



MODERN MARKETS
INITIATIVE

OVERVIEW: INTELLIGENT TICK SIZE IN SECURITIES TRADING

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I. Purpose of Report: Review of Intelligent Tick Size Reference Material

A. Acknowledgements & Introduction

This report was drafted in conjunction with MMI's Spring Research Fellowship program. Modern Markets Initiative (MMI) is a nonprofit organization dedicated to education and advocacy for innovation in today's markets.

This report provides a high-level introductory overview and comparative analysis of papers on tick size. Topics presented include: what a tick size is, how tick size works, proposed metrics for calculating an optimal tick size, the negative impact of a tick too wide or too narrow, and the unintended consequences if a tick size is incorrectly calibrated. The review comes amid a Securities and Exchange Commission (SEC) proposal released on December 14, 2022, to establish an "intelligent tick" regime (herein referred to as "the Proposal" or "the Intelligent Tick Size Proposal"). As discussed in this report, there are numerous competing methodologies from scholars for calculating an optimal tick size, and an inherent balancing act of making sure a tick is not too wide or too narrow. Although there is broad industry support for the concept of an intelligent tick, there is growing industry consensus around approaching tick size on an incremental pilot basis, allowing for an initial single smaller tick size increment to be tested on the markets, data to be collected, and an empirical review, before deciding on the need or impact of further changes (Securities and Exchange Commission, Dec 22).

A "tick size" is the minimum pricing increment of a stock on an exchange – currently set at a penny for most stocks since 2001 decimalization. Proponents of an "intelligent tick size" argue that the markets have changed since 2001 decimalization, with technology evolving to make trading more efficient and bid-ask spreads narrower, raising problems of tick-constrained stocks where a bid-ask spread would be narrower if not for the minimum penny tick. Critics of the SEC's intelligent tick size proposal argue that the markets are working well for investors, that the SEC's approach is overly prescriptive, and that changing ticks all at once – rather than testing out one increment at a time – may invite harm to price discovery, cause disruption and quote flickering, and other consequences.

This report reviews the varying expert opinions on tick size and the questions presented: Should the tick size be wider for some stocks to incentivize liquidity? What are competing schools of thought on "intelligent tick" metrics - e.g., the stock's spread, price, volume of trading, or other metrics?

B. Definitions

At the outset of the report, it was useful to compile a list of definitions referenced in the academic literature, studies, and other sources.

- i. **Broker:** A broker is any person that engages in the buying and selling of securities for others.

- ii. **Dealer:** A dealer is any person engaged in securities transactions from that person's own account. As many securities firms perform functions of both the broker and dealer, they are referred to as broker-dealers.
- iii. **Tick Size:** The tick size is the smallest price increment in which prices are quoted. It is the minimum increment the price of stocks can move. Many markets are interested in finding the optimal tick size. Prior to implementing decimal pricing in April 2001, fractions of a dollar were used to represent the minimum pricing increments for the United States equity markets (e.g., 1/8, 1/16, and 1/32 of a dollar). However, in 2016, the SEC approved a rule change that allowed certain small-cap and mid-cap stocks to have tick sizes greater than one cent. This was done to increase liquidity and encourage more research coverage and trading activity in these stocks. The SEC Tick Size 2022 proposal "observed that, on average, increasing the tick size resulted in deteriorating market quality for stocks that became tick-constrained under the pilot."

Tick size increments also apply to other financial instruments such as futures, options, and foreign exchange. The tick sizes for these instruments are generally determined by the exchange or regulatory authority that oversees their trading. For example, the tick size for the E-mini S&P 500 futures contract is 0.25 index points, while the tick size for the Euro/U.S. Dollar forex pair is 0.0001.

- iv. **European Tick Size:** Tick size increments have a history in Europe similar to that in the United States. In the early days of securities trading, stock prices in Europe were quoted in fractions, such as 1/8 or 1/16 of a unit of currency. However, as electronic trading and computerized markets became more prevalent, the move to decimalization in Europe followed a similar trajectory to that of the U.S. The European Union introduced the Markets in Financial Instruments Directive (MiFID), which aimed to create a single market for financial services in the E.U. MiFID required that European equity markets quote prices in decimals and establish a minimum tick size of 0.01euro. Since then, European exchanges have generally adhered to the MiFID tick size regime, although some have implemented tick sizes of 0.001 euro or less for certain securities. In addition, the tick sizes for other financial instruments, such as futures, options, and foreign exchange, are generally determined by the relevant exchange or regulatory authority.
- v. **MiFID II and Tick Size:** In 2018, MiFID II was implemented, which expanded the scope of MiFID to include new asset classes and increased transparency requirements. MiFID II also requires trading venues to publish data on the quality of execution for individual transactions, including the impact of tick size on execution quality. This has led to increased scrutiny of tick size increments and their impact on market quality in Europe. As this paper discusses further, the experience in European markets presents lessons learned about the need for dynamic review mechanisms and the value of establishing common metrics to allow for adjustments.

