program. Each bar represents the mean across stock-year estimates, grouped by treatment group and time period. The left panel shows stock trade share informativeness, while the right panel shows option trade share informativeness. While the visual differences across groups and periods appear relatively small, the regression analysis in Table 3.1 reveals statistically significant shifts for the treated firms following the implementation of the SEC Tick Size Pilot Program. Specifically, the informativeness of stock trades declined while that of option trades rebounded, indicating a reversal of the Pilot-induced reallocation of informed trading and a return toward pre-Pilot equilibrium in cross-market price discovery.



3.2 Stock effective spread and noise share results

This section extends and validates the findings from the previous analysis by linking the observed shifts in informativeness to underlying changes in trading frictions and price efficiency. Results are presented for effective spread and noise share.

For stock effective spread, the regression results are reported in Table 3.2. The coefficient on the interaction term (Treated × Post = 0.0329, $p < 0.01$) is statistically significant at the 1% level[5]. This indicates that, relative to control stocks, treated stocks experienced a 329-basis-point increase in their effective spread following the tick size reform.

Although the percentage change may appear modest, even small increases in effective spreads can have meaningful economic consequences. Wider spreads directly translate into higher trading costs for all market participants, particularly when trading is frequent or involves large volumes. For informed traders who coordinate positions across markets, higher stock execution costs diminish the efficiency, confirming Hypothesis 2.

Moreover, the negative and significant coefficient on the post variable (–0.0021, $p < 0.01$) indicates that, on average, stock effective spreads (SES) decreased for all stocks over the sample period, likely reflecting market-wide improvements in liquidity or trading technology. However, the fact that treated stocks ran counter to this market-wide decline and experienced an increase in spreads reinforces the conclusion that the Pilot Program had a distinct and adverse effect on execution costs for those securities.

Taken together, this evidence suggests that regulatory changes designed to enhance market quality can generate unintended cross-market distortions. The SEC's intervention indirectly reduced the efficiency of cross-market trading and weakened the incentive to use options as an information-expressing vehicle.

For the Pilot vs post-Pilot period, the results are presented in the second column of Table 3.2. The coefficient on the interaction term (Treated × Post = –0.0292, $p < 0.01$) is negative and statistically significant at the 1% level, indicating that effective spreads for treated stocks narrowed by 292 basis points following the end of the program. This reversal suggests that the widening of spreads observed during the Pilot period was transitory and policy-driven rather than structural.

From an economic perspective, this decline in trading costs implies that once the regulatory constraint on minimum tick sizes was lifted, market competition and liquidity

[5] For illustration, a 3.29 basis point increase in the effective spread on a $50 stock with 500,000 shares of daily trading volume would raise aggregate trading costs by roughly $82,250 per day (0.000329 × $50 × 500,000).

provision quickly improved, allowing spreads to return toward pre-Pilot levels. In other words, market makers resumed finer pricing increments and tighter quoting behavior, restoring a more efficient trading environment for small-cap stocks.

The significant post-Pilot contraction in effective spreads also reinforces the interpretation that the Tick Size Pilot's enforced widening of tick sizes directly impaired market liquidity, rather than revealing an underlying equilibrium adjustment. Treated stocks effectively re-aligned with the broader market once the constraint was removed, underscoring that the adverse effects observed during the Pilot Program were a direct consequence of the regulatory intervention.

Table 3.2: Difference-in-differences regression for stock effective spread

This table presents the results of a Difference-in-Differences (DinD) regression between 10/2015-10/2017 that evaluates whether the stock leg of an options strategy became costlier following the implementation of the SEC Tick Size Pilot Program. A positive and statistically significant coefficient supports the hypothesis that trading the stock leg became more expensive after the implementation of the program.

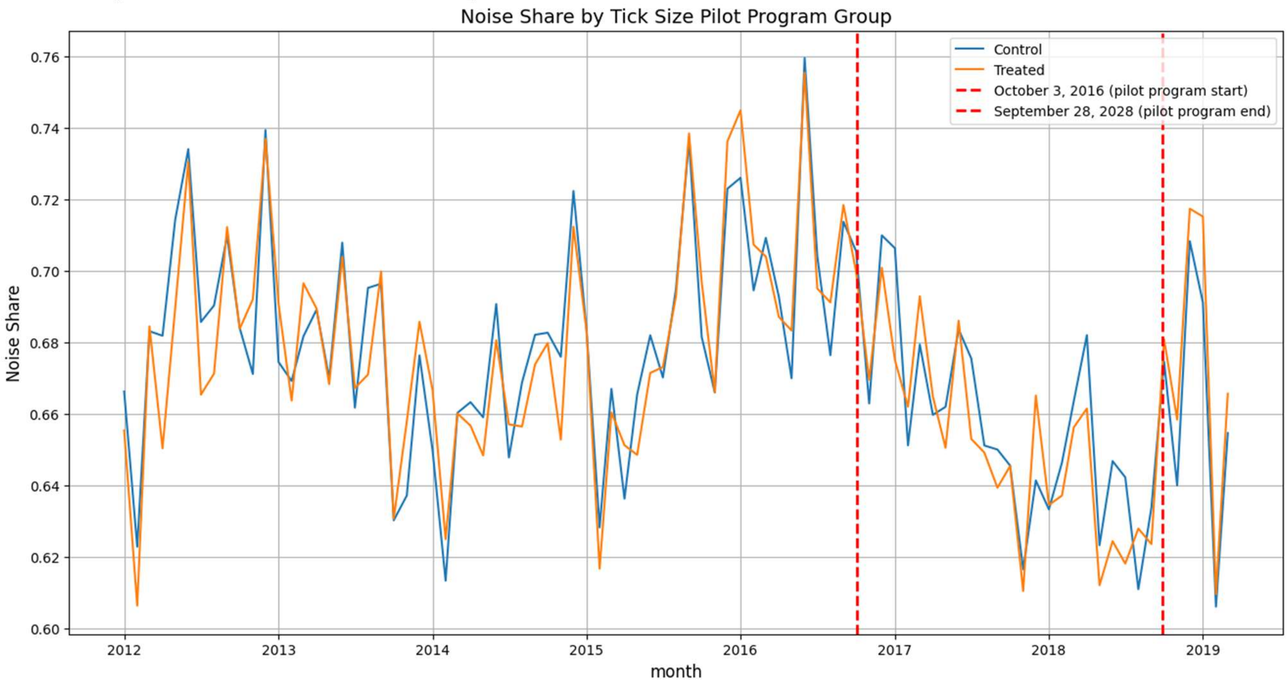
	Effective Bid-Ask Spread for Stocks (SES)	
	pre-Pilot vs Pilot	**Pilot vs post-Pilot**
Intercept	0.0274 ***	0..253***
	(0.001)	(0.001)
Treated	0.0002	0.0332***
	(0.001)	(0.001)
Post	-0.0021 ***	0.0096***
	(0.001)	(0.001)
Treated × Post	0.0329 ***	-0.0292***
	(0.001)	(0.001)
F-statistic	491.3***	528.6***

***, **, * indicate significant at 1%, 5%, and 10% levels, respectively.
The data in parentheses are standard errors.
Errors are clustered at firm level.

This section presents empirical evidence on whether the SEC Tick Size Pilot Program contributed to increased noise in stock returns, an outcome that would signal deteriorating price efficiency. Figure 3.3 plots the average monthly noise share per stock for treated and control firms from January 1st, 2012, to December 31st, 2019. Both series exhibit a pronounced decline beginning in 2016, and the parallel downward movement suggests that the reduction in noise share reflects broader market-wide improvements rather than a treatment-specific effect. If the treated and control groups did not decline together, the divergence would suggest the opposite. To formally assess the parallel trend, we employ a dynamic difference-in-differences (DinD) framework that extends the baseline specification used throughout the thesis by replacing the single post-treatment indicator with a full set of event-time dummies centered on the Pilot's Program implementation date (October 3rd, 2016). The estimation sample contains monthly observations of noise share for all treated and control stocks within a symmetric twenty-four-month window around the program's start. For each stock and month, an event-time index measures the number of months relative to the introduction date. A joint pre-trend test under the null that all pre-Pilot interaction coefficients equal zero fails to reject the null ($F = 0.689$, $p > 0.05$), supporting the parallel-trends assumption. This observed pattern in Figure 3.3 appears to contradict Hypothesis 3, though this interpretation must be verified through formal regression analysis.