- vi. **Spread Leeway:** The spread leeway is defined as the following ratio to compare the minimum tick size to the bid-ask spread, calculated as:

$$\text{Spread Leeway} = \frac{\text{Average Quoted Spread}}{\text{Minimum Tick Size}} - 1$$

A small spread leeway number, such as values from 1 to 2, suggests that the minimum tick size is too big, or “tick-constrained,” and it is hard for traders to offer or bid a better price; a large spread leeway number, such as values of 7 or more, suggests a minimum tick is too narrow, and there is a risk of a flickering quote. As discussed later, research points to a value of a 4-6 spread leeway being within an optimal range (and to avoid outliers of under 2 or over 9).

- vii. **Flickering Quotes:** A flickering quote is an order in which a stock’s quote changes rapidly between two or more values in a manner that causes an order to be repeatedly submitted and then canceled shortly after submission. A flickering quote is negative to price discovery because it creates a large volume of quote data traffic but does not help investors clarify the true price of a stock.
- viii. **Tick-Constrained Stocks:** “Tick-constrained” stocks are stocks that consistently have quoted spreads near \$0.01, leading us to expect that a tighter spread would develop if quotes were allowed at smaller increments.
- ix. **Bid-ask spread:** The bid-ask spread is the difference between the highest price that a buyer is willing to pay (the bid) and the lowest price that a seller is willing to accept (the ask) (also sometimes called the “offer”) for a particular asset, such as a stock, bond, or currency. The bid-ask spread represents the cost of trading the asset, and it is typically expressed as a percentage of the asset’s price.
- x. **Price:** The price of the stock is relevant to the current regime around tick size, e.g., for stocks with a price over \$1, a penny tick, or \$0.01, is utilized; stocks with a price under a dollar utilize a tick size of \$0.0001. The SEC’s Tick Size Proposal utilizes the spread, rather than the price, as a metric for calculating tick size. While some academic studies have utilized price as a metric, industry experience indicates that price can be a challenging metric, alone, for calculating tick size. For example, some high-priced stocks that are very liquid may still be penny tick-constrained; whereas some low-priced stocks may have wide spreads if they are illiquid or very volatile.
- xi. **Wholesalers:** Broker-dealers who receive and execute retail orders off-exchange on a large scale are sometimes referred to as “wholesalers.”
- xii. **Price Discovery:** a process in which market prices are determined by the interactions between buyers and sellers. It is specifically focused on finding the equilibrium price that will encourage the most liquidity for that asset; it represents the price buyers are willing to pay and what sellers are willing to accept.

C. Background

A key discussion point referenced by SEC Chair Gensler is the notion of “leveling the playing field” between on- and off-exchange trading. What does this reference? The U.S. equity market structure is comprised of different types of trading centers, including (1) on exchanges (also referred to as “lit” markets) that are registered as national securities exchanges, which create a “displayed quote” for a stock that publicly displays the size and price of an order; these exchanges are bound to have penny tick size; and (2) alternative trading systems (or “ATS”) (including some referred to as “dark pools” because they do not display the price and size of their orders) which are hosted by broker-dealers. An ATS, or a broker-dealer trading bilaterally, can execute trades at less than a penny increment. Some critics of off-exchange trading venues have noted that increase in off-exchange trading over the past years, at some points making up more than half of the daily trading volume and pointing to questions of whether having so much trading off-exchange may compromise the integrity of the “displayed quote” (which is the on-exchange trading price of a stock). At the same time, proponents for off-exchange trading venues argue that the ATS can deliver substantial price improvement for retail investors by internalizing trading off-exchange, delivering an economic benefit to investors utilizing those venues; that more competition in trading venues is beneficial for investors.

At present, the exchanges face restrictions of a penny price increment, whereas the off-exchange ATS can often offer pricing increments under a penny. This is because Rule 612 under Reg NMS limits the quoting, but not the trading, under various conditions, such that wholesalers can execute sub-penny increments. There has been discussion for several years from exchanges regarding “leveling the playing field” such that they are able to attract orders through sub-penny increments that are perceived as commensurate to the market conditions on and off exchange.

The SEC’s tick size proposal would modify Rule 612 to establish variable increments for both quoting and trading of stocks. The proposed rule would set tick sizes smaller than a penny for stocks that have been observed to be “tick-constrained” – that is, stocks that are usually found to have a bid-ask spread of \$.01, leading to the assumption that the spread would likely be tighter if sub-penny quotes were allowed. The overt goal of the proposal would be to enable more “price discovery” and, therefore, better trade prices, especially for retail orders.¹

Numerous reports exist with competing theories on tick size – various opinions on getting it “just right.” This report compares the competing schools of thought on tick size into a matrix (Page 7), a discussion (Page 11), and key takeaways (Page 17).

D. Stated Goals of the SEC Tick Size Proposal

The SEC Tick Size Proposal’s stated goal is to modernize equity market structure to adapt to narrower bid-ask spreads of modern technology on some stocks. The Proposal moves away from a one size fits all penny increment of trading to a variable minimum pricing increment system – or “intelligent tick” for the quoting and trading of stocks. An implicit goal of SEC Chair Gensler

¹ Prior experience with a 2016 SEC Tick Size Pilot, which was later withdrawn, indicated that market quality impact of a tick size proposal may be different in practice than in theory. Notably, it would be helpful to back-test the competing academic theories on tick size, as well as the SEC’s Tick Size Proposal. To conduct such sort of back-testing, it would be necessary to have historic bid-ask spread data on Reg NMS stocks. However, such data has not yet been made publicly available to academics.

is “leveling the playing field” to incentivize more trading on lit exchanges, with criticism of a growing amount of off-exchange trading potentially compromising the integrity of the displayed quote. SEC Chair Gensler noted:

“A great deal has changed....: technologies, markets, and business models continually have evolved.[3] In particular, a large and growing amount of equity trading now goes into what many call the dark markets, particularly off-exchange market centers such as wholesalers and dark pools.[4] As of September 2022, as much as 42 percent of share volume is executed off-exchange.[5]... today’s proposal...[will] help drive greater efficiency, competition, and fairness in our equity markets (Gensler, Dec 22).”

The Proposal’s move from a one penny minimum increment to an intelligent tick is characterized by Gensler as a modernization of market structure; Gensler refers to the penny tick size as “outdated” for many stocks and “too wide for today’s markets.” Instead, the Proposal moves to a “tailored range of price increments, tiered according to the stock’s average spread.” Many securities would have a tick size of half a penny or further narrowed if the average spread would be tick-constrained at half a penny.

Looking at the SEC Tick Size Proposal’s stated goals, initial questions identified by MMI Research Fellows included:

- How does modifying tick size meet the intent of “leveling the playing field”? Is this between wholesalers and exchanges?
- Why is the current penny increment believed to be outdated by some?
- How does the movement to an “intelligent tick” differ from the current penny tick?
- What are the potential benefits and risks of changing the tick size?
- What tick is too wide or too narrow, and what are the consequences of each?
- What metrics should be used to calculate a “just right” tick size?

Examining various academic studies on tick size helps provide further context around these questions as it relates to the SEC’s Tick Size Proposal.

E. The Current Regime

Since 2001, stocks in U.S. equities exchanges have traded at an interval of \$0.01, or one cent, where the quote is more than \$1 per share. Under Reg NMS, for stocks priced less than \$1.00 per share, the minimum tick – or pricing increment – is \$0.0001.

F. SEC Intelligent Tick Size Proposal: Four Thresholds

The SEC’s Tick Size Proposal moves away from the penny tick to a variable tick size, depending on factors. The SEC’s approach uses a Time Weighted Average Quoted Spread over a period of one month. This metric would be computed every four months to determine the Tick Size increments.

The four different tick size thresholds – (thus, an “intelligent” tick – rather than a one-size fits all approach) – in the Proposal are:

1. NMS stocks with a Time Weighted Average Quoted Spread that is \$0.04 or less: \$0.005 increment
2. NMS stocks with a Time Weighted Average Quoted Spread that is \$0.016 or less: \$0.002 minimum pricing increment
3. NMS stocks with a Time Weighted Average Quoted Spread that is greater than \$0.016 but less than or equal to \$0.04: \$0.005 minimum pricing increment
4. NMS stocks with a Time Weighted Average Quoted Spread that is greater than \$0.04: \$0.01 minimum pricing increment

G. First Impression of the Tick Size Proposal

The concept of an “intelligent tick” tailored to different stocks as an alternative to a “one size fits all” approach raised many initial questions. Among them: the benefits, risks, consequences, trade-offs, methods of testing, and measurement. Further, how much confidence can anyone have in these theories, and whether a pilot might be appropriate?

A robust review of data on bid-ask spreads would be helpful to backtest various theories and reports on tick size, as well as to backtest the SEC’s Tick Size Proposal. It would be useful for such historical bid-ask spread data to be made available to the public for purposes of backtest findings for the “intelligent tick” four thresholds, as well as to test theories in prevailing scholarship and studies. For example, historic bid-ask data would be useful to calculate the “Spread Leeway” of various stocks, utilizing historic bid-ask spread data and checking if it fits into a reasonable, range as explained in a report by Richard Gorelick (Gorelick, 2014).

II. Review and Analysis of Various Studies on Tick Size

This matrix provides an overview; a discussion is later included of various aspects of these papers in more detail.