Figure 3.3: Average monthly noise share per stock by Tick Size Pilot Program group, 1/2012–12/2019

This figure shows the average daily noise share per stock, aggregated monthly, for the control and treated groups under the SEC Tick Size Pilot Program. Noise share reflects the proportion of return variance attributed to noise and information not driven by trades components. Although a post-treatment decline in noise share is observed (contrary to initial expectations) the parallel downward trend in both groups suggests the change may reflect broader market improvements rather than a treatment-specific effect.



To formally assess this relationship and account for broader market dynamics, the subsequent regression incorporates market-level control variables, including the VIX, the average bid–ask spread across Pilot Program stocks, and aggregate S&P 500 trading volume. These controls help isolate whether the observed changes in noise share stem from the Tick Size Pilot Program itself or from broader shifts in overall market conditions.

The results, reported in Table 3.3, indicate that the Treated × Post coefficient (− 0.0053, $p > 0.05$) is negative and statistically insignificant, implying that the program did not generate a measurable increase in return noise for affected stocks. Consequently, Hypothesis 3 is not supported. While earlier findings showed higher transaction costs and a reallocation of price discovery away from the options market, these frictions did not translate into a noisier component of return variance. This nuanced result suggests that the policy altered where information is incorporated, between stock and option markets, without compromising the overall quality of price formation. Importantly, several control variables exhibit economically meaningful effects. The coefficient on the average bid-ask spread across Pilot Program stocks is positive and highly significant, indicating that wider spreads are associated with higher noise share. This relationship is consistent with the interpretation that greater transaction costs and trading frictions coincide with reduced pricing efficiency. Finally, S&P 500 volume also enters positively and significantly, although its economic magnitude remains small due to scaling.

Table 3.3: Difference-in-differences noise share regression

This table reports the results of a DinD regression evaluating whether the SEC Tick Size Pilot Program led to an increase in noise-induced trading frictions from 10/2014 to 09/2018. The analysis compares changes in price efficiency between control and treated stocks post-implementation. Controls include VIX, average bid-ask spread across SEC Pilot Program stocks, and S&P 500 volume.

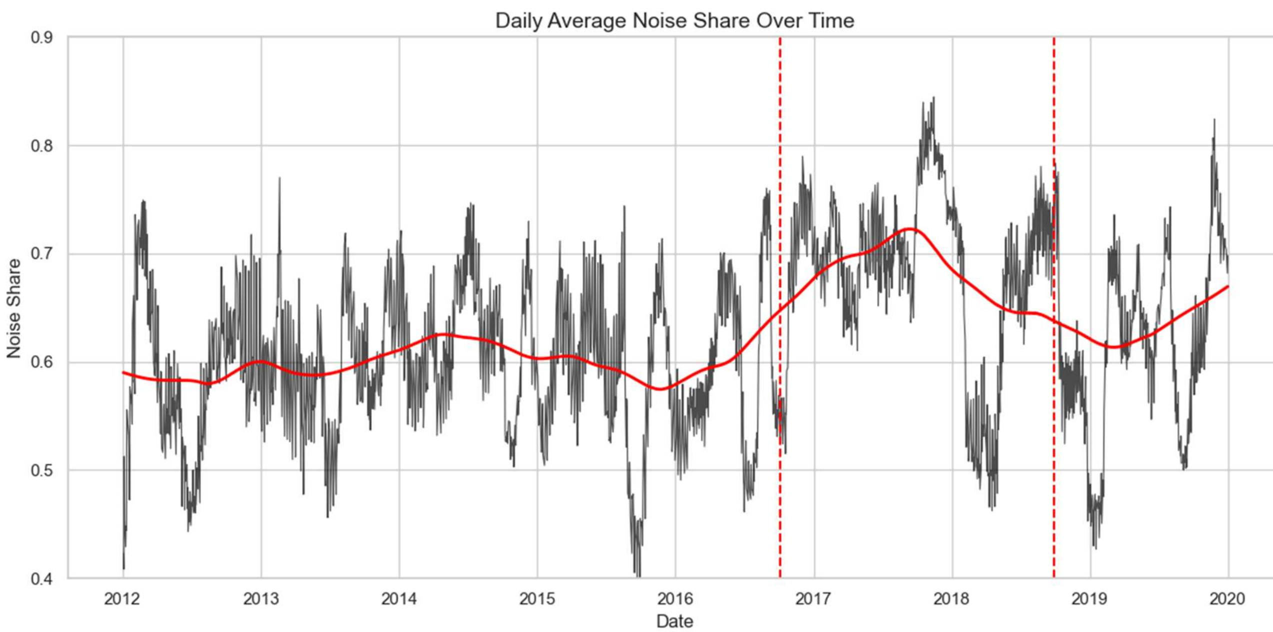
	Noise Share Regression
Intercept	0.5238 ***
	(0.015)
Treated	0.0007
	(0.006)
Post	-0.0147***
	(0.005)
Treated × Post	-0.0053
	(0.006)
VIX	0.0003
	(0.000)
Average bid-ask spread entire Pilot Program stocks	0.0448 ***
	(0.007)
S&P 500 Volume[1]	0.021***
	(0.002)
F-statistic	22.88 ***