A. Matrix: Comparison of Intelligent Tick Size Sources

Source	Optimal Metric	Supporting Intelligent Tick Size	Tick Too Narrow	Tick Too Large	Follow Up Questions and Comments
SEC proposed changes to Rule 612 (2022)	Time Weighted Average Spread over a measurement period.	Supports moving from a one size fits all to a step-wise system.	A too narrow tick may reduce market depth and trigger flickering quotes.	A too large tick may prevent finding the true price, costing investors money.	Without a pilot, or incremental changes, will the proposed, wholesale changes have unintended consequences? Can the proposed changes be expected, with confidence, to have the desired effect?
Cohen et al. (2019)	Like the SEC proposal, “stocks would be categorized based upon their duration weighted average quoted spread over the measurement period.”	Supports an intelligent tick size as the title of their paper suggests, considering a stepwise system an “intelligent tick.”	“When ticks are too narrow, time priority for resting orders diminishes in value: traders patiently awaiting passive executions are outbid by economically insignificant amounts.”	“Many low-priced stocks are tick-constrained, meaning they nearly always trade one tick wide. The market appears willing to trade with a narrower spread that has the potential to reduce costs for traders and investors.”	How do the authors define a too narrow tick or a too wide tick? For the tick-constrained, the authors graphically show the constraints for certain stocks. Big ticks tend to artificially widen the spread, but how should define or observe the too narrow tick?
Gorelick (2014)	Spread Leeway as defined earlier. The best spread leeway is between 2 and 9. “A small spread leeway indicates that bid-ask spreads	In favor of a balance avoiding too small and too large spread leeway.	“Reduces incentive for traders to leave orders resting in order books + leads to higher message rates, as traders fine-tune prices + benefits retail	“Reduces opportunities for traders to compete on price + favors the fastest traders who can get to new price levels first + creates artificially wide	Optimal range for tick size is a Spread Leeway range of 2-9. “While improvement from our one-size-fits-all regime is certainly possible, setting tick increments is inherently a balancing act with different classes of market

	are constrained by the minimum tick increment, and it is more difficult for traders to post a new and better bid or offer.”		investors, potentially at the expense of institutions.”	bid-ask spreads that cost retail investors + drives volume off public markets to dark pools and internalization.”	participants having different interests and preferences.” “Spread Leeway is a useful metric to identify the extent to which the bid-ask spread is constrained by the minimum tick increment.”
Pan European Tick Size Pilot, BATS Europe, (2009)	Ideal spread leeway is between 3 and 10.	Conducted tick size testing on different groups of various stocks and control groups.	A large spread leeway indicates an inability to form price levels on the order book.	A low spread leeway indicates a stock may be tick-constrained, and tick too wide.	A spread leeway between 3 and 10 is a more “conservative premise” than Deutsche Börse ideal spread leeway of 5 to 19. This paper was written in 2009 – what has changed in calculating ideal spread leeway, if anything, since then?
BATS US letter to SEC (2013) ²	Ideal spread leeway is 1 to 10				
Deutsche Börse ³	Ideal spread leeway is between 5 and 19	N/A	N/A	N/A	Ideal spread leeway referenced in BATS letter.
NYSE/Schwab/Citadel Consensus Comment Letter (Year)	N/A	Agree with the need to propose a new tick for tick-constrained stocks.	Tick-constrained stocks have a time weighted average spread of 1.1 cents or less	N/A	Supports an incremental approach to evaluating tick size to minimize disruption.

² BATS letter to SEC referenced in Gorelick/RGM (2014) Page 8, <https://www.sec.gov/comments/4-657/4657-40.pdf>

³ The Deutsche Boerse spread leeway metric is referenced in *Pan European Tick Size Pilot, BATS Trading Limited* (2009), Page 2, Footnote 2 as “See email from Dr Miroslav Budimir on 27 March 2009.”

NYSE Research Paper (Year)	Reference price improvement as a key metric in the scenarios proposed.	Support different tick sizes based on liquidity characteristics.	45.2% of trades using a 4th decimal place have a 1 or 9 in that place, suggesting a negligible impact from the pricing flexibility that comes from trading 1/100 of a cent.	Some stocks have liquidity characteristics that could allow them to be traded with tighter than a \$.01 spread	Proposes a scenario where harmonizing on and off exchange trading to a minimum trading increment of ¼ of a cent (\$.0025)
CBOE Comment Letter	Uses the Quote-Trade ratio.	Tick framework should be updated bi-annually to adapt to market conditions.	Based on the percentiles of the quote-trade ratio, there is an abundance of liquidity, but trading costs are too high.	There are price benefits to be found inside tightly quoted spreads, which could be quoted in finer increments.	Thinly traded securities should not be the focus of the tick reduction framework, as they have low notional turnover.
Nasdaq comment letter	N/A	Agree with the need to propose a need for tick-constrained stocks.	Add a single tick size below one penny at \$.005 to help tick-constrained stocks	N/A	
Bacidore, 2020	Tick size should be a function of the price.	Against the Nasdaq proposal but in favor of an update of the current regime.	N/A.	A too large tick would widen the spread.	Argues that the price is a major component of the tick size. “The [Nasdaq proposed] Intelligent Ticks regime does not allow ticks to adjust immediately when the price of the stock moves, even though price is perhaps the biggest determinant of optimal tick. A simple price-based tick regime, by contrast, could respond immediately.” (Bacidore’s other papers have indicated that bid-ask spread, market