***, **, * indicate significant at 1%, 5%, and 10% levels, respectively.
The data in parentheses are standard errors.
Errors are clustered at firm level.
[1]S&P 500 trading volume is rescaled by one million to improve interpretability

However, these statistical results should be interpreted alongside additional time-series evidence. Figure 3.4 plots the average daily market noise share for the S&P 500 from 2012 to 2019. Although the firm-level difference-in differences (DinD) regression shown above shows no significant rise in noise for treated firms, the broader market trend reveals a persistent elevation in noise share after the program's introduction. This pattern suggests that increasing idiosyncratic risk may have offset the efficiency gains implied by higher order-flow informativeness. Accordingly, this is why in Table 3.1 the total return variance explained by trades is statistically insignificant (-0.0027, $p > 0.05$). The effect is market-wide improvements unrelated to the program.

Figure 3.4: Average daily market noise share, 1/2012–12/2019

This figure shows the average market (S&P 500) daily noise share from January 1st, 2012, to December31st, 2019, constructed from systematic and idiosyncratic risk. Despite a rise in the relative informativeness of stock order flow post- Pilot Program treatment, the persistent elevation in noise share indicates that increasing idiosyncratic risk may have offset these gains.



3.3 Hedge cost results

The analysis of at-the-money 30-day straddle costs summarized in Table 3.4 shows that hedging became more expensive during the Pilot period versus the pre-Pilot period. Across the five randomly selected pilot stocks, the equal-weighted average straddle cost increased from 3.11 in the pre-Pilot period to 3.30 during the Pilot. This represents an absolute increase of 0.19, or 6.1%, compared to the pre-Pilot period average. The upward shift in straddle costs suggests that the SEC Tick Size Pilot was associated with a meaningful rise in the cost of hedging short-term exposures, consistent with the notion that wider tick sizes made executing the stock leg of option hedges more costly and less predictable for informed traders.

Table 3.4: Average one-month at-the-money straddle costs, pre-Pilot vs. Pilot Period

This table reports per-ticker average one-month at-the-money straddle costs for five randomly selected Pilot Program stocks across the Pre-Pilot (October 2nd, 2014–October 2nd, 2016) and Pilot (October 3rd, 2016–September 28th, 2018) periods. The "Change" column represents the absolute difference between Pilot and Pre-Pilot averages, while "Change (%)" expresses this difference relative to the Pre-Pilot level.

pre-Pilot vs Pilot straddle averages				
Ticker	**pre-Pilot**	**Pilot**	**Change**	**Change (%)**
BBW	2.030	1.354	-0.678	-33.364
HZO	2.179	2.007	-0.172	-7.911
IDCC	3.920	5.216	1.297	33.084
NSIT	2.643	3.675	1.033	39.083
RGR	4.793	4.264	-0.529	-11.033
Total Average	3.113	3.3034	0.190	6.110

It is important to note, however, that this straddle analysis is illustrative rather than inferential. The results are based on a small, non-representative sample of five stocks and are not directly linked to the treated and control groups used in the main regressions. No formal statistical test is performed, and the findings should therefore be interpreted as anecdotal evidence intended to visualize the mechanism rather than to estimate its magnitude.