					depth and volume are indicators for calculating tick).
Bacidore, 1996	Analyzes the quality of the market after the change using three metrics: bid-ask spread, market depth and volume.	N/A on intelligent tick size. Supports decimalization.	“Narrower quotes reduce liquidity provider profits, resulting in a decline in their willingness to supply liquidity to the market.”	N/A. Not mentioned; focus of decimalization is mostly a tick size reduction.	Indicates that liquidity providers lose profits when tick sizes are reduced. Bid-ask spreads influence profits for liquidity providers, while commissions are revenue for retail brokers, each as two different parties to a trade. This paper was written in 1996; in a modern market, the link between retail brokers and liquidity providers profit is payment for order flow (PFOF, paid by the liquidity provider (wholesaler) to the retail broker. If spreads are narrowed, then PFOF will most likely be less of a result, and therefore retail brokers may need to raise commissions to make up lost revenue.
Yang et al., 2020,	Proposes an original way of using different metrics: price and volume.	In favor of an intelligent tick size a stepwise system. However, advocates for a combination of 2 stepwise systems using volume and price.	Cautions that a too narrow tick “might reduce the profits for liquidity suppliers and further reduce the liquidity provision in the limit order book.”	A smaller tick size “can further encourage the price competition in the market and decrease trading cost.”	The spread is not the only metric that can be used to define the optimal tick size: “some researchers have found that the optimal tick size should be determined by the trading environment, such as quote size and trade volume.” Combine different stepwise systems to find an even more “intelligent” tick size. Why did authors not try to combine a stepwise system using the spread? Would the results have been better?

B. Discussion of Source Material

i. Discussion of Market Quality and Tick Sizes, RGM – 2014

Among the clearest reports on tick size is Richard Gorelick’s 2014 comment letter to the SEC titled “Discussion of Market Quality and Tick Sizes” (“the RGM Paper”) (Gorelick, 2014). This paper clearly explains what tick size is, the balancing act of optimizing tick size, and explains the concept of “spread leeway” of a 2-9 range as a metric for calculating optimal tick size.

For example, Gorelick notes that when the tick size is too small:

- Reduces the incentive for traders to leave orders resting in order books
- Creates higher message rates as traders fine-tune prices; and
- Favors retail investors, potentially at the expense of institutions

Gorelick notes that when a tick size is too large:

- Diminishes opportunities for traders to compete on price
- Benefits favor the fastest traders who can get to new price levels first
- Results in artificially wide bid-ask spreads that cost retail investors; and
- Drives volume off public markets to dark pools and internalization

Reading the report, questions arose including:

- Why is 2-9 a good range for the spread leeway? It is noteworthy that the spread leeway range articulated by Gorelick differs from other sources, including BATS, which has an ideal stated spread leeway of 3-10, and Deutsche Börse’s ideal spread leeway of 5-19, as noted in this report’s Matrix.
- Is there any feature other than the spread which should be taken into account? Should we consider the price of the stocks and the market depth? Research from other papers indicated that there are other factors, such as the market depth and the price, which are important features, and the tick size may take them into account, but it was unclear how to incorporate the factors. The benefit of looking at spread leeway as a good first step toward intelligent tick is that it is a readily definable metric that is easy to understand.

ii. Nasdaq, Intelligent Ticks – 2019

The Nasdaq paper “Intelligent Ticks” was written in 2019 by Tal Cohen and Lauren Dillard (Cohen et al., 2019). The paper favors an intelligent tick size and suggests that stocks should trade in 6 increments (\$0.005, \$0.01, \$0.02, \$0.05, \$0.10, and \$0.25) based on a duration weighted average quoted spread over the measurement period. This is very similar to the SEC’s Tick Size Proposal.

Like the RGM paper (Gorelick, 2014), the authors mention the risks of having too narrow a tick size and too wide a tick size. When the tick size is too small or too narrow: “increased prevalence of odd-lots, flickering quotations, and non-displayed trading that does not support price discovery. When ticks are too narrow, time priority for resting orders diminishes in value,

and “traders patiently awaiting passive executions are outbid by economically insignificant amounts.” When the tick size is too wide, “many low-priced stocks are tick-constrained, meaning they nearly always trade one tick wide. The market appears willing to trade with a narrower spread that has the potential to reduce costs for traders and investors. Tick-constraints create long quotation queues, slowing fulfillment. The resulting inefficiency drives traders and investors to focus on time priority and speed while diminishing price priority and, therefore, price discovery.”

This intelligent tick proposal should be easy to implement, but it is not clear how the authors decided on the 6 increments. The NASDAQ proposal sets forth the following buckets for the following average quoted spreads:

- Up to \$.011 would be placed in the \$.005 bucket
- Between \$.011 and \$.02 would be placed in the \$.01 bucket
- Greater than \$.02 and less than or equal to \$.05 would be placed in the \$.02 bucket
- Greater than \$.05 and less than or equal to \$.10 would be placed in the \$.05 bucket
- Greater than \$.10 and less than or equal to \$.25 would be placed in the \$.10 bucket
- Greater than \$.25 would be placed in the \$.25 bucket

Reading the paper, questions arose including:

- Why the tick size is only based on the spread, while the authors claim to “have developed a smarter tick proposal that would create an easy-to-implement table of trading increments to account for a wide variety in size, volume, and stock price”?
- How do the authors arrive at the proposed numbers, and how can one backtest the data and methodology? It could be interesting to know what the Spread Leeway would be for these stocks. It would be in a good range as bigger stocks tend to have bigger spread, thus they need a bigger tick size and vice versa.
- Why do the authors only use the duration weighted average spread to determine the tick size? Why not also the price, as the SEC used to do? Why not the size weighted average spread? What are the tradeoffs of the different methodologies?

iii. NYSE/Schwab/Citadel Consensus Comment Letter – March 2023

On March 6, 2023, a joint “consensus” comment letter of NYSE, Schwab, and Citadel was submitted regarding the SEC’s Tick Size Proposal. In the relevant part, the comment letter recommends reducing the minimum quoting increment to a half-penny for symbols trading at or above \$1.00 per share that are tick-constrained to significantly narrow the number of symbols covered in the Proposal. The authors define “tick-constrained” as stocks that have a time-weighted average spread of 1.1 cents or less and a “reasonable amount of available liquidity” at the National Best Bid and Offer (NBBO). The NBBO is the highest displayed bid price and lowest displayed offer price available for a stock across the different exchanges or liquidity providers.

Further, the authors recommend establishing a market-wide harmonized trading increment of \$.001 for all stocks with a price at or above \$1.00. In the authors' view, the minimum *quoting increment* and the *minimum trading increment* need not be the same.

In addition, the authors recommend an incremental approach to regulatory reform, where the SEC the first implements Tick Size Proposal before moving on to other reforms and leaves a "measurement period to assess the cumulative impact on market liquidity, efficiency, and competition."

Reading the comment letter, questions arose including:

- How long should a measurement period be to review tick size, and what metrics should be used to measure success or failure?
- How does a measurement period fit in with a pilot regime for tick size?

How does the *quoting increment* and *minimum trading increment* being different impact Gensler's stated goal of "leveling the playing field" between ATS and stock exchanges?

iv. **Tick Size and Market Quality: Simulations based on agent-based artificial stock markets – 2019**

In 2019 Xinhui Yang, Jie Zhang and Qing Ye authored a paper titled, "Tick Size and Market Quality: Simulations based on agent-based artificial stock markets" (Yang et al., 2020). The authors explained that an "extremely large tick size damages the profit of liquidity demands, whereas an extremely small tick size damages the profit of liquidity suppliers." The authors support a stepwise system they describe as "plausible" for tick size. The authors expect to demonstrate that a "combination of the price stepwise system and the volume stepwise system can further promote market quality."

An artificial stock market (ASM) is modeled to backtest the theory. The authors present their model as an order-driven market with heterogeneous traders that interact with each other in a dynamic network structure. The model used, one can see that there are two different kinds of assets (one risk-free bond and one risky asset). The authors set different parameters, such as the number of traders and the number of strategies.

The authors conducted 16 experiments, including one with one tick size, one with Price stepwise tick size, one with volume stepwise tick size, and two with combination stepwise tick size.

The authors concluded that one combination of stock price and trade volume (which they referred to as a minimal combination) has the best quality in terms of liquidity, volatility, and price efficiency.

Reading the paper, questions arose including:

- Why such a mixed stepwise system was not included in the SEC's Tick Size Proposal

- Impact of a stepwise proposal on administrative burden of implementation versus accuracy
- Whether to consider volume and price in tick size calculations separately or together
- Why do the authors not take the spread into account? What would the performance of mixed stepwise systems with spread metrics be?

v. The Impact of Decimalization on Market Quality: An Empirical Investigation of the Toronto Stock Exchange – 1996

This paper, written in 1996 by Jeffrey Bacidore, provides a historic backdrop to tick size at a time before decimalization, when fractions of a dollar – e.g., 1/8 and 1/16 of a dollar – were used instead of a penny (Bacidore, 1996). Bacidore responds to the question of whether the U.S. equity exchanges should switch to decimal pricing. He does so by using Toronto Stock Exchange data, as Canadian stock exchanges switched to a decimal-pricing system and reduced the minimum tick size on April 15, 1996.

To Bacidore, “decimalization led to a reduction in the cost of trading to investors, and liquidity does not appear to have been significantly impacted. Nevertheless, decimalization does not appear to be Pareto improving for the TSE due to the fact that liquidity providers experienced a decline in profits.”

Reviewing the paper, questions presented included:

- What lessons can be learned from the debate on decimalization that are applicable to today’s discussions of intelligent tick?
- Are the stated tradeoffs the same or different looking at tick size in 1996, pre-automation, versus in modern markets in 2003? Notably, since decimalization, broker fees decreased have decreased significantly, as explained in a *WSJ* article titled, “The Race to Zero Commissions” (Beilfuss & Osipovich, 2019): what would the impact on the markets with a tick size so narrow that there might be price flickering on investors and liquidity provision?

vi. Why Markets Should Not Necessarily Reduce Tick Size – 2002

In “Why Markets Should Not Necessarily Reduce Tick Size,” Fanny Declerck and David Bourghelle analyze data on tick size from the Paris Bourse (Declerck & Bourghelle, 2002). The authors contrast findings regarding the U.S. market. The authors found that, in some instances, a reduction in tick size harmed the market depth – the market’s ability to accept large market orders without significantly impacting the price of the underlying security.