Conclusion

Motivated by concerns regarding the unintended consequences of regulatory changes in market structure, this thesis empirically evaluates the impact of the SEC Tick Size Pilot Program on price discovery dynamics, trading costs, and market noise. We implement a series of difference-in-differences (DinD) regressions combined with a Hasbrouck-style variance decomposition to examine how widening the minimum tick size affected the relative informativeness of stock and option trades, the cost of executing the stock leg of multi-leg strategies, and the noise component of stock return variance.

Our analysis reveals a measurable shift in price discovery toward the stock market, as evidenced by an increase in share informativeness of stock trades pre-Pilot vs Pilot period. At the same time, we document a statistically significant rise in effective bid-ask spreads for treated stocks, confirming that the program increased trading costs and made the stock leg of an options strategy became costlier. Interestingly, although transaction frictions increased and the informativeness of stock order flow rose, our noise share analysis finds no significant increase in the noise (non-informational) component of returns for treated firms. Complementary time-series evidence supports the interpretation that these results may reflect a rise in idiosyncratic risk, offsetting the expected gains from more informative stock trading.

When the Pilot Program concluded and normal tick-size increments were reinstated, both markets gradually returned to their pre-Pilot equilibrium. The post-Pilot results show that the temporary increase in stock informativeness dissipated, while option informativeness recovered to previous levels, indicating that the policy's effects were transitory and regulatory in nature rather than structural. Similarly, the effective bid-ask spreads that had widened significantly during the Pilot period narrowed once again after the program's conclusion, signaling a recovery in market liquidity and trading efficiency. In other words, once the artificial constraint on price discreteness was removed, cross-market price discovery mechanisms realigned to their original balance, and both informational efficiency and transaction costs reverted to their normal levels. Taken together, our findings suggest that while the Tick Size Pilot Program achieved a reallocation of price discovery from options to stocks, it also introduced frictions that may have reduced the efficiency of cross-market strategies. Finally, these frictions translated into higher hedging costs for informed traders, who depend on rapid, low-cost execution in the stock market to manage option exposures. It made hedging costlier. This work contributes to the market microstructure regulation by highlighting the complex, sometimes offsetting effects of structural reforms on trading behavior and market quality.

A shift of private information between stocks and options has concrete regulatory and economic implications because equities remain the primary focus of regulatory surveillance, best-execution rules, and market-quality monitoring. When informed trading migrates into or out of options markets, regulators face greater detection challenges because a shift of informed trading into options moves informational pressure away from the equity market they primarily supervise. Execution quality and transaction costs also adjust to the market in which informed activity becomes concentrated, influencing the cost and efficiency of trading. For investors, knowing whether informed traders concentrate in stocks or in options shapes hedging efficiency, execution timing, and the design of cross-market trading strategies.

Although the Pilot Program imposed a specific shift from a one-cent to a five-cent tick, the mechanism documented in this thesis extends beyond that specific change. Reductions in tick size generally compress equity trading frictions, lower the cost of dynamic hedging, and thus encourage informed traders to express private information through option positions. Conversely, increases in tick size raise the cost of stock-based hedging and shift information revelation toward the equity market. In this sense, informed traders systematically reallocate between stocks and options in response to the prevailing level of trading frictions.

Future research may expand upon these findings by switching up the variable's order in the Hasbrouck-style VAR model or separating option order flows into three distinct components: call pressure, put pressure, and net aggregate pressure. This could yield valuable insights into the differing informational roles of calls and puts. Aggregating separately over calls and puts may reveal asymmetric dynamics in how investors process and act on information, especially under changing market frictions. Such an extension offers a rich opportunity for further academic inquiry, potentially through a follow-up thesis or a dedicated empirical study. Also, examining informativeness across moneyness categories could help reinforce or refine the narrative presented in this thesis. Additionally, extending the sample beyond the five pilot stocks for the hedge cost analysis would provide stronger empirical support. A larger, randomly selected sample, potentially stratified by trading volume, liquidity, or treatment group could help assess whether the observed increase in straddle costs generalizes across the broader market.

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