The paper notes: *“To attract liquidity demand, designers of trading systems have to stimulate investors to fully display their orders. A relatively coarse pricing grid does not always result in excessively large spreads, but enhances quoted depth, encourages liquidity providers to expose their trading interest and stimulates investors to quote the competitive spread. Our analysis indicates that regulators may be well advised to avoid reducing tick size if they want to attract*

liquidity providers, and if order exposure is profitable for a market. Yet, the significant competition between trading mechanisms highlights the need for future research related to the consequences of tick size on trading costs and the dynamics of liquidity supply.”

Reading the paper, questions arose including:

- Are the findings of a paper from 2002 relevant to tick size discussions in modern markets in 2023 - with automation of the markets since then? Bid-ask spreads have narrowed substantially since then, impacting calculations on spread leeway.

vii. The Trouble with Small Tick Sizes – 2012

A 2012 paper titled, “The trouble with small tick sizes” focuses on IPO liquidity (Weild et al., 2012). The authors recommend introducing a range of tick size and a vote from the board of directors of the company. The authors alternatively suggest an increment of one half of the quoted spread.

This notion of a tick size that is half the quoted spread is a contrast to other authors’ suggestions of optimal spread through a calculation of spread leeway.

Reading the paper, questions arose including:

- Should tick size be a corporate governance question that individual companies should determine? What would the impact be on the complexity of the markets?
- If one could test the theories in the paper, should underlying data in the report be made available to the public to conduct backtesting?

viii. CBOE Tick Size Reduction Framework – February 2023

On February 28, 2023, CBOE commented on the SEC’s Tick Size Proposal (Securities and Exchange Commission, Feb 2023). In the letter, CBOE noted that it had published a tick reduction framework in order to identify tick-constrained securities. CBOE noted that applying a 1/2 cent tick to those securities would permit the marketplace to more safely understand and process the implications of tick reform while avoiding the need for immediate, sweeping changes that could result in potential operational complexity and risk.

CBOE’s tick reduction framework noted that of 10,125 securities, only 9% (877) were classified as “tick-constrained” — those with an average quoted spread of 1.1 cents or less. However, the volume of the stocks traded represented roughly half of the trading volume in Reg NMS stocks. CBOE advised that regulatory reform should focus on a subset of securities that are tick-constrained, rather than the more sweeping changes proposed by the SEC in December (Cboe, Sept 22).

Under CBOE’s Tick Reduction Framework, the following process is set forth for measuring “Objective Criteria” on what is tick-constrained, utilizing the following elements: (1) Constraint: tight average inside quoted spread (of average daily quoted spread at or below 1.1 cents) (2) high

quote size to trade size ratio; and (3) high notional turnover rate – to focus on securities with high turnover that would benefit from the ability to be traded in finer increments.

CBOE issued its support for a tick-reduction framework based on objective criteria that targets true tick-constrained securities, starting with an initial tick-reduction to 0.5 cents, rather than 0.1 cents; that the framework should be reevaluated quarterly or bi-annually for the parameters to “remain nimble to changing market conditions”; that there should be a decoupling of the quoting increments from trading increments, among other observations.

Reading the paper, questions arose including:

- Does the CBOE paper reflect a growing consensus with other comment papers –like the NYSE/Citadel/Schwab paper – on incremental approach to tick size and beginning with an initial tick-reduction to 0.5 cents, on a pilot basis?
- How is tick size in the options market different to tick size in equities markets? At present, of most equity options priced under \$3, the tick size is \$0.05, and for options greater than \$3, the tick size is \$0.10.

ix. Ticked Off: Five Arguments Against the Nasdaq Intelligent Tick Proposal – 2020

Jeff Bacidore’s 2020 article in *Traders Magazine*, “Ticked Off: Five Arguments Against the Nasdaq Intelligent Tick Proposal” (Bacidore, 2020), offers a view against the Nasdaq proposal. Bacidore suggests that tick be a function of price of the stocks. He does not articulate why the tick should be defined by price and not, for example, spread.

Notably, in a follow-up article in *Traders Magazine* in 2022, Bacidore questions why the SEC did not implement an intelligent tick size proposal and appears to offer support in favor of an SEC modification of tick size (Bacidore, 2022). He appears to believe this proposal is imperfect but better than nothing. This article makes a defensible argument for having a tick size dependent on price.

Reading the article, questions arose including:

- If the author opposes the NASDAQ proposal, what does the author support? (The author does not provide an alternative proposal, so the answer is not clear).
- Does Bacidore believe that the SEC’s ticks size proposal is better than the status quo of doing nothing?

x. Nasdaq Comment Letter – March 2023

On March 30, 2023, Nasdaq submitted a comment letter regarding the SEC’s Tick Size Proposal. In the executive summary, Nasdaq outlines that they hold market modernization in high regard and agree with the need for SEC proposals to keep pace with market changes. In regard to tick size, Nasdaq supports adjusting the minimum pricing increment, but opposes the idea of several new tick sizes that could put a strain on liquidity. Instead, Nasdaq proposes an approach of adding a single tick size below one penny (at \$.005), which would help tick-constrained

securities trade more. More generally, Nasdaq proposes a wider minimum tick size of \$0.05 for less liquid securities trading with wider spreads. Although the SEC pushed these proposals out in the hopes of leveling the retail investor field, Nasdaq finds it important to harmonize tick sizes across different trading venue types to eliminate artificial competitive disparity. Overall, Nasdaq proposes a different approach to restructuring tick sizes in order to avoid collateral harm to investors and to prevent the erosion of lit markets.

III. Author Review/ Critique - Key Takeaways

A review of the numerous studies and research on tick size over the past decades provides several key takeaways: (a) calculating tick size is a “balancing act” – it is difficult to get right, and a limited and modified version of the SEC’s Tick Size Proposal would be useful as a first step on a single change to tick size increment first; (b) numerous experts agree on “spread leeway” as among the key metrics in calculating tick size that is referred to by multiple expert papers; (c) a dynamic review mechanism would be useful, incorporating lessons learned from MiFID II; (d) there is a lack of consensus and unanswered questions on methodology for calculating optimal tick size, and too much change at once should be avoided as unnecessary and potentially disruptive.

A. Balancing Act: Avoiding Flickering Quotes, Tick-Constrained Stocks

There is broad consensus among the various authors on the importance of getting tick size right – that it is a “balancing act.” If a tick size is too narrow, this could cause flickering quotes and excessive market data volume; if a tick size is too wide, the problem of tick-constrained stocks emerges.

In looking at changes to the U.S. equities markets, it is difficult to try to forecast precisely how such changes will impact the markets in practice without real world analysis of outcomes. Empirical data would be helpful in evaluating the balancing act and utilizing a limited roll-out and evidence-based review mechanism to safely manage any changes.

B. Spread Leeway a Key Metric for Tick Size, But Other Metrics Also Discussed

There appears to be consensus around “spread leeway” as a key metric to calculate optimal tick size, varying from a range of 2-9 (as in R. Gorelick), to 1-19 (as in BATS USA, 2013), to 5-19 (as in Deutsche Börse, 2009). Other studies have pointed to price, volume, a corporate governance decision of an issuer, or a combination “stepwise system” (O’Hara, Saar, and Zhong) as further useful metrics in approaching tick size. The SEC’s Tick Size Proposal aligns with spread leeway as a key metric for calculating optimal tick size.

Notably, given the variable methods for calculating the optimal tick size, there is some consensus around an incremental approach to tick size. It could make sense, for example, if/when the SEC decides to move forward with tick reform, to proceed initially with a temporary single change increment to tick size first, for example, for tick-constrained stocks; and gather data on market impact, before deciding whether there is a need to move ahead with any further tick size changes.

C. Need for Dynamic Review Mechanism, Backtesting, and Data Transparency

Drawing off the experience of MiFID II, there is value in having a dynamic review mechanism to test spreads in practice, establishing metrics and parameters around spread leeway and allowing for further adjustments. It would be useful to have common, agreed-upon metrics for adjusting tick sizes in the future. It is foreseeable that there may be changes in market dynamics, future changes in technology, or other reasons, for further iterative planning and implementation.

It would be useful to build adaptability and feedback loops into a proposed plan. It should be assumed that incremental changes may be ongoing after the first iteration. In this way, the Commission can avoid the complexity of trying to predict the compound effects of multiple changes to tick size increments if evidence from initial changes supports refinements to the size of increment and/or extension to additional stocks.

D. Areas Without Clear Consensus: Varying Methodologies

A variety of methodologies exist for calculating tick size, including the difference between using time weighted average quoted spread versus trade size weighted average quoted spread. The SEC's Tick Size Proposal uses the Time Weighted Average Quoted Spread, calculated quarterly over a period of 1 month. Time Weighted average means that the longer a spread will remain, the bigger its weight will be when computing the average. This may have some issues as a spread between two investors may not represent the reality of the market belief.

By contrast, other industry participants have referenced the **trade** size weighted average quoted spread. The trade weighted exchange average quoted spread is calculated by averaging all series' daily average quoted spread and weighting that by the number of trades in the price range associated with that series bid.

Although seemingly technical in nature, the difference between the type of "average" number to use for calculations could have an impact on the spread leeway metric. It would be useful to get further clarification from the SEC on the reasoning behind the selection of methodology.

IV. Conclusion and Recommendations

The U.S. equity markets are the best markets ever for investors, but there is always room for improvement. A robust, scientific, non-speculative approach is a must, to ensure that investors' interests are protected and not harmed.

The body of research points to a consensus that a tick too narrow can cause flickering, and a tick too wide may artificially constrain the bid-ask spread. The task of "getting it right" is one that must be conducted on an empirical, data-driven basis on an initial single tick change to collect information and conduct analysis. It would be prudent for the SEC to carefully test a smaller tick size on an incremental basis, to gather data and evaluate agreed upon metrics, and to include a dynamic review mechanism for further adjustments, following lessons learned from MiFID II. With competing schools of thought on what spread leeway number is "just right" for tick size, backtesting and empirical review of data are crucial.

